CSIR

वार्षिक प्रतिवेदन
Annual Report
2011–12

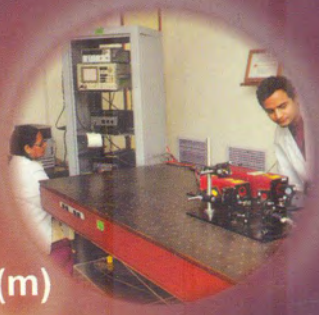
CSIR–NPL

CSIR-NPL moving towards Quantum Metrology

mole (mol), length (m), candela (cd), time (s), current (A), mass (kg), temperature (K)

(mol)

(K)



(m)

(s)

(kg)

(cd)

(V)

सीएसआईआर - राष्ट्रीय भौतिक प्रयोगशाला
CSIR - National Physical Laboratory
New Delhi - 110 012

Honorable Minister of Science and Technology &
Vice-President CSIR visits CSIR-NPL
September 22, 2011

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With Best Compliments from :

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सीएसआईआर–राष्ट्रीय भौतिक प्रयोगशाला
CSIR-National Physical Laboratory

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निदेशक की लेखनी से...

वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद् (सी एस आई आर) – राष्ट्रीय भौतिक प्रयोगशाला (एन पी एल) की वर्ष 2011–12 की वार्षिक रिपोर्ट आपके समक्ष प्रस्तुत है। इस रिपोर्ट को प्रस्तुत करते हुए मुझे अत्यधिक हर्ष की अनुभूति हो रही है।

सी एस आई आर – एन पी एल एक अग्रणी भौतिकी प्रयोगशाला तथा साथ ही भारत का राष्ट्रीय मापिकी संस्थान भी है। यह संस्थान भौतिक विज्ञान एवं माप विज्ञान में अनुसंधान के अग्रणी क्षेत्रों में सक्रिय रूप से कार्य कर रहा है। वर्ष 2011–12 हमारे लिए अत्यधिक सृजनात्मक, उद्बोधक और साथ ही प्रेरक रहा है। उन्नत अनुसंधान के अग्रणी क्षेत्रों में बृहत्तर बाह्य दृ यता प्राप्त करने के लिए पुनःस्थापन तथा रूपांतरण की प्रक्रिया इस वर्ष भी जारी रही। सी एस आई आर–एन पी एल ने अंतर्राष्ट्रीय स्तर पर हो रहे परिवर्तनों के अनुरूप पहले से कहीं अधिक सामंजस्य स्थापित करके अपने कार्य के परिमाण तथा गुणवत्ता को निरंतर उन्नत बनाया।

वर्ष के दौरान, अनुसंधान के प्राथमिकता वाले क्षेत्रों में अत्याधुनिक अभिलक्षणन सुविधाएं विकसित करने तथा स्थापित करने तथा सर्वोत्तम श्रेणी की प्रयोगात्मक व्यवस्था सृजित करने के संबंध में प्रयास जारी रखा गया। इस अवधि में, एक केंद्रित आयन किरण पुंज (एफ आई बी) सूक्ष्मदर्शी, निम्न ताप (3.5 केल्विन से अधिक या इसके बराबर) संलग्नक तथा पराबैंगनी प्रदीप्ति सुविधा से युक्त एक्स तथा क्यू बैंड ई पी आर स्पेक्ट्रममापी तथा एस क्यू यू आई डी (स्किवड) आधारित मैग्नेटोमीटर संस्थापित किए गए जबकि राइबर आण्विक किरण पुंज अधिरोहण (एम बी ई) प्रणाली का संस्थापन कार्य पूरा किया गया। एक नई स्पंदित लेजर निक्षेपण प्रयोगशाला स्थापित की गई। एक प्राथमिक आवृत्ति मानक (भारत–CsF1) के रूप में सीजियम (Cs) परमाण्विक फाउंटेन पूरी तरह से प्रचालित कर दिया गया। एन आई एस टी, संयुक्त राज्य अमेरिका के सहयोग से 10 वोल्टता के स्तर पर एक प्रोग्रामनीय जोसेफसन वोल्टता मानक संस्थापित किया गया। लंबाई, कठोरता, कंपन, ध्वनि तथा विद्युत से संबंधित प्राचलों (पैरामीटरों) के लिए अनेक अन्य प्राथमिक तथा द्वितीयक मानक स्थापित किए गए। उच्च गुणवत्ता से युक्त युवा अनुसंधानकर्ताओं को विकसित करने तथा उन्हें सभी प्रकार की सुविधाएं उपलब्ध कराने से संबंधित हमारी योजना

जारी रही तथा 15 नए वैज्ञानिकों की भर्ती की गई।

इस वार्षिक रिपोर्ट में विभिन्न अनुसंधान कार्यक्रमों के अंतर्गत हुई प्रगति तथा प्राप्त की गयी उपलब्धियों पर प्रकाश डाला गया है तथा अन्य ऐसी सभी सूचनाओं का भी सार प्रस्तुत किया गया है, जिनसे वर्ष 2011–12 के दौरान संस्थान द्वारा किए गए सभी कार्यों के संबंध में एक सम्यक जानकारी प्राप्त होती है। इसमें 12वीं पंचवर्षीय योजना के अंतर्गत अनुसंधान के क्षेत्र में निर्धारित की गई प्राथमिकताओं की रूपरेखा भी प्रस्तुत की गई है।

प्रयोगशाला के विभिन्न संघटक प्रभागों के अधीन सकेंद्रित अनुसंधान तथा विकास कार्य किए गए। प्रयोगशाला के अंतर्गत कार्य कर रहे प्रभागों का प्रतिपाद्य विषय के आधार पर नवगठन किया गया है, जिनके नाम क्रमशः (1) ऊर्जा संचयन भौतिकी प्रभाग, (2) पदार्थ भौतिकी और इंजीनियरिंग प्रभाग, (3) रेडियो एवं वायुमंडलीय विज्ञान प्रभाग, (4) समय तथा आवृत्ति प्रभाग, (5) शीर्ष स्तरीय मानक एवं औद्योगिक मापिकी प्रभाग, तथा (6) क्वांटम परिघटना एवं अनुप्रयोग प्रभाग हैं। पदार्थ अभिलक्षणन हेतु एक सहायक एकक के रूप में परिष्कृत एवं विश्लेषणात्मक उपकरण प्रभाग का गठन किया गया।

नवगठित ऊर्जा संचयन भौतिकी प्रभाग द्वारा एकल क्रिस्टल तथा बहुल क्रिस्टलयुक्त सौर सेलों के लिए नवीन प्रतिपरावर्तन तथा पृष्ठ निष्क्रियण प्रक्रम के विकास में उल्लेखनीय प्रगति की गई है। उन्नत कार्बनिक प्रकाशवोल्टीय युक्तियों के लिए दीप्त ग्रैफीन क्वांटम बिंदुओं तथा विलयशील अभिलक्षणित फुलरीन के प्रयोग की संभावना ज्ञात की गई। उन्नत ताप वैद्युत युक्तियों के लिए निम्न विमीय बिस्मथ टेल्युराइड मिश्र धातुओं के विकास में प्रगति हासिल की गई। ट्राइबोलॉजिकल आवरणों तथा तनु परतयुक्त सौर सेलों के लिए उन्नत प्लाज्मा सहाय्य निक्षेपण प्रक्रम विकसित किए गए।

पदार्थ भौतिकी और इंजीनियरिंग प्रभाग ने सी एस आई आर नेटवर्क परियोजना – नेटवर्कों के माध्यम से सौर ऊर्जा के उपयोग हेतु प्रौद्योगिकियां तथा उत्पाद (टी ए पी एस यू एन) के अंतर्गत "सौर ऊर्जा तथा अपशिष्ट ऊष्मा के उपयोग हेतु नए ताप वैद्युत पदार्थों तथा युक्तियों का विकास" तथा "लिथियम आयन एवं हलके भार वाली सीसा–अम्ल बैटरी" नामक दो नए क्रियाकलाप शुरू किए हैं। इन क्रियाकलापों को SiGe, Mg_2Si, अर्ध–हाइसलर तथा अन्य वर्धित योग्यता युक्त पदार्थों जैसे नए ताप वैद्युत पदार्थों को विकसित करने के लिए आरंभ किया गया। नैनो संरचनाओं के अभिकल्पन, संश्लेषण, अभिलक्षण तथा ताप वैद्युत गुणों के मूल्यांकन हेतु कार्य करने के लिए एक पूर्णतः सुसज्जित ताप वैद्युत प्रयोगशाला स्थापित की गई। सी एस आई आर–एन पी एल तथा भाभा परमाणु अनुसंधान केंद्र (बी ए आर सी) के बीच हस्ताक्षरित एक समझौता ज्ञापन के अंतर्गत बी.ए.आर.सी. द्वारा प्रस्तावित किए जा रहे संगत उच्च ताप नाभिकीय रिऐक्टर में प्रयोग हेतु कार्बन–कार्बन (C/C) सम्मिश्र ईंधन नलिकाओं को विकसित करने की क्षमता प्रदर्शित की गई। कार्बन–कार्बन (C/C) सम्मिश्र उच्च ऊष्मा चालकता, निम्न तापीय प्रसार गुणांक, उच्च ऊष्मीय आघात प्रतिरोध, उच्च सामर्थ्य तथा रासायनिक दृष्टि से अक्रियता जैसे उच्च ताप यांत्रिक गुणों से युक्त होने के कारण अधिक उपयुक्त पदार्थ हैं। इस समझौता ज्ञापन के निर्दे ानुसार चार कार्बन–कार्बन (C/C) सम्मिश्र नलिकाएं, बी.ए.आर.सी. के वैज्ञानिकों को फील्ड परीक्षणों तथा पश्च–किरणन मूल्यांकन हेतु सौंपे गए।

संदीप्ति के क्षेत्र में जल–विरोधी (हाइड्रोफोबिक) सिलिका जेल नैनो कणों से समस्वरणीय प्रकाश संदीप्ति कोर–कवच अप–कनवर्जन नैनो फॉस्फर्स तथा प्रकाशीय द्विक्रियात्मक नैनो फॉस्फर्स को प्रदर्शन, सौर सेल दक्षता संवर्धन तथा जैव–चिकित्सीय अनुप्रयोगों के लिए विकसित किया गया। गत वर्ष कुछ नए जैव संवेदकों को विकसित किए जाने के साथ ही विद्यमान जैव संवेदकों (बायो सेंसरों) के संवर्धन भी किया गया। ल्युकीमिया (रक्त कैंसर) के लिए विशिष्ट डी एन ए अनुक्रम अभिज्ञात किया गया तथा ल्युकीमिया के लिए अत्यधिक संवेदनशील एक जैव संवेदक (बायो सेंसर) का संरचन किया गया। इस संवेदक का सेना अस्पताल (आर एंड आर) द्वारा रोग लक्षण से युक्त प्रतिदर्शों के आधार पर वैधीकरण किया जा रहा है। कोलेस्टेरॉल जैव संवेदक संसूचन रेंज (रैखिक रेंज) का 50 मिलीग्राम प्रति डेसि लीटर से लेकर 300 मिली ग्राम प्रति डेसि लीटर तक की रेंज में संवर्धन किया गया। कम लागत पर जैव संवेदक के संरचन हेतु कागज की पट्टियों पर वैद्युत रासायनिक बहुलकीकरण का एक नया प्रक्रम विकसित किया गया। ई–कोलाई (जलवाहित रोग) के संसूचन हेतु जैव सुसंगत डेन्ड्राइमर आधारित जैव संसूचक को विकसित किया गया। फॉस्फेट बफर विलयन में अनुकूलतम दशाओं के अंतर्गत लक्षित हृद्–जैव मार्करों के प्रमात्रीकरण हेतु वैद्युत रासायनिक संवेदकों के रूप में प्रयुक्त आई टी ओ–कांच इलैक्ट्रोडों के आशोधन के लिए 5–10 नैनो मीटर अमाप के कार्बोक्सिल अभिलक्षणयुक्त जिंक सल्फाइड, स्वर्ण तथा प्लैटिनम के नैनो कणों का संश्लेषण किया गया।

रेडियो एवं वायुमंडलीय विज्ञान प्रभाग ने 12वीं पंचवर्षीय योजना के अंतर्गत एक नेटवर्क परियोजना का आरंभ किया। इस परियोजना का लक्ष्य भारत में स्थित गंगा के समतल मैदानी भागों तथा हिमालय क्षेत्रों में मानवीय तथा प्राकृतिक विक्षोभ के

कारण परिवर्तित हो रहे वायुमंडल का अन्वेषण करना तथा परिवर्तित हो रहे वायुमंडल के कारण कृषि, वनस्पतियों की विविधता तथा मानव स्वास्थ्य पर पड़ने वाले प्रभावों का अन्वेषण करना है। रेडियो विज्ञान क्षेत्र में एशियाई जोन में विभिन्न स्थानों से आयनसोण्डे आंकड़ों का प्रयोग करके अनेक समतापमंडलीय ऊष्मायन घटनाओं के प्रति आयनमंडलीय अनुक्रियाओं का अन्वेषण किया गया। दिल्ली तथा उत्तरी भारत के शहरी तथा अर्ध–शहरी क्षेत्रों में 1.8 गीगा हर्ट्ज सेल्युलर आवृत्ति संकीर्ण बैंड मापों का प्रयोग करके विभिन्न पूर्वानुमान मॉडलों की उपयुक्तता की जांच करने का एक प्रयास किया गया।

कचरों के भराव स्थल (लैंड फिल) मिथेन गैस के उत्सर्जन के प्रमुख स्रोत हैं, जो भूमंडलीय तापन (ग्लोबल वार्मिंग) तथा जलवायु परिवर्तन में योगदान करता है। शहरीकरण में वृद्धि होने से इस स्रोत से ग्लोबल वार्मिंग में योगदान निरंतर बढ़ रहा है। भारत के विभिन्न शहरों में भराव स्थलों में निक्षेपित नगरपालिका ठोस कचरों से सी एस आई आर–एन पी एल द्वारा निर्धारित मिथेन उत्सर्जन गुणक का प्रयोग करके वार्षिक मिथेन उत्सर्जन का आकलन किया गया। इसके अतिरिक्त, जलवायु प्रतिरूपण हेतु भारत के विभिन्न राज्यों में प्रयुक्त विभिन्न प्रकार के जैव ईंधनों के लिए कार्बोनिक कार्बन तथा तात्विक कार्बन उत्सर्जनों के संबंध में उत्सर्जन गुणकों का आकलन किया गया। भारत में गंगा के समतल मैदानी भागों के ऊपर अकार्बनिक ऐरोसॉल (वायु में विलीन कणों) के निर्माण में परिवेशी अमोनिया की भूमिका का भी अध्ययन किया गया। क्षोभमंडल में N_2O और C_2H_6 के वास्तविक प्रोफाइलों की पुनः प्राप्ति हेतु ब्रूकर 125 एच आर का प्रयोग करके दिल्ली में सौर उपगूहन स्पेक्ट्रम दर्ज किए गए हैं। दिल्ली में मौसमी, वार्षिक तथा मध्य–वार्षिक परिवर्तनों की जांच करने के लिए ऐरोसॉल प्रकाशीय गहराई तथा ऐंग्स्ट्रॉम प्राचलों के दीर्घकालिक स्पेक्ट्रम परिवर्तनों का अध्ययन किया गया है।

भारत तथा दक्षिण एशियाई क्षेत्र में पृष्ठीय ओजोन मापनों में अनुमार्गणीयता प्रदान करने के लिए एक प्राथमिक ओजोन मानक सुविधा स्थापित की गई तथा अत्यधिक सावधानीपूर्वक की गई समीक्षा के सफलतापूर्वक समापन के पश्चात् इसके लिए अंशांकन मापन क्षमता (सी एम सी) के बारे में जानकारी प्रस्तुत की गई है। अंटार्कटिका में लार्समैन पहाड़ियों पर "भारती" नामक एक नए भारतीय अनुसंधान केंद्र (69^0 24' दक्षिण, 76^0 11' पूर्व) जो वर्तमान "मैत्री" (70^0 45' दक्षिण, 11^0 44' पूर्व) केंद्र से 3000 किलोमीटर दूर है, में अंतरिक्ष भौतिकी प्रयोगशाला स्थापित करने के प्रयास किए गए। यह एक अत्यधिक प्रसन्नता का विषय है कि "भारती" के लिए जाने वाले "31वें भारतीय अंटार्कटिका अभियान दल" का नेतृत्व पहली बार हमारी इस प्रयोगशाला से डॉ. रूपेश एम. दास कर रहे हैं।

शीर्ष स्तरीय मानक एवं औद्योगिक मापिकी प्रभाग देश की अंशांकन तथा परीक्षण प्रयोगशालाओं को न केवल अंशांकन के माध्यम से अनुमार्गणीयता उपलब्ध कराने के लिए बल्कि प्रशिक्षण उपलब्ध कराकर तथा विभिन्न प्राचलों में प्रवीणता परीक्षण आयोजित करके इन प्रयोगशालाओं के मापन आश्वासन कार्यक्रम (एन ए पी) के अनुरक्षण हेतु भी सहायता करता रहा। इस प्रभाग के अनेक समूह अंतर्राष्ट्रीय अंतर तुलन की क्षमता के अनुरक्षण हेतु कार्य कर रहे हैं। इस प्रभाग द्वारा हमारे देश में तथा पड़ोसी देशों में भी मापिकी के क्षेत्र में कुशल जनशक्ति के विकास हेतु विभिन्न प्राचलों में प्रशिक्षण कार्यक्रमों का आयोजन किया गया। प्राप्त की गई कुछ उल्लेखनीय उपलब्धियों में निम्नलिखित शामिल हैं: (i) चार मीटर तक के लम्बे गेज ब्लॉक, (ii) उच्च ताप कृष्णिका स्रोत, (iii) रॉकवेल, विकर्ज तथा ब्रिनेल स्केलों के लिए द्वितीयक कठोरता मानकीकरण मशीन, (iv) मानक प्रेरक के अध्ययन हेतु एक नई सुविधा, (v) रेडियो फ्रीक्वेंसी (आर एफ) विद्युत के अभिलक्षणन हेतु 1 मेगा हर्ट्ज से 2 गीगा हर्ट्ज तक फ्रीक्वेंसी रेंज में मापन सुविधा। इस प्रभाग द्वारा प्राप्त की गई एक अन्य उपलब्धि $k = 2$ पर ± 28 µg के रूप में एक किलो ग्राम की अंशांकन तथा मापन क्षमता (सी एम सी) प्राप्त करना था, जिसे पी टी बी (जर्मनी) तथा के आर आई एस एस (कोरिया) जैसी कुछ राष्ट्रीय मापिकी संस्थानों द्वारा ही प्राप्त की गई हैं।

समय तथा आवृत्ति प्रभाग, जो अति स्थायी परमाण्विक फ्रीक्वेंसी स्रोतों, अतप्त परमाणुओं की भौतिकी तथा परिशुद्ध समय मापन प्रणालियों जैसे क्रियाकलापों को करता है, द्वारा कुछ महत्त्वपूर्ण वैज्ञानिक उपलब्धियां प्राप्त की गईं। इस प्रभाग द्वारा प्राप्त की गई उपलब्धियों में सीजियम (Cs) फाउंटेन को एक प्राथमिक आवृत्तिमानक के रूप में पूरी तरह से प्रचालित करना; टाइमस्केल–यू टी सी (सी एस आई आर–एन पी एल आई) को एक स्टियर्ड हाइड्रोजन मेसर आउटपुट पर आधारित तथा पांच Cs घड़ियों के समूह द्वारा समर्थित और अधिक स्थायी रूप में उन्नयन करना; सी एस आई आर–एन पी एल के अंतर्राष्ट्रीय बाट तथा माप ब्यूरो (बी आई पी एम) अनुमार्गणीयता की परिशुद्धता में वृद्धि हेतु एक दोहरे आवृत्ति बहु–चैनलयुक्त जी पी एस रिसीवर तथा द्विदिशिक उपग्रह, समय तथा आवृत्ति अंतरण (टी डब्ल्यू एस टी एफ टी) लिंक संस्थापित करना शामिल हैं। इसके अतिरिक्त, दूसरी पीढ़ी के Cs फाउंटेन जो एक नूतन प्रकाशीय प्रणोदित Cs फाउंटेन है, का अभिकल्पन तथा विकास आरंभ किया गया। इस प्रभाग ने इसरो के आई आर एन एस एस नेविगेशन प्रणाली के लिए एक Rb आवृत्ति मानक

के लिए अभिकल्प वैधीकरण मॉडल पर भी कार्य किया तथा स्टॉप वाचों, टाइमरों, फ्रीक्वेंसी काउंटरों, Cs तथा Rb घड़ियों, जी पी एस एवं टेलीक्लॉक रिसीवरों के रूटीन अंशांकनों से संबंधित कार्यों का भी निर्वहन किया। वर्ष के दौरान, अधिप्राप्त तथा स्थापित प्रमुख सुविधाओं में हाइड्रोजन मेसर, टी डब्ल्यू एस टी एफ टी लिंक तथा वाणिज्यिक Cs घड़ी जैसी सुविधाओं के नाम उल्लेखनीय हैं।

परिष्कृत और विश्लेषणात्मक उपकरण प्रभाग (एस ए आई डी) जिसमें चार समूह अर्थात एक्स किरण विश्लेषण, इलेक्ट्रॉन तथा आयन सूक्ष्मदर्शिकी, ई पी आर और आई आर स्पेक्ट्रमविज्ञान तथा विश्लेषणात्मक रसायन विज्ञान से संबंधित समूह शामिल हैं, पदार्थ के विभिन्न पहलुओं से संबद्ध मूलभूत अभिलक्षणों अर्थात रासायनिक संघटन, शुद्धता, संरचना (त्रुटियों सहित) और क्रिस्टलीय पूर्णता से संबंधित अध्ययन करने के कार्य के प्रति समर्पित रहा। इस प्रभाग में उच्च वियोजन क्षमतायुक्त एक्स किरण विवर्तनमापी (एच आर एक्स आर डी) एवं एक्स किरण परावर्तनमापी (एक्स आर आर प्रणाली), पूर्णतः स्वचालित एक्स किरण दीप्ति स्पेक्ट्रममापी, परिवर्ती दाब क्रमवीक्षण इलेक्ट्रॉन सूक्ष्मदर्शी (एस ई एम), उच्च वियोजन क्षमतायुक्त संचरण इलेक्ट्रॉन सूक्ष्मदर्शी (टी ई एम) जो ऊर्जा परिक्षेपी एक्स किरण स्पेक्ट्रमदर्शी तथा क्रमवीक्षण टी ई एम सुविधा से युक्त हैं, इलेक्ट्रॉन अनुचुम्बकीय अनुनाद (ई पी आर) स्पेक्ट्रममापी, परमाणु बल सूक्ष्मदर्शी/चुम्बकीय बल सूक्ष्मदर्शी (एफ एम/ एम एफ एम), गौण आयन द्रव्यमान स्पेक्ट्रममिति (एस आई एम एस) तथा क्रमवीक्षण अन्वेषी सूक्ष्मदर्शी (एस पी एम) आदि जैसे उच्च गुणवत्तायुक्त उपकरण उपलब्ध हैं। प्रेरण युग्मित प्लाज्मा – उच्च वियोजन द्रव्यमान स्पेक्ट्रममिति (आई सी पी–एच आर एम एस) तथा एक नया एक्स एवं क्यू बैंड ई पी आर स्पेक्ट्रममापी को हाल ही में संस्थापित किया गया है।

परिष्कृत और विश्लेषणात्मक उपकरण प्रभाग (एस ए आई डी) के क्रिस्टल वृद्धि तथा एक्स किरण विश्लेषण समूह ने लौह तथा जस्ता मादित $LiNbO_3$, BSO, LC- योजित बेंजोफेनॉन आदि जैसे प्रौद्योगिकीय दृष्टि से महत्त्वपूर्ण एकल क्रिस्टलों का जोक्रैल्सकी विधि द्वारा तथा अनेक प्रकार के अरैखिक प्रकाशीय कार्बनिक तथा अर्ध–कार्बनिक छस्ट क्रिस्टलों {क्रोमियम मादित ZTS, LHN, L-ऐलानिन मादित KDP, मैंगनीज मादित, L–ऐलानिन, ग्लाइसीन फॉस्फाइट, ट्रांस–स्टिलबिन आदि} का विलयन विकास विधियों द्वारा सफलतापूर्वक उत्पादन किया है। NLO क्रिस्टलों में मादन को विशेष रूप से लक्षित किया गया ताकि इसके गुणों को तदनुकूल अनुप्रयोगों के लिए उपयोग में लाया जा सके। सी ई ई आर आई–पिलानी द्वारा किए गए क्रियाकलापों तथा संस्था के भीतर किए गए क्रियाकलापों की सहायता से वर्धित क्रिस्टलों तथा विभिन्न प्रकार के MOCVD एवं MBE द्वारा विकसित की गई GaN आधारित सॉलिड स्टेट प्रकाश उत्सर्जी डायोड संरचनाओं का विभिन्न प्रकार की तकनीकों के द्वारा अभिलक्षणन किया गया। इलेक्ट्रॉन तथा आयन सूक्ष्मदर्शिकी समूह की मुख्य उपलब्धियां निम्नवत रहीं: (i) वायुमंडलीय परिवेशी कणों के आकारिकी अभिलक्षणन द्वारा ऐरोसॉल प्रकाशीय प्रतिरूपण हेतु डेटाबेस तैयार करना (आई आई टी, कानपुर के सहयोग से); (ii) सामान्य ताप पर एक सक्षम गैस संवेदक के रूप में ZnO सज्जित संदीप्तिशील ग्रैफीन को एक बृहत संवेदक अनुक्रिया तथा शीघ्र पुनः प्राप्ति समय से युक्त तथा कार्बन मोनोऑक्साइड और अमोनिया जैसी इलेक्ट्रॉन दाता गैसों के प्रति अधिमानित चयन क्षमता से युक्त रूप में विकसित किया गया; तथा (iii) जिंक परऑक्साइड नैनो कणों का प्रयोग करके जल से आर्सेनिक तथा क्रोमियम को हटाने के लिए एक अमेरिकी पेटेंट दर्ज कराया गया। ई पी आर स्पेक्ट्रम विज्ञान समूह द्वारा स्व–संवर्धित तथा तापानुशीतित अवस्थाओं में $Ni_{0.5}\ Zn_{0.5}\ Gd_x\ Fe_{2-x}\ O_4$ ($x = 0.1, 0.2, 0.3$) नैनो कणों के संबंध में स्पेक्ट्रमी अध्ययन किए गए। विश्लेषणात्मक रसायन विज्ञान समूह में O_3 तथा तात्विक विलयनों में 13 सी एम सी हेतु अंतर्राष्ट्रीय स्तर पर अत्यधिक सावधानीपूर्वक समीक्षा कार्यों को सफलतापूर्वक पूरा किया गया। पांच नए तात्विक जलीय प्रमाणित संदर्भ पदार्थों अर्थात Pb (2 प्रकार), Cr, Ca तथा SO_4 तैयार किए गए तथा उन्हें गुणवत्ता प्रबंधन प्रणाली के अनुरूप प्रमाणित किया गया।

मानव संसाधन विकास के क्षेत्र में सी एस आई आर–एन पी एल ने देश भर में फैली विभिन्न शैक्षिक संस्थाओं से एम एस सी/एम टेक/ एम सी ए या इनके समकक्ष उपाधि पाठ्यक्रमों में अध्ययन कर रहे विद्यार्थियों को प्रशिक्षण प्रदान किया। वर्ष के दौरान लगभग 126 विद्यार्थियों को अल्पकालिक तथा दीर्घकालिक प्रशिक्षण प्रदान किए गए। सी एस आई आर–एन पी एल ने "उन्नत पदार्थ भौतिकी तथा इंजीनियरी" विषय में इंजीनियरी में एक स्नातकोत्तर अनुसंधान कार्यक्रम (पी जी आर पी ई) आरंभ किया जिसमें 10 विद्यार्थियों को प्रवेश दिया गया। वर्ष के दौरान राष्ट्रीय भौतिक प्रयोगशाला में शामिल होने के लिए 29 नए अनुसंधान अध्येता अभिप्रेरित हुए जिससे इनकी कुल संख्या 96 हो गई। वैज्ञानिक तथा नव अनुसंधान अकादमी (ए सी एस आई आर)[1] के अंतर्गत 34 विद्यार्थियों का भौतिक तथा रासायनिक विज्ञान में पीएच डी के लिए पंजीकरण किया

[1] वैज्ञानिक तथा नव अनुसंधान अकादमी की स्थापना दिनांक 07 फरवरी, 2012 के भारत के राजपत्र संख्या 15 द्वारा जारी तथा 03 अप्रैल, 2012 को अधिसूचित संसद के एक अधिनियम, वैज्ञानिक नव अनुसंधान अकादमी अधिनियम, 2011 द्वारा की गई।

गया। अन्य विश्वविद्यालयों जैसे कि भारतीय प्रौद्योगिकी संस्थानों, दिल्ली विश्वविद्यालय, दिल्ली प्रौद्योगिकीय विश्वविद्यालय तथा जवाहर लाल नेहरू विश्वविद्यालय आदि में पीएच डी की उपाधि के लिए पहले से ही 60 विद्यार्थी पंजीकृत हैं। मापिकी तथा अन्य विशिष्ट विषयों से संबंधित क्षेत्रों में औद्योगिक प्रशिक्षण कार्यक्रम का भी आयोजन किया गया। इन प्रशिक्षण पाठ्यक्रमों में विभिन्न राष्ट्रीय तथा अंतर्राष्ट्रीय संगठनों ने भाग लिया। राजभाषा एकक द्वारा 1–3 सितंबर, 2011 के दौरान "सौर ऊर्जा अनुप्रयोगों हेतु पदार्थ युक्तियों में हाल में की गई प्रगति" विषय पर हिंदी में भी एक राष्ट्रीय सेमिनार का आयोजन किया गया।

विद्यालयों, महाविद्यालयों, विश्वविद्यालयों, तकनीकी संस्थानों, विज्ञान तथा प्रौद्योगिकीय संगठनों से विद्यार्थियों, शिक्षकों, संकाय सदस्यों को शामिल करके संस्थागत दौरों का आयोजन करना सी एस आई आर–एन पी एल का एक महत्त्वपूर्ण क्रियाकलाप है। वर्ष के दौरान 11 संस्थागत दौरे आयोजित किए गए जिनसे समाज में सी एस आई आर–एन पी एल की साख को बढ़ाने में सहायता प्राप्त हुई। मापिकी तथा गुणवत्ता प्रबंधन प्रणाली के क्षेत्र में औद्योगिक प्रशिक्षण भी आयोजित किए गए। इस प्रकार के चार पाठ्यक्रम आयोजित किए गए जिनमें विभिन्न उद्योगों, परीक्षण तथा अंशांकन प्रयोगशालाओं एवं अन्य विभिन्न राष्ट्रीय तथा अंतर्राष्ट्रीय विज्ञान एवं प्रौद्योगिकी संगठनों के कार्मिकों ने भाग लिया।

वर्ष के दौरान, एस सी आई में सूचीबद्ध पत्रिकाओं में कुल 330 वैज्ञानिक तथा तकनीकी शोध पत्रों का प्रकाशन किया गया। 42 शोध पत्रों का प्रभाव गुणक 4 से 13 की रेंज में था। विदेश में 10 पेटेंट दर्ज कराए गए तथा 6 पेटेंट भारत में दर्ज कराए गए। पूर्व के वर्षों में दर्ज कराए गए 6 अंतर्राष्ट्रीय पेटेंटों तथा 5 भारतीय पेटेंटों को 2011–12 के दौरान स्वीकृति प्रदान की गई। वर्ष के दौरान, 17 नई परियोजनाएं (प्रायोजित और परामर्शदात्री) शुरू की गईं तथा 2243 अंशांकन रिपोर्टें जारी की गईं जिससे लगभग 425 लाख रुपए का ई सी एफ अर्जित किया गया।

20 मई, 2011 को "विश्व मापिकी दिवस" और साथ ही "राष्ट्रीय प्रौद्योगिकी दिवस" का भी आयोजन किया गया। जैसा कि ब्यूरो इंटरनेशनल डेस पोइड्स एट मेजर (बी आई पी एम, पेरिस) द्वारा निर्णय लिया गया था, "विश्व मापिकी दिवस" की विषय–वस्तु (थीम) "विज्ञान एवं प्रौद्योगिकी में मापिकी–मापन : नव प्रवर्तन की दिशा में एक सेतु" था। इस विषय की, इस अवसर पर आमंत्रित किए गए प्रोफेसर श्रीकुमार बनर्जी, अध्यक्ष, ए ई सी तथा सचिव, परमाणु ऊर्जा विभाग, भारत सरकार तथा भारतीय राष्ट्रीय विज्ञान अकादमी (इन्सा) के अध्यक्ष डॉ. कृष्ण लाल जैसे विशिष्ट वक्ताओं द्वारा, उदाहरण सहित विस्तृत व्याख्या प्रस्तुत की गई। डॉ. लाल ने इस अवसर पर आरंभिक भाषण दिया तथा डॉ. बनर्जी ने "रसायन विज्ञान तथा नाभिकीय ऊर्जा" विषय पर एक अत्यधिक रोचक तथा ज्ञानवर्धक प्रमुख भाषण दिया।

माननीय विज्ञान एवं प्रौद्योगिकी, पृथ्वी विज्ञान मंत्री तथा वैज्ञानिक एवं औद्योगिक अनुसंधान परिषद् (सी एस आई आर) के उपाध्यक्ष श्री विलासराव देशमुख[2] ने 22 सितंबर, 2011 को राष्ट्रीय भौतिक प्रयोगशाला का सद्भावना दौरा किया। इस दौरान, आपने राष्ट्रीय भौतिक प्रयोगशाला में कार्य कर रहे वैज्ञानिकों के साथ भेंट की और उनके साथ काफी घनिष्ठ वार्तालाप किया और साथ ही उन्हें संबोधित भी किया। आपने कुछ महत्त्वपूर्ण अनुसंधान क्रियाकलापों और हाल में सृजित की गईं अत्याधुनिक सुविधाओं का भी दौरा किया तथा उनकी सराहना की। इस अवसर को यादगार बनाने के लिए आपने वैज्ञानिक एवं औद्योगिक अनुसंधान परिषद् (सी एस आई आर) तथा सी एस आई आर–एन पी एल के अधिकारियों के साथ मिलकर राष्ट्रीय भौतिक प्रयोगशाला के मुख्य भवन के सामने *कैलिस्टीमॉन लैनसिओलैटस* का पौधरोपण भी किया।

खुला दिवस समारोह वैज्ञानिकों तथा राष्ट्रीय भौतिक प्रयोगशाला में किए जा रहे अत्याधुनिक अनुसंधान कार्यों के बारे में जानने में रुचि रखने वाले व्यक्तियों के बीच पारस्परिक संपर्क स्थापित करने का एक अवसर है जो वर्ष में एक बार आता है। सी एस आई आर–एन पी एल द्वारा वैज्ञानिक एवं औद्योगिक अनुसंधान परिषद् (सी एस आई आर) के स्थापना दिवस समारोहों के एक हिस्से के रूप में 28 सितंबर, 2011 को खुला दिवस समारोह आयोजित किया गया। इस समारोह में विद्यालयों तथा महाविद्यालयों के विद्यार्थियों सहित लगभग 1900 व्यक्तियों ने भाग लिया।

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[2] श्री विलास राव देशमुख की 13 अगस्त, 2012 को अत्यंत दुखद तथा असमय मृत्यु के बारे में जानकर अत्यधिक आघात पहुंचा। यह एक अविश्वसनीय घटना थी। हम अभी भी एन पी एल के उनके दौरे पर आने तथा यहां के कर्मचारियों के साथ उनके द्वारा की गई बातचीत की मधुर स्मृतियों से ओत–प्रोत हैं। मैं अपनी ओर से तथा सी एस आई आर–एन पी एल के समस्त कर्मचारियों की ओर से शोक संतप्त परिवार के लिए अपनी हार्दिक संवेदना व्यक्त करता हूं।

सर सी वी रामन द्वारा किए गए वैज्ञानिक अनुसंधानों तथा उनके द्वारा 28 फरवरी, 1928 को रामन प्रभाव की खोज करने की स्मृति में उन्हें सम्मानित करने के लिए 28 फरवरी, 2012 को राष्ट्रीय विज्ञान दिवस–2012 मनाया गया। पूर्व में आई आई टी, दिल्ली से सम्बद्ध प्रोफेसर केहर सिंह ने "सुरक्षा होलोग्राम" विषय पर अपना उद्घाटन व्याख्यान दिया। इस अवसर पर एक पोस्टर प्रस्तुतीकरण कार्यक्रम भी आयोजित किया गया जिसमें सी एस आई आर–एन पी एल के सभी अनुसंधान अध्येताओं के कार्यों की प्रदर्शनी आयोजित की गई। प्रोफेसर केहर सिंह ने विद्यार्थियों के साथ अत्यधिक घनिष्ठ संपर्क स्थापित किया तथा उन्हें प्रोत्साहित करने के लिए आपने 5 सर्वोत्तम पोस्टर पुरस्कार भी वितरित किए।

वैज्ञानिक अनुसंधान कार्यों से हटकर हमने 25–26 फरवरी, 2012 के दौरान आई ए आर आई, दिल्ली में आयोजित पूसा बागबानी प्रदर्शनी में भी भाग लिया। इस प्रदर्शनी में 16 श्रेणियों में प्रस्तुत की गई 105 प्रविष्टियों में से हमने 103 पुरस्कार जीते जिनमें 33 प्रथम पुरस्कार, 58 द्वितीय पुरस्कार, 12 तृतीय पुरस्कार तथा 7 चैलेंज कप/शील्ड शामिल थे। हमारे बागबानी अनुभाग द्वारा किए गए प्रयास अत्यधिक प्रभावोत्पादक थे।

ये सभी उपलब्धियां सी एस आई आर–एन पी एल में कार्य कर रहे सभी कर्मचारियों तथा युवा अनुसंधानकर्ताओं द्वारा एकजुट होकर पूरी निष्ठा के साथ की गई सहायता के कारण संभव हो पाई। मैं इसकी हृदय से सराहना करता हूं। मैं इस अवसर पर सी एस आई आर मुख्यालय, अनुसंधान परिषद् तथा प्रबंध परिषद् से समय–समय पर प्राप्त मूल्यवान मार्गदर्शन, सहायता तथा प्रोत्साहन, जो हमें हमारे लक्ष्यों को पूरा करने में अत्यधिक सहायक सिद्ध हुए, की भी सराहना करता हूं। सी एस आई आर–एन पी एल में राष्ट्रीय तथा अंतर्राष्ट्रीय विशेषज्ञों द्वारा किए गए नियमित दौरे अत्यधिक लाभकारी तथा मूल्यवान सिद्ध हुए हैं।

अंत में, मैं इस रिपोर्ट को प्रकाशित करने के लिए डॉ. वीरेंद्र शंकर के नेतृत्व में प्रकाशन समिति द्वारा किए गए योगदान के लिए उनका आभार व्यक्त करता हूं। डॉ. शंकर, श्री राघवेंद्र, श्री एन.के. वाधवा, श्री प्रेम चंद, सुश्री अनीता शर्मा, सुश्री सरोज उपाध्याय और श्री सुभाष चंद्र द्वारा किए गए सहयोग तथा विशेष प्रयास अत्यधिक सराहनीय हैं।

(आर सी बुधानी)
निदेशक

From the Director's Desk...

The Annual Report of CSIR-National Physical Laboratory (NPL) for the year 2011-12 is placed before you. It was a pleasure preparing the same.

CSIR-NPL is a premier physics laboratory as well as the National Metrology Institute of India. It is actively pursuing frontier areas of research in Physical Sciences and Metrology. The year, 2011-12, had been very creative, exciting as well as inspiring for us. The process of reorientation and transformation continued for achieving greater external visibility in forefront areas of advance research. One could feel the steady increase in the volume and quality of work as CSIR-NPL kept evolving into an ever more internationally oriented institute.

Efforts continued during the year to develop and establish the state-of-the-art characterization facilities and best-in-class experimentation setup in priority areas of research. A focused ion beam (FIB) microscope, X&Q band EPR spectrometer with low temperature (≥ 3.5K) attachment and UV illumination facility and SQUID based magnetometer were installed while the commissioning of Riber Molecular Beam Epitaxy (MBE) System was completed. A new Pulsed Laser Deposition laboratory was set up. Cesium (Cs) atomic fountain became fully operational as a primary frequency standard (India-CsF1). A programmable Josephson Voltage Standard at 10 V level was installed with the support of NIST, USA. A number of other primary and secondary standards were established for the parameters of length, hardness, vibration, sound and power. Our plan to grow and nurture high quality young researchers continued and 15 new scientists were recruited.

The Annual Report highlights the progress and achievements made under different research programmes and also summarize other information that provides an overview of the institute during the year 2011-12. It also outlines the research priorities of XII Five Year Plan.

Focused R&D was done under various constituent divisions of the laboratory. The seven newly structured theme-wise Divisions are recognized as (1) Physics of Energy Harvesting, (2) Materials Physics and Engineering, (3) Radio & Atmospheric Sciences, (4) Time & Frequency (5) Apex Level Standards & Industrial Metrology and (6) Quantum Phenomena & Applications. For Materials Characterization, Sophisticated & Analytical Instruments Division has been put in place as a support unit.

Newly created, Division of Physics of Energy Harvesting showed significant progress on the development of novel anti reflection and surface passivation processes for single crystal and multi-crystalline solar cells. Use of luminous graphene quantum dots and soluble functionalized fullerenes for advanced organic photovoltaic devices were investigated. Progress was achieved in the development of low dimensional bismuth telluride alloys for advanced thermoelectric devices. Improved plasma assisted deposition processes for tribological coatings and thin film solar cells were developed.

The Division of Materials Physics and Engineering initiated two new activities, under the CSIR Network Project - Technologies and Products for Solar-energy Utilization through Networks (TAP-SUN), namely, "Development of novel thermoelectric materials and devices for harnessing solar energy and waste heat" and "Lithium ion and light weight lead-acid battery". Work was started to develop novel thermoelectric materials such as, SiGe, Mg_2Si, half-Heusler and others with enhanced figure-of-merit. A well-equipped thermoelectric laboratory was established to work on the design, synthesis, characterization and thermoelectric property evaluation of nanostructures. Under an MoU between CSIR-NPL and Bhabha Atomic Research Center (BARC), the capability to develop carbon-carbon (C/C) composite fuel tubes for the application in Compact High Temperature Nuclear Reactor being proposed by BARC was demonstrated. Carbon-Carbon (C/C) composites were found to be more suitable materials due to their superior thermo – mechanical properties such as high thermal conductivity, low coefficient of thermal expansion, high thermal shock resistance, high strength and chemical inertness. Four numbers of C/C composite tubes as specified in the MoU, were handed over to the scientists of BARC for field trials and post irradiation evaluation.

In the area of Luminescence, tunable photoluminescence from hydrophobic silica gel nanoparticles, core-shell upconversion nanophosphors and optical bifunctional nanophosphors were developed for displays, enhancement of solar cell efficiency and biomedical applications. During the year, while some new biosensors were developed, performance enhancement of the existing ones was achieved. The DNA Sequence specific to Leukemia had been identified and a biosensor, very sensitive to leukemia (Blood cancer) was fabricated. The sensor is being validated with clinical patient samples from Army hospital (R&R). Cholesterol biosensor detection range (linear range) was improved to the range of 50 mg/dl to 300mg/dl. A new process of electrochemical polymerization onto paper strips was developed, for cost effective biosensor fabrication. Biocompatible dendrimer based biosensor was fabricated for e-coli (water borne disease) detection. Carboxyl functionalized ZnS, Au and Pt nanoparticles of 5-10 nm size were synthesized for modifying ITO-glass electrodes used as electrochemical sensors for the quantification of target cardiac biomarkers in phosphate buffer solution under optimum conditions.

Radio & Atmospheric Sciences Division initiated a network project under XII five year plan. The project aims at investigating the changing atmosphere due to human and natural perturbations over Indo-Gangetic plain and Himalayan regions and the impacts of changing atmosphere on agriculture, floral biodiversity and human health. In the Radio Science area, the investigation of ionospheric response to a number of stratospheric warming events using ionosonde data from different stations in the Asian zone was carried out. An attempt was made to investigate the suitability of various prediction models using the 1.8 GHz cellular frequency narrowband measurements conducted in urban and suburban areas of Delhi in northern India.

Landfills are major sources of methane emission contributing to the Global Warming and Climate Change. With the increasing urbanization, the contribution from this source is increasing. Annual Methane emission estimation from Municipal Solid Waste deposited in the Landfills in the different cities of India using the methane emission factor developed by CSIR-NPL was made. Further, for climate modeling, estimation of Emission Factors for organic carbon and elemental carbon emissions for different kinds of biofuel used in various Indian States was developed. Role of ambient ammonia in the formation of inorganic aerosol over Indo Gangetic Plain were also studied. Solar occultation spectra have been recorded in Delhi using Bruker 125 HR for retrieval of realistic profiles of N_2O and C_2H_6 in the troposphere. Long term spectral variations of Aerosol Optical Depth and Angstrom parameters have been studied to examine the seasonal, annual and inter-annual variations at Delhi.

A Primary Ozone Standard facility was established for providing traceability in surface Ozone measurements in India and South Asian Region and calibration measurement capability (CMC) for same has been submitted after successful completion of peer review. Efforts were made to set up Space Physics Laboratory at a new Indian Research Station "Bharati" (69°24'S, 76°11'E), at Larsemann Hills, Antarctica which is 3000 km away from the present "Maitri" (70°45'S, 11°44'E) Station. It is heartening that Dr. Rupesh M. Dass from the Laboratory is leading the 31st Indian Antarctica Expedition as its first leader to "Bharati".

The Division of Apex Level Standards and Industrial Metrology continued to help calibration and testing laboratories of the country not only for providing traceability through calibration but also for maintaining their Measurement Assurance Programme (MAP) by providing training and conducting proficiency testing in different parameters. Many groups of this division are participating in international inter comparisons to maintain their capability. Training programs in various parameters were organized for development of skilled man power in the field of metrology in the country as well as neighboring countries. Some of the significant achievements included: Establishing (i) Long Gauge Blocks up to 4 meter (ii) High Temperature Blackbody Source, (iii) Secondary hardness standardizing machines for Rockwell, Vickers and Brinell scales, (iv) A new facility for the Study of Standard Inductor, (v) Measurement facility in the frequency range of 1 MHz to 2 GHz for the characterization of RF power etc. Another accomplishment was CMC of 1 kg as ±28µg at k=2, which only a few other NMIs like PTB (Germany) and KRISS (Korea) have achieved.

Time and Frequency Division, which covers activities such as ultra stable Atomic Frequency Sources, Physics of Cold Atoms and Precise Timing Systems, had some significant scientific achievements. These included: Cs fountain becoming fully operational as a primary frequency standard; time scale –UTC (CSIR-NPLI) was upgraded to a more stable version based on a steered hydrogen maser output and backed up by an ensemble of five Cs clocks; Installation of a dual frequency multichannel GPS receiver and a Two Way Satellite Time & Frequency Transfer (TWSTFT) link to enhance the accuracies of CSIR-NPL's BIPM traceability. In addition to this, design and development of a second generation Cs fountain – Novel

Optically pumped Cs fountain was initiated. The division also worked on a Design Validation Model of a Rb frequency standard for ISRO's IRNSS navigation system and carried out routine calibrations of stop watches, timers, frequency counters, Cs and Rb clocks, GPS and Teleclock receivers. Major facilities that had been procured and installed during the year included: Hydrogen Maser, TWSTFT link and Commercial Cs clock.

Sophisticated & Analytical Instruments Division (SAID) comprising of four groups namely X-ray Analysis, Electron and Ion Microscopy, EPR & IR Spectroscopy and Analytical Chemistry remained dedicated to the basic characterization of materials regarding different aspects, namely, chemical composition, purity, structure (including defects) and crystallographic perfection. The division houses high quality facilities like High-Resolution X-ray Diffractometer (HRXRD) cum X-ray Reflectometer (XRR) system, Fully Automated X-ray Fluorescence Spectrometer, variable pressure Scanning Electron Microscope (SEM), high-resolution Transmission Electron Microscope (TEM) with Energy Dispersive X-ray Spectroscopy and Scanning TEM attachments, Electron Paramagnetic Resonance (EPR) spectrometer, Atomic Force Microscope/Magnetic Force Microscope (FM/MFM), Secondary ion mass spectrometry (SIMS) and Scanning Probe Microscope (SPM) etc. Inductively Coupled Plasma–High Resolution Mass Spectrometry (ICP-HRMS) and a new X and Q band EPR Spectrometer were recently installed.

Crystal Growth and X-ray Analysis group of SAID successfully grew technologically important single crystals like Fe and Zn doped $LiNbO_3$, BSO, LC-added Benzophenone etc by Czochralski method and variety of nonlinear optical organic and semiorganic NLO crystals [Cr-doped ZTS, LHN, L-alanine doped KDP, Mn-doped L-alanine, Glycine Phosphite, trans-stilbene etc.] by solution growth methods. Doping in NLO crystals were specially targeted as the properties could be engineered for tailor-made applications. The grown crystals and variety of MOCVD and MBE grown GaN based solid state light emitting diode structures from CEERI-Pilani and in-house activity were characterized by variety of techniques. The major achievements of Electron and Ion Microscopy group were: (i) Preparation of database for aerosol optical modeling by morphological characterization of atmospheric ambient particles (in collaboration with IIT, Kanpur) and (ii) ZnO decorated luminescent graphene as a potential gas sensor at room temperature was developed with a large sensor response and quick recovery time with preferred selectivity towards electron donor gases like CO and NH_3 and (iii) A US patent was filed for the removal of As and Cr from water using zinc peroxide nanoparticles. EPR Spectroscopy group carried out spectroscopic studies on $Ni_{0.5}$ $Zn_{0.5}$ $Gd_xFe_{2-x}O_4$ (x = 0.1, 0.2, 0.3) nanoparticles in as-grown and annealed states. In the Analytical Chemistry group, International Peer Review in O_3 & elemental solutions was completed successfully for 13 CMCs. Five new elemental aqueous certified reference materials namely Pb (2 types), Cr, Ca and SO_4 were prepared and certified according to quality management system.

Towards Human Resource Development, CSIR-NPL provided training to students, pursuing M.Sc./M. Tech./MCA, or their equivalent degree programmes from different educational institutions spread all across the country. During the year, about 126 students underwent short and long term training. A Post Graduate Research Programme in Engineering (PGRPE) in "Advanced Materials Physics & Engineering" was initiated at CSIR-NPL, with an intake of 10 students. Twenty nine fresh research fellows were motivated to join the laboratory during the year, making a total strength of 96. Under the Academy of Scientific and Innovative Research (AcSIR)[1], 34 students were registered for Ph.D. in Physical and Chemical Sciences. 60 students

[1]AcSIR was established by an Act of Parliament, the Academy of Scientific and Innovative Research Act, 2011 vide The Gazette of India No.15 dated February 7, 2012 and notified on 3rd April 2012.

were already registered for Ph.D. at other universities such as IITs, Delhi University, Delhi Technological University and JNU etc. Industrial training was also organized in the area of Metrology as well as other specialized topics. Such training courses were attended by various national and international organizations. A national seminar on "Recent development in Materials Devices for Solar Energy Applications" was also organized in Hindi by Raj Bhasha Unit during September 1-3, 2011.

Organization of institutional visits involving students, teachers, faculty members from school, colleges, universities, technical institutes, S&T organizations is an important activity of the CSIR-NPL. Eleven institutional visits were arranged which helped enhancing CSIR-NPL's visibility in the society. Industrial training was also organized in the area of Metrology and Quality Management System. Four of such courses were organized and were attended by the personnel belonging to various industries, testing & calibration laboratories and other various national and international S&T organizations.

During the year, a total of 330 scientific and technical papers were published in SCI indexed Journals. Forty two papers had impact factor in the range of 4 to 13. Ten patents were filed abroad and six patents were filed in India. Six international patents and five Indian patents filed in previous years were granted during 2011-12. Seventeen new projects (sponsored and consultancy) were undertaken and 2243 calibration reports were issued, which contributed to generation of an ECF of about 425 lakhs.

"World Metrology Day" together with "National Technology Day" was celebrated on May 20, 2011. The theme of "World Metrology Day", as decided by Bureau International des Poids et Measures (BIPM, Paris) was Metrology-Measurement in Science and Technology: a Bridge to Innovation. This was exemplified by the distinguished speakers invited on the occasion, Prof. Srikumar Banerjee, Chairman, AEC and Secretary, DAE, Govt of India and Dr. Krishan Lal, Chairman, INSA. Dr. Lal gave a preamble to the occasion and Prof. Banerjee delivered a very interesting and informative key note address entitled "Chemistry & Nuclear Energy".

Hon'ble Minister of Science & Technology, Earth Sciences and Vice President, CSIR, Sh. Vilasrao Deshmukh[2] paid a goodwill visit to the laboratory on 22nd September, 2011. He met and keenly interacted with scientists as well as addressed them. He also visited and appreciated some of the important research activities and recently created state-of-art facilities. To mark the occasion, he along with officials of CSIR and CSIR-NPL planted the seedlings of *Callistemon lanceolatus* in front of the main building.

The Open-Day is once a year opportunity for interaction between scientists and the interested public eager to know more about the cutting edge research being conducted at the laboratory. The CSIR-NPL open day was held on 28th September, 2011 as part of CSIR's Foundation Day Celebrations. Around 1900 visitors including students from schools and colleges turned up on the occasion.

In honour of Sir C.V. Raman, for his legacy and discovery of the Raman Effect on February 28, 1928, the National Science Day 2012 was celebrated on 28th Feb, 2012. Prof. Kehar Singh, formerly with IIT Delhi, delivered the inaugural lecture entitled "Security Holograms". A Poster Presentation Event was also organized where the work of all research fellows of CSIR-NPL was exhibited. Prof. Kehar Singh had a lively interaction with the students and to encourage them further distributed five best poster awards.

[2] It was really shocking to learn about the sad and sudden demise of Shri Vilasrao Deshmukh on 13th August, 2012. It was unbelievable. We still cherish the sweet memories of his visit to NPL and interaction with staff members. I, on my own behalf and on behalf of CSIR- NPL staff, convey our heart felt condolences to the bereaved family.

Apart from scientific endeavors, we also participated in Pusa Horticulture Show held at IARI, Delhi, during February 25-26, 2012. Out of 105 entries that were submitted in 16 categories, we won 103 prizes which included 33 first prizes, 58 second prizes, 12 third prizes and 7 Challenge Cups/Shields. The efforts made by our Horticulture Section were quite impressive.

All these achievements could be possible due to the whole hearted support of each and every member of CSIR-NPL staff and young researchers. I, earnestly, appreciate the same. I also take this opportunity to acknowledge the valuable help, support and encouragement received from CSIR Head Quarters, Research Council and Management Council which assisted us to a large extent in achieving our aims. The regular visits of national and international experts at CSIR-NPL had been highly rewarding and valuable.

Last, but not the least, I would also like to acknowledge the contribution of the Publication Committee under the leadership of Dr.Virendra Shanker in bringing out this report. The co-operation and special efforts of Dr. Shanker, Sh Raghavendra, Sh. N.K. Wadhwa, Sh Prem Chand, Ms Anita Sharma, Ms Saroj Upadhyay and Sh Subhash Chandra are also appreciated.

(R. C. Budhani)
Director

CSIR-National Physical Laboratory

Preamble

CSIR-National Physical Laboratory is one of the first National laboratories set-up under CSIR. Its foundation stone was laid by the first Prime Minister of India, late Pandit Jawaharlal Nehru on 4th January 1947. Late Dr. K.S. Krishnan, FRS, was the first Director of the laboratory. The main building was opened by the then Deputy Prime Minister, late Sardar Vallabhbhai Patel on 21st January 1950.

CHARTER

The main objectives of NPL have been a) to establish, maintain and improve National Standards of Measurements and to realize the Units based on International system, b) to identify and conduct research in areas of Physics, which are most appropriate to the needs of the Nation and for the advancement of the field, c) to assist industries, national and other agencies in their developmental tasks by precision measurements, calibration, development of devices, processes and other allied problems related to physics and d) to keep itself informed of and study critically the status of physics.

CUSTODIAN OF NATIONAL STANDARDS OF MEASUREMENT

National Physical Laboratory has the responsibility of realizing the units of physical measurements based on the International System (SI units) under the subordinate legislations of Weights & Measures Act 1956 (reissued in 1988 under the 1976 Act). NPL also has the statutory obligation to establish, maintain and update the national standards of measurement & calibration facilities for different parameters. The seven SI base units are metre, kilogram, second, Kelvin, Ampere, candela, mole and the SI supplementary units are radian (rad) & steradian (sr). The other derived units for physical measurement, that the laboratory currently maintains, are: force, pressure, vacuum, luminous flux, sound pressure, ultrasonic power; ac voltage; current and power; low frequency voltage; impedance and power; high frequency voltage; attenuation and noise; microwave power and frequency.

NATIONAL APEX BODY FOR CALIBRATION

The laboratory provides apex level calibration services in the country, offering National Accreditation Board for Testing and Calibration (NABL), the national accreditation body in the country, (i) its qualified assessors as needed for establishing best measurement capability of the applicant laboratory; (ii) its technical input to enable NABL to decide the suitability of the applicant laboratory for accreditation, and (iii) its faculty to train testing laboratories for estimation of uncertainty in their measurements.

Besides, the laboratory is engaged in development of Certified Reference Materials to ensure high quality measurement and traceability of

analytical measurements to national/international measurement system (SI unit) in order to fulfill the mandatory requirement of quality systems (ISO/IEC-17025) and of the NABL.

MAJOR ACHIEVEMENTS

National Physical Laboratory has to its credit innumerable number of achievements, a few major achievements are: a) Introduction of Metric system of measurements in India, b) Development of Indelible ink-the indelible contribution to Indian democracy, c) Estimation of methane gas emission from India-a nationwide measurement campaign giving countrywide advantage in environment protection, d) Setting up a pilot plant for development of Electronic Components (ferrites), which led to setting up a public sector Unit called Central Electronics Ltd. (CEL) in 1973, e) Development of know-how of the Electrostatic Photocopying machine using indigenous materials and f) Indian Standard Time.

THE MAJOR THRUST AREAS OF R & D

(A) Metrology

- ✓ Calibration & Testing Services to Industries
- ✓ Electrical & Electronic Standards
- ✓ Physico - Mechanical Standards
- ✓ Metrology in Chemistry
- ✓ Nano Metrology
- ✓ Primary Standards
- ✓ Realization of SI units

(B) Materials

- ➢ Light weight, high strength metallic materials
- ➢ Bulk Nanometallic and Nanocomposite materials
- ➢ Carbon & Carbon composites
- ➢ Plasma Processed Materials
- ➢ Organic and Inorganic Photovoltaics
- ➢ Luminescent Materials
- ➢ Organic Light Emitting Diodes
- ➢ Conduction Polymers & Composites
- ➢ Superconducting materials and Superconductivity
- ➢ Fuel cells
- ➢ Sensors (based on Bio, Gas, Chemicals, MEMS)
- ➢ Advanced Characterization Techniques

(C) Radio and Atmospheric Sciences

- Ionosphere & Troposphere
- Atomospheric Environment
- Global Climate Change
- Antarctica and Arctic studies
- Radio-Propagation
- Communications (Fixed, mobile and marine)

ORGANIZATION AND MANAGEMENT

The laboratory has structured its total activities under seven scientific decision units. These are: (i) Physics of Energy Harvesting, (ii) Materials Physics and Engineering, (iii) Radio and Atmospheric Sciences, (iv) Time and Frequency Standards, (v) Apex Level Standards and Industrial Metrology, (vi) Quantum Phenomena and Applications (vii) Sophisticated and Analytical Instruments.

In addition, it has set-up eight support units for its organization and management. These are (i) Administration (ii) Finance & Accounts, (iii) Stores & Purchase, (iv) Works and Services, (v) Workshop and Cryogenics, (vi) Computation & Network Facility, (vii) Directorate, (viii) Intellectual Property and Human Resource.

CSIR–NPL

Organizational Structure

Research & Development Divisions

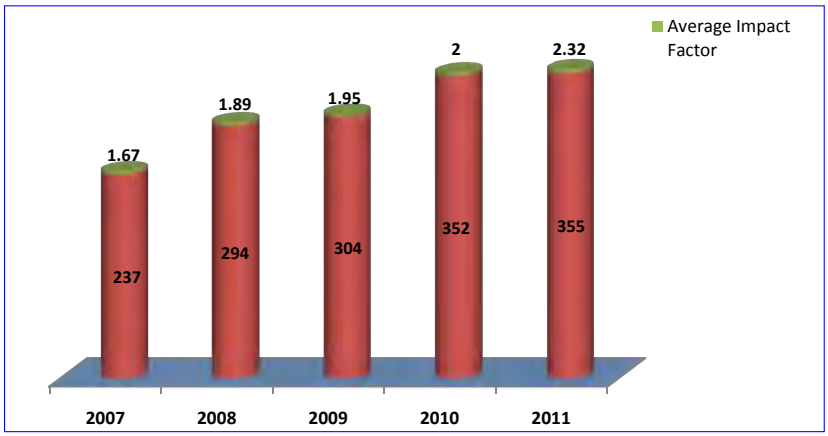
- **Physics of Energy Harvesting** Division - 01
- **Materials Physics & Engineering** Division - 02
- **Radio & Atmospheric Sciences** Division - 03
- **Time & Frequency Standards** Division - 04
- **Apex Level Standards & Industrial Metrology** Division - 05
- **Quantum Phenomena & Applications** Division - 06

Scientific & Administrative Support Divisions

- **Administration** SASD - 01
- **Finance & Accounts** SASD - 02
- **Stores & Purchase** SASD - 03
- **Works & Services** SASD - 04
- **Workshop & Cryogenics** SASD - 05
- **Computation & Network Facility** SASD - 06
- **Directorate** (Sophisticated & Analytical Instruments, PME, QS) SASD - 07
- **Intellectual Property & Human Resource** (HRD, ISTAG, ILG, IPR, CFCT, Library) SASD - 08

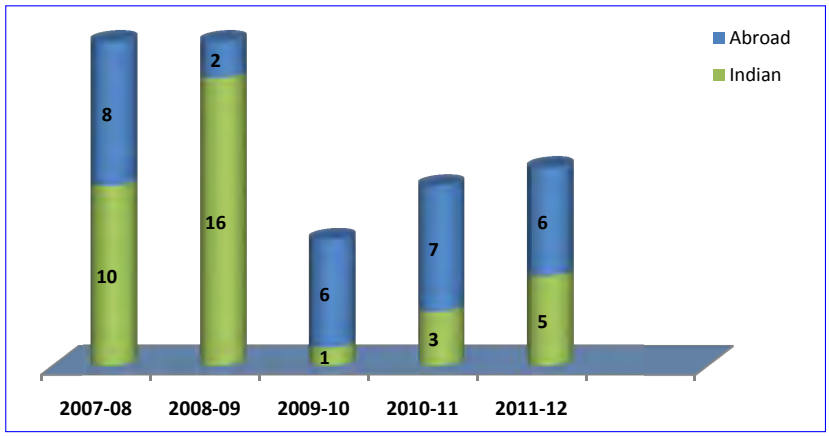
Performance Indicators

PUBLICATIONS

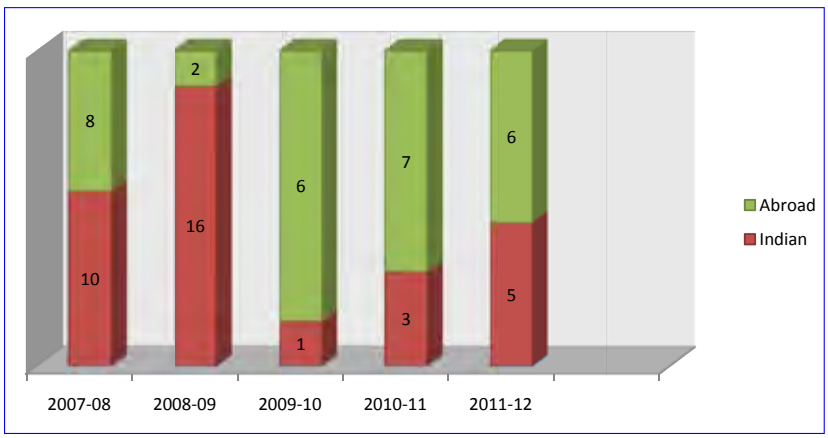


PATENTS

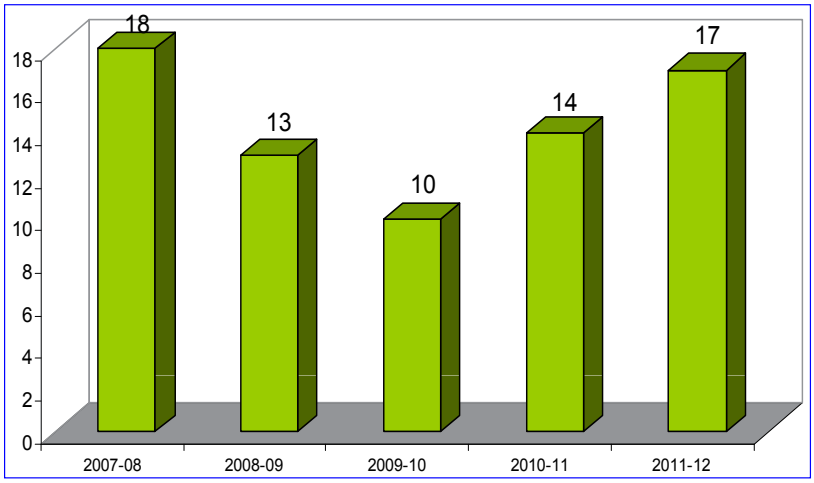
PATENTS FILED



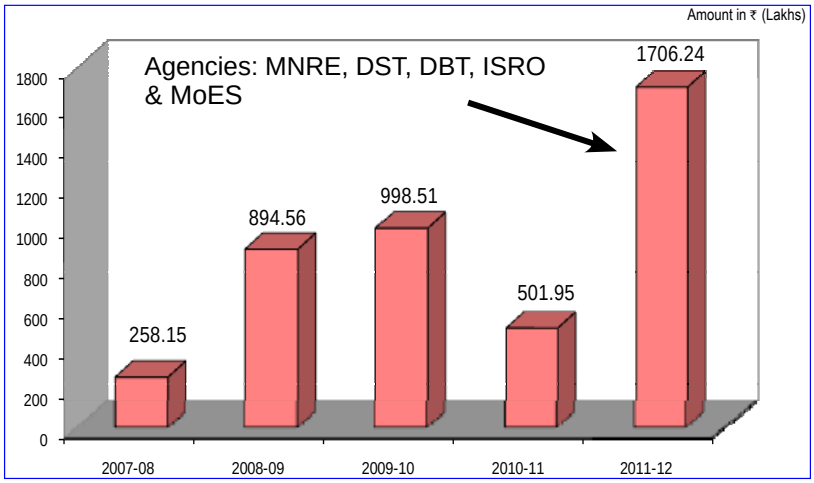
PATENTS GRANTED



NEW EXTERNALLY FUNDED PROJECTS UNDERTAKEN DURING LAST FIVE YEARS

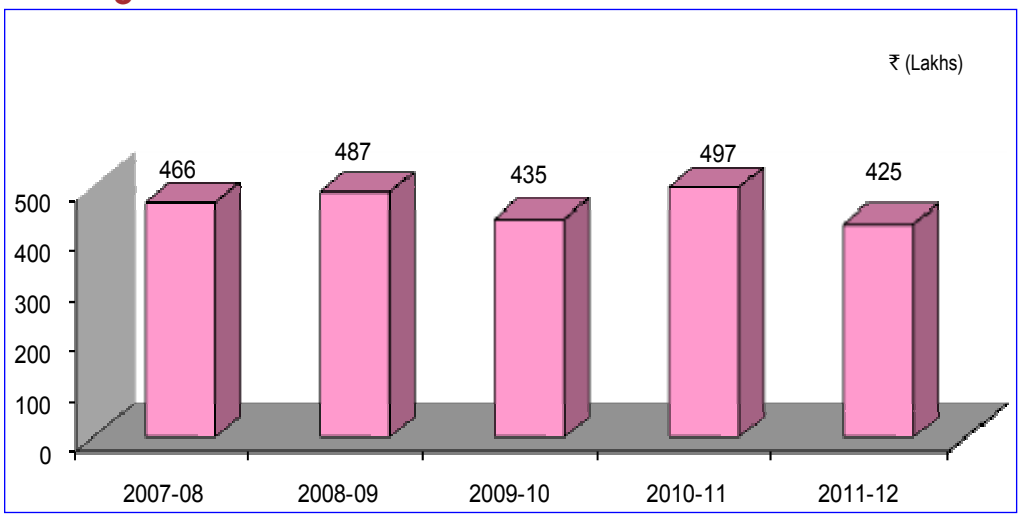


RECEIPT THROUGH EXTERNALLY FUNDED PROJECTS DURING LAST FIVE YEARS

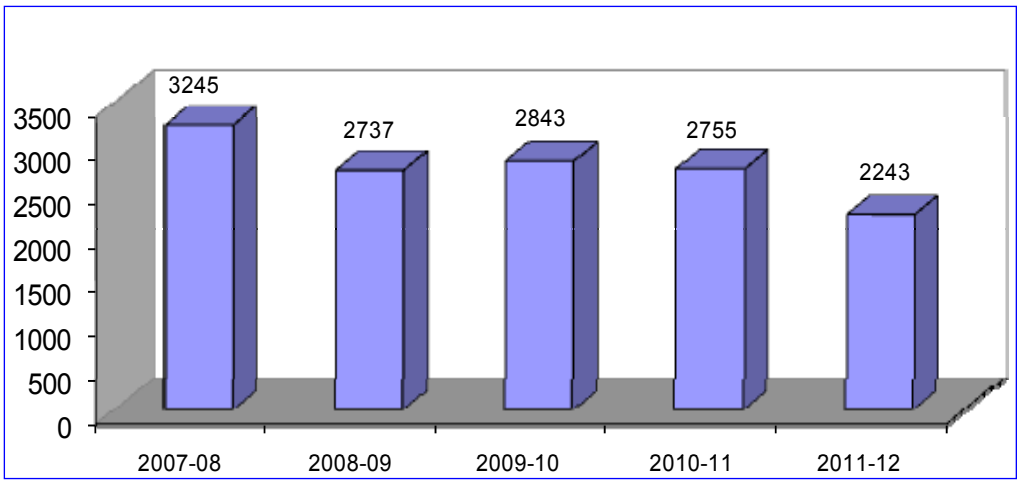


CALIBRATION AND TESTING AT NPL

Earnings



No. of Reports



Inception of AcSIR

AcSIR | Academy of Scientific & Innovative Research

The Academy of Scientific and Innovative Research (AcSIR) has been notified through an Act of Parliament published in Gazette notification dated February 7, 2012 and enacted through a Gazette notification dated April 2, 2012 .

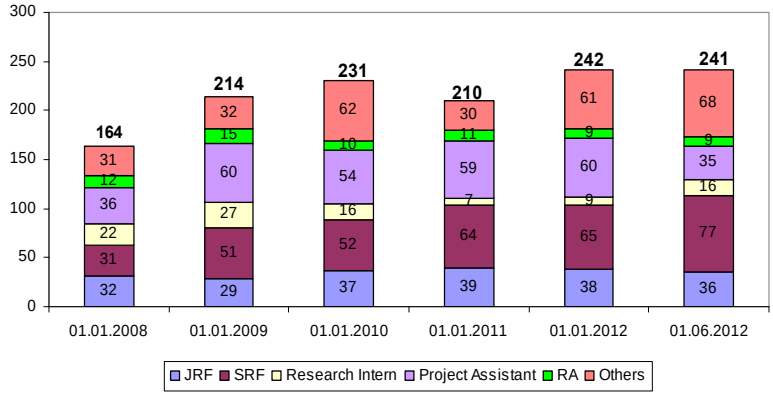
Ph.D. Programme

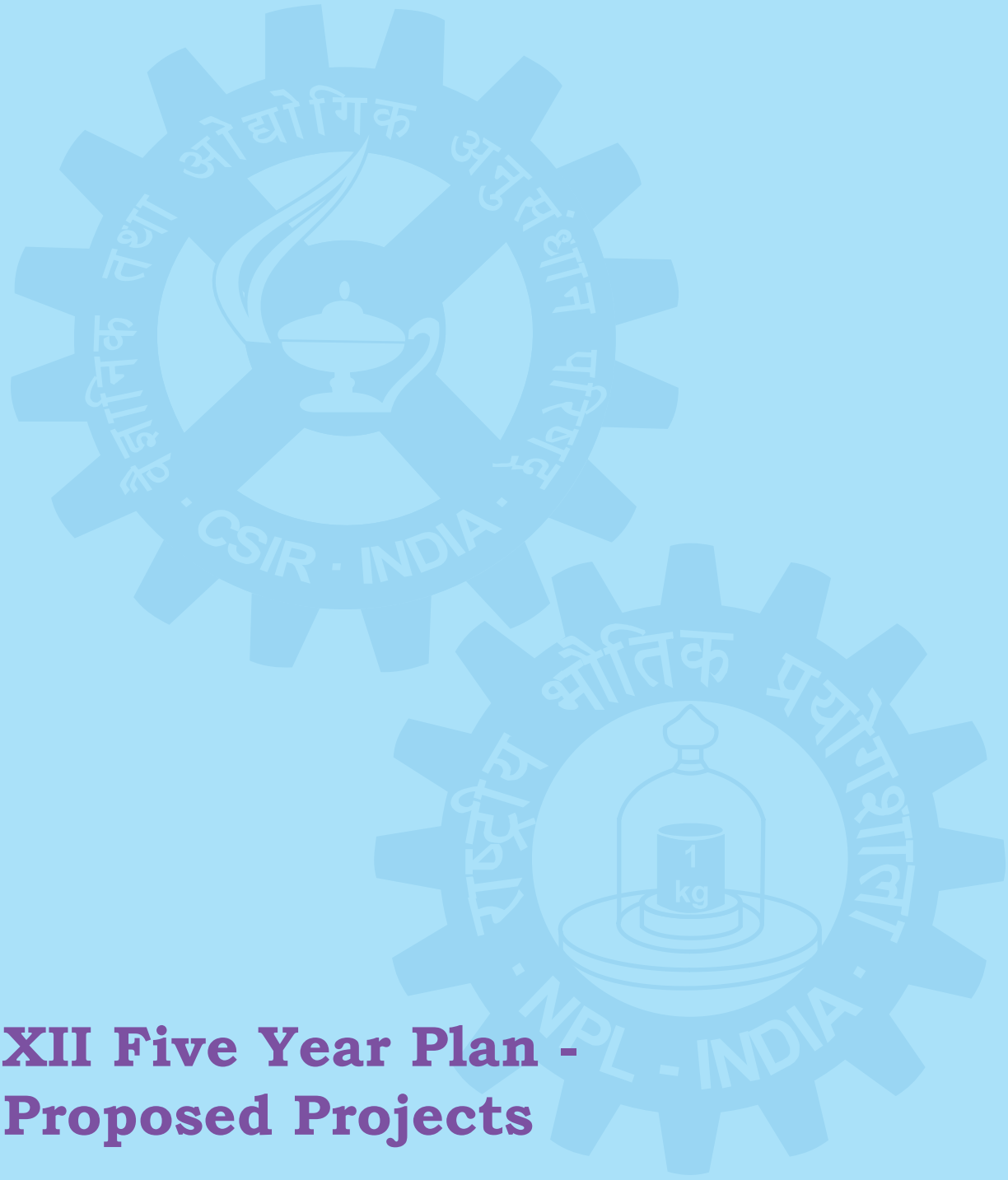
- As on date, 35 students are registered for Ph.D. under AcSIR in Physical & Chemical Sciences
- For the January 2012 Semester, 68 Ph.D. students have been shortlisted for interviews, under AcSIR, which will be held on June 26-27, 2012
- In order to induct more engineers, NPL has advertised for the positions of JRF-GATE, under which we plan to induct 10 students for Ph.D in different engineering disciplines
- 60 Ph.D. students are currently registered at other universities (IITs, DU, DTU, JNU, etc.) jointly with CSIR-NPL.

PGRPE (M.Tech.) Programme

- ✓ 8 students of PGRPE will complete the IInd Semester (Jan-May 2012)
- ✓ The IIIrd Semester commences on 16th August 2012
- ✓ During the IInd semester 4 courses were offered :
  - ➢ Research Methodology, Technical Writing & Communication Skills
  - ➢ Superconducting & Magnetic Materials
  - ➢ Advanced Measurement Techniques & Metrology
  - ➢ Advanced Computational Physics

Floating Research Staff





XII Five Year Plan - Proposed Projects

XII Five Year Plan - Proposed Projects

NETWORK PROJECTS

- Measurements for Innovation, in Science & Technology, and for improvement of Quality & Economy of Life **(MISTQUE)**
- Advanced Quantum Research and Innovation with Ultra Small Systems **(AQuaRIUS)**
- Development of Advanced Materials for Next-Generation Energy-Efficient Devices **(D-NEED)**
- Probing the Changing Atmosphere and its Impacts in the Indo-Gangetic Plains (IGP) and Himalayan Regions **(AIM-IGPHim)**

SUPRA INSTITUTIONAL PROJECT

- Research and Development of Single Trapped Ion based Optical Frequency Standard **(STIOS)**

TECHNOLOGIES AND PRODUCTS FOR SOLAR ENERGY UTILIZATION THROUGH NETWORK (TAPSUN PROJECTS)

Novel approaches for solar energy conversion
(Dr Suresh Chand)
(Rs. 3446.25 Lakhs)
(NWP-54)

Efficient silicon photovoltaics with smart electronics and lighting systems
(Dr P K Singh)
(Rs. 4130.45 Lakhs)
(NWP-55)

Innovative solutions for solar energy storage
(Dr R B Mathur / Dr S K Dhawan)
(Rs. 647.50 Lakhs)
(NWP-56)

Funding Agency: CSIR

R&D on thin film solar cells
(Dr Shushil Kumar)
(Rs. 4906.60 Lakhs)
(GAP 113532)

Funding Agency: MNRE

Significant Achievements

Establishing New Standards

Force

Force Standards - Hardness Standardizing machine

The New Primary Hardness Machines are Established for Realization of hardness scale

Great Demand of the Nation - Testing of Concrete and Hard materials (wide utilization in Defense, Space, Highway, Metro, Over Bridge, Tunnel etc.) with traceability to International standards

Standard Rockwell Hardness machine

Standard Vickers Hardness Machine

Standard Brinell Hardness Machine

Acoustics

Acoustics, Vibration and Ultrasonic Standards

- *Establishment of Primary Standard of Vibration using Laser Interferometer for calibration of reference standard accelerometer with an uncertainty of 0.3 % (at 160 Hz) at par with PTB Germany.*
- *Establishment of Secondary Sound Standard for providing calibration services for microphones and other sonic devices*

Secondary Sound Standard

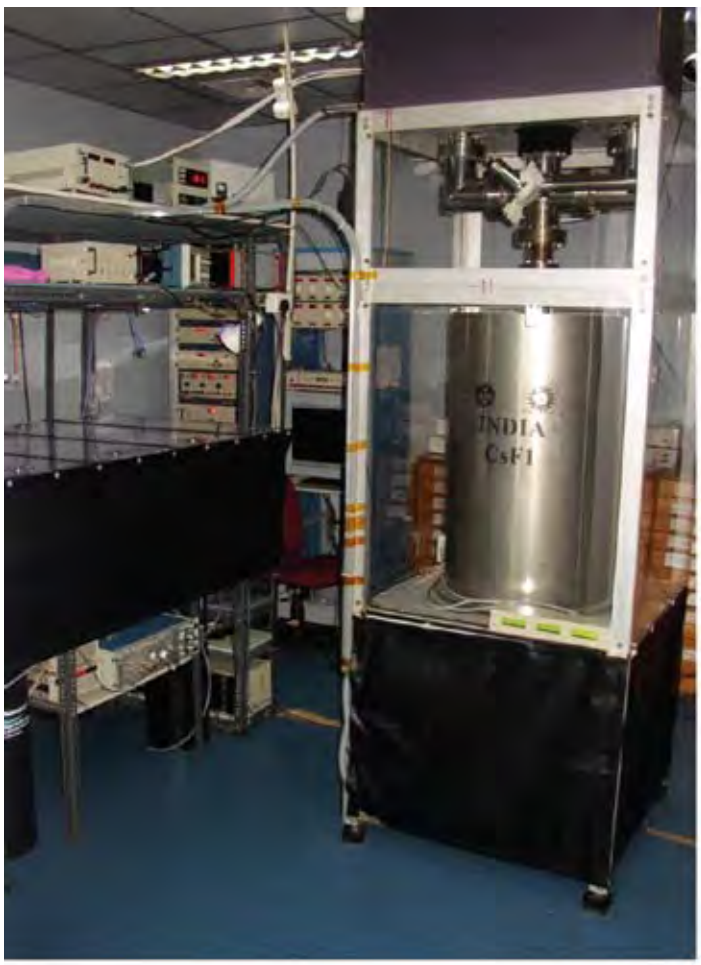
Primary Vibration Standard

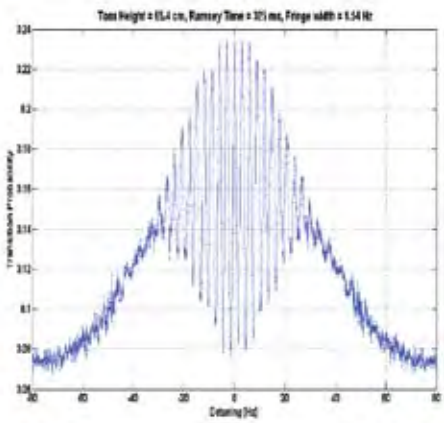
Time

First Cold Atom Cesium Fountain (CsF1) primary frequency standard.

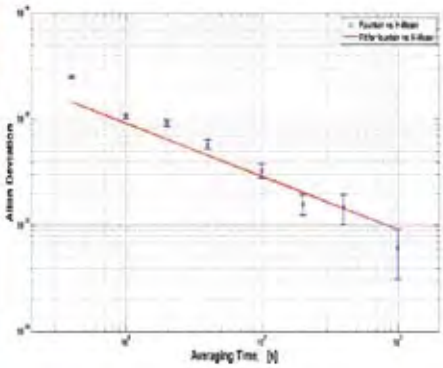
India-CsF1 has become operational.

- *C-field mapping, frequency locking with H maser and stability analysis being performed.*
- *State selection is being implemented and accuracy evaluation is under progress.*





First Ramsey Fringes observed from Cesium Cold Atom Fountain



Dimension

Long Gauge Blocks Measurement
using He-Ne Laser Interferometer

Nominal Range :
0-4000 mm
Working Range:
0-3700 mm
Resolution:
0.01 µm
Maximum Error:
1.5 µm
Repeatability:
0.1 µm

AC High Voltage & High Current

(Standards for Power Sector)

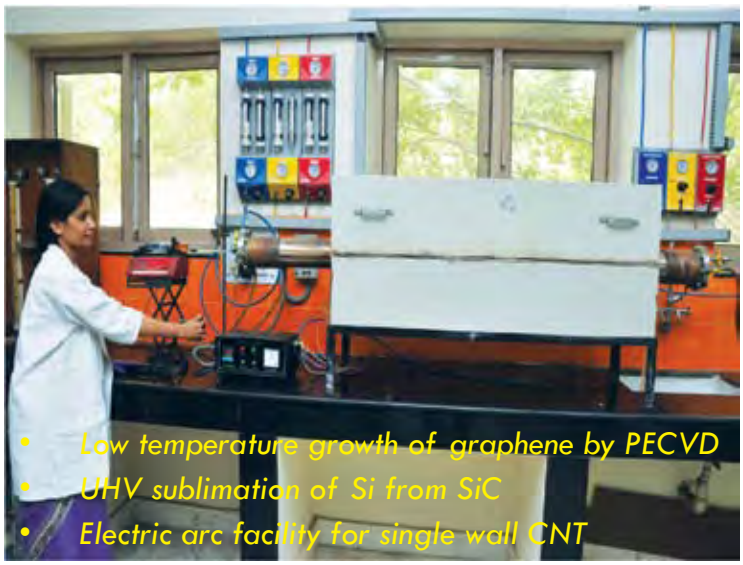
An innovative idea of the measurement of HV Divider up to 200kV almost double of our present 100kV capacity has been generated. A 200kV HV Divider from M/s. KVTEK Gurgaon has been calibrated.

Set up for 200 kV HV Divider

Materials & Products

CVD reactor for multiwalled CNTs

Very high yield – Key facility of fuel cell program



CSIR-NPL ECG Machine

(Compact, low cost, PC-Plug-in 12-lead ECG device)

ECG Machine

DST-Lockheed Martin Gold Medal 2012

Carbon–carbon composite fuel tubes

(for Compact High Temperature Nuclear Reactors at BARC)

- *Carbon-carbon composite tubes were successfully developed and handed over to Scientists from BARC for the high temperature nuclear reactor.*
- *The technology involves weaving 3-D carbon fibre preform followed by repeated cycles of coal tar pitch impregnation, high pressure carbonization and graphitization to achieve a density of 1.8 g/cc*
- *These tubes will encounter temperature of 800-900^{0}C and are designed to carry molten lead as heat exchanger and also to store nuclear fuel.*

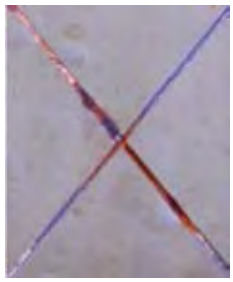
Dimensions : 500 mm x 75 mm OD x 35 mm with 12 holes of 10 mm dia. Each up to 400/450 mm depth on 55 mm PCD.

Conducting polymer paints and coatings for corrosion protection

An outcome of joint efforts under NWP-12 (CSIR-NPL; CSIR-CECRI & CSIR-NCL)

NDA signed with M/s Krishna Conchem Products Pvt. Ltd., Navi Mumbai

Conventional Epoxy Coatings



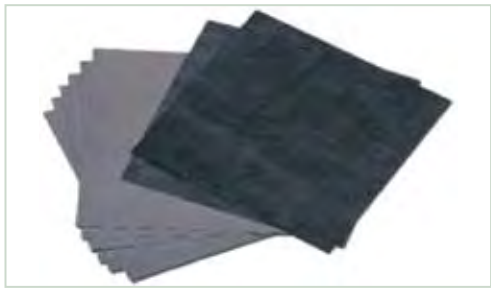
Conducting Polymers Based Coatings

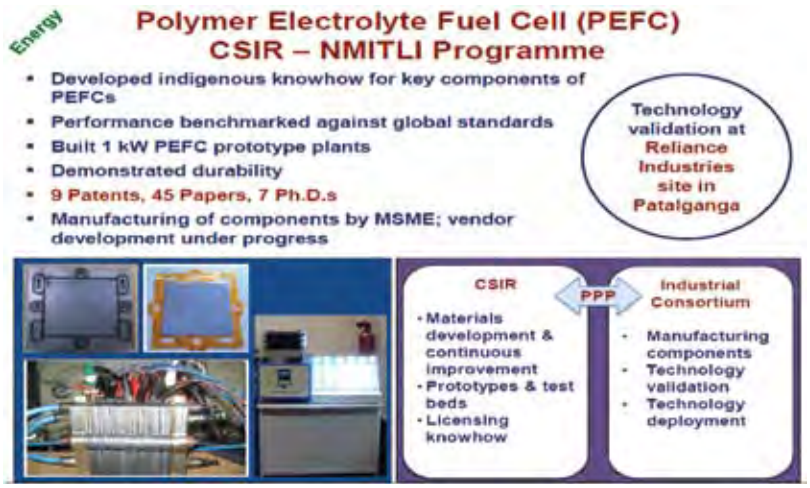
Composites bipolar plate

- *Separate the individual fuel cells from Each other*
- *Distribute fuel and oxidant.*
- *Carry current away from the cell.*
- *Support for MEA.*

Porous carbon paper

- *Provide reactant gases access from flow filed channels to catalyst layer*
- *Provide passage for removal of product water from catalyst layer*
- *Mechanical support to MEA*





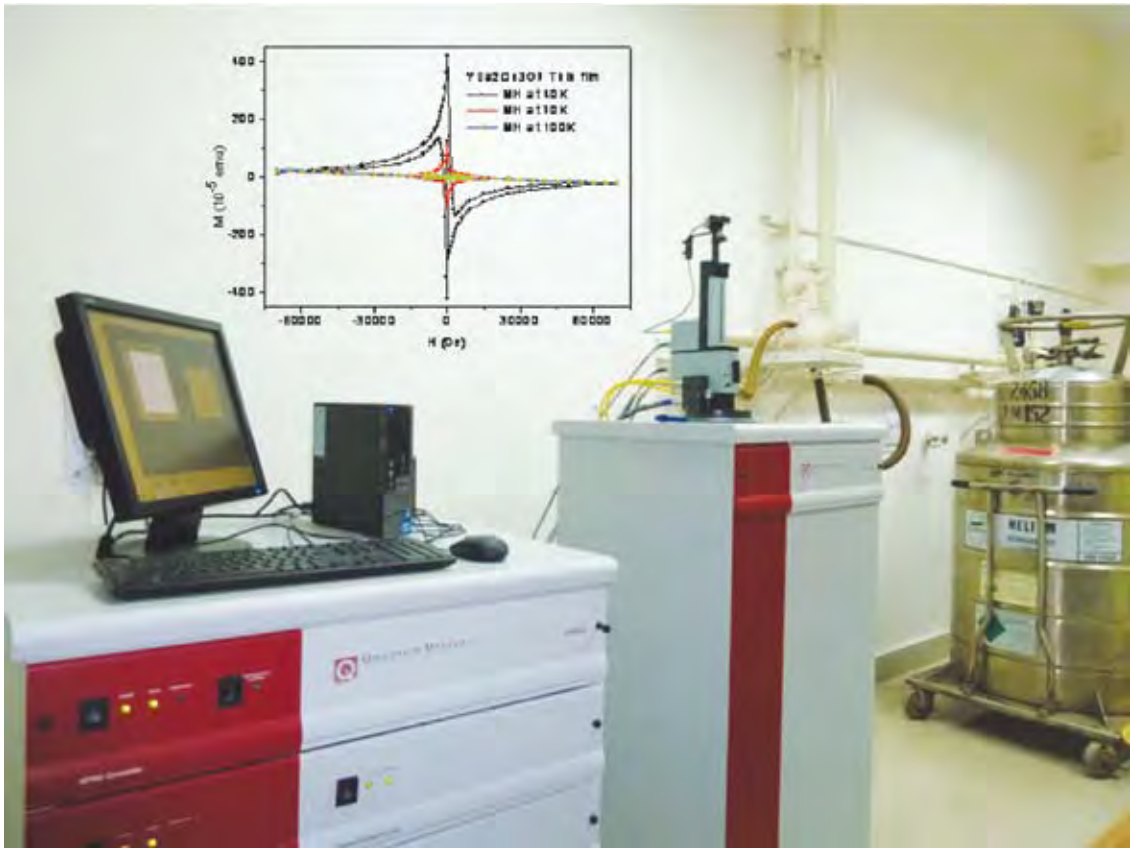
Facilities Created

Focused Ion Beam (FIB) system

Pulsed Laser Deposition (PLD) set up

Facilities Created Continued ...

SQUID based Magnetometer facility
(T=1.8 – 400 K, B=0 – 7 Tesla)



7 Tesla SQUID Magnetometer with options for anisotropy, transport and photoexcitation measurements

**Standards of nanoparticles*

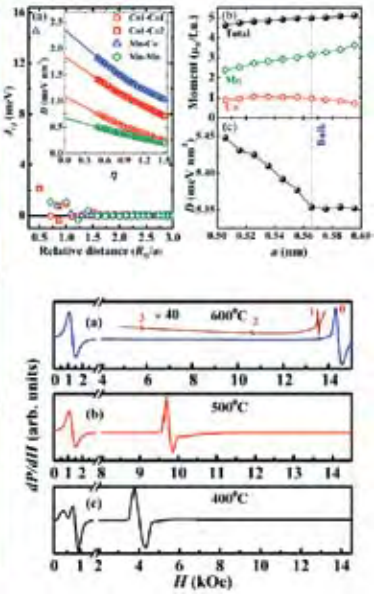
**Photomagnetism*

**Superconductivity*

Facilities made Operational

X and Q band EPR Spectrometer

(With 3.5 K and UV illumination facility)



Riber Molecular Beam Epitaxy (MBE) system

- *GaN-GaAlN and GaN-GaInN 2D electron gas*
- *Quantum wells for Light Emitting Diodes and high mobility devices*

Facilities made Operational Continued ...

Spark Plasma Sintering (SPS) system

Radio & Atmospheric Sciences

Antarctica

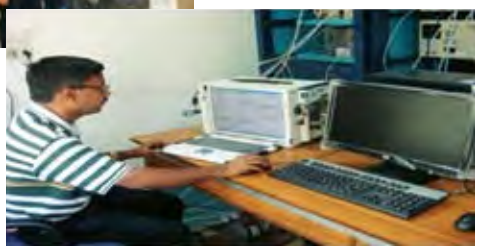
Efforts are on to setup Space Physics Laboratory at New Indian Research station 'Bharati' (69° 24'S, 76° 11' E) at Larsemann Hills, Antarctica. The new station is 3000 kilometre away from the present Maitri station). Ionospheric total electron content and polar ionosphere scintillation related to its dependence on space weather events will be studied.

Dr. Rupesh M. Dass from CSIR-NPL participated in 31st Indian Antarctica Expedition as its first leader at new station Bharati.

New station "BHARATI" at Larsemann Hills, Antarctica.

Real Time Ambient Air Monitoring & Data Acquisition System

(Established at CSIR-NPL)



Fourier transform High Resolution Far Infrared Spectrometer (to monitor atmospheric gases above Delhi)

श्रद्धाजंलि

26 मई 1945–14 अगस्त 2012

Glimpses of Important Events

Honorable Minister of Science and Technology &
Vice-President CSIR visits CSIR-NPL
September 22, 2011

Minister's Visit Continued...

Minister's Visit Continued...

Minister's Visit Continued...

Research Council Meeting
June 01, 2011

Research Council Meeting
December 26, 2011

Independence Day Celebrations at CSIR-NPL
August 15, 2011

National Seminar in Hindi entitled

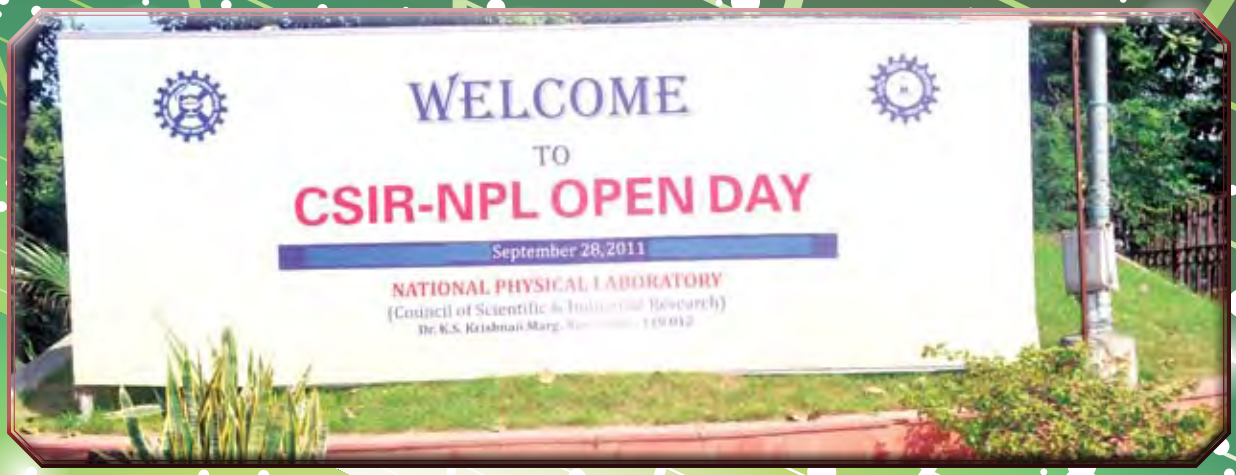
" Saur Urja Anuprayogon ke liye Padhartho aur Sadhano mein Vartaman Pragati"

September 1-2, 2011

CSIR Foundation Day Celebrations
(Lecture by Dr N. Rathnasree, Director, Nehru Planetorium, New Delhi)
September 26, 2011

CSIR Foundation Day Celebrations Continued...

Indo-German Technical Co-operation in the Area of
"Metrology in Chemistry"
February 26, 2012



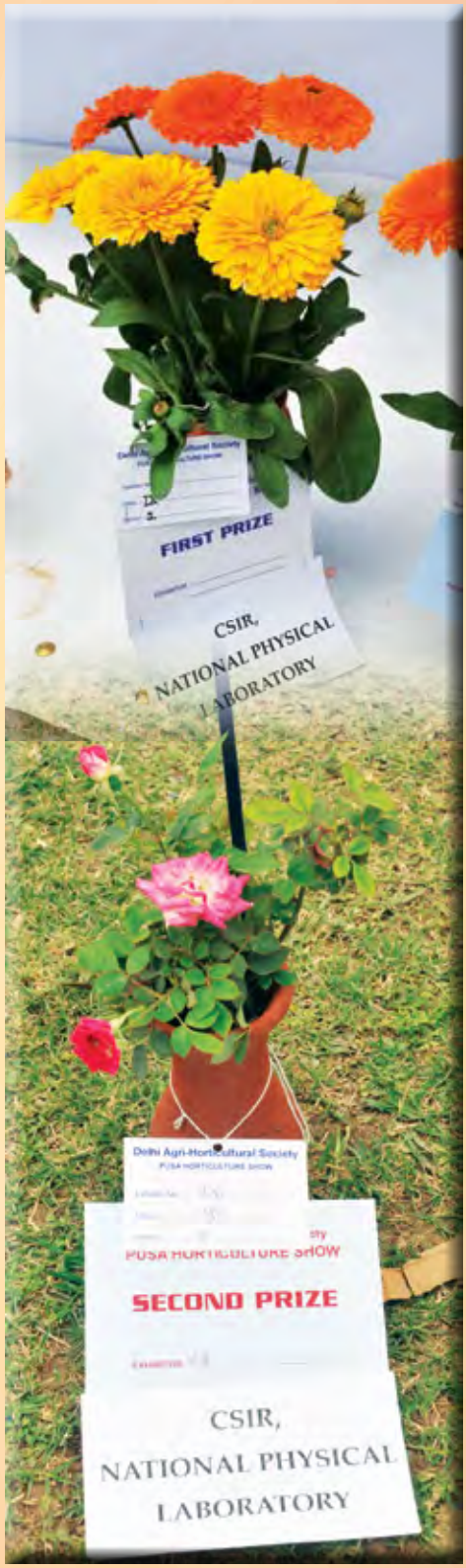
CSIR-NPL Open Day Celebrations
September 28, 2011

CSIR-NPL Open Day Celebrations Continued...

CSIR-NPL Sports Club Competitions
December 27, 2011

National Science Day Celebrations
February 28, 2012

National Science Day Celebrations Continued...



Participation of CSIR-NPL in Pusa Horticulture Show
February 25-26, 2012

Participation of CSIR-NPL in Pusa Horticulture Show Continued...

Lessons on Spirituality by Sister Shivani
May 25, 2011

Divisional Activities


वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद
CSIR · INDIA ·


राष्ट्रीय भौतिक प्रयोगशाला
1
kg
· NPL - INDIA ·

ऊर्जा संचयन भौतिकी

Physics of Energy Harvesting

ऊर्जा संचयन भौतिकी

ऊर्जा संचयन भौतिकी प्रभाग द्वारा कार्बनिक प्रकाश वोल्टीय तथा प्रकाश उत्सर्जी उपकरणों, अकार्बनिक प्रकाश उत्सर्जी डायोडों, अक्रिस्टलीय तथा क्रिस्टलयुक्त सिलिकन सौर सेलों से संबंधित क्रियाकलापों तथा ताप वैद्युत युक्तियों हेतु पदार्थों एवं प्रकाशीय तनु फिल्मों से संबंधित क्रियाकलापों का निष्पादन किया जा रहा है। सिलिकन और अक्रिस्टलीय सिलिकन सौर सेलों (एस आई पी 17) तथा प्रकाश उत्सर्जी युक्तियों (एन डब्ल्यू पी 25) से संबंधित सी एस आई आर नेटवर्क परियोजनाओं के अंतर्गत क्रियाकलाप इस प्रभाग द्वारा किए जाने वाले मुख्य क्रियाकलाप हैं। वर्ष के दौरान, कार्बनिक इलेक्ट्रॉनिक युक्तियों विषय पर इस प्रभाग द्वारा किए गए उत्कृष्ट अनुसंधान कार्यों से संबंधित अनेक शोध पत्र अत्यधिक प्रतिष्ठित पत्र–पत्रिकाओं में प्रकाशित हुए हैं। बारहवीं पंचवर्षीय योजना के दौरान, सी एस आई आर–टी ए पी एस यू एन (CSIR-TAPSUN) कार्यक्रम के अंतर्गत नेटवर्क परियोजनाएं एन डब्ल्यू पी 54 और 55, तनु फिल्म सौर सेलों से संबंधित एम एन आर ई परियोजना जी ए पी 113532 तथा भारत–यूनाइटेड किंगडम (यू के) सहयोगात्मक कार्यक्रम ए पी ई एक्स प्रमुख क्रियाकलापों के क्षेत्र हैं।

वर्तमान वर्ष के दौरान विज्ञान तथा प्रौद्योगिकी के क्षेत्र में अनेक महत्त्वपूर्ण योगदान किए गए। नवीन प्रति परावर्तन तथा एकल क्रिस्टलीय एवं बहु क्रिस्टलीय सौर सेलों के लिए पृष्ठीय निष्क्रियण प्रक्रम को विकसित करने के मामले में उल्लेखनीय प्रगति की गई है। पी ई सी वी डी तथा एफ सी वी ए प्रक्रमों का प्रयोग करके Si:H, DLC तथा a:C तनु फिल्मों को तैयार करने के क्षेत्र में अनेक संशोधन किए गए हैं। इन संशोधनों का उपयोग करके ट्राइबोलोजिकल आवरणों तथा तनु परत सौर सेलों के लिए उन्नत प्रक्रम विकसित किया गया है। उन्नत कार्बनिक प्रकाशवोल्टीय युक्तियों के लिए दीप्त ग्रैफीन क्वांटम बिंदुओं तथा विलयशील अभिलक्षणित फुलरीन के प्रयोग की संभावना ज्ञात की गई तथा इससे संबंधित परिणामों को अत्यधिक प्रतिष्ठित पत्र–पत्रिकाओं में प्रकाशित किया गया। असंलग्नी–विनिमय प्रक्रम द्वारा कार्बनिक–अकार्बनिक नैनो कम्पोजिटों हेतु आवेश अंतरण तंत्र को उन्नत बनाने की दिशा में कार्य किए गए है। उन्नत ताप वैद्युत युक्तियों के लिए निम्नविमीय बिस्मथ टेल्युराइड मिश्रधातुओं को विकसित करने की दिशा में प्रगति हासिल की गई है। कार्बनिक प्रकाश उत्सर्जी डायोडों में प्रकाश निष्कर्षण में वृद्धि करने के लिए नैनो–संविरचित परतों को प्रयोग में लाया गया है। GaN आधारित प्रकाश उत्सर्जी डायोड युक्तियों के लिए अधिरोही परतों के विकास का कार्य भी आरंभ किया गया है। उन्नत प्रकाशीय तनु परतों के रूप में प्रयोग में लाए जाने की संभावना को ध्यान में रखते हुए नैनो–संविरचित जिंक तथा टिटैनियम ऑक्साइड परतों का आविष्कार किया गया है। समसामयिक वैज्ञानिक क्षेत्र में किए गए इन आविष्कारों से संबंधित अनेक अनुसंधान लेख अत्यधिक प्रतिष्ठित पत्र–पत्रिकाओं में प्रकाशित किए गए हैं। अनेक प्रमुख सुविधाएं जिनमें से एक सौर सेलों के अभिलक्षणन हेतु, एक अन्य अल्पांश वाहक आयु के मापन हेतु तथा एक अन्य अर्ध–चालक पदार्थों के गहन स्तर अल्पस्थायी स्पेक्ट्रमिकी हेतु संस्थापित की गई है।

Physics of Energy Harvesting

The division, Physics of energy harvesting comprises activities on organic photovoltaics and light emitting devices, inorganic light emitting diodes, amorphous and crystalline silicon solar cells, materials for thermoelectric devices and optical thin films. The activities under the CSIR network projects on silicon and amorphous silicon solar cells (SIP17) and light emitting devices (NWP25) form the core of the division. During the year, drawing on the excellent research in organic electronic devices, several papers have been published in journals with very high impact factor. During the XII plan, Network Projects NWP54 and 55 under the TAPSUN program, the MNRE project on thin film solar cells GAP113532 and the INDO-UK collaborative program APEX are the major thrust activities.

Many important contributions to science and technology were achieved during the current year. There has been significant progress on the development of novel anti reflection and surface passivation processes for single crystal and multi-crystalline solar cells. Many improvements have been realized in the preparation of a-Si:H, DLC and a:C thin films using the PECVD and FCVA processes. These improvements have been converted into improved processes for tribological coatings and thin film solar cells. Use of luminous graphene quantum dots and soluble functionalized fullerenes for advanced organic photovoltaic devices has been investigated resulting in publication in journals with very high impact factor. Enhancement in Charge Transfer Mechanism by Non-Ligand-Exchange Process for organic-inorganic nano-composites has been investigated. Progress has been achieved in the development of low dimensional bismuth telluride alloys for advanced thermoelectric devices. Nano-structured films have been employed to enhance light extraction in organic light emitting diodes. Growth of epitaxial films for GaN based LED devices has also been initiated. Nano-structured zinc and titanium oxide films have been investigated for possible use as advanced optical thin films. These results in contemporary scientific areas has resulted in a significant number of research publications in journals with high impact factors. Major facilities, one for the characterization of solar cells, one for measurement of minority carrier life times and another for deep level transient spectroscopy of semiconducting materials have been setup.

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Silicon Solar Cells Group

Owing to its superior optical and structural properties titanium dioxide (TiO_2) thin films have potential application as antireflection coatings on crystalline silicon solar cells. Sol–gel method is an attractive route for the synthesis of such layers as they offer the advantage of producing metal oxides at fairly low temperatures with good reproducible optical and structural properties. Titanium di-isopropoxidebis (acetylacetonate), an organo-metallic precursor, was synthesized which being less hygroscopic compared to other metal alkoxides is easy to use under ambient conditions. TiO_2 layers were obtained after sintering at elevated temperatures. The effect of titanium content in the precursor, spin rate, sintering duration and temperature has been studied and their effect on coating thickness and optical properties was investigated in order to optimize process conditions. TiO_2 coatings were applied to silicon solar cells that showed more than 20% enhancement in short circuit current density in comparison to a cell devoid of the TiO_2 coating.

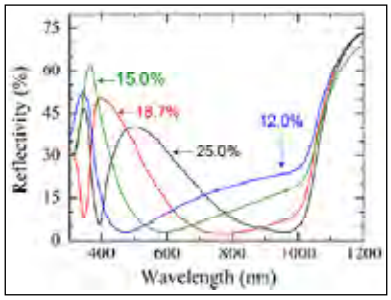


Fig. 1.1 Reflectivity variation as a function of wavelength for different concentrations of titanium

The surface passivation of crystalline silicon solar cell improves efficiency by suppressing the surface recombination losses that can be reduced either by chemical passivation or by field effect passivation. We have observed surface passivation (i.e., enhanced lifetime) by application of hydrogen annealed aluminum rich zinc oxide (AZO) films on p-Si. The feasibility of these films as passivation layer on the p-back surface of n^+-p silicon solar cells and its usefulness as an antireflection coating on n^+ front surface has been studied.

Monocrystalline (c-Si) and multicrystalline (mc-Si) bifacial solar cells are made. AZO films of 20% Al/Zn ratio are applied on the front and back surface of the cells and annealed at 500°C in hydrogen ambient. I-V and spectral response in both conditions are measured. The current densities in front and back illuminated conditions are enhanced due to antireflection properties of the AZO films. The observed improvement in open circuit voltage (V_{oc}) was more than expected from the enhancement in I_{sc} and the unaccounted excessive improvement in V_{oc} could be attributed to surface passivation.

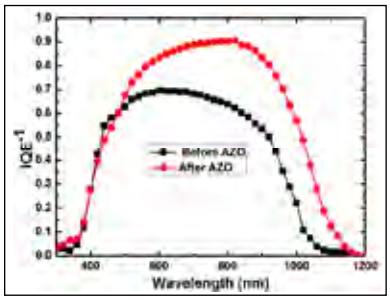


Fig. 1.2 IQE of front illuminated bifacial mc-Si solar cell at 25°C.

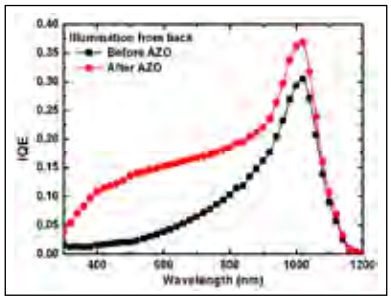


Fig. 1.3 IQE of back illuminated bifacial mc-Si solar cell at 25°C

The effectiveness of surface passivation can be determined by the minority carrier lifetime which indeed is important to determine the bulk lifetime and is also used as a measure of process conditions. We have developed process protocols using ethanolic iodine (I-E) and bromine (B-E) solutions to reduce surface recombination velocity. Minority carrier lifetime was measured using microwave photoconductive decay method. A strong dependence of surface pre-conditioning had seen after I-E and B-E treatment. It was observed that, without native oxide samples show higher effective lifetime in case of I-E passivation as compared to with native oxide, which is just opposite of B-E passivation results. X-ray photoelectron spectroscopic measurements were carried out to understand its origin. XPS results of I-E passivated samples show twice Si-I bonding in Si core level spectra for the case of without native oxide compared to with native oxide, whereas B-E passivated samples show twice Si-Br bonding in Si core level spectra for with native oxide compared to without native oxide. It may be the cause of the observed minority carrier lifetime behaviour. Higher O-Br bonding in O core level spectra of B-E passivated samples with native oxide compared to without native oxide, confirms better surface passivation in with native oxide samples.

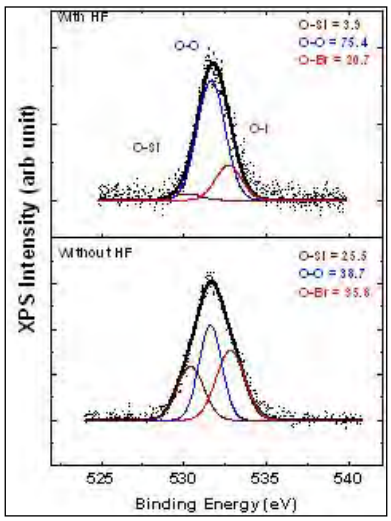


Fig. 1.4 XPS results

Amorphous & Micro-crystalline Silicon Solar Cells Group

Silicon thin films by Very High Frequency-PECVD Process

Hydrogenated nano/micro-crystalline silicon (nc/μc-Si:H) thin film has recently been paid much attention for the next generation of stable, large area and high-efficiency thin film solar cells. Although the material and the deposition process are compatible with the conventional hydrogenated amorphous silicon (a-Si:H) technology, there are still some issues unresolved regarding the optimization of the quality and growth rate combination of these films. The material properties around the a-Si:H / μc-Si:H growth transition is ideally known to be best for active layer of thin-film solar cell. The process parameters (pressure, power, flow rate, temperature and frequency) play an important role in achieving the better film properties in plasma enhanced chemical vapour deposition (PECVD) process. The advantage of very high frequency (VHF) PECVD is deposition of good quality films due to the reduction in ion energy bombardment during the growth at high rate.

Silicon thin films were deposited by variation of pressure, power, silane flow rate and argon dilution using VHF (60 MHz) PECVD technique. These films were characterized by Raman spectroscopy, low angle X-ray diffraction (XRD), Fourier transform infrared (FTIR) spectroscopy, atomic force microscopy (AFM) and UV-visible (UV-Vis) spectroscopy to see the effects of process parameters

on deposition rate, crystalline volume fraction, hydrogen bonding and morphology of Si:H thin films. Films were grown at different power from 5 W to 60 W. The highest deposition rate ~ 6 A^0/Sec has been achieved for the film deposited at 20 W power. All the films contain low crystalline volume fraction ~20-30%. Further, mixed-phase structures consisting of amorphous and nano-crystalline silicon were deposited in low pressure regime (0.10-0.62 Torr) at high growth rate (at VHF power of 20 W). Growth rate 8.3 A^0/sec was achieved at a deposition pressure of 0.47 Torr. These films showed high dark conductivity values (>10^{-6} Ω^{-1} cm^{-1}). Stress of these nc/μc-Si:H films decreases as the deposition pressure increases which results micro-structural changes in the films that can be observed by the change in the microstructure parameter deduced from FTIR analysis. Deposition pressure strongly changed the shape of IR spectrum in the range 1900–2200 cm^{-1}. Samples deposited at 0.10 Torr and 0.17 Torr pressure, SiH stretching was predominant, while with further increase in pressure, the intensity of SiH_2 stretching increases. The increase in SiH_2 stretching may arise due to the small particle size of nc-Si:H thin films at these pressure which attribute to the greater extent of grain boundary region. HRTEM result confirms the lower crystallites size (~ 2nm) of these nc-Si:H thin films. Due to non-uniform distribution of grains and lower crystalline volume fraction of the films, Raman spectra shows broad peak centered around 480 cm^{-1}. A transition region from amorphous to nanocrystalline structure has been found by the variation of silane flow rate (5-30 sccm). Different crystalline volume fraction (22 % to 60 %, estimated from Raman spectra) and band gap (1.58 eV to 1.96 eV) were achieved by the variation of silane concentration. The films deposited by the variation of argon concentration shows transition from amorphous to nanocrystalline in the argon concentration range of 82-87%. Films deposited below 82% of argon concentration showed lower dark conductivity values (10^{-10}-10^{-9} Ω^{-1} cm^{-1}) and high photosensitivity (>10^5).

Diamond like carbon thin films by RF PECVD process

Electrical, optical and mechanical properties of diamond-like carbon (DLC, a-C:H) and modified DLC (nitrogen incorporated DLC, a-C:N:H) thin films were deposited using radio frequency-plasma enhanced chemical vapour deposition (RF-PECVD) have been explored. a-C:N:H/Si and a-C:H/Si hetrojunction diodes (rectifying circuits), metal (Ti and Cu)/Si/a-C:H based multijunction devices etc. have also been explored. The possible application of DLC and modified DLC films as window layer for amorphous silicon (a-Si:H) based p-i-n solar cell has also been explored using theoretical simulation.

In addition, efforts have also been made to prepare DLC and modified DLC based hard and super-hard coatings. The super-hard and hard coatings realized by employing combination of various layers such as titanium/DLC bilayer and multilayer structure, nitrogenated DLC, oxygen modified DLC, copper/DLC bilayer structure and copper incorporated DLC films. The DLC deposition followed by oxygen plasma treatment performed for the improvement of the properties of DLC coating deposited on large area (size ~15 cm x 13 cm) glass substrate.

In case of plasma deposition, plasma parameters greatly influence the property of material. Hence, in order to use optimum parameters for growth of DLC and modified DLC films, plasma diagnostic by VI probe was also conducted. By this several plasma parameters are evaluated and further correlated with the properties of the material.

Carbon and silicon based thin films using filtered cathodic vacuum arc (FCVA) process : R&D on undoped and doped amorphous carbon thin films having embedded nanocrystallites

(i) The hydrogen and nitrogen incorporated amorphous carbon films having embedded nanocrystallites have been deposited using cathodic jet carbon arc (CJCA) techniques. The films deposited have been characterized by various measurements. XRD dominantly confirms the amorphous nature of the films deposited. Ultrafine nanocrystallites of 4-6 nm size may be of diamond are seen in HRTEM in a-C: N films which are surrounded by extensive amorphous region. In a-C: H films, the films microstructure was uniform with ultrafine grains distributed throughout the film. The grain size was measured between 8-25 nm with the separation of diffused grain boundaries among each other. The effect of substrate bias on the microstructure, conductivity, activation energy, optical band gap, optical constants, residual stress, hardness, elastic modulus, plastic index parameter, percentage elastic recovery and density of states of a-C: N and a-C:H have been studied and the properties obtained are found to depend on the applied substrate bias. All the properties evaluated show a point of inflexion (maxima and minima) in the films deposited at -60 V substrate bias in both a-C: N and a-C: H films.

(ii) Undoped and nitrogen incorporated amorphous carbon films having embedded nanocrystallites have been deposited using filtered anodic jet carbon arc (FAJCA) techniques. The films deposited have been characterized by XRD, HRTEM, SEM, AFM, XPS, Raman, electrical conductivity, optical band gap, nanoindentation and field emission measurements and the results obtained are being analyzed. XRD dominantly confirms the amorphous nature of the films deposited. HRTEM exhibits initially an amorphous structure but on closer examinations of the films the film was constituted of amorphous phase with the nanoparticle embedded in the amorphous matrix.

Filtered cathodic vacuum arc (FCVA) technique for the deposition of nitrogen incorporated amorphous/ microcrystalline silicon films

An alternative technique of filtered cathodic vacuum arc (FCVA) has been used to deposit nitrogen doped amorphous / microcrystalline silicon films using nitrogen doped silicon ingot as cathode material. Various process parameters such as arc current, magnetic field and substrate temperature and effect of hydrogen incorporation have been attempted. The main advantage of this process is that no hazardous and toxic gases like phosphine and silane have been used in this process and this is a high deposition rate process. A growth rate of 10A°/s has been achieved using 100 A arc current. The films deposited have been characterized by the electrical conductivity, activation energy, optical band gap, XRD, EDAX, and SEM. The dark conductivity in the range 10^{-4}-1 $ohm^{-1}cm^{-1}$, activation energy from 0.06-0.31 eV and band gap in the range 1.4-2.1 eV have been obtained by varying the deposition temperature of the substrate in the range 30 - 375°C. Effort is being made (i) to make heterostructure by depositing n-type a-Si films on p- type Si wafer to judge the quality of the silicon films deposited and (ii) to deposit boron-doped a-Si/ /μ-Si silicon films using B-doped silicon ingot.

Organic and Hybrid Solar Cell group

R&D work was carried out on different aspect in organic and hybrid solar cell during 2011-12. Fundamental and applied investigations were made in conjugated polymer, hybrid-polymer inorganic nano-structure / quantum dots, and tertiary (polymer-fullerene-carbon nanotube) bulk hetrojunction solar cells, degradation, etc.

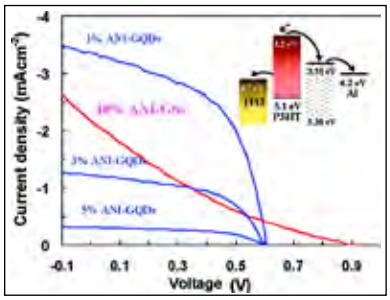


Fig. 1.5 J-V characteristics of the photovoltaic devices based on ANI¬GQDs with different GQDs content and ANI-GS (under optimized condition) annealed at 160 °C for 10 min, in AM 1.5G 100 mW illumination.

The focus of these investigations during the year was to study the device physics and device development in existing fullerene based electron acceptors as well as modified or new alternate acceptors in combination with conjugated polymers. Some important and significant contributions were made during the year as mentioned below in brief.

Luminescent Graphene Quantum Dots for Organic Photovoltaic Devices

Recent research in organic photovoltaics (OPV) is largely focused on developing low cost OPV materials such as graphene. However, graphene sheets (GSs) blended conjugated polymers are known to show inferior OPV characteristics as compared to fullerene adduct blended with conjugated polymer. We have found that graphene quantum dots blended with regioregular poly (3-hexylthiophene -2, 5-diyl) or poly (2-methoxy-5-(2- ethylhexyloxy) -1, 4 phenylenevinylene polymer results in a significant improvement in the OPV characteristics as compared to GSs blended conjugated polymers. This work has implications for inexpensive and efficient solar cells as well as organic light emitting diodes. P3HT/ANI-GQD-based hybrid solar cells were fabricated by spin-casting a solution of 15 mg mL^{-1} P3HT in dichlorobenzene (DCB) with ANI-GQDs contents of 0.5, 1, 3, and 5 wt % (ratio to P3HT) onto indium tin oxide (ITO), coated with poly(ethylene dioxythiophene)-polystyrene sulfonic acid (PEDOT:PSS) conductive polymer, which acted as the bottom electrode. LiF and Al were then vacuum deposited as the top contact to form an OPV device have the structure ITO/PEDOT:PSS/P3HT:ANI-GQDs/LiF/Al. For comparison, the solar cells of P3HT/ANI-GSs with ANI-GSs contents of 0.5, 1, 3, 5, 10, and 15 wt % (ratio to P3HT) were also fabricated. The solar cell characteristics were measured under 100 mW AM 1.5G illumination. As shown in Figure 1.5. Maximum values of power conversion efficiency (PCE) = 1.14%, V_{oc}= 0.61V, J_{sc}= 3.51m Acm^{-2} and FF = 0.53 were obtained for 1 wt % ANI-GQD in P3HT. In comparison, maximum values of PCE = 0.65%, V_{oc} = 0.88 V, J_{sc} = 2.65 m A cm^{-2} , and a low FF = 0.28 were obtained for 10 wt % ANI-GSs in P3HT.

Soluble functionalised fullerenes for photovoltaics

Two mono-adducts of fullerene C60 were synthesised using new aryl azides in good yields. These were characterized with spectroscopic techniques and then used to fabricate bulk heterojunction solar cells with P3HT. A photocurrent density of 3.89 mA/cm^2, open circuit voltage of 0.53V and PCE of 0.89% for adduct I and photocurrent density of 2.93mA/cm^2, open-circuit voltage of 0.53V and PCE of 0.71% for adduct II have been achieved as shown in Figure 1.6.

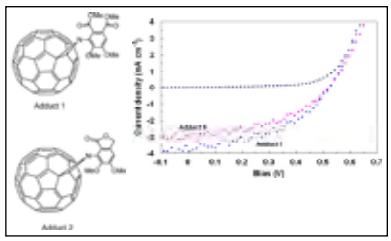


Fig. 1.6 I–V curve of P3HT:C60 adduct (1:1), measured at AM 1.5

Enhancement in Charge Transfer Mechanism by Non-Ligand-Exchange Process for Colloidal Hybrid Organic (MEH-PPV): Inorganic (CdSe) Nanocomposites

In this work, the effect of surface modification of as-synthesized oleylamine-capped spherical CdSe QDs of size (5-7 nm) was investigated. The as prepared CdSe QDs are highly luminescent, monodispersive and

exhibit energy transfer effects upon their dispersion in MEH-PPV polymer matrix. However, repetitive washing of CdSe QDs upon suitable chemical treatment leads to enhancement in charge transfer process as observed in their corresponding MEH-PPV:CdSe nanocomposites. Here, no evidence of agglomeration effects and surface states were found. This enhancement in charge transfer is mainly due to the partial removal of oleylamine capping ligand as shown in Fig. 1.7, which acts as a hindrance in the interaction between polymer and CdSe QDs. The importance of this study is that as-synthesized CdSe QDs shows effective energy transfer whereas after chemical treatment, it shows enhanced charge transfer mechanism which makes their corresponding nanocomposites useful for different applications in organic devices such as efficient electroluminescent (OLED) and photovoltaic (OPV) devices respectively.

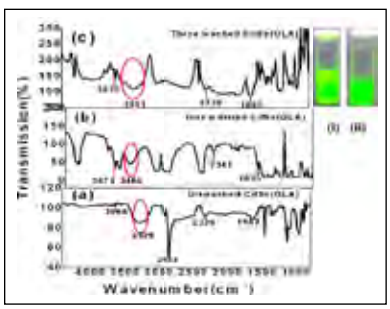


Fig. 1.7. FTIR spectra of CdSe QD's (a) unwashed (as-synthesized) (b) one-time washed (c) three-times washed. (i) & (ii) corresponds to UV photographs of unwashed and three-times washed CdSe QD's.

Effect of in-situ quantum dots, CNT's and degradation studies

Besides this inorganic quantum dots such as CdS and CdSe, etc were grown in-situ with P3HT (rather than being dispersed in polymer matrix) and charge transport parameters were suitably modulated with incorporation of these quantum dots for improvement in the PCE. Also investigations have been carried out in exploring the π-π interaction between CNTs and conjugated network of polymer for modifying microstructural morphology (crystallinity) as well as photophysics (absorption) for development of polymer-fullerene-carbon nanotube) bulk hetrojunction solar cells. Further, investigations were carried on understanding the degradation in organic solar cells. Experiments were performed on ITO/PEDOT:PSS/P3HT:PCBM/Al solar cells where photovoltaic response was studied with time in forward and reverse sweeps. The solar cell exhibited exponential degradation in efficiency and polarization effect due to degradation. This is an important observation in degraded organic solar cells.

Thermoelectric Materials Group

Bismuth telluride is a narrow band gap (0.15eV) layered semiconductor material having trigonal structure with high melting point (585°C), also it is a heaviest stable binary compound. These interesting properties attracted the researchers for its wide range of applications in the field of thermoelectric material used for power generation and refrigeration.

We are working on low Dimensional Bismuth telluride based alloys. It is of interest to us due to enhanced thermoelectric properties at room temperature as compared to their bulk counterparts. The performance of thermoelectric materials is a function of the dimensionless figure of merit, which is defined as $ZT = \alpha 2\sigma T/k$, where α, σ, k and T are the Seebeck coefficient, the electrical conductivity, the thermal conductivity and the absolute temperature respectively. The enhancement in the performance can be achieved by maximizing the Seebeck coefficient and electrical conductivity and minimizing the thermal conductivity. Interest in low dimensional material such as Quantum wells (2D), Quantumwires (1D), Quantum dots (0D) are due to 1) High surface density of states at the nanoscale, 2) Improvement of electronic properties via quantum effects. 3) Increased phonon scattering causing reduced lattice thermal conductivity.

We are using different techniques such as Hydrothermal Synthesis (HS), Chemical Synthesis (CS), Microwave assisted flash combustion synthesis (MFCS).

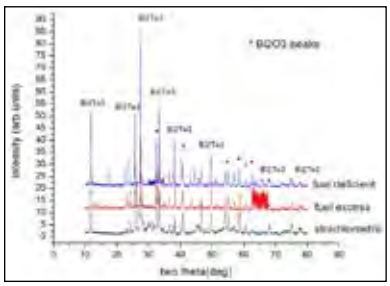


Fig. 1.8 X-ray diffraction patters of MFCS sample

Figure 1.8 shows the X-ray diffraction pattern of MFCS samples.

Organic and inorganic LEDs Group

Enhancement of light extraction efficiency of organic light emitting diodes using nanostructure indium tin oxide

Organic light emitting diodes (OLEDs) have attracted great attention due to their potential applications in full color displays and solid state lighting. Typically an OLED consists of a glass substrate, a transparent indium tin oxide (ITO) anode, organic layers, and a reflective cathode. In an OLED, electrons and holes are injected from a cathode and an anode, respectively.

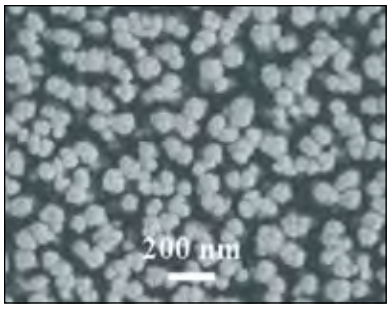


Fig. 1.9a SEM image of the ITO films grown at a glancing angle 85°

Electrons and holes then traverse through the electron transport and the hole transport layer, respectively, and form a bound pair (exciton) in an emissive layer. This bound pair then decays radiatively to produce a photon. The emitted photon has then to cross several organic layers, an anode, and a glass substrate to escape from this structure. The external quantum efficiency of an OLED is the product of internal quantum efficiency and outcoupling efficiency. OLEDs with phosphorescent emitters are now operating with almost 100% internal quantum efficiency . However, major fraction of light generated inside the emissive layer is trapped in the organic, ITO and glass substrate due to a large refractive index difference between these layers. According to the classical ray optics, only 20% of generated light escapes from the OLED, while the remaining 80% of light is trapped inside the structure as waveguided modes in organic and ITO layers and substrate modes and emitted from the edges. This low outcoupling

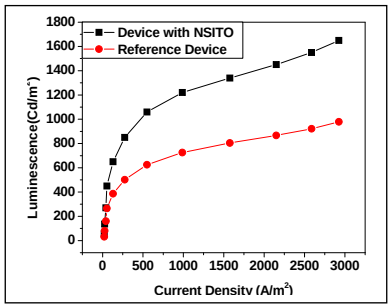


Fig. 1.9b Current density-luminescence characteristics for OLED with NSITO film and reference OLED

efficiency is the main limitation in the development of high efficiency OLEDs. A number of techniques have been employed to efficiently outcouple the light trapped inside the glass and ITO. Some of these methods have been very successful, such as surface roughening and the use of microlenses and shaped substrates and the incorporation of textured surfaces, microcavities, surface plasmons, ordered structures or photonic crystals and a low refractive index silica aerogel layer. But most of the afore mentioned techniques incorporated inside the device, such as microcavities, surface plasmons and photonic crystals, though found to be very effective, require expensive fabrication techniques. OLEDs are meant for large area display and illumination. It is very expensive to fabricate microstructure and photonic crystals for a large area. Hence a low cost method is required that can outcouple the trapped light in ITO/organic and ITO/glass interfaces effectively and that is capable of producing direction independent and uniform light outcoupling. We have demonstrated the use of a nanostructured film of ITO (NSITO) grown by the glancing angle deposition technique to efficiently outcouple the light trapped inside the ITO and organic layer.

We have fabricated nanostructured films of ITO

(Fig. 1.9a) by using glancing angle deposition technique at an angle of 85° from that of substrate normal. Conducting ITO films were grown on the NSITO films and these films were characterized for transparency. Transparency has been found to increase with incorporation of NSITO films in between glass and conducting ITO films. Sheet resistance of conducting ITO films was found to be 80±5 Ω/□. Hole injection properties of the conducting ITO films were checked and found to be almost unaffected with the incorporation of NSITO films. OLEDs with the NSITO films inserted between glass and conducting ITO were found to have enhanced outcoupling efficiency in comparison to the reference OLED. About 1.8 times enhancement has been observed with the insertion of NSITO films between glass and conducting ITO (Fig. 1.9b) without introducing any detrimental effects to current density inside the device and to emission spectra of the OLED. Electroluminescence spectrum at various viewing angles was found to be unchanged and the technique was found to be direction independent unlike the other techniques for outcoupling efficiency enhancement.

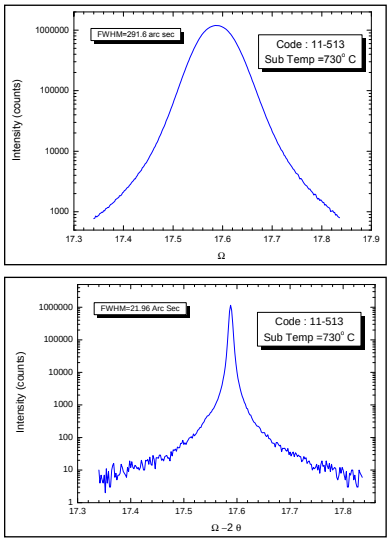


Fig. 1.10 HR-XRD experiments were performed using "PANALYTICAL XRD" with CuKα1 on epitaxial GaN grown on 2" epi-layer/sapphire confirms the epitaxial growth with FWHM 291.5 arc Sec and 21.96 arc sec as function of omega Ω and Ω2θ theta, respectively.

Inorganic LEDs

The growth of Gallium nitride has been performed on newly established RIBER-Molecular Beam Epitaxy machine at CSIR-National Physical Laboratory. The growth of GaN has been carried out on a commercially purchased MOCVD grown GaN epi-layer on a single crystalline C-Sapphire (0001) substrate. By optimizing the growth parameters and under the control flux of Gallium metal & nitrogen plasma source, high quality GaN material was grown on 2-inch substrate. The photoluminescence (PL) experiments of 1.2μm thick GaN film on GaN/c-Sapphire were carried out on Nanometrics, RPM. A 325.5nm excitation source was used to record the PL data. PL data shows an emission peak at 362.2nm corresponding to GaN while a broad peak centered at 565nm related yellow band emission. Photoluminescence mapping on the 2-inch substrate confirms the emission at 362.2nm

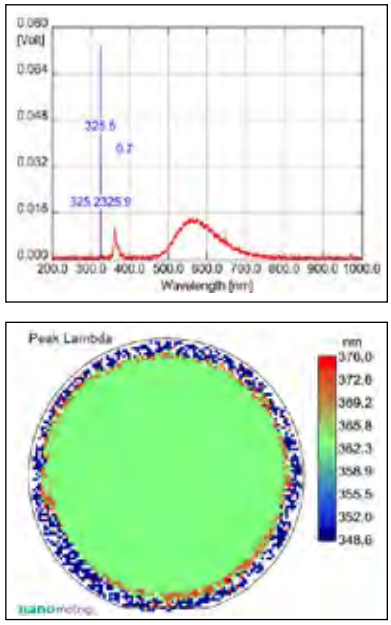


Fig. 1.11 PL data shows an emission peak at 362.2 nm and Photoluminescence mapping

(SD 4.607nm, 1.27%) from the entire wafer with an average peak intensity 10mV and average FWHM ~ 4.9nm. The PL mapping data shows the uniformity of better than ±2%.

Optical Thin Film group

ZnO nanostructures have been grown by thermal CVD technique by using thermal evaporation of Zn powder in oxygen ambient on different substrates under various growth parameters. Various ZnO morphologies have been observed by SEM viz. self aligned rods in the form of cellular network, branched patterns etc. The X-ray diffraction has confirmed the crystallinity and hexagonally faceted ZnO (wurtzite). The PL studies show high quality ZnO nanostructures. However, it has been observed

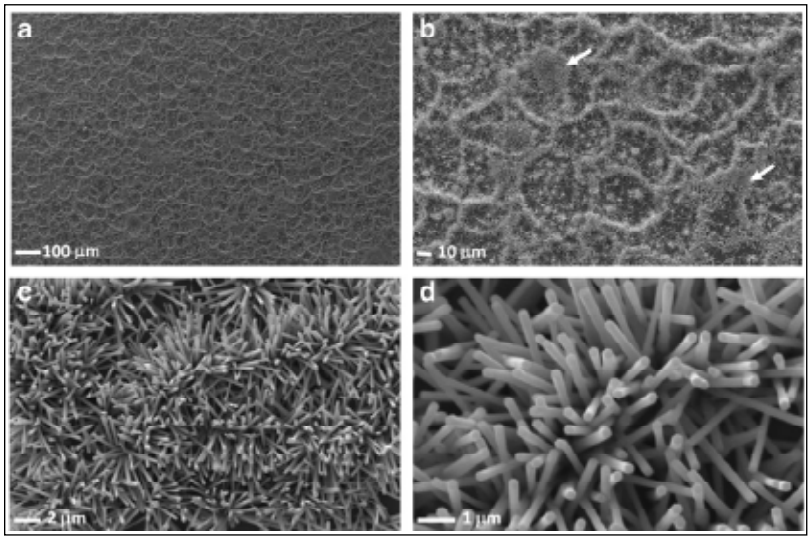


Fig. 1.12 SEM images of self-assembled ZnO rods network grown on Si (100) substrate measured at different magnifications: (a) 200 X, (b) 1 KX, (c) 10 KX and (d) 30 KX.

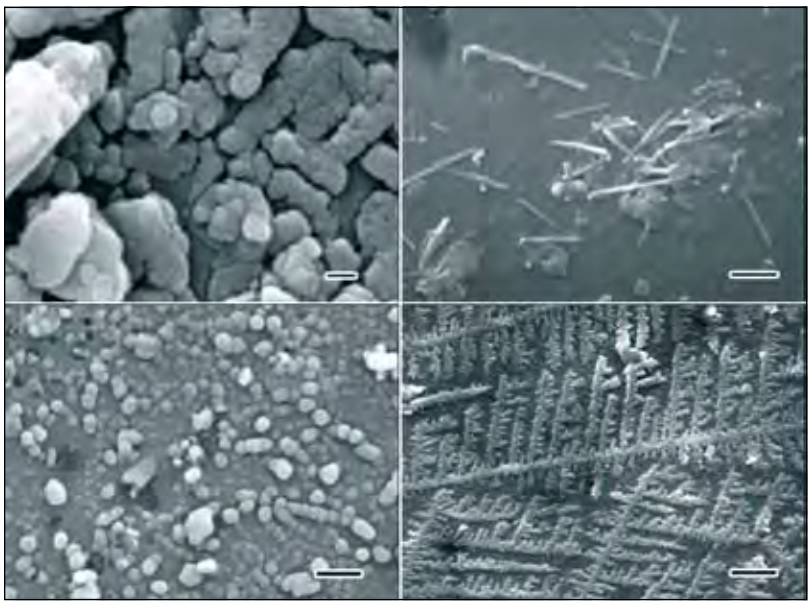


Fig. 1.14 SEM micrographs of as-deposited anatase titania synthesized by PECVD at room temperature and with DC bias of □150 V: (a) clusters of nanocrystals at 30 Pa (0.3 mbar), (b) nanorods at 50 Pa (0.5 mbar), (c) nanoparticles at 80 Pa (0.8 mbar), (d) comb-like structure at 100 Pa (1 mbar)

that the admittance temperature of oxygen has great effect on the quality of nanostructures.

It is for the first time that various titania nanostructures have been observed by PECVD technique at room temperature, simply by changing the substrate bias and the deposition pressure. The X-ray diffraction studies has confirmed the crystallinity and phase as anatase titania.

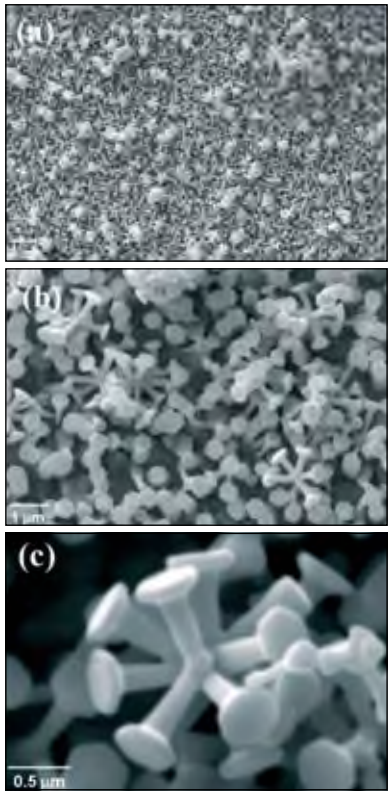


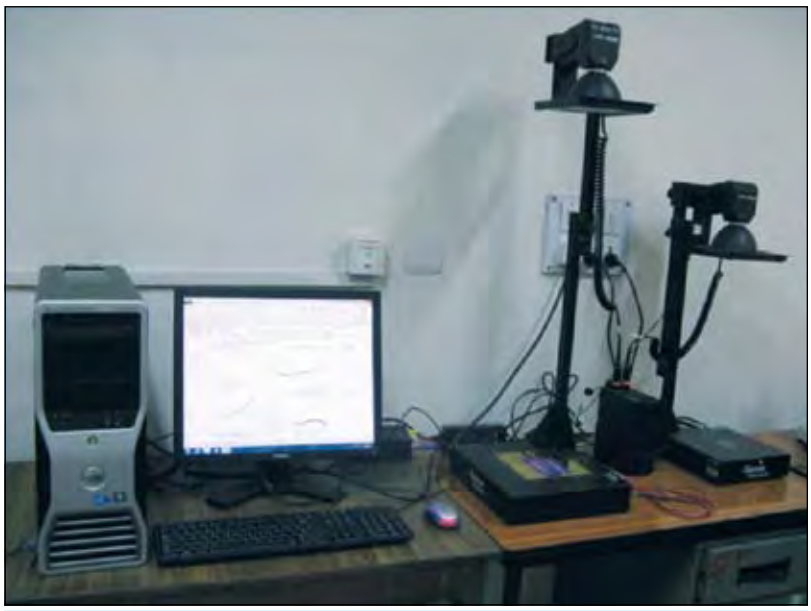
Fig. 1.13. SEM images of ZnO nanonails (Sample C), grown on sapphire substrate at 700°C with 1.0 SLPM O_2 gas flow, measured at different magnifications (a) 5 KX, (b) 30 KX, and (c) 100 KX

Major facilities established :

1. **I-V measurement system:** Capability of measuring I-V characteristics of cell size ranging from 2x2 to 20x20 cm^2 under AM1.5 condition.

I-V measurement system

2. **Minority carrier lifetime measurement system with Suns-Voc stage:** Capable of measuring minority carrier lifetime in micro- to millisecond range and I-V characteristics of diffused wafers (without considering series resistance effect).



Minority carrier lifetime measurement system with Suns-Voc stage

3. **Deep Level Transient Spectrometer (DLTS)**

For the study of deep level traps in thin films a Deep level Transient spectrometer (DLTS), SULA Tech. (USA) make, has been procured. The system contains all the basic modes of operation including Optical DLTS. It has MMR (USA) make probe station with 4 probe manipulators and a cryo system (Joule-Thomson Refrigerator) to carry out DLTS measurements in the temperature range 80K – 730K. Its four correlators allow measurements for 8 differenet rate-windows in a complete temperature cycle (during waming up and cooling cycles). There is also a provision to apply fast pulses externally to distinguish slow and fast traps.

Deep Level Transient Spectrometer (DLTS)


वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद
CSIR · INDIA ·


राष्ट्रीय भौतिक प्रयोगशाला
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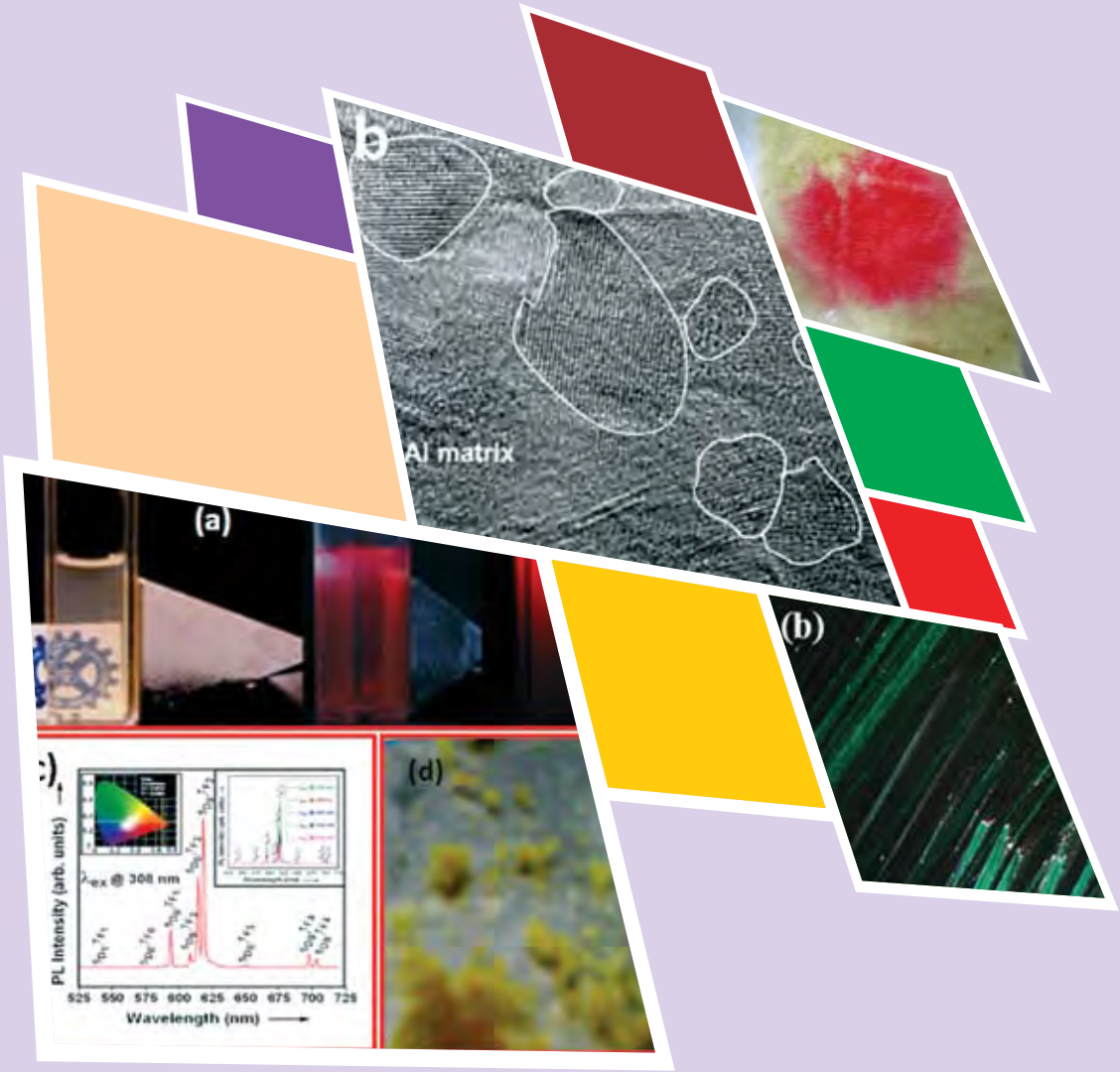
पदार्थ भौतिकी एवं इंजीनियरिंग



Materials Physics and Engineering

पदार्थ भौतिकी एवं इंजीनियरिंग

पदार्थ भौतिकी एवं इंजीनियरिंग प्रभाग का कार्यक्षेत्र मुख्य रूप से बहुलक एवं मृदु पदार्थों, कार्बन की भौतिकी एवं इंजीनियरिंग, संदीप्तिशील पदार्थों, बहु–लौह एवं चुंबकीय पदार्थों एवं जैव–आण्विक यंत्रीकरण, प्रकाशीय तनु परतों एवं सिरैमिक एवं धातुओं तथा मिश्रधातुओं से संबंधित है। इस प्रभाग का उद्देश्य उपर्युक्त क्षेत्रों में अवयवों, युक्तियों, संवेदकों और प्रणालियों हेतु पदार्थों, प्रक्रम और प्रौद्योगिकियों को विकसित करना है। इस प्रभाग द्वारा किए गए प्रमुख अनुसंधान एवं विकास क्रियाकलापों में औद्योगिक तथा कार्यनीतिक महत्त्व की वायु–आकाशीय धात्विक युक्तियों, नए कार्बन उत्पादों, तथा अनेक प्रकार के सुचालक बहुलकों और जैव–संवेदकों को विकसित करना शामिल है। इस प्रभाग के प्रत्येक समूह द्वारा किए गए अनुसंधान कार्यों का सारांश नीचे दिया गया है:

बहुलक और मृदु पदार्थ

द्रव क्रिस्टलों जैसे मृदु पदार्थों, जैव–मार्करों हेतु सूक्ष्म चैनलों के लिए फोटोलिथोग्राफी, वैनेडियम ऑक्साइड के संश्लेषण हेतु सॉल–जेल प्रक्रम, तथा बहुलक–फेरिक ऑक्साइड सम्मिश्र तैयार करने के लिए गतिक अध्ययन किए जा रहे हैं। विभिन्न अनुप्रयोगों हेतु उनके गुणों में संवर्धन के लिए विभिन्न प्रकार के अति सूक्ष्म कणों का प्रयोग किया जा रहा है।

कार्बन की भौतिकी और इंजीनियरिंग

कार्बन की भौतिकी और इंजीनियरिंग अनुभाग ऊर्जा तथा संरचनात्मक अनुप्रयोगों हेतु व्यापक रेंज के उन्नत कार्बन पदार्थों के अनुसंधान और विकास से संबंधित कार्य कर रहा है। ये हैं: कार्बन नैनो ट्यूब, उनका संश्लेषण तथा सम्मिश्रों, कार्बन–कार्बन सम्मिश्रों, कार्बन और बोरोन नाइट्राइड नैनो ट्यूबों में उनका प्रयोग तथा धातु–मैट्रिक्स सम्मिश्रों, ग्रैफीन और इलेक्ट्रोस्पन नैनो फाइबरों, उन्नत सम्मिश्र द्वि–ध्रुवीय प्लेटों तथा सरंध्र चालक कार्बन पेपर का पोलिमर इलेक्ट्रोलाइट मेम्ब्रेन (पी ई एम) ईंधन सेल में प्रयोग के लिए विकास में उनका प्रयोग।

संदीप्तिशील पदार्थ और युक्ति समूह

यह समूह सौर सेलों के लिए संवर्धित अप–कनवर्जन संदीप्ति दक्षता युक्त नैनो फास्फर को विकसित करने के कार्य में संलग्न है। वर्तमान में इस समूह द्वारा प्रदर्श युक्तियों हेतु संवर्धित नील संदीप्ति हेतु डोपित नैनो क्रिस्टलों और क्वान्टम डॉटों, सौर स्पेक्ट्रम आशोधन हेतु क्रोड़–कवच नैनो फास्फर प्रकाश उत्सर्जी डायोडों के लिए नव नैनो फास्फर, जैव–संबद्ध अनुप्रयोगों हेतु संदीप्तिशील और चुंबकीय खोखले क्रोड़ युक्त नैनो फास्फर के संश्लेषण पर विशेष रूप से ध्यान दिया जा रहा है।

जैव–आण्विक यंत्रीकरण

जैव–आण्विक इलेक्ट्रॉनिक्स से संबद्ध डी एस टी केंद्र ऐसे अनेक जैव–संवेदकों को विकसित करने की दिशा में सक्रिय रूप से कार्य कर रहा है, जिनका प्रयोग इच्छित परीक्षण प्रदर्शों में कॉलेस्टेरोल, निम्न घनत्व युक्त लाइपो प्रोटीन, ट्राइ ग्लाइसेराइड्स, ग्लूकोस, यूरिया, रोगजनकों (ई–कोलाई, एम ट्यूबरकुलोसिस, नाइसिरीया गनोरिया), खाद्य पदार्थों में मौजूद विषाक्त पदार्थों और नाशीजीव मारक रसायनों जैसे विभिन्न संघटकों का आकलन करने के लिए किया जा सकता है।

धातु एवं मिश्रधातु समूह

इस वर्ष जनरल मोटर्स द्वारा "मैग्निशियम–दुर्लभ मृदा मिश्रधातु के उत्खनन के दौरान पुनः क्रिस्टलीकरण तथा कण परिशोधन तंत्र से अवगत होना" विषय पर प्रायोजित योजना को सफलतापूर्वक पूरा कर लिया गया तथा इसके सभी इच्छित उद्देश्यों की उपलब्धि हुई। दो चालू नेटवर्क परियोजनाओं पर कार्य जारी रहा तथा विशिष्ट परिणामों को प्राप्त करने की दिशा में उल्लेखनीय प्रगति हुई। वर्ष के दौरान अति सूक्ष्म संघटन युक्त ताप इलेक्ट्रिक पदार्थों और युक्तियों के विकास तथा अति सूक्ष्म संघटन युक्त स्थायी चुंबकीय पदार्थों के विकास विषय पर इस समूह द्वारा दो नए अनुसंधान क्रियाकलाप शुरू किए गए। नेटवर्क परियोजना के अंतर्गत स्पार्क प्लाज्मा सिन्टरन नामक एक नया उपकरण संस्थापित किया गया।

Materials Physics and Engineering

The Division of Materials Physics and Engineering mainly comprises of Polymer and Soft Materials, Physics and Engineering of Carbon, Luminescent Materials, Multiferrites and Magnetics, Biomolecular Instrumentation, Optical Thin Films & Ceramics and Metals & Alloys Groups. The objective of this division is to develop materials, processes and technologies for components, devices, sensors and systems in the above mentioned areas. The R&D output of this division includes the development of aerospace metallic devices, new carbon products which hold industrial and strategic importance, and a variety of conducting polymers & biosensors. The summary of the research work carried out by each group is as follows:

Polymer and Soft Materials

The dynamic studies of soft materials like liquid crystals, photolithography for micro-channels for bio-makers, sol-gel process for synthesis of vanadium oxide and conducting polymer-Fe_2O_3 composite is being carried out. Various kinds of nanoparticles are being used to enhance their properties for different applications.

Physics and Engineering of Carbon

The Physics and Engineering of Carbon section is engaged in the research & development of a wide range of advanced carbon materials for energy and structural applications. These are carbon nonotubes, their synthesis and application in composites, carbon-carbon composites, carbon and boron nitride nanotubes and their application in the development of metal-matrix composites, graphene and electrospun nanofibers, advanced composite bipolar plates and porous conducting carbon paper for application in Polymer Electrolyte Membrane (PEM) fuel cell.

Luminescent Materials and Devices Group

This group is engaged in the development of nanophosphors with enhanced up-conversion luminescence efficiency for solar cells. Synthesis of doped nanocrystals and quantum dots for enhanced blue luminescence for display devices, core-shell nanophosphors for solar spectrum modification, novel nanophosphors for LEDs, luminescent and magnetic hollow core nanophosphors for bio-related applications are the current thrust of the group.

Biomolecular Instrumentation

The DST Centre on Biomolecular Electronics has been actively engaged towards the development of various biosensors that can be utilized for estimation of various analytes like cholesterol, low density lipo protein, triglyceride, glucose, urea, pathogens (E.Coli, M.tuberculosis, Neisseria ghonorhea), food toxins and pesticides in desired test specimens.

Metals & Alloys Group

This year the General Motors sponsored project, entitled "Understanding the mechanism of recrystallization and grain refinement during extrusion of Magnesium-Rare Earth alloys" was successfully completed achieving all the desired objectives. Work was continued on the two on-going Network projects and significant progress made in achieving the specified deliverables. Two new research activities were initiated in the group during the year on the development of nanocomposite thermoelectric materials & devices and development of nanocomposite permanent magnet material. A new equipment, namely, Spark Plasma Sintering was installed under the network project.

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D 02.01 Polymer & Soft Materials

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Sh Parveen Saini
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D 02.02 Physics & Engineering of Carbon

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Sh Sanjay Rangnate Dhakate
Sh. Bhanu Pratap Singh
Ms Priyanka Heda Maheshwari
Dr (Ms) Saroj Kumari
Sh Pinaki Ranjan Sen Gupta
Sh Rajesh Kumar Seth

D 02.03 Luminescent Materials

Dr Virendra Shanker
Dr (Ms) Santa Chawla
Dr Divi Haranath
Dr Bipin Kumar Gupta

D 02.04 Multiferroics and Magnetics

Dr R K Kotnala
Dr Aloysius R P
Dr Nirmalya Karar
Dr Gounda Abdul Basheed

D 02.05 Biomedical Instrumentation

Dr (Ms) G Sumana Gajala
Dr Ved Varun Agrawal
Sh Manoj Kumar Pandey

D 02.06 Metals & Alloys

Dr Ajay Dhar
Dr Narinder Kumar Arora
Dr (Ms) Gurusharan Kaur Padam
Sh Vipin Jain
Dr Dinesh Kumar Misra
Dr (Ms) Nidhi Singh
Sh Bathula Sivaiah
Sh M Saravanan
Sh Rajiv Sikand
Sh Rakesh Khanna

D 02.07 Piezo Electric Sensors and Actuators

Sh Subodh Kumar Singhal

Polymeric and Soft Materials

Liquid Crystals

Display devices based on liquid crystal (LC) materials have been in great demand for last few decades due to their advantages over other display devices. The LC materials have been employed in various switchable electro-optic devices due to their essential anisotropic (optical and dielectric) behaviour. The majority of the display and non-display devices realized have been based on nematic LCs. Recently, various interesting electro-optical properties such as good optical contrast, low threshold voltage, memory effect, fast response of ferroelectric liquid crystals (FLCs) have attracted a great deal of attention of the researchers in the world. The incorporation of nanomaterials such as carbon nanotubes, zinc oxide nanoparticles and gold nano-particles in FLCs have further improved their electro-optical properties in the form of faster response, low threshold and non-volatile memory. However, the presence of undesired ionic impurities in LC materials is still a major challenge to be taken care of as these impurities can cause the degradation of the display devices based on these materials. These impurities enter within LCs either through the atmosphere or alignment layer or during their synthesis. Ions within LCs generate electric field which could lead to polar surface interactions and thus anchoring energy and driving voltage could be changed. These ions may cause grey-level shift, image sticking and slow response time of the LC device. We at CSIR-NPL planned to minimize the ionic effects in liquid crystals for the first time by employing porous alumina nanoparticles. The suppression of ionic effects of FLC materials doped with alumina nanoparticles (AL-NPs) has been carried out at NPL. The effect of AL-NPs doping has been analyzed by means of dielectric spectroscopy and resistivity/ conductivity measurements. We found that the defect sites existing over the surfaces of AL-NPs have adsorbed the undesired ionic impurities present in FLCs. Dielectric loss spectra of AL-NPs

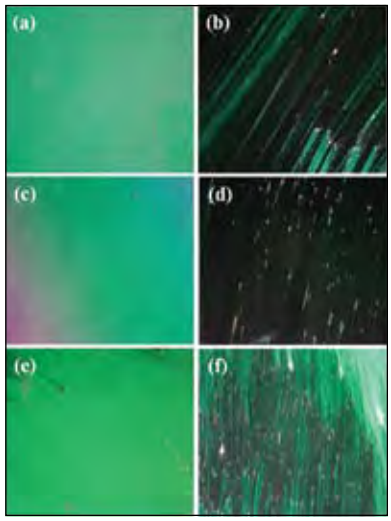


Fig. 2.1: Polarizing micrographs showing the bright and dark states of 1 wt % AL-NPs of different size (a), (b) for 4-7 nm; (c), (d) for 20-30 nm and (e), (f) for 30-50 nm doped KCFLC 7S material at room temperature (RT).

doped FLC cells clearly reflected the suppression of ionic effects in the form of disappearance of low frequency relaxation, generally caused by ions. The FLC material, KCFLC 7S, has been used in the present study. Highly conducting ITO coated glass plates were used to fabricate the LC sample cells. The FLC material was then filled into the sample cell by means of capillary action at above the isotropic temperature to ensure the proper filling. The cells then cooled gradually to room temperature.

The effect of AL-NPs of various sizes on the alignment of FLCs was analyzed by observing the optical micrographs of the pure and AL-NPs doped KCFLC 7S cells. Figure 2.1 shows the optical micrographs of the bright and dark states of 1 wt % AL-NPs (of different sizes) doped KCFLC 7S material. The presence of AL-NPs in the FLC material can be clearly seen from the micrographs of dark states in the form of light scattering centers [Fig. 2.1 (b), (d) and (f)]. We found that the doping of 1 wt % of AL-NPs in the size range 4-30 nm did not perturb the alignment of FLC material much. However, on increasing the size (> 30 nm) of AL-NPs, the alignment of FLC material was degraded which can be seen in the form of large aggregates [Fig. 2.1 (e) and (f)]. As AL-NPs in the size range 20-30 nm did not perturb the FLC alignment remarkably, we carried out further studies on KCFLC 7S/AL-NPs composites by doping 1 wt % AL-NPs of size 20-30 nm. The effect of AL-NPs on the dielectric relaxation processes was analyzed by observing the behaviour of pure and AL-NPs doped KCFLC 7S cells. The effect of doping concentration of AL-NPs on their adsorption capability have been observed by varying the concentration of 20-30 nm AL-NPs into KCFLC 7S material from 0.5 to 3 wt %. We found that 1 wt % AL-NPs with 20-30 nm size range is suitable to effectively suppress the ionic contributions of FLC material. It is noticeable that the presence of AL-NPs did not affect the behaviour of GM and SmC*-SmA* transition temperature of KCFLC 7S material. The effect of dc bias field on the low frequency mode was also observed by applying different dc biases across the cells [Fig. 2.2]. The low frequency peak has been shifted towards low frequency side by applying dc bias.

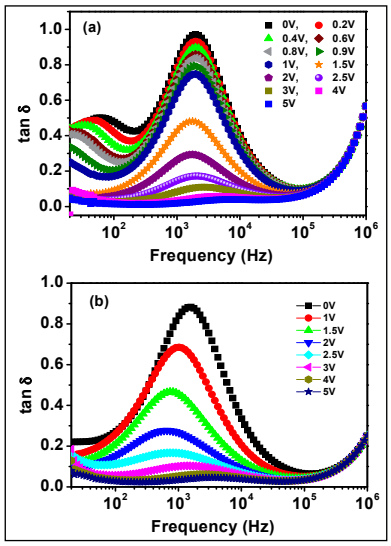


Fig. 2.2: Behaviour of low frequency relaxation peak of (a) pure and (b) 1 wt % AL-NPs of size 20-30 nm doped KCFLC 7S material on the application of different dc biases at room temperature.

We calculated and plotted the electrical conductivity of pure and 1 wt % AL-NPs doped KCFLC 7S materials [Fig.2.3]. It is clear from the figure that the value of σ was increased with increase in temperature for both pure and doped materials. In case of AL-NPs doped KCFLC 7S material [Fig. 2.3 (b)], the value of σ was significantly reduced. For instance, at 50°C and 60 Hz frequency, its value was 46 S/m for pure KCFLC 7S [Fig. 2.3 (a)] while for AL-NPs doped KCFLC 7S material it reduced to 19.6 S/m [Fig. 2.3 (b)]. It can be concluded

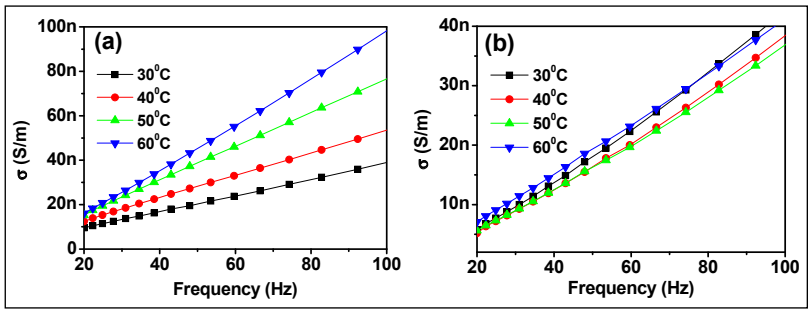


Fig. 2.3: Behaviour of electrical conductivity (σ) with frequency of pure (a) and 1 wt % AL-NPs (b) of size 20-30 nm doped KCFLC 7S material respectively.

that doping of 1 wt % AL-NPs of 20-30 nm size range is suitable to effectively suppress the ionic contributions of FLC material. The study will certainly provide an effective tool to remove the undesired ionic impurities present in the FLC mixtures.

Recognition

- Article, "Enhancing the photoluminescence of ferroelectric liquid crystal by doping with ZnS quantum dots," published in Applied Physics Letters vol. 100, p.p. 134101 (2012), has been selected for the April 9, 2012 vol. 25, issue 15 of Virtual Journal of Nanoscale Science & Technology.
- Article, "Alumina nanoparticles find an application to reduce the ionic effects of ferroelectric liquid crystal", published in J. Phys. D: Appl. Phys. vol. 44 p.p. 315404-1-315404-7 (2011) has been selected as Research Highlight entitled "Smarter Liquid-Crystal Display" in Nature India, 23 August 2011.

Electrochemical impidimetric technique for the detection of cardiac biomarkers

Cardiac biomarkers are the molecules that are released into the blood when there is some damage to the heart. C-reactive protein (CRP) is a 118 kD protein that is produced in the liver during episodes of acute myocardial infarction (AMI). It is classified as a characteristic acute phase reactant in human serum and a classic marker of inflammation. CRP level of more than 3.0 mg L^{-1} in blood is an indication of a high risk of cardiovascular disease (CVD). We have recently reported a simple and direct one step procedure for the electrochemical synthesis of 3-Mercaptopropionic acid (MPA) capped ZnS modified PPy nanocomposite film on to the surface of Indium tin oxide (ITO) coated glass plate (ZnS(MPA)-PPy/ITO-glass plate). The small-sized ZnS nanocrystals with free carboxyl groups from MPA on its surface provided more binding sites for covalent immobilization of protein antibody in the polymer nanocomposite film, making this an excellent choice as transducer material, for the design of electrochemical impedimetric immunosensor for the detection of C-reactive protein (CRP). The ZnS-PPy composite film was characterized by transmission electron microscopy (TEM), atomic force microscopy (AFM) and electrochemical techniques. The modified film showed good biocompatibility with efficient binding to protein antibody (aCRP-Ab) molecules through ZnS nanocrystals, exhibited an attractive platform for immunosensor fabrication. The modified electrode, as prepared, was tested as an impedance immunosensor with different concentration of protein antigen, aCRP-Ag in aqueous solution. It was found that with each successive addition of the aliquots of different concentration of aCRP-Ag in a sample solution increases the diameter of Nyquist circle, indicating increased electron transfer resistance of immunosensor [Figure 2.4(a)]. This is due to the protein antibody-antigen coupling at the immunosensor surface, which acts as a kinetic barrier for the electron transfer. This is more pronounced in the Bode diagram [inset of Fig. 2.4(a)], which shows an increasing trend in both

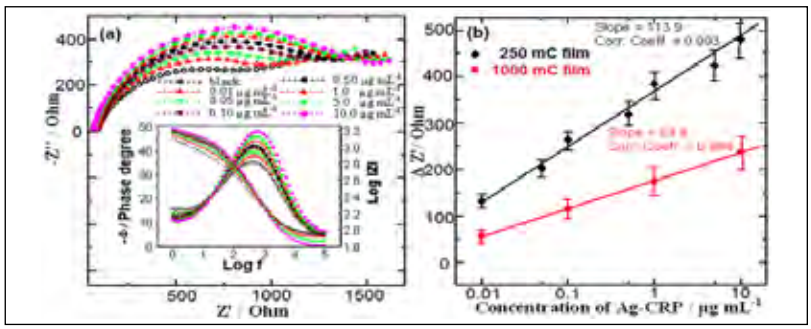


Fig. 2.4: (a) Nyquist diagrams for CRP-Ab/ZnS(MPA)-PPy/ITO-glass prepared at 250 mC cm-1 injected charge density with different concentration of CRP-Ag in aqueous solution, inset: Bode plots of the corresponding immunoreaction; (b) Concentration dependence calibration curve for CRP-Ab/ZnS(MPA)/PPy/ITO-glass immunosensor towards CRP-Ag detection.

impedance module and phase angle on increasing antibody-antigen coupling at the electrode surface. Figure 2.4(b) showed a linear relationship between the electron-transfer resistance and logarithmic value of aCRP-Ag concentration in the range of 10 ng mL^{-1} to 10 µg mL^{-1} with correlation coefficients of 0.993 and 0.998 for immunosensor with polymer composite films prepared at injected charge densities of 250 and 1000 mC cm^{-2}, respectively. The above linear range of CRP detection is wide enough to cover the whole range of relative risk categories: low risk (<1 µg mL^{-1}), average risk (1–3 µg mL^{-1}) and high risk (>3 µg mL^{-1}) for patients with an intermediate 10-year CVD risk.

Conducting Polymers Group

Reduced graphene oxide/y-Fe_2O_3/carbon fiber sandwich for excellent electromagnetic interference shielding in the X-band

Composite sheet consisting of a reduced graphene oxide (RGO)/y-Fe_2O_3 carbon fiber sandwich has been produced by compression molding. Its electrical conductivity lies in the range 0.48–171.21 S/cm. Transmission and scanning electron microscopy observations confirm the presence of nano particles of y-Fe_2O_3 (~9.8 nm) and carbon fiber (~1 mm) which gives flexural strength to the RGO sandwich. Thermogravimetric analysis show that the thermal stability of the RGO sandwich depends upon the amount of RGO and phenol resin in the sandwich. Complex parameters, i.e., permittivity ($\varepsilon^*=\varepsilon'-i\varepsilon''$) and permeability ($\mu^*=\mu'-i\mu''$) of RGO/y-$Fe_2O_3$/carbon fiber have been calculated from experimental scattering parameters (S_{11} & S_{21}) using theoretical calculations given in Nicholson–Ross and Weir algorithms. The microwave absorption properties of the paper have been studied in the 8.2-12.4GHz (X–Band) frequency range. The maximum shielding effectiveness observed is 45.26 dB, which strongly depends on dielectric loss and volume fraction of y-Fe_2O_3 in RGO matrix.

RGO has been incorporated with varying amount of y-Fe_2O_3 to make a sandwich along with carbon fiber and its effect on mechanical, electrical and the EMI shielding properties have been investigated. Carbon fibers have been used to strengthen the sandwich. Also, the effect of varying phenol resin on the electrical and mechanical properties has been studied. The vibrating sample magnetometer (VSM) study of paper with different amounts of y-Fe_2O_3 has been carried out to find their magnetic induction and hence its effect on EMI shielding absorption. The sandwich paper having thickness 0.2-0.4 mm has shown high value of shielding effectiveness ranging from 16.98 to 42.83dB (~99.99%) in the microwave range (X-band).

Scanning electron microscopy (SEM) was carried out to determine the distribution of RGO or RGO platelets and carbon fibers in the sandwich. The RGO particle size is seen up to few nanometers as shown in Fig. 2.5 (b). Determination of thickness of RGO platelets is considered difficult by SEM. Figure 2.5(c)

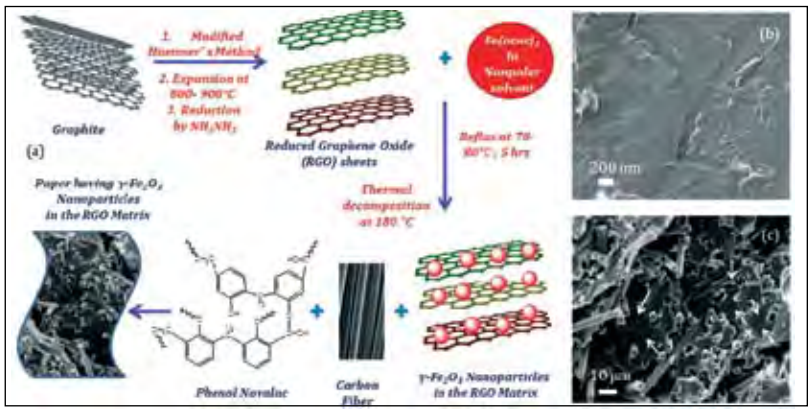


Fig. 2.5: (a) Schematic representation of preparation of RGO sandwich containing different wt % of y-Fe_2O_3 nanoparticles using phenol resin in the organic medium (b) SEM images of RGO and (c) RGO/y-Fe_2O_3 sheet having 1% carbon fiber and 50 wt% of phenol resin showing the pullouts of carbon fibers and the fracture surface of sheet.

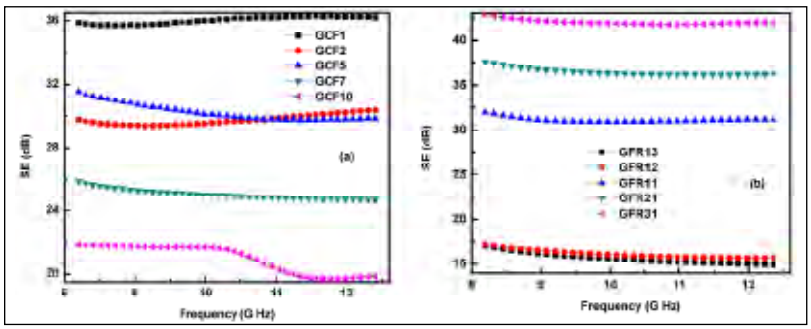


Fig. 2.6: Variation in EMI SE of sandwich consisting RGO/y-Fe_2O_3/carbon fiber (a) having fixed 50% wt ratio of phenol resin and different weight ratio of carbon fiber GCF1 having 99:1 % wt ratio of RGO and carbon fiber, respectively, GCF2 98:2, GCF 95:5, GCF 93:7, GCF 90:10 accordingly, (b) having fixed 1% wt ratio of carbon fiber and different weight ratio of y-Fe_2O_3: GFR13, GFR12, GFR11, GFR21 and GFR31.

shows the fracture surface of paper where pullouts of carbon fibers can be easily seen. The arrows show the distribution of nanoparticles of y-Fe_2O_3 on the upper surface of RGO in the sandwich. It is well known that the back scattered electrons image provides information on the composition of the sample. The bright areas represent the areas of Fe and the dark areas are C and hence it can be concluded that the Fe_2O_3 disperse on RGO surface having some spacing between them.

Figure 2.6 shows the variation of the SE with frequency in the 8.2-12.4 GHz range. From the experimental measurement, the shielding effectiveness due to absorption (SEA) has been found to vary from 9.14–33 dB with decrease in the y-Fe_2O_3 content while the SER varies from 11 to 7.66 dB for the same. Thus, the total SE achieved for the GF sandwich is 42.83dB (GFR31) which is much higher than the pristine RGO sheet (GFR10). It has been observed that for conducting RGO/y-Fe_2O_3 sheet, SE is mainly dominated by absorption while the shielding effectiveness due to reflection (SE_R) is constant and contributes comparatively little. To further investigate the reasons behind the observed increase in SE, the electromagnetic attributes (complex permittivity and permeability) have also been evaluated.

Graphene oxide–ferrofluid–cement nanocomposites were also designed to evaluate the electromagnetic interference (EMI) shielding effectiveness (SE) in the 8.2–12.4 GHz frequency range. It has been observed that incorporation of graphene oxide along with an appropriate amount of ferrofluid in the cement matrix leads to a shielding effectiveness of 46 dB (>99% attenuation). The presence of graphene oxide and ferrofluid in the cement leads to strong polarizations and magnetic losses that consequently result in higher shielding effectiveness compared to pristine cement. The resulting nanocomposites have shown Shore hardness of 54 and dc conductivity of 10.40 S cm^{-1}. SEM reveals the homogeneous dispersion of graphene oxide and ferrofluid in the cement matrix.

Figure 2.7 shows the variation of SEA and SER with frequency in the 8.2–12.4 GHz range. From the experimental measurements, the shielding effectiveness due to absorption (SEA) has been found to vary from 10 to 40 dB with increase in the GO content while SER varies from 11 to 2 dB for the same increase. Thus, the total SE_T achieved for the cement–GO–FF composite is 46 dB (cfg30) which is much higher than for the pristine cement. It has been

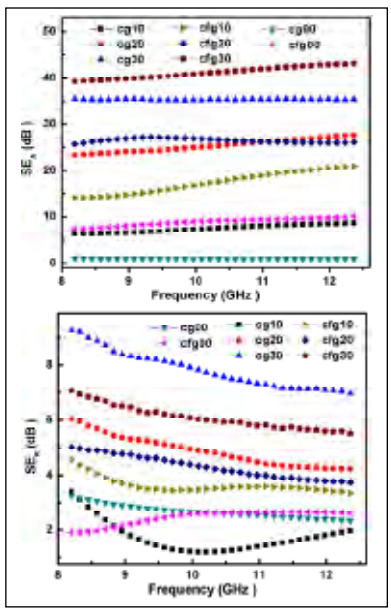


Fig. 2.7: Variation in the EMI shielding effectivenesses, SE_A and SE_R, of cement composites having different weight ratios of graphene oxide, cg10, cg20, cg30 and cfg10, cfg20, cfg30, with frequency.

observed that for conducting cement–GO–FF composite, the shielding effectiveness (SE) is mainly dominated by absorption while the shielding effectiveness due to reflection (SE_R) is nominal and contributes very little.

Technology/Process developed

A process for the preparation of graphene oxide- ferrofluid-cement composite was developed which can be used for the shielding of electromagnetic radiations in X-band and Ku-band.

Know how transfer

CSIR Network Technology was developed (An outcome of joint efforts under Network Project NWP-12 (NPL, New Delhi; CECRI, Karaikudi & NCL, Pune)

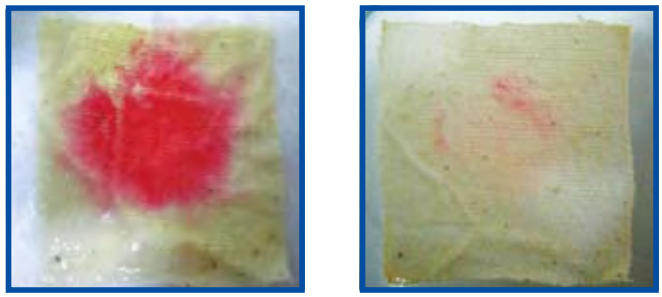
Non-Disclosure Agreement for the technology on Conducting Polymer Paints & Coatings was signed with M/s Krishna Conchem Products Pvt. Ltd., Navi Mumbai on April 2010 and consequently the technology transfer go ahead was given by the Industry in August 2011).

Sol-gel Synthesis of Materials And Thin Film Fabrication

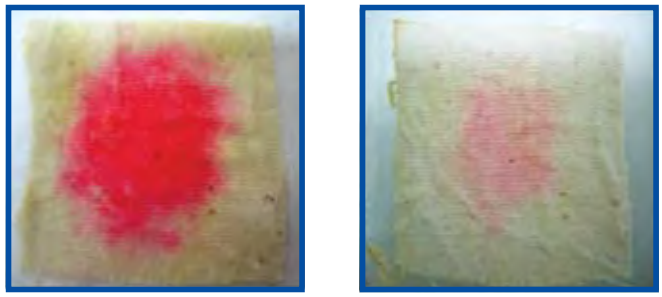
High quality titanium oxide films doped with Fe, Ni and Co metal cations were fabricated onto TCO glass substrates. Optical, electrical and structural properties of these films were investigated systematically. Effect of dopant and its concentration on the film crystallization properties were studied. We have studied the effectiveness of tungsten doped titanium oxide films in the degradation of environmental pollutants so as to purify the air we breathe in. TiO_2 film doped with nickel) coated glass substrates were also given to CCMB Hydrabad (a CSIR laboratory) for development of biosensor and bio-functional studies. Tungsten doped TiO_2 nanoparticles synthesized at NPl by sol-gel route are being investigated by RAMAN studies, initial results show that W doping shifts the phase transition temperature of TiO_2 to higher values, however detailed results are awaited. These studies have resulted in six papers in SCI journals and six papers in internationally organized symposia/ seminars.

A. Eosin stained samples.

Fabric coated with Pure TiO_2 nano-particles



Fabric coated with Ni-TiO_2 nano-particles



B. Green Tea stained samples – fabric coated with pure TiO_2 nano-particles.

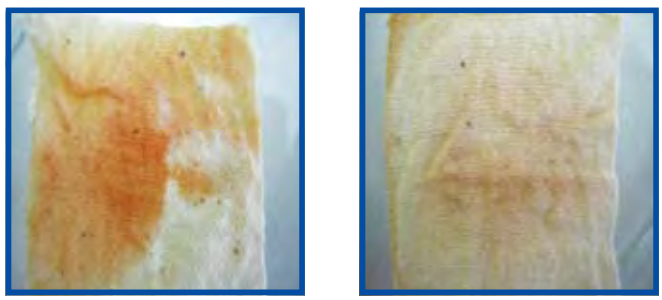


Fig. 2.8: Self cleaning studies of TiO_2 nanoparticle coated fabric (camera Pictures) : left side sample - before exposure, right side sample after exposure.

Good quality uniform films of vanadium oxide have been successfully fabricated on glass substrates by sol-gel dip coating process, an inexpensive process to apply highly uniform films on large area substrates. Thin films of this phase change material find number of device applications e.g. thermal cut off switching, energy efficient window etc. We are also making efforts to tune the transition temperature of the material by incorporation of dopants and/ or inducing strain.

Investigations on the development of self cleaning cloth with antibacterial property are being carried out by coating the fabric with titanium oxide nano-particles. We have also synthesized high quality bismuth oxychloride, visible light sensitive photocatalyst (highly useful for several applications) by solution route. XRD and photocatalytic activity studies have been carried out, while other investigations are going on.

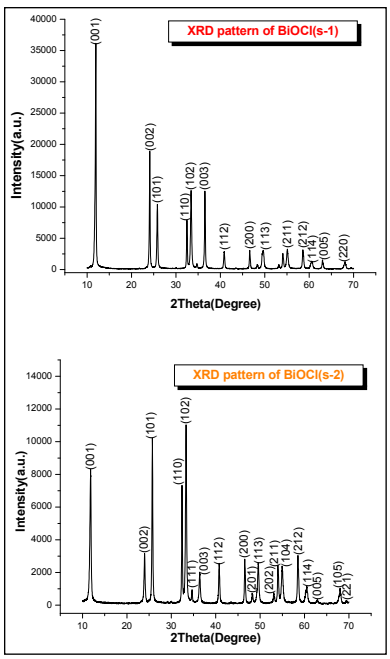


Fig. 2.9 XRD pattern of BiOCl sample synthesized by two different routes. [s1 – from bismuth nitrate; s2 – from bismuth oxide]

We are developing a facility to study the photocatalytic hydrogen generation by water splitting at the surface of photocatalyst film or bulk nano-particle.

We are having dialogue with two companies (listed below) to transfer the technology self cleaning glass for architectural applications, developed at NPL.

1. C and C Constructions Ltd.

Represented by: **Mr. Tarun Singh**
Address: Plot No. 70, Sector 32 Gurgaon – 122001 (Haryana)
Phone: +91-1244536666
Fax: +91-124 4536799
Email: candc@candcinfrastructure.com

2. Sharda Group

Represented by: **Arun Sharma**
Address: Sharada Centre, 11/1 Erandawane, Off Karve Road, Pune 411 004.
Tel.No: 020 25466390
Fax No: 020 25467170
Email ID: sharadagroup@vsnl.com
Website: http://www.sharadagrp.com

Prepared a technical report (white paper) on lithium ion batteries - depicting the present status and future direction in this technology.

One research scholar submitted his thesis for the award of Ph. D degree in physics from Kurukshetra University. Title: "Study of Doped And Undoped TiO_2 Films Obtained By Sol-Gel Route"

Physics & Engineering of Carbon

Multi-layer graphene nanoribbons from thermally reduced unzipped MWCNTs

An easy and scalable approach is reported for the production of multi-layer graphene nanoribbons (GNRs) from thermally treated unzipped multi-walled carbon nanotubes (MWCNTs) by controlled oxidation and intercalation, which is followed by heat treatment at 1000 and 2500°C. After oxidation and intercalation, unzipped MWCNTs thickness varies depending on the diameter of starting MWCNT and the variation in width could be due to the displacement of graphene layers during sonication. The sonication process is responsible for chemo-mechanical breaking and the separation of multi-layer nanoribbons.

On thermal treatment of unzipped MWCNTs at 1000°C, some individual GNRs are

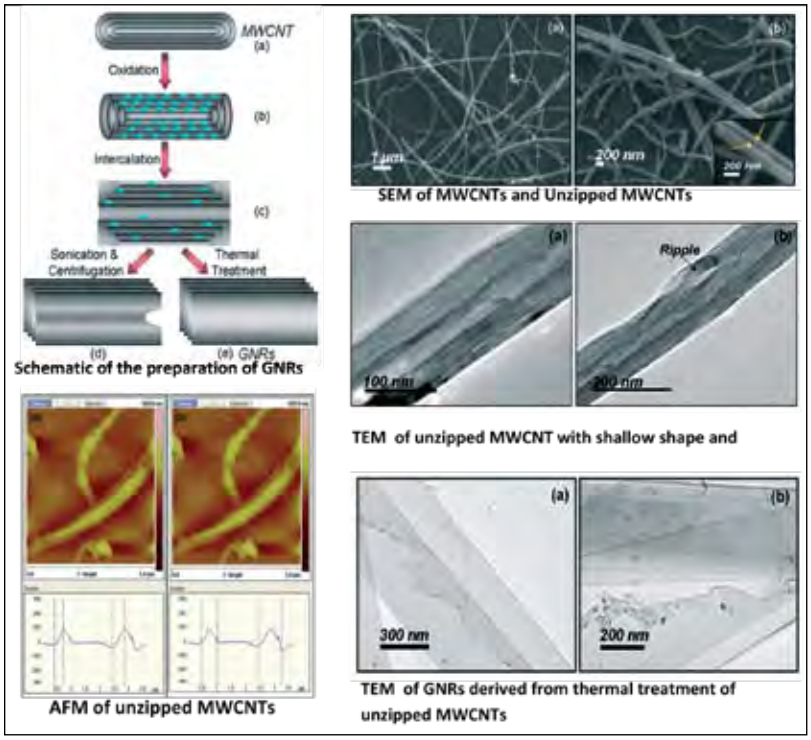


Fig. 2.10: Schematic of preparation of graphene nanoribbons (GNRs), SEM, AFM, and TEM of unzipped MWCNTs, TEM of GNRs derived from thermal treatment of unzipped MWCNTs.

observed due to the exfoliation which might be caused by the sudden evolution of volatiles product between the layers. However, after heat treatment at 2500°C, the GNRs produced are of high purity and quality with a yield of > 70 %. The high temperature (2500°C) treatment can able to restore π-conjunction in the GNRs which can help in improving transport properties. In contrast to corresponding 3-D graphite, electrons in a multi-layer GNR may confine along one crystallographic direction can open up enormous opportunities to take advantage of the unique properties of GNRs for many technological applications. Figure 2.10 shows the SEM and TEM image of nanoribbon.

Development of MWCNTs decorated Graphitic Foam

Multi-wall carbon nanotubes (MWCNTs) -decorated mesophase pitch-based graphitic foam (GF) is produced by impregnating mesophase pitch into a polyurethane foam template, and MWCNTs are grown on it by chemical vapor deposition. The original and MWCNTs-decorated foams are characterized by scanning electron microscopy, Raman spectroscopy and X-ray diffraction. Figure 2.11 shows micrograph of graphitic foam(GF), multi-walled carbon nanotubes decorated graphitic foam (M-GF), M-GF at higher magnification and MWCNTs grown on GF. It is observed that MWCNTs grow on the outer surface, in pores and on ligaments of GF. This is the reason for the decrease in

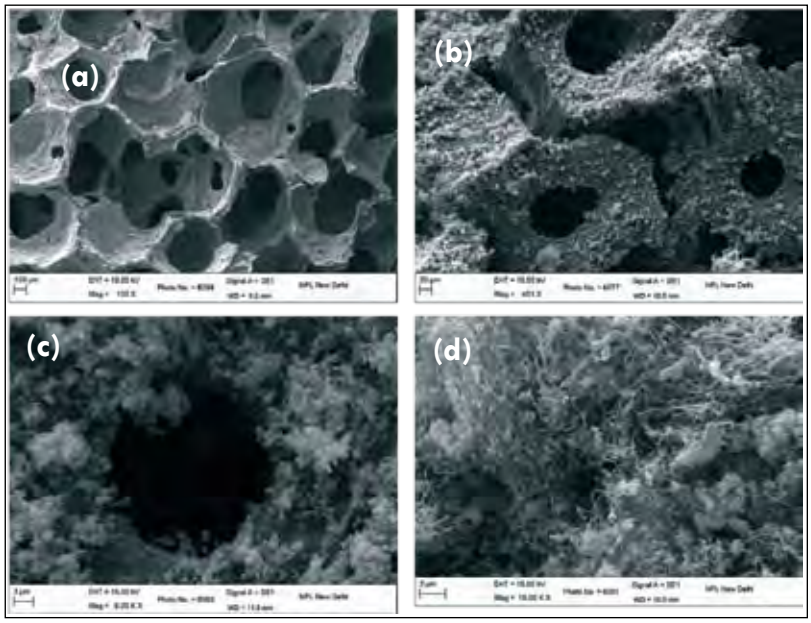


Fig. 2.11: SEM micrographs of (a) GF, (b) M-GF, (c) M-GF at higher magnification (d) Micrograph of MWCNTs grown on GF.

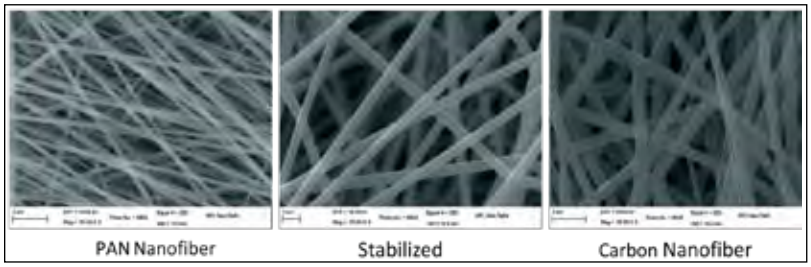


Fig. 2.12 : SEM micrograph of electrospun nanofiber at different stages.

the pore size and increases in the ligament size. The electrical and thermal conductivity of MWCNT-decorated GF increases by 76 and 56 % respectively. The increase in electrical and thermal properties may be due to the positive synergistic effect of MWCNTs. The compressive strength of the GF increases by 75 %, as a result of MWCNT growth on it. The changes in the properties of GF, as a result of the direct growth of MWCNTs demonstrates good anchoring and reduced the stress concentration centers in GF.

Thus, direct growth of MWCNTs on GF is an attractive route for improving the properties of highly porous graphitic materials, which can be used for different applications.

Development of Continuous Electrospun Carbon nanofibers (DST project)

In this project continuous electrospun nanofibers different polymer is drawn from different i.e. PAN, PMMA, PVA, PCL, Sodium Alginate etc. These nanofibers have different applications. Figure 2.10 shows the carbon nanofibers derived from PAN after stabilization and carbonization. During stabilization and carbonization, nanofiber diameter decreases due to conversion of polymer nanofibers into carbon nanofibers, as a consequence evolution of volatile by product. The fiber diameter of PAN polymer nanofiber varies between 500-600 nm, on stabilization it reduced to 500-550 nm whereas on carbonization it further reduced to 450-500 nm.

Development of Porous Conducting Carbon Paper

Carbon paper have been developed by effectively employing carbon nano tubes in very small amounts in a manner so as to utilize its extraordinary properties and achieve high fuel cell performance without any additional set up or cost.

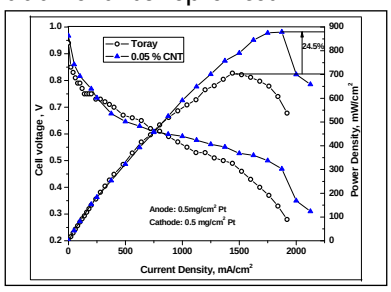


Fig. 2.13: Comaparative performance of PEMFC using NPL and Toray carbon paper (0.5 mg/cm² Pt)

The peak power density obtained from improved NPL carbon paper shows an increase of 24.5% (for 0.5 mg/cm² Pt loading on anode and cathode) and 24.3 % (with 0.3 mg/cm² Pt loading) as compared to the commercially available standard Toray carbon paper (Japan) tested under similar conditions as shown in Fig. 2.13 and 2.14 This shows the reproducibility of the results which are of great significance for India's self reliance in fuel cell technology. The performance evaluation was done at CSIR-CECRI, Chennai.

Studies have been carried out to find the effect of thickness of the carbon electrode support on its various properties and its performance in a PEM fuel cell. The carbon paper samples thus prepared had thickness of 0.046, 0.04, 0.035, 0.031, 0.028 and 0.023 cm while maintaining a uniform density of 0.50 g/cc.

The fuel cell polarization curves obtained using carbon paper samples with varying thickness are shown in Fig. 2.15. From the curves it is clear that the peak

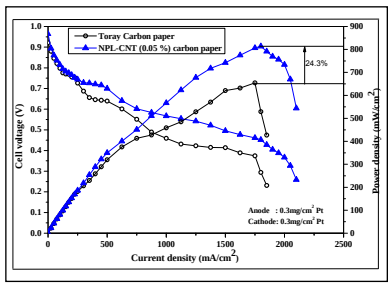


Fig. 2.14: Comaparative performance of PEMFC using NPL and Toray carbon paper (0.3 mg/cm² Pt)

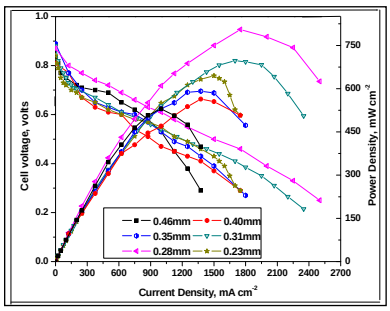


Fig. 2.15: Comparative performance of the fuel cell using carbon paper samples of different thickness.

power density obtained for the fuel cell increases as the thickness of the carbon paper is reduced from 0.46 mm to 0.28 mm. Power density as high as 805 mW/cm^2 has been obtained for 0.28 mm thick sample, i.e. an increase of more than 55 % over 0.46 mm thick sample (510 mW/cm^2). It is also observed that decreasing thickness of the carbon paper increases its current carrying capacity resulting in the peak shifts of the I-V curve towards higher current densities. However further reduction in thickness to 0.23 mm leads to a decrease in the fuel cell performance and the peak power density drops down to 645mW/cm^2.

From the above results it was concluded that decreasing the thickness of the carbon support samples enhances the fuel cell performance due to reduced electrical resistance and gas diffusion distance. However beyond a certain limit, thin samples may create problems due to the poor PSD and low mechanical strength.

MWCNTs reinforced Low Density Polyethylene Composites for Electrical and EMI shielding applications

High aspect ratio multi-walled carbon nanotubes (MWCNTs) reinforced low density polyethylene (LDPE) composites were prepared by solvent casting followed by compression molding technique. Electromagnetic interference (EMI) shielding effectiveness (SE) of these composites was investigated in the frequency range of 12.4–18 GHz (Ku-band) for the first time. The experimental results indicate that the EMI-SE of these composites is sensitive to the MWCNT loading. The average value of EMI-SE reaches 22.4 dB for 10 wt% MWCNT-LDPE composites, indicating the usefulness of this material for EMI shielding in the Ku-band. The main reason for improved SE has been attributed to significant improvement in the electrical conductivity of the composites by 20 orders of magnitude, i.e., from 10^{-20} for pure LDPE to 0.63 S/cm for MWCNT-LDPE, which is three order of magnitude higher than the previous reports for MWCNT-LDPE composites. Differential scanning calorimetry of the MWCNT-LDPE composites showed around 37% improvement in the crystalline contents over pure LDPE samples which resulted into enhanced thermal stability of the composites. The thermal decomposition temperature of LDPE is shifted by 40°C on addition of 5 wt% MWCNT. The studies therefore show that these composite can be used as light weight, thermally stable EMI shielding and antistatic material.

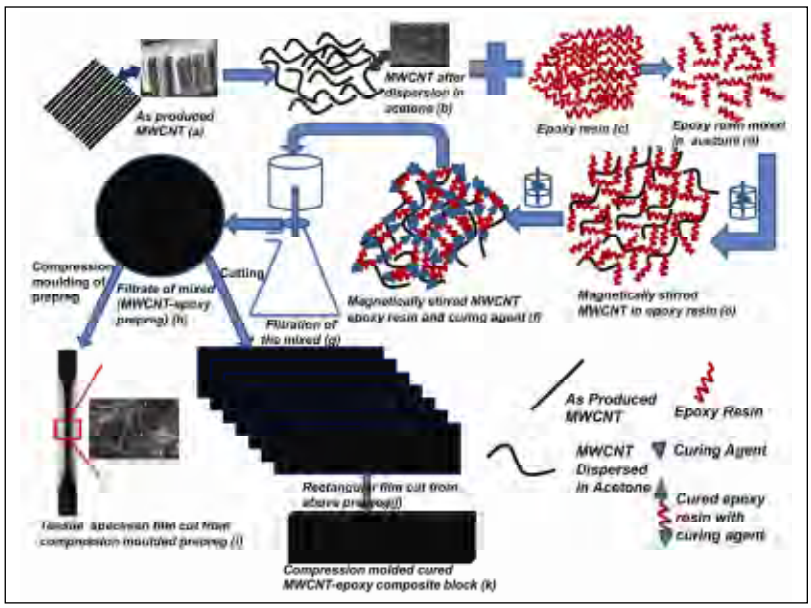


Fig. 2.16: Schematic diagram of preparation of high loading MWCNT-epoxy composites by filtration followed by compression moulding

A new technique to introduce high loading of MWCNT in epoxy composites for effective electrical and mechanical properties

Dispersion of high volume of carbonnanotubes(CNTs)inepoxy resin is a challenging issue for the development of efficient and thin electromagnetic interference (EMI) shielding material. Upto 20wt. % of multiwalled carbon nanotubes (MWCNTs) loading in the composite was achieved by forming CNT prepreg in the epoxy resin as a first step. These prepreg laminates were then compression molded to form composites which resulted into EMI shielding effectiveness of -19 dB at 0.35 mm thickness and -60dB at 1.75mm thickness of the composites in the X band (8.2-12.4GHz). One of the reasons for such high shielding is attributed to the high electrical conductivity of the order of 9S/cm achieved in these composites which is at least an order of magnitude higher than previously reported results at this loading. Additionally these composites show an improvement of 40% in the tensile strength over the net resin value. Thermal conductivity of the MWCNTs-epoxy composite reached to 2.2 W/mK as compared to only 0.14 W/mK for cured epoxy.

Studies on Development of carbon based materials suitable for multistage depressed collection of electron tubes

This is a part of the XIth plan CSIR sponsored network project on "Design and fabrication/ capabilities for very high power microwave tubes" with CEERI, Pilani as the nodal agency. The objectives of this project are: to prepare high density graphite and copper reinforced graphite (carbon- copper composite) suitable for multistage depressed collector of electron tubes useful for space applications. These products are not developed in India and cost huge amount of foreign exchange.

The objective of this is to develop high density graphite and carbon-copper composites suitable for multistage depressed collector of electron tubes useful for space applications.

Development of high density graphite

Samples of high density graphite were prepared from coal tar pitch derived green coke (GC) material modified (mixed) with natural graphite (NG, 8-10%) through ball milling. These modified powders were moulded into plates/blocks and carbonized to 1000 °C, 1400 °C and finally to 2500 °C in an inert atmosphere to obtain high density graphite products. The graphitized samples possessed bulk density of 1.87-1.97 gcm^{-3}, improved compressive strength of 138-145 MPa, electrical resistivity of 1.9-2.4 mΩcm and shore hardness of 82-96. The samples also showed open porosity of 0.5%.

In another batch, high density graphite was made from GC material mixed with 5% NG and 5% SG through ball milling. The mixed powder was moulded in plates/blocks and carbonized at 1000, 1400 °C and finally graphitized at 2500 °C in an inert atmosphere. These samples exhibited bulk density of 1.90 gcm^{-3}, improved compressive strength of 142 MPa, electrical resistivity of 2.0 mΩcm, shore hardness of 95 and open porosity of 0.5%.

The samples of high density graphite were also developed from nano carbon black incorporated in the GC powder. After moulding, samples were heat treated at different temperatures and finally graphitized at 2500 °C in an inert atmosphere showed improved characteristics. The addition of 12% CB in the GC exhibited bulk density of 1.93 gcm^{-3}, bending strength of 103 MPa, high compressive strength of 150 MPa, electrical resistivity of 1.7 mΩcm and shore hardness of 91. The sample also showed less open porosity (0.2%) compared to the imported sample (0.7%).

Samples of high density graphite developed at NPL, New Delhi were tested for vacuum compatibility at CEERI, Pilani. The testing was performed by heating samples in nitrogen

Fig.2.17: SEM images of: (A) CNTs, (B) 0.25 wt% CNTs reinforced C-Cu composite and (C) fracture surface of 0.25 wt% CNTs reinforced C-Cu composite

atmosphere at 900 °C followed by heating at temperatures 1000 °C and 1050 °C under a vacuum of 10^{-5} torr. It was observed that NPL developed high density graphite sample showed much better vacuum compatibility test as compared to the imported POCO graphite (DFP-2).

Development of C-Cu composites

Carbon-copper composites (Cu/C=1.0) reinforced with CNT of different mass fraction varying from 0 to 3.0 wt% were prepared by mixing CNT with copper and green coke powders by using powder metallurgy method and finally heat treated at 1000 °C in inert atmosphere. CNT reinforced C-Cu composites showed excellent bending strength and improved thermal conductivity. The lower amount of CNTs with 0.25 wt% reinforced C-Cu composite showed maximum bending strength of 162 MPa and compressive strength of 260 MPa, which are much higher than those composites prepared without CNTs and with higher amount of CNTs. The electrical resistivity was observed to be gradually decreased by the addition of the CNTs in the C-Cu matrix. The maximum thermal conductivity of 17.57 W/mK (perpendicular to the plane) was found for 0.50 wt% CNT reinforced C-Cu composite. SEM images (Fig. 2.17) confirmed that the CNTs were homogeneously distributed in the C-Cu matrix.

In another experiment, nano particles of Cu (Cu/C = 0.57) were deposited by chemical reduction method (electroless) on already Ni coated natural graphite (NG) powders. The nano particles of Ni in different concentrations (Ni/C = 0.01 to 0.50) were coated on the surface of NG by electroless method. The Cu-Ni-NG powders were consolidated into plates using hydraulic press and heat treated at 750°C in inert atmosphere of

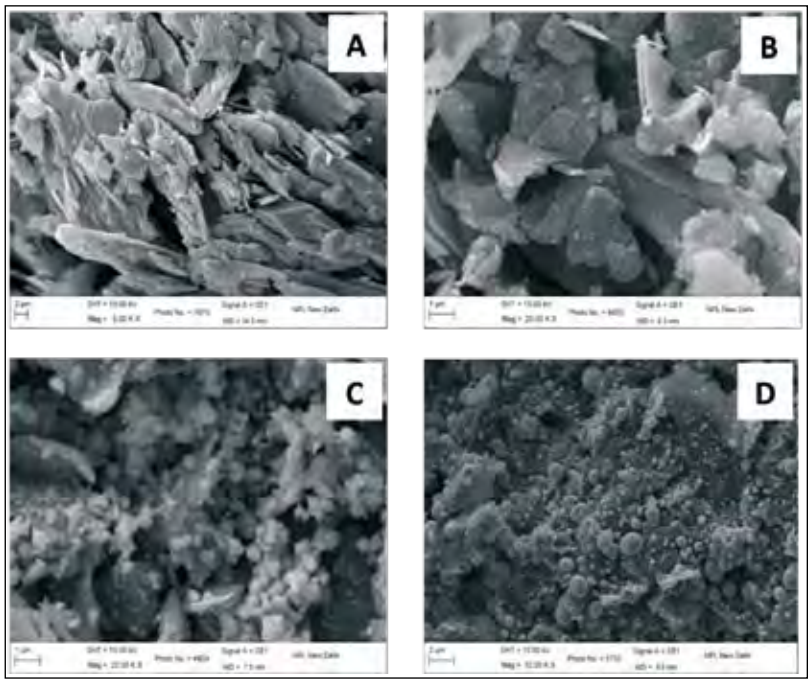


Fig. 2.18: SEM images of: (A) natural graphite (NG), (B) Ni nanoparticles coated on NG (Ni/C=0.10) and (C) Cu nanoparticles coated on Ni-NG powder and (D) Cu-Ni-NG after consolidation (heat treated at 750°C)

nitrogen. SEM images (Fig. 2.18) confirmed the deposition of Ni on NG and Cu on Ni coated NG. Detailed characterization such as strength and thermal conductivity is under process.

Development of carbon nanotubes reinforced metal-matrix composites

Under this project, R&D work was carried out to develop Cu composites reinforced with multiwalled carbon nanotubes (MWCNTs) using the powder metallurgy process. In order to develop these composites, copper nanoparticles were synthesized using a molecular-level-mixing method in which a copper salt was reduced using a number of reducing agents. The composites were fabricated by cold pressing followed by sintering under a vacuum of 10^{-2} torr at temperatures varied from 600 to 900°C for 2 hours. The resultant Cu/CNTs composites showed much improvement in mechanical properties as compared to those observed for pure Cu composites fabricated under similar conditions. Cu/CNTs nanocomposite powder was also used in the antimicrobial study of few bacteria's as well as in reducing the decomposition temperature of methanol direct in methanol fuel cells.

Synthesis of Boron Nitride (BN) Nanosheets

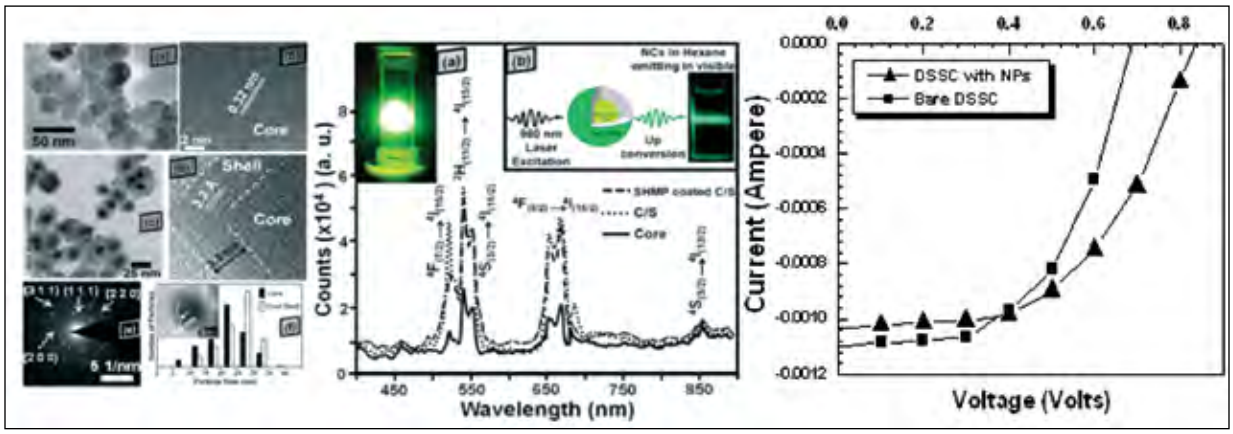
BN nanosheets were successfully synthesized by the exfoliation of pure hexagonal boron nitride powder in presence of a number of polar solvents. The synthesized BN few layer nanosheets were also decorated with Au and Ag nanoparticles by chemical process. By depositing Au or Ag nanoparticles on BN nanosheets we could tune the wide band gap observed between the two walls of BN nanosheets. The R&D work was carried out in collaboration with Ion & Electron microscopy group of NPL.

Luminescent Materials and Devices

Development of nanophosphors with enhanced down and up-conversion luminescence efficiency for solar cells, synthesis of doped nanocrystals and quantum dots for enhanced blue luminescence for display devices, core-shell nanophosphors for solar spectrum modification, novel nanophosphors for LEDs and luminomagnetic nanophosphors for bio-related applications are the current thrust of the group.

Core-Shell upconversion nanophosphor for enhancement of solar cell efficiency

A novel approach for harnessing the hitherto unutilized part of solar IR radiation through spectrum modification by nanophosphor (NP) for enhancing solar cell efficiency is being carried out. Terrestrial solar energy encompasses the photon energy range of 4.24 - 0.41 eV, only a fraction of which can be utilized by existing solar cells for conversion into electrical energy. Up-conversion (UC) nanophosphor coupled to the solar cell can convert the long wavelength IR photons to visible radiation that can be gainfully absorbed by solar cell for photo voltage generation. Success of this process depends on development of highly efficient UC NP that is excitable by low intensity IR radiation. One of the most efficient NIR-Visible upconverting UC lattices is $NaYF_4$. Synthesis of ultra small $NaYF_4$ particles require complicated process and high reaction temperature resulting in toxic fumes of harmful fluorides. Moreover, due to large number of incompletely bonded atoms on the surface of NP providing non radiative pathways, UC efficiency is usually low. A green chemistry approach has been taken to synthesize monodisperse monophasic core-shell nanoparticles with the core (~20 nm) and shell (~5 nm) [Fig.2.19a]. Hydrophobic core/shell nanoparticles have been further made hydrophilic by coating a transparent SHMP layer without affecting luminescence. A distinct enhancement of upconversion luminescence from core to core-shell (C/S) structure under low flux NIR excitation at 976 nm has been achieved in Lanthanide (Er^{3+},Yb^{3+}) doped $NaYF_4$ core with undoped $NaYF_4$ shell nanoparticles (NP) as shown in Fig.2.19b. Core shell ($NaYF_4$:Er,Yb/$NaYF_4$) UCNP



(i) (ii) (iii)

Fig. 2.19: (i) TEM image of $NaYF_4:Er^{3+},Yb^{3+}$ core and core/shell NPs showing uniformity in size and morphology of the particles. HRTEM image and lattice fringes of a single $NaYF_4:Er^{3+},Yb^{3+}$ core particle and $NaYF_4:Er^{3+},Yb^{3+}/NaYF_4$ core/shell NPs clearly show core shell formation and shell thickness of 3.5 nm; (ii) UC PL spectra of $NaYF_4$: Er^{3+}, Yb^{3+} core (solid line), $NaYF_4$: Er^{3+}, Yb^{3+} /$NaYF_4$ core/shell (dotted line) and SHMP coated core /shell (dashed line) NPs under diode laser excitation at 976 nm. Inset (a) Photograph showing green emitting $NaYF_4$: Er^{3+}, Yb^{3+} /$NaYF_4$ core/shell nano powder under 976 nm laser excitation and inset (b) shows schematic drawing of $NaYF_4$:Er,Yb/ $NaYF_4$ core/shell structure and scatter free NIR to green UC luminescence in colloidal NPs; (iii) I-V characteristic of DSSC coupled with upconverting core shell nanoparticles of $NaYF_4:Er^{3+},Yb^{3+}/NaYF_4$. The plot clearly depicts increase in V_{OC} due to incorporation of NPs.

integrated dye sensitized solar cell (DSSC) indicated 11.9% enhancement in overall conversion efficiency under AM 1.5 conditions, due to NIR-Visible spectrum modification by fluorescent NPs [Fig.2.19c]. The results indicate the potential of such upconverting C/S nanophosphor in solar cell applications.

Tunable photoluminescence from hydrophobic silica gel nanoparticles for displays:

Luminescent materials have been utilized widely in applications involving lighting to sensing. The photoluminescence (PL) properties of silica have also been an important topic of research for a long time, but the difficulty in the incorporation of rare-earth (RE) ions attached covalently to the silica (SiO_2) network is still considered a great challenge. The weak PL bands with peak energies ~1.9-4.3 eV for both bulk and thin films of SiO_2 have been reported so far. It has been observed that monodisperse silica nanospheres formed by hydrolysis and condensation of alkoxides using Stober-Fink-Bohn (SFB) process gives negligible luminescence. Hence, we proposed a novel methodology to prepare alkoxide-based silica gel nanospheres doped with Eu^{3+} ions that show enhanced PL brightness, uniform size distribution and improved quantum efficiencies.

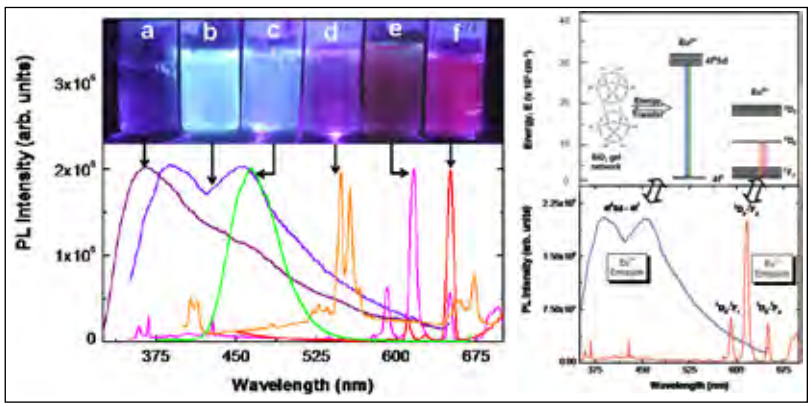


Fig. 2.20: Tunable photoluminescence ranging from UV (373 nm) to deep-red (655 nm) colours exhibited by $SiO_2:Eu^{3+}$ gels with Eu concentration of a) 0 mol-%, b) 0.02 mol-%, c) 0.04 mol-%, d) 0.06 mol-%, e) 0.08 mol-% and f) 0.1 mol-%. Anomalous blue-green photoluminescence aroused from $4f^65d^1–4f^7$ transition of Eu^{2+} and deep-red emission from $^5D_0–^7F_2$ transition of Eu^{3+} ions. In both the cases, SiO_2 gel networks act as an effective sensitizer.

This is a process by which highly disordered but doped silica gels could be effectively made useful for practical applications involving luminescence. The tunable photoluminescence ranging from UV (373 nm) to deep-red (655 nm) colours has been achieved in SiO_2:Eu^{3+} gels with various Eu concentrations as shown in Fig. 2.20. Anomalous blue-green photoluminescence aroused from $4f^6 5d^1 – 4f^7$ transition of Eu^{2+} and deep-red emission from $^5D_0 – ^7F_2$ transition of Eu^{3+} ions are attributed to the effective sensitizing action of the SiO_2 gel network.

Probing a Bifunctional Luminomagnetic Nanophosphor for Biological Applications

In nature, materials that exhibit significant magnetism and efficient luminescence rarely exist. Such materials are highly desirable in a number of potential biological applications including drug and gene delivery, bio-sensing and bioimaging with magnetic resonance imaging (MRI) contrast. LMD group has developed such a luminomagnetic material in the form of $GdVO_4$:Eu nanoparticles used as nanoprobes for bioimaging applications. We have developed a simple and effective method for the high quality ultra-fine europium doped gadolinium vanadate ($Gd_{1-x}Eu_xVO_4$, x=0.35) luminomagnetic nanophosphor, with a particle size measuring ~ 30 nm, by facile sol-gel method, which can be produced on a large-scale. Probing the luminomagnetic nanophosphor using photoluminescence, time-resolved spectroscopy, magnetization measurement and cytotoxicity assay reveal its suitability for biological applications. The photoluminescence emission (PL) spectrum recorded at 308 nm excitation shows a sharp intense hypertensive red emission peaking at ~618 nm at room temperature (Fig. 2.21a and c). We have carried out magnetization measurements using a super conducting quantum interference device (SQUID) magnetometer (see Fig. 2.21b). The synthesized luminomagnetic nanophosphor exhibits typical paramagnetic behavior with high magnetic moment. We have investigated the cell viability of $GdVO_4$:Eu^{3+} luminomagnetic nanoparticles using Prokaryotic algal (*Aphanothece* sp in the class of cyanobacteria/blue-green algae) for biological applications (see Fig. 2.21d). We observed that the synthesized luminomagnetic nanophosphors were not only biocompatible with cells but also relatively nontoxic over reasonable concentrations, which is of significance for applications in biomedical diagnostics and analyses requiring luminescence and magnetic tracking.

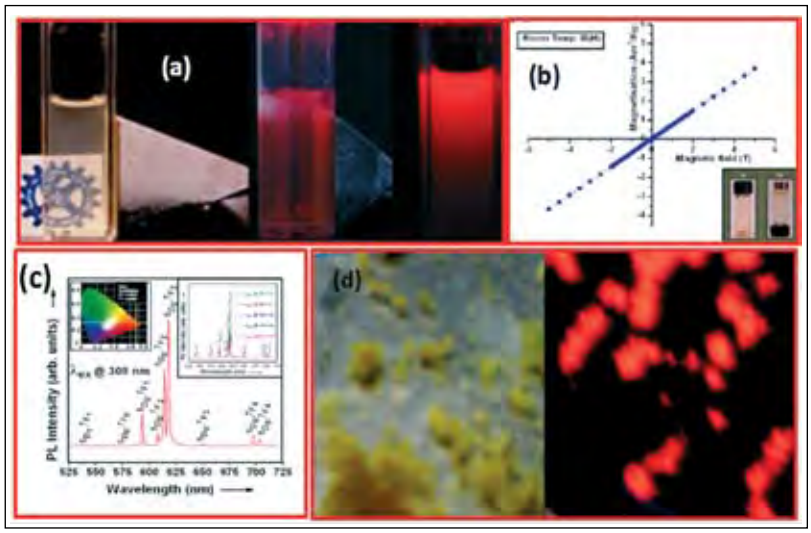


Fig. 2.21: Colloidal solution of luminomagnetic nanophosphor in de-ionized water(2μgmL^{-1}) (a) Transparency of suspended luminomagnetic nanophosphor, second photograph shows the magnetic tracking through permanent magnet (~ 2000 Oe) as well as shows strong red emission under UV 254 nm wavelength (b) Room temperature M-H curves of as-synthesized $Gd_{0.65}Eu_{0.35}VO_4$ nanophosphor; Photographs of luminomagnetic nanophosphors in glass vials (i) without and (ii) with external permanent magnet (~ 1000 Oe) are shown in inset (c) Room temperature PL emission spectrum recorded at 308 nm excitation. The right inset shows the other emission spectra at 362, 382, 395, 416 and 465 nm excitation wavelengths and the left inset shows the color coordinates(d) High resolution digital micrographs of the Aphanothece sp cells treated with 2 mg/mL $Gd_{0.65}Eu_{0.35}VO_4$ nanophosphor after 2 days of incubation both under room light and UV light (254 nm).

Optical Bifunctionality of Europium-complexed Luminescent Graphene Nanosheets

LMD group in joint collaboration with Rice University, USA has successfully synthesized the luminescent graphene which offers a new paradigm shift in the engineering of graphene analogs for tuning optical and electronic properties see (Fig. 2.22). The synthesis of luminescent graphene or europium complexed-graphene nanosheets is achieved through a simple and efficient high temperature thermal dissociation and reduction process. The introduction of Eu(III) ions in the graphene lattice was proven by XPS analysis and EDS mapping. Spectroscopic results convincingly show the complexation of trivalent europium with graphene oxygen functionalities (Fig. 2.23). More specifically, a shift

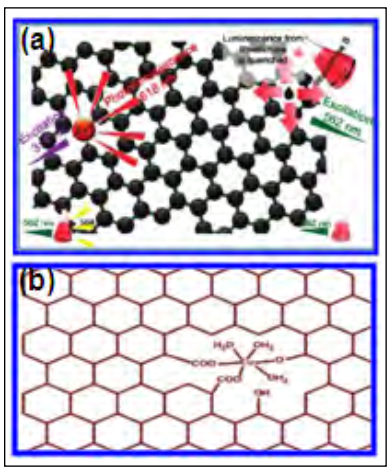


Fig.2.22: a) Demonstration of dual functionality of graphene by the quenching of luminescence of Rhodamine-B while displaying its own red emission. b) Plausible structural model of europium-complexed graphene.

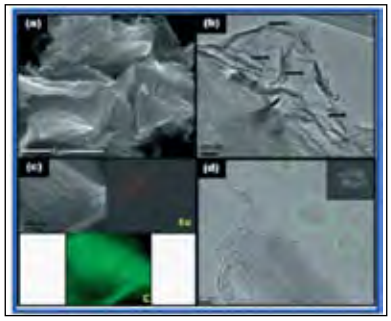


Fig.2.23: a) SEM image of europium complexed-graphene. b) TEM image of the LG. Arrows indicate the presence of mono or double layer LG. c) carbon and europium elemental mapping of a selected region. d) Atomic HRTEM Images of the LG. The inset is the FFT pattern of the selected region.

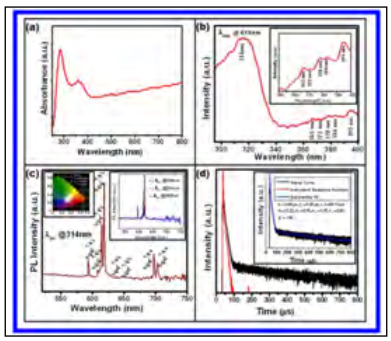


Fig.2.24: a) UV-visible spectrum of the LG. b) PL excitation of the LG (emission at 618 nm) exhibiting a strong peak at 314 nm. c) Photo-luminescence (PL) emission of the LG (excitation at 314 nm) exhibiting hypersensitive red emission at 614 and 618 nm. d) TRPL decay profile of the LG. The inset shows the lifetime data.

in the photoluminescence red emission of the starting material, europium oxide, from 611 nm to a hypersensitive red emission for the europium (III) complexed-graphene at 618 nm was observed (Fig. 2.24 a-c). The luminescent graphene had a triple decay lifetime with an average value of 391.13 μs, which contrasts with the single decay lifetime (65.68 μs) of europium oxide as shown by time-resolved spectroscopy (Fig. 2.24 d).

We have successfully

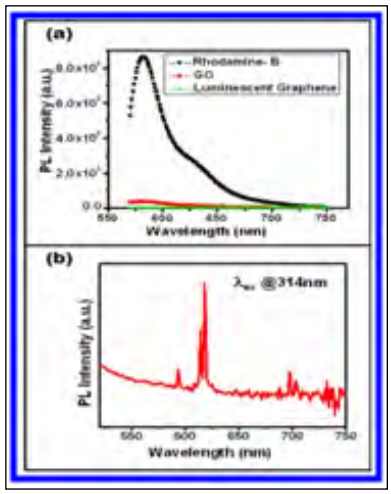


Fig.2.25: a) PL spectrum of pristine Rhodamine-B, LG and GO in Rhodamine-B (excitation at 562 nm) exhibiting Complete quenching. b) Self-luminescence of the LG / Rhodamine-B solution (excitation at 314nm) exhibiting the hypersensitive red emission at 614 and 618 nm.

demonstrated the concurrent fluorescence quenching of Rhodamine-B by the luminescent graphene as well as its self-luminescence (Fig. 2.25). The importance of such luminescent materials is in biological application where cells showing their own luminescence (e.g. MCF-7GFP, Human Breast Cancer Cell displays strong green luminescence) and are difficult to target/label those cells without quenching their luminescence. We envision that such accomplishments will be milestone in developing the much-awaited high-performance applications of graphene and its analogs in the fields of optoelectronics and nano-biotechnology.

Binding of chloroquine–conjugated gold nanoparticles with bovine serum albumin

The thiol functionalized gold nanoparticles were conjugated to therapeutic drug chloroquine. The gold-chloroquine conjugates were studied for their interaction with a model serum protein BSA. The binding of chloroquine to gold nanoparticles was studied using UV-Vis and FTIR spectroscopy. The characteristic surface plasmon absorption band for GNPs was observed at 522 nm and the average particle size was found to be 5-7 nm from transmission electron microscopy. The interaction of gold-chloroquine with BSA was studied using thermodynamic as well as spectroscopic methods. The interaction was found to be driven by enthalpy and entropy, accompanied with a minor alteration in protein's structure. Competitive drug binding assay revealed that the gold-chloroquine binds at binding site I in subdomain IIA of BSA and was further supported by the intrinsic fluorescence quenching measurement. Unraveling the nature of interactions of gold-chloroquine with BSA would pave the way for the design of nanotherapeutic agents with improved functionality, enriching the field of nanomedicine.

The work has been published in *J. Colloid Interface Sci.*355, 402–409 (2011) and is selected as **"Article of the Month" by Colloid and Nanomedicine 2012.** Further details are given at the link: http://www.colloidsandnanomedicine.com/conference-supporting-journal.html

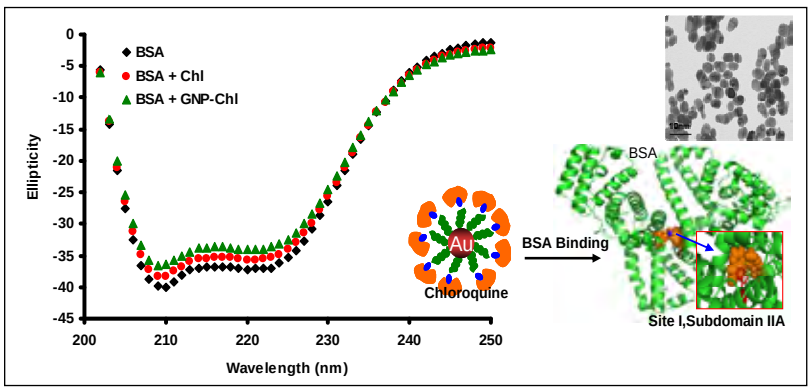
Biomedical Instrumentation

Nanopatterned Quantum dots based Leukemia biosensor

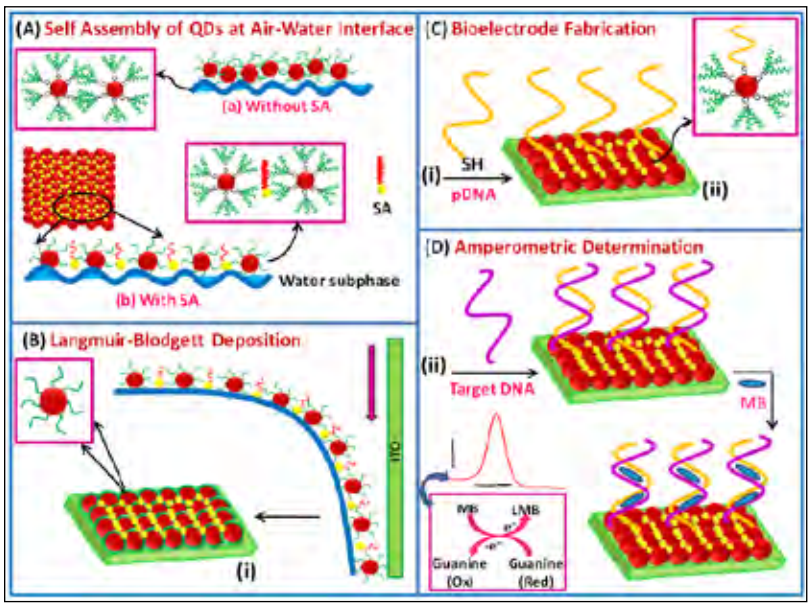
The studies relating to preparation of Langmuir–Blodgett (LB) monolayers of tri–n–octylphosphine oxide capped cadmium selenide quantum dots (QCdSe) onto indium–tin–oxide (ITO) coated glass substrate have been carried out (Scheme 1). The monolayer behaviour has been studied at the air–water interface under various subphase conditions. This nanopatterned platform has been explored to fabricate an electrochemical DNA biosensor for detection of Chronic Myelogenous Leukemia (CML) by covalently immobilizing the thiol–terminated oligonucleotide probe sequence using displacement reaction. The results of electrochemical response studies reveal that this biosensor can detect target DNA in the range of 10^{-6} to 10^{-14} M within 120 s, has a self life of 2 months and can be used for about 8 times. Besides this, the nucleic acid sensor has been found to distinguish the CML positive and the negative control clinical patient samples.

Polyaniline Iron oxide carbon nanotube based N. gonorrhea sensor

Biotinylated probe DNA (BDNA) is immobilized onto electrochemically deposited polyaniline- iron oxide-carbon oxide nanotube (PANI-nFe_3O_4–CNT) electrode using avidin-biotin interaction. For this purpose, 10 µl of 1 mg/mL activated avidin (activated using 15 mM EDC and 30 mM NHS for 2 h at 298 K) is first immobilized onto PANI-nFe_3O_4–CNT/ITO electrode. The Avi-PANI-nFe_3O_4–CNT/ITO electrode is then washed and subject to 300 s incubation



The representative CD spectra of BSA in presence of chloroquine and Au- chloroquine (left); binding of Au-chloroquine to BSA (right) and TEM micrograph of Au-chloroquine (upper right).



Scheme 1: Fabrication of Leukemia biosensor using nanopatterned CdSc quantum dots.

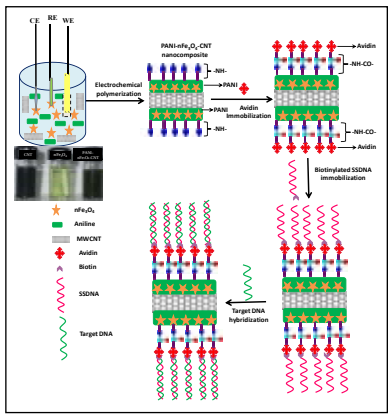
with 20-mer biotinylated oligonucleotide probe (BDNA, 10 µl and 1.0 µM) in a humid chamber at 298 K (Scheme 2). The incubation of BDNA solution on Avi-PANI-nFe_3O_4–CNT/ITO bioelectrode results in the biotin- avidin interaction due to high affinity between immobilized avidin and biotin attached to DNA. The BDNA–Avi-PANI-nFe_3O_4–CNT/ITO bioelectrode has been optimized for hybridization time and was subject to incubation in the concentration range (1×10^{-19} M to 1×10^{-6} M) of complementary (compDNA) target DNA for 45 s at 298 K. Further, the studies have been carried out by incubating the bioelectrode with non-complementary (ncompDNA) and one-base mismatch (obmDNA) target DNA to prove specificity of the electrode. These electrodes have also been tested with positive and negative PCR amplicons of gonorrhoea affected patient samples. Subsequently, the DPV measurements of BDNA–Avi-PANI-nFe_3O_4–CNT/ITO electrode have been carried out in 20 µM MB, pre-treatment at +0.1 V for 10 s, at step potential of 3 mV and modulation amplitude of 50 mV, 0.05 M PBS (pH 7.0, 0.9% NaCl). The detailed mechanism of fabricating the BDNA-Avi-PANI-nFe_3O_4–CNT/ITO bioelectrode is depicted in Scheme 2.

Hybridization studies with patient samples

The BDNA-Avi–PANI-nFe_3O_4-CNT/ITO bacterial sensor has been used to detect sequence specific DNA based on the DPV current change of MB before and after hybridization. Fig. 2.26a shows DPV response of the fabricated bacterial DNA immobilized bioelectrode. The performance of the BDNA-Avi–PANI-nFe_3O_4-CNT/ITO bioelectrode has been investigated by incubating it with DNA extracted from *N. gonorrhoeae* culture isolated sample, pus sample spiked with *N. gonorrhoeae* and *N. gonorrhoeae* positive male patient sample. The observed significant decrease in the DPV signal shows that the complementary DNA present in the clinical sample hybridizes with the probe DNA (Fig. 2.26a). As there is sample-to-sample variation in the bacterial DNA load that cannot be presently quantified perhaps results in variation of the observed signal.

Hybridization studies with PCR Positive and negative amplicons

Figure 2.26b shows performance of the bacterial sensor for detection of *N. gonorrhoeae* positive and the negative amplicons. The exposure of



Scheme 2. Preparation of PANI–nFe_3O_4–CNT nano-composite and immobilization process of biotinylated DNA using avidin-biotin coupling followed by hybridization for bacterial (*N. gonorrhoeae*) detection.

BDNA-Avi-PANI–nFe_3O_4–CNT/ITO bioelectrode to PCR positive amplicons of *N. gonorrhoeae* results in significant decrease in the peak height indicating hybridization. And the incubation of the bioelectrode with the PCR negative amplicons results in negligible change in the peak height indicating specificity of the fabricated sensor for the detection of *N. gonorrhoeae*.

Nanostructured zirconium oxide based V. cholerae sensor

Nanostructured ZrO_2 film was prepared using zirconium (IV) propoxide solution (70 wt%) as a precursor. The Nano ZrO_2 film fabricated onto indium-tin-oxide (ITO) coated glass plate using dip coating method and used for immobilization of O1 gene based 24 mer single stranded deoxyribonucleic acid probe (ssDNA) to detect *Vibrio cholerae*. The X-ray diffraction and Atomic Force Microscopy techniques have been used to characterize the nanostructured ZrO_2 (particle size of ~ 30-40 nm) and the ssDNA/ZrO_2 bioelectrode. The hybridization of ssDNA/ZrO_2 bioelectrode with the complementary and genomic DNA has been investigated using differential pulse voltammetry. The results of electrochemical studies suggest that highly electro-active and cationic Nano ZrO_2 provides an effective surface to bind with the phosphate group of DNA resulting in enhanced electron transport.

The ssDNA/Nano ZrO_2 bioelectrode shows detection range from 1×10^{-8} to 10 nM of complementary DNA of *V. cholerae* within 60s of hybridization time at 25°C using methylene blue as an electro-active indicator. This O1 gene based metal oxide (ZrO_2) sensor exhibits sensitivity for ssDNA/NanoZrO_2/ITO bioelectrode as 0.48 µA/nM cm^{-2} for complementary DNA and 2.34 µA/nM cm^{-2} for genomic DNA (Fig.2.27) with regression coefficient (R) as 0.991 and 0.995, respectively. This DNA bioelectrode is stable for about 15 weeks when stored at 4°C.

Self-assembled monolayer based Cholesterol biosensor

Self-assembled monolayer of (SAM) of 4-aminothiophenol (4-ATP) has been investigated for immobilization of multi-enzymes (ChOx and ChEt) towards development of enzyme biosensors for detection of free and total cholesterol. This enzyme immobilized SAM surface has been characterized by scanning electron microscopy and electrochemical studies. The results of electrochemical response studies reveal fast enzymatic reaction in phosphate buffer saline solution without any artificial mediator. This may be attributed to the molecular wire type behaviour of short 4-ATP molecule that provides direct electron transfer between enzyme and the electrode due to its conjugated backbone. Interference free estimation of

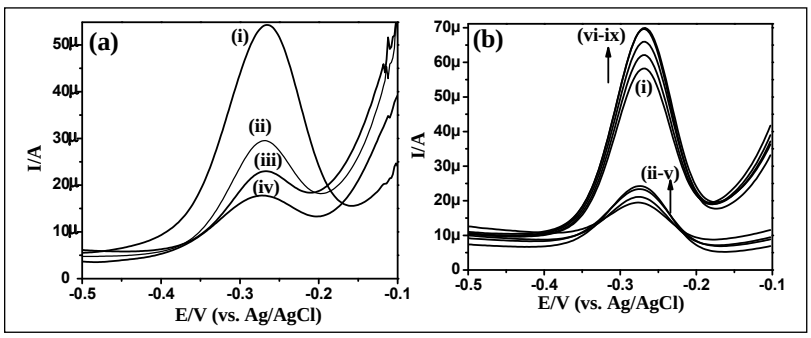


Fig. 2.26: (a) DPV of (i) BDNA-Avi-PANI–nFe_3O_4–CNT/ITO bioelectrode after treatment with (ii) culture isolated sample, (iii) spiked pus sample and (iv) patient sample (b) DPV of (i) BDNA-Avi-PANI–nFe_3O_4–CNT/ITO bioelectrode after treatment with 4 PCR positive (ii-v) and 4 negative amplicons (vi-ix) at step potential of 3 mV and modulation amplitude of 50 mV, in 20 µM MB, pre-treatment at +0.1 V for 10 s, 0.05 M PBS (pH 7.0, 0.9% NaCl).

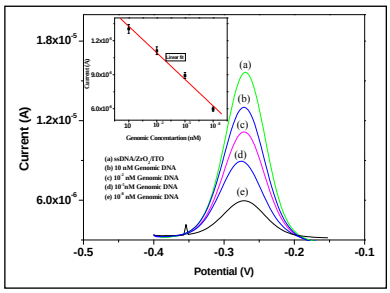


Fig.2.27: DPV response of dsDNA/NanoZrO$_2$/ITO bioelectrode after hybridization with genomic DNA concentration. Inset (i) is linear graph between genomic DNA concentration vs current variation.

free and total cholesterol has been realized at low operating potential of 0.33 V with linear range from 25 to 400 mg/dl (Fig.2.28), sensitivity of 542.3 nA mM^{-1} (for ChOx/4-ATP/Au) and 886.6 nA mM^{-1} (for ChEt-ChOx/4-ATP/Au) with a response time of 20 s at pH 7.4.

Nickel nanoparticles based aflatoxin detection

The self-assembled ring like nickel (RnNi ~10-20 nm) nanoparticles have been prepared by pulsed laser ablation method and confirmed by transmission electron microscopy. These RnNi nanoparticles electrophoretically deposited onto the indium-tin-oxide (ITO) glass substrate have been functionalized with dimethyl sulfoxide (DMSO) for covalent immobilization of anti-aflatoxin (a-AfB1) monoclonal antibodies and bovine serum albumin as blocking agent. The electrochemical response studies of a-AfB1/DMSO/RnNi-film/ITO bioelectrode reveal linearity as 5-100 $ngdL^{-1}$ (Fig. 2.29), detection limit of 32.7 $ngdL^{-1}$,

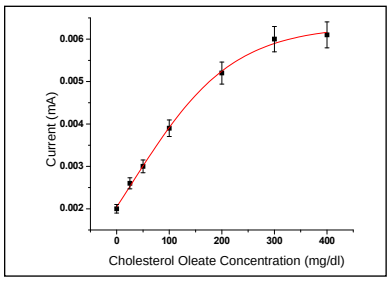


Fig.2.28: Linear calibration plots of current obtained for ChEt-ChOx/4-ATP/Au bioelectrode as a function of cholesteryl oleate concentrations

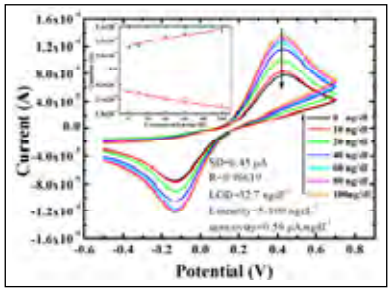


Fig. 2.29: Electrochemical response studies of BSA/a-AfB1/DMSO/RnNi-film/ITO bioelectrode with respect to AfB1 concentration (5–100 $ngdL^{-1}$).

sensitivity of 0.59 IA/ng dL^{-1}, and shelf-life of 60 days. The low value (1.3 x10^{14} $molL^{-1}$) of association constant (Ka) shows high affinity towards aflatoxin.

Major facilities established

Facilities for electrochemical measurements, thin film preparation and characterization, microbial culture growth, extraction and isolation of DNA/enzyme, optical characterizations (FTIR and UV), microbiology, preparation of SAM, surface characterizations (hydrophobic/hydrophilic nature), microfluidic system and device testing and fabrication have been established. Also facilities for preparation of screen printed electrodes, synthesis of metal oxides, quantum dots, magnetic NPs, nobel metal nanoparticles and composite nanoparticles have been established. Laboratory with world class facilities has been established, with power backup upto ~60 min, supply of various gases for dedicated experiments, dedicated computational facility, dust and noise free working condition

Technology/Process developed: We have developed colorimetric unit for detection of cholesterol and we have also established methodologies to modify existing screen printed electrodes with novel materials to improve stability, immobilization of enzyme and to obtain higher current response.

Know how transfer: IIIM2011 was organized as part of project to increase the collaborative efforts among institutes, industries and hospitals, which resulted in useful collaborations, MoU, and international publications.

Metals & Alloys Group

This year research on two on-going Network Projects, NWP-51 & NWP-28, was continued and these projects were successfully completed, meeting all the objectives and targeted deliverables, envisaged in these two projects. A new CSIR Network Project - Technologies and Products for Solar energy utilization through Networks (TAP-SUN) on "Development of novel thermoelectric materials and devices for harnessing solar energy and waste heat" (Network Project – NWP 54) was initiated this year and work was carried out to develop novel thermoelectric materials with enhanced figure-of-merit. Under this project a well-equipped thermoelectric laboratory was established in the group. This year the work was mainly

focused on the design, synthesis, nanostructural characterization and thermoelectric property evaluation of several bulk nanostructured thermoelectric materials such as SiGe, Mg_2Si, half-Heusler and other novel thermoelectricmaterials. Research work was also initiated on the development of rare-earth free permanent magnet materials. The magnetic τ-phase of MnAl was synthesized employing powder metallurgy and subsequent heat-treatments and this work is presently underway to increase its magnetization.

[A] NETWORK PROJECTS

(1) Development of bulk nanocomposites of aluminium alloys reinforced with ceramic particulates employing high energy ball-milling and spark plasma sintering (CSIR Network Project NWP-051)

The work under this on-going project was further continued this year. Al5083 alloy was ball-milled with SiC_p nanoparticulates under argon atmosphere for 15 h and subsequently these powders were consolidated and sintered employing spark plasma sintering technique (SPS). Detailed characterization employing HR-TEM of SPS nanocomposites elucidated some important features at nano and lattice scale. Apart from the reinforcement, neither voids nor cracks were detected and nanoparticles of SiC_p surrounded with the nanostructured Al 5083 grains have been clearly observed (Fig.2.30a). The high magnification micrographs revealed a fine grained microstructure with networked dislocations (Fig. 2.30b).

Fig. 2.31 shows the compressive testing results of sintered Al 5083/10wt.% SiC_p nano-composite compared to that of milled and un-milled Al 5083 alloy. Nanocomposite after 15 h of milling and SPS resulted in compressive strength of 824 MPa, whereas the compressive strength of un-milled Al 5083 alloy was found to be 305 MPa. Percentage elongation was observed to be 2.5% for Al 5083/SiC_p nanocomposite and 13.8% for un-milled Al 5083 alloy.

Fig. 2.32 shows the enhancement in hardness and elastic modulus of the nanocomposite with the variation of SiC_p content. Measured hardness and elastic modulus values for un-milled Al 5083 alloy were found to be 98 HV and 68 GPa, respectively and after ball milling of Al 5083 alloy for 15 h, these values were enhanced to 148HV and 78 GPa. In these nanocomposites, an addition of 10 wt.% SiC_p to Al 5083 alloy exhibited significant improvement in hardness of 280 HV and elastic modulus of 126 GPa. Significant enhancement in the compressive strength of nanocomposite Al5083/10 wt.% SiC_p, due to dislocation pile-ups

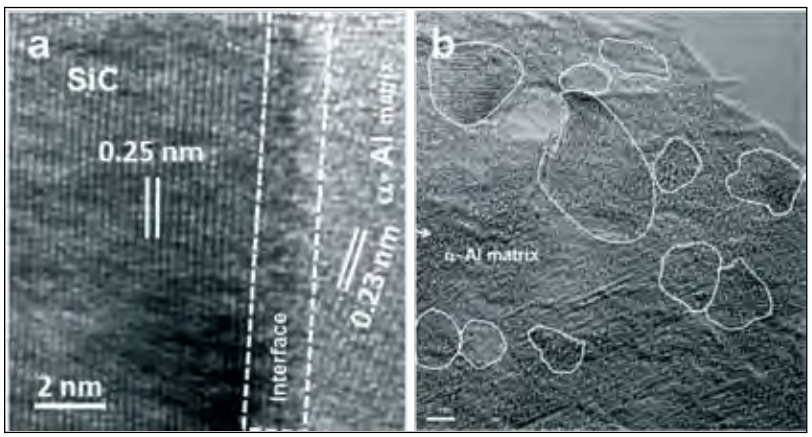


Fig. 2.30: HRTEM images of spark plasma sintered Al 5083/6 wt.% SiC_p nanocomposites (a) Interface between Al 5083 and SiC_p (b) Retained nanostructured grains after SPS

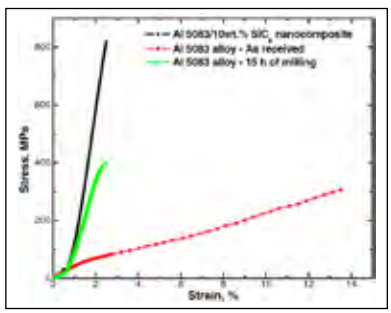


Fig. 2.31: Typical stress - strain curves from the compression test for un-milled Al5083 alloy, nanostructured Al 5083 alloy and Al 5083/SiC_p nanocomposite (SPSed at similar conditions)

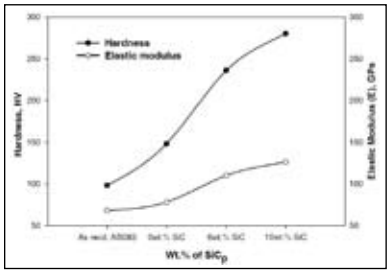


Fig. 2.32: Hardness and Elastic Modulus of Al5083/SiC_p nanocomposite with increasing SiC_p content

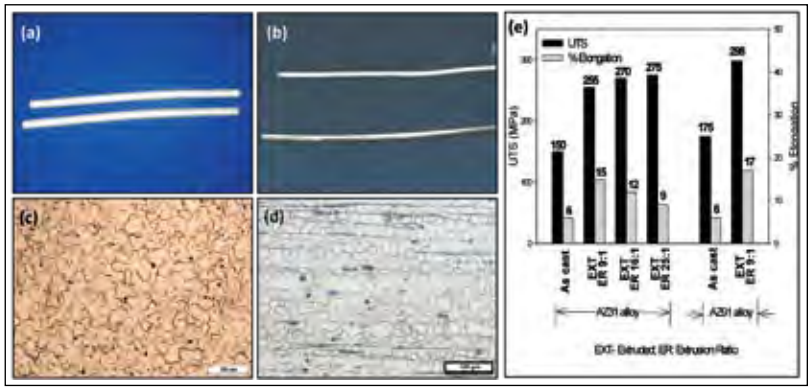


Fig. 2.33: Photograph of as-extruded circular rod of (a) AZ31 alloy and (b) AZ91C alloy; Optical micrographs of (c) as-extruded rod of AZ31 alloy and (d) as-extruded rod of AZ91C alloy. Both the micrographs show refined and equiaxed grain structure; (e) mechanical properties of AZ31 and AZ91C alloy in as-cast and as-extruded conditions.

related to Orowan strengthening at grain boundaries and the homogeneous dispersion of SiC_p.

(2) Development of light-weight Al and Mg wrought products employing secondary processing such as extrusion technique (CSIR Network Project No. NWP28)

The objectives of this network project were (i) optimization of process parameters for hot extrusion of Mg-Al-Zn alloys, (ii) development of indigenous technology for lightweight magnesium alloy products using the optimized extrusion parameters and (iii) microstructural and mechanical characterization of the extruded materials to enable development of high strength and high ductility alloys. The project has been successfully completed achieving the envisaged objectives. Under this project, two different Mg-Al-Zn alloys, such as AZ91C and AZ31 were procured indigenously and technology for their hot extrusion into defect-free circular rods was successfully developed. In this network project, several experiments were conducted to optimize the process parameters for hot extrusion for these alloys into different shapes, such as, circular solid rods, square section rods and hollow circular tubes. Microstructural characteristics and mechanical properties were investigated under different processing conditions (Fig.2.33). Compared to as-cast condition, substantial improvement in the mechanical properties was observed in the extruded condition. Extruded single-phase microstructure for AZ31 alloy was obtained, whereas for AZ91C alloy, a two-phase microstructure comprising of β-$Mg_{17}Al_{12}$ precipitates in α-Mg was produced. The distribution of the two phases in microstructure varied depending upon the extrusion conditions. Transmission electron microscopy (TEM) of the extruded AZ91C alloy showed presence of continuous β-$Mg_{17}Al_{12}$ precipitates in different morphologies, such as, lathes/globules/cuboids, etc. These precipitates are responsible for strength improvement in Mg-Al-Zn alloys in addition to the grain refinement.

[B] CSIR TAP-SUN PROJECT

Technologies and Products for Solar energy utilization through Networks (TAP-SUN): "Development of novel thermoelectric materials and devices for harnessing solar energy and waste heat" (CSIR Network Project NWP 54)

Thermoelectric phenomena, which involve the conversion between thermal and electrical energy, are expected to play an increasingly important role in meeting the energy challenge of the future. Thermoelectric devices may help to overcome this challenge by supplying means to produce energy by scavenging of waste heat with thermoelectric generators using thermoelectric

materials. Therefore, currently there is an increasing emphasis on the development of advanced thermoelectric materials and their devices for generation of "clean" energy. Thermoelectrics have long been too inefficient to be cost-effective in most applications, because most of the existing conventional thermoelectric materials have figure-of-merit ~ 1. Thus, the main technological challenge worldwide is in developing thermoelectric materials with higher figure-of-merit in order to make their devices more efficient and thus commercially viable and this is the main objective of this project.

During this year, the focus was on the design, synthesis, nanostructural characterization and thermoelectric property evaluation of several bulk nanostructured thermoelectric materials such as SiGe, Mg_2Si, half-Heusler and other novel materials.

(1) Development of Si-Ge nanocomposites as an efficient thermoelectric material

The nanostructured n-type and p-type Si-Ge thermoelectric alloys were synthesized using high energy ball milling of elemental powders of Si & Ge with phosphorous and boron, respectively, as dopants followed by spark plasma sintering (SPS). The ball-milling and spark plasma sintering process parameters were optimized to obtain nanostructured SiGe alloys. After 90 h of ball milling, a complete dissolution of germanium (Ge) in silicon (Si) matrix was observed forming the nanostructures Si-Ge alloys. X-ray diffraction analysis of Si-Ge nanostructured alloys indicated the crystallite size to be ~8 nm with a strain of 0.68 and this was confirmed by HRTEM analysis (Fig.2.34a). HR-TEM observations on spark plasma sintered Si-Ge alloys further confirmed that the reduction in thermal conductivity was mainly due to the retained nano-grained network after SPS with a crystallite size of ~15 nm and larger density of interfaces as shown in Fig.2.34b. Figure-of-merit (ZT) of Si-Ge thermoelectric nanostructured alloy exhibited a significant improvement, which is above the value reported so far at this temperature. This enhancement in ZT is directly proportional to the efficiency of the thermoelectric device.

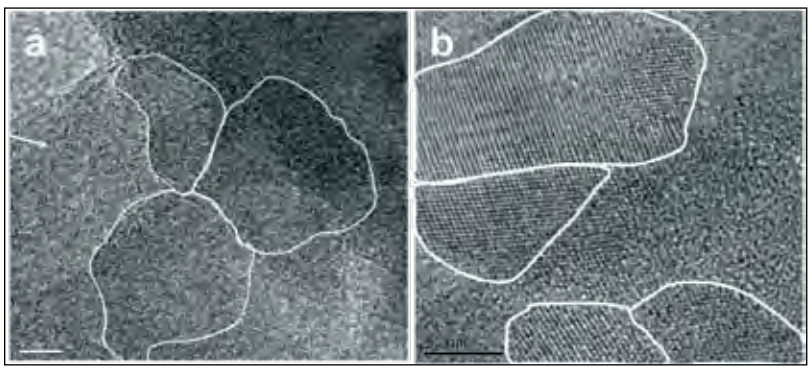


Fig. 2.34: HR-TEM images of *n-type* Si-Ge alloy (a) milled for 90 h, showing large number of fine grains aligned in different directions (b) Retained nano-grained microstructure after SPS at 11000C-10min

(2) Development of Magnesium Silicide and related alloys with enhanced figure-of-merit

Cost-effective and high-performance Mg_2Si based materials are of prime interest in thermoelectric conversion primarily due to their low density resulting in high conversion efficiency per unit mass as compared to other thermoelectric materials. Single-phase Mg_2Si was synthesized using powder metallurgy route and employing high-energy ball-milling of elemental powders of Mg & Si in stoichiometric proportions, followed spark plasma sintering of the resulting powders, by optimizing various processing parameters. The X-ray diffraction (Fig 2.35a) shows the complete formation of single-phase Mg_2Si after spark plasma sintering at temperature 873 K, pressure 50 MPa, sintering time of 10 minutes. The temperature dependence of thermal conductivity (Fig. 2.35b), Seebeck coefficient

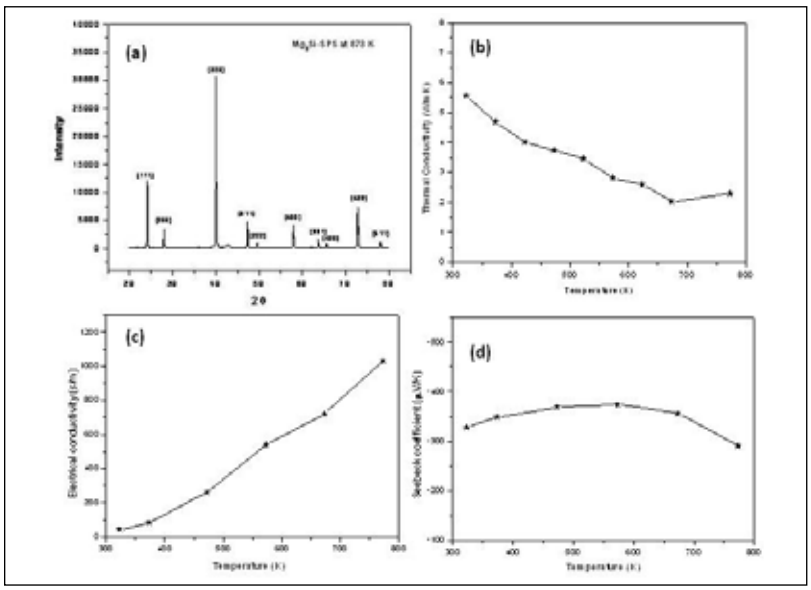


Fig. 2.35: Properties of thermoelectric Mg2Si (a) XRD showing formation of single phase

(Fig.2.35c) and electrical conductivity (Fig.2.35d) of spark plasma sintered Mg_2Si are similar to that of the reported literature values. The improvement in figure-of-merit by doping third element in Mg_2Si is presently under investigation.

(3) Development of nanostructured half-Heusler $Zr_{0.25}Hf_{0.75}NiSn$ as potential thermoelectric materials

Among promising thermo-electric materials for power generation, half-Heusler (HH) phases with general compositions (Hf,Zr)-NiSn and (Hf,Zr)CoSb have attracted tremendous attention because they involve cheap, abundant, lightweight and environmental friendly elements. However, it is well known that the ability to synthesize half-Heusler based materials with appreciable thermoelectric figures of merit, is hindered by their very large thermal conductivities in comparison to the other state-of-the-art TE materials. The main aim of this work was to enhance thermoelectric figure of merit via simultaneous increase in the power factor and reduction in total thermal conductivity resulting due to nanostructuring followed by ball milling and spark plasma sintering (SPS) techniques in a simple n-type composition of HH $Zr_{0.25}Hf_{0.75}NiSn$ compound without doping of Sb (Fig.2.36 & Fig 2.37) which is a unique result in achieving significantly increased ZT at 773 K than earlier reports. The thermoelectric figure of merit has been observed to be drastically increased by nanostructuring in a simple n-type composition of HH $Zr_{0.25}Hf_{0.75}NiSn$ compound without doping of Sb. A peak ZT value of 1.09 achieved at 773 K in nanostructured $Zr_{0.25}Hf_{0.75}NiSn$ alloy (Fig. 2.38). The increase in the Seebeck coefficient, which is electronic in origin, is shown to be due to the increase in the expansion of unit cell volume, resulting in the localization of the upper valence transition metal d-states. On the other hand, the observed reduction in the thermal conductivity is attributed to be associated with the dense interfaces scattering the phonons. The transport parameters calculated using the Boltzmann's equation within the constant relaxation time approximation match well with the experimental results (Fig. 2.39).

[C] IN-HOUSE PROJECTS

(1) Synthesis of Rare Earth free Permanent Magnetic Materials

The main objective of this project is to synthesis rare-earth free permanent magnetic material Mn-Al employing powder metallurgy. Elemental Mn and Al powders were ball milled for few hours under argon atmosphere in a high energy ball mill at 400 rpm using stainless steel bowl together with 10 mm SS balls with ball to powder ratio of 15:1. The ball milled powder was then cold pressed for further treatment. The magnetic τ-phase of MnAl, which is a metastable phase, was obtained by high temperature (1050-1150°C) solutionizing in

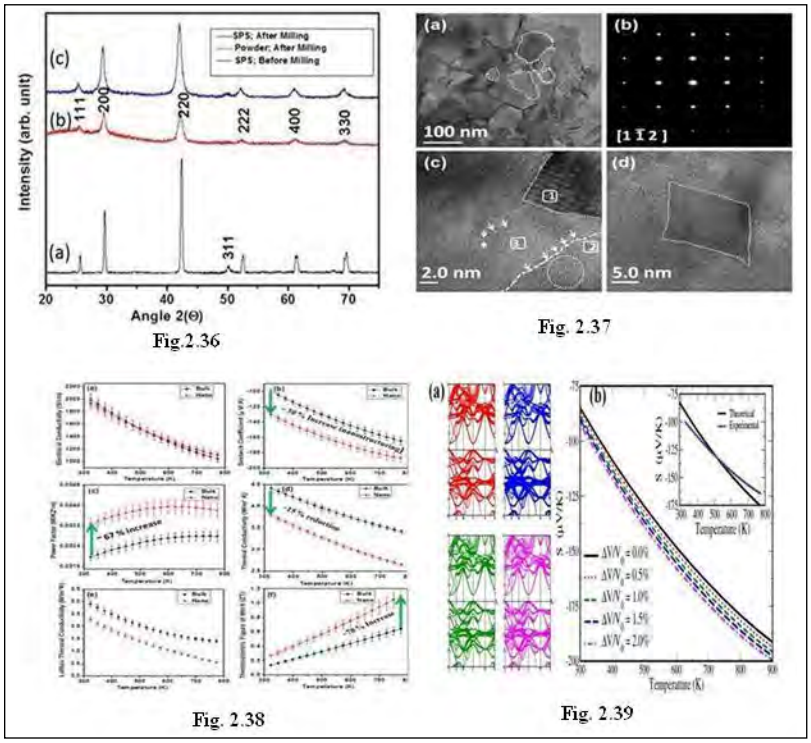


Fig.2.36

Fig. 2.37

Fig. 2.38

Fig. 2.39

Fig. 2.36: X-ray diffraction patterns of HH samples at several stages of processing

Fig. 2.37 TEM images of SPS nanostructured $Zr_{0.25}Hf_{0.75}NiSn$ HH samples; (a) Bright field TEM image, (b) SAED patterns showing the single crystalline nature of the individual grains, (c) high magnification image showing lattice distortion and highly dense grains (d) a nanoscale precipitates coherently embedded in the matrix.

Fig.2.38: Temperature-dependent thermoelectric properties and figure of merit (ZT) of bulk and nanostructured $Zr_{0.25}Hf_{0.75}NiSn$ HH samples

Fig. 2.39: (a) The fully relativistic band structure of $Zr_{0.25}Hf_{0.75}NiSn$ half-Heusler calculated at equilibrium cell volume. The atom resolved band character of $Zr_{0.25}Hf_{0.75}NiSn$, along certain high symmetry points in the Brillouin zone with energy scale (y-axis) in units of eV. The flat bands highlight the band character of (top-left) Hf bands, (bottom-left) Zr bands, (top-right) Ni bands and (bottom-right) the Sn derived band characters. The horizontal dotted line along E=0 eV (Y-axis) refers to the Fermi energy. (b) Variation in the Seebeck coefficient as a function of temperature, calculated using the Boltzmann transport equation. The curves are for different cell volumes, as indicated by the legends.

ε-phase (hcp structure) followed by water quenching. Subsequent to that Mn-Al alloy was annealed at around 450-600°C for synthesis of τ phase. The samples were characterized by XRD and SEM and magnetic properties were measured using a vibrating sample magnetometer. Efforts are presently underway to increase the magnetization of this alloy by optimizing the synthesis technique and their process parameters.

(2) High Temperature Superconducting Materials & Devices

For the development of joint tubes of BPSCCO based HTS, a post-sintering process for making a long-length tube assembly of (Bi,Pb)-2223 (L = 430mm, OD = 43mm & ID = 40mm), having superconducting properties with minimum losses at the superconducting joints, which can carry more than 1000A at 77K, has been developed and is presently under optimization. A joint HTS tube assembly made from such a process can be cost-effective as it reduces the total loss to $1/10^{th}$ when used as a current lead particularly in SC magnet systems.

To understand the nature of pairing and pinning in search of effective pinning centers, some basic studies (XRD, SEM/EDAX, R vs T, χ_{ac} vs T, I_c and ESR) were carried out on (Bi,Pb)-2223 samples doped with various rare earth (Dy, Pr, Tb, Yb, Sm, Eu) ions (0-0.10 mole%) employing solid state route (T_c decreases from 110K for pristine sample to 108~70K for RE doped samples) and MgB_2. These studies revealed that J_c (at 60K, 0.05T) from 912 A/cm^2 for pristine sample increases and reaches to a maximum of 1368-1720A/cm^2 for the lower RE concentration

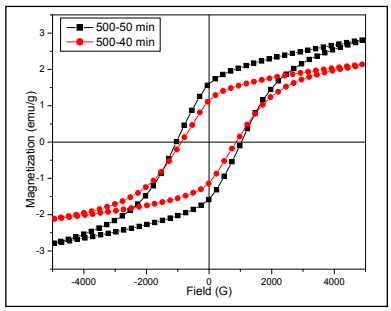


Fig.2.40 VSM of high energy ball milled MnAl alloy after solutionizing at 1150°C for 5h followed by annealing at 500°C

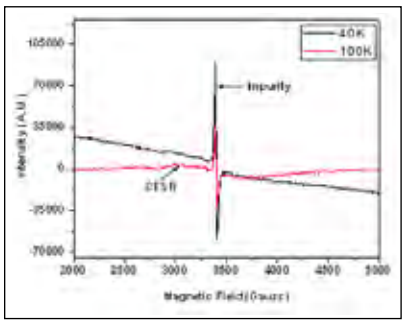


Fig. 2.41a

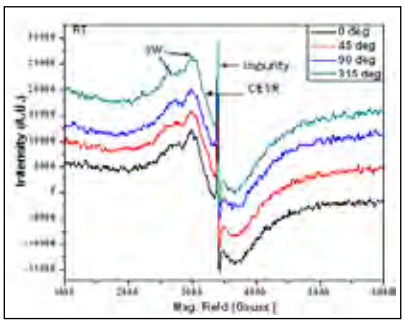


Fig. 2.41b

(0.005-0.01). A detailed study suggested this effect may be due to the occurrence of possibly virtual bound states (VBS) formed as a result of RE dopings, which serve as effective pinning centers for magnetic flux lines hence contributing to enhancement of J_c.

Studies of ESR in MgB_2 at different temperatures and for different orientations (0-360°) were carried and are typically shown in Fig.2.41. In the normal state, it shows two signals: sharp and broad. The sharp signal (g~ 2.00) increases (by several folds) on cooling (as shown in Fig.2.41a) is the typical behaviour of a paramagnetic impurity. The broad signal on which the sharp signal is overlapped, disappears in the superconducting state is assigned to CESR. The disappearance of CESR indicates the pairing of electrons/holes on the formation of total ground state at E_f. Interestingly, the broad signal (CESR) has humps (as shown in Fig.2.41b), which shows movement around on CESR on sample orientation through 0 to 360° are due to Platzmann-Wolf spin waves. Appearance of CESR along with Platzmann-Wolf SW is suggestive of enhanced exchange interactions in conduction band which can play a crucial role in electron/hole pairing and superconductivity.

Major Facilities developed/ created/established during the academic year 2011-12

Under the TAP-SUN project (NWP-54), Thermoelectric Materials Laboratory was set-up which is equipped with a Thermal Analyzer (Linseis, Germany model LFA 1000), Seebeck & Electrical Conductivity measuring unit (Ulvac-Riko, Japan, model ZEM-3), Vario-Planetary High Energy Ball Mills (Fritsch, Germany, model P-4 & P-5), X-ray Diffraction unit (Rigaku, Japan, model miniflex II), Spark Plasma Sintering Unit (SPS Syntex, Japan, model 725), controlled atmosphere rapid-sintering Muffle furnace (Nabertherm, Germany, model P330) and thermoelectric sample preparation equipments.

BOOKS

(1) G.K.Padam, "Non Resonant Microwave Absorption (NRMA) Anomalies in High Temperature Superconductors (HTS) - Relevance of Electromagnetic Interactions (EMI) and Energy Stabilized Josephson (ESJ) Fluxons" in Superconductors - Properties, Technology, and Applications, Ed. by Y.Grigorashvili, Chapter, 5, pp 83-104, March 2012.


वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद
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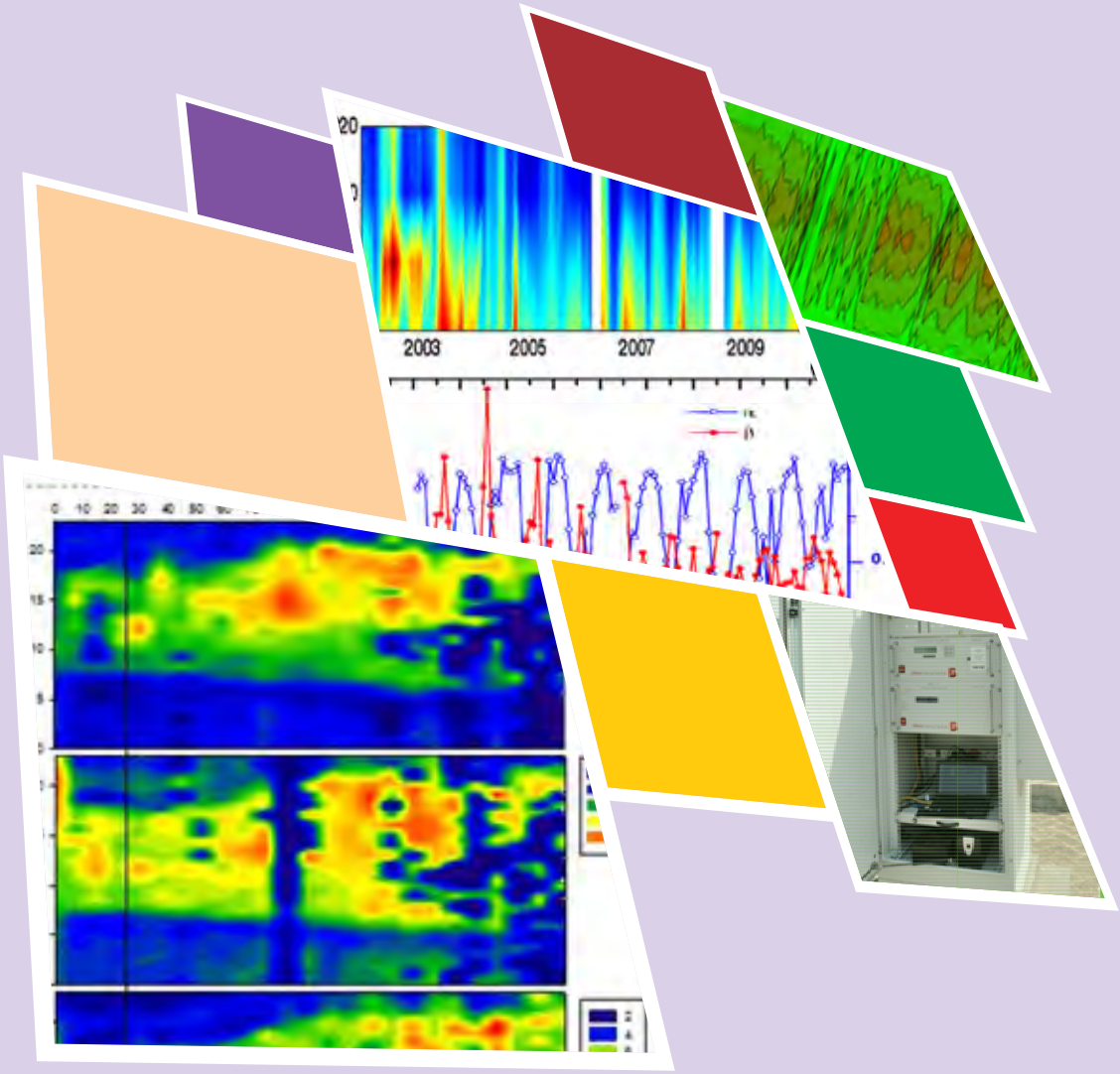
रेडियो एवं वायुमंडलीय विज्ञान



Radio and Atmospheric Sciences

रेडियो एवं वायुमंडलीय विज्ञान

राष्ट्रीय भौतिक प्रयोगशाला का रेडियो एवं वायुमंडलीय विज्ञान प्रभाग (आरएएसडी) रेडियो भौतिकी और अनुप्रयोग, अंतरिक्ष मौसम और आयनमंडल, पृथ्वी के वायुमंडल का रसायनिक और भौतिक संगठन, वायुमंडलीय प्रदूषण और जलवायवी परिवर्तन आदि के क्षेत्रों में राष्ट्र की वैज्ञानिक आवश्यकताओं की पूर्ति करता है। इस प्रभाग में किए जा रहे विभिन्न अनुसंधान एवं विकास कार्यों को चार व्यापक क्रियाकलापों की श्रेणी में विभाजित किया गया है : (i) रेडियो विज्ञान, (ii) वायुमंडलीय रयायन, (iii) वायुमंडल का स्पेक्ट्रम विज्ञान, और (iv) वायुमंडलीय भौतिकी हेतु अनुकार और मॉडलिंग।

रेडियो विज्ञान : इस क्रियाकलाप के अंतर्गत मुख्यतः भारतीय और ध्रुवीय क्षेत्रों के ऊपर आयनित और अनायनित वायुमंडलीय प्रक्षेत्र के अभिलक्षणों को ज्ञात करने तथा रेडियो संचार, नौवहन और अन्य उन्नत अनुप्रयोगों में सुधार लाने की दृष्टि से रेडियो संचरण का अध्ययन संबंधी कार्य आते हैं। इसमें 150, 320, 440, 900 और 1800 मेगा हर्ट्ज के सन्निकट विभिन्न फ्रीक्वेंसी बैंडों में संकीर्ण बैंड सिग्नल स्तरों का मापन, जीपीएस, टोमोग्राफिक रिसीवरों, आयन सोंद आदि सहित उपग्रह और भू–आधारित निगरानी प्रणालियों का उपयोग करके आयनमंडलीय/स्थलमंडनीय पैरामीटरों से संबंधित निगरानी और मॉडलिंग से संबंधित क्रियाकलाप शामिल हैं। हम अपने अंतरिक्ष–मौसम क्षेत्रीय चेतावनी केंद्र (आरडब्ल्यूसी, एनपीएल, भारत) के माध्यम से अपने विश्व भर के प्रयोक्ताओं के लिए आयनमंडल संबंधी पूर्वानुमान/समाचार प्रयारण से संबंधित कार्य भी करते हैं तथा हमने अंतर्राष्ट्रीय संदर्भ आयनमंडल (आईआरआई) मॉडल में निरंतर सुधार भी किया है।

वायुमंडलीय रसायन विज्ञान : इस विभाग का एक वैज्ञानिक समूह विभिन्न स्रोतों से ग्रीन हाउस गैसों के उत्सर्जन के संबंध में जानकारी हासिल करने, देश के ग्रामीण क्षेत्रों में प्रयोग में लाए जा रहे बायोमास ईंधनों से निकलने वाले कणिकामय पदार्थों और सूक्ष्ममात्रिक गैसों (सल्फर डाई ऑक्साइड, नाइट्रोजन ऑक्साइड और नाइट्रोजन डाई ऑक्साइड) तथा लैंडफिलों और खेतों में लगी गेंहू एवं धान की फसलों से होने वाले उत्सर्जनों की मात्रा का आकलन करता है। इसके साथ ही हम अत्याधुनिक तकनीकों का प्रयोग करते हुए तथा स्रोत पर ही जानकारी हासिल करके, देश के विभिन्न क्षेत्रों तथा इसके परिवेशी महासागरों, हिमालय और ध्रुवीय क्षेत्रों में स्थित कणिकामय पदार्थों और इनसे पूर्व उत्सर्जित पदार्थों का रायायनिक अभिलक्षण ज्ञात करने से संबंधित क्रियाकलापों में संलग्न हैं। यह समूह विभिन्न मॉडलों का प्रयोग करके और निगरानी के जरिए वायुमंडलीय ओजोन, इसके रासायनिक संगठन और इसकी गतिकी का अध्ययन (इसके कारण मानव के स्वास्थ्य पर पड़ने वाले लाभकारी/प्रतिकूल प्रभावों का अध्ययन) भी करता है।

वायुमंडलीय स्पेक्ट्रम विज्ञान : इस प्रभाग में पराबैंगनी, दृश्य और अवरक्त स्पेक्ट्रम रेंज में वायुमंडल सम्बंधी स्पेक्ट्रोस्कोपी करके वायुमंडलीय ऐरोसोल, सूक्ष्म मात्रिक गैसों, सौर विकिरण और उनके प्रभावों के संबंध में व्यापक सूचना संगृहीत की जाती है। इनसे वायुमंडलीय ऐरोसॉल के प्रकाशीय और भौतिक अभिलक्षणों को ज्ञात करने तथा गैस सैम्पलों या वायुमंडलीय स्तंभ में उपस्थित सूक्ष्म मात्रिक रसायनों की रायायनिक संरचना को ज्ञात करने में सहायता प्राप्त होती है। इस प्रभाग द्वारा हाल ही में उच्च विभेदन विवक्त–पथ एफटीआईआर, लिडार जैसे आधुनिक उपकरण अधिप्राप्त किए गए हैं जिनसे ऐरोसॉल की प्रकाशीय गहराई, ऐरोसॉल का ऊर्ध्वाधर प्रोफाइल, ऐरोसॉल के अमाप वितरण, ऐरोसॉल के प्रकीर्णन और अवशोषण गुणांकों, एकल प्रकीर्णन ऐल्बिडो (एसएसए), प्रकाशीय गुणों, रायायनिक गुण–धर्म आदि पर ऐरोसॉल की आकृति और इसके अमाप के प्रभाव का अध्ययन करने में सहायता प्राप्त होती है।

वायुमंडलीय भौतिकी हेतु अनुकार और मॉडलिंग : हालांकि गणितीय मॉडलिंग इस प्रभाग के समग्र क्रियाकलापों का एक समेकित क्रियाकलाप है, तथापि इस विशिष्ट समूह का उद्देश्य वायुमंडलीय प्रक्रमों का अनुकार और अवबोधन प्राप्त करने के लिए स्पेक्ट्रम विज्ञान, रायायनिक और भौतिक गुण–धर्म निर्धारण आदि के जरिए प्रभाग में संगृहीत विभिन्न आंकड़ों को समेकित करना है। वर्तमान में प्रयोग में लाए जा रहे कुछ मॉडलों में, जलवायु परिवर्तन, परिदृश्य विकास मॉडल, एमएजीआईसीसी, मी कोड का प्रयोग करके ऐरोसॉल प्रकाशील मॉडल, डिस्क्रीट डाइपोल एपरोक्सिमेशन (डीडीए) और टी–मेट्रिक्स, रेडिएटिव ट्रांसफर मॉडल, एसबीडीएआरटी और मध्यम क्षमता वाले वायुमंडलीय ट्रांसमिशन मॉडल (मॉडट्रान) तथा वायुमंडलीय प्रक्रमों हेतु प्रतिक्रामी प्रकाश रायायनिक और गतिकीय मॉडल के नाम उल्लेखनीय हैं।

Radio and Atmospheric Sciences

The Radio and Atmospheric Sciences Division (RASD) of NPL caters to the scientific needs of the nation in the area of radio physics and applications, space weather and ionosphere, chemistry and physics of the earth atmosphere, atmospheric pollution and climate change etc. Different R&D works being done in this division have been categorized into four broad activities as follows :

Radio Science : Here we are mainly involved in the characterization of the ionized and non-ionized atmospheric media over the Indian and Polar Regions and studying radio propagation for the purpose of betterment of radio communication, navigation and other advance applications. This involves narow band signal level measurements in various frequency bands near 150, 320, 440, 900 and 1800 MHz, monitoring and modeling related to ionospheric/tropospheric parameters using satellites and ground based monitoring systems, including GPS, Tomographic Receivers, Ionosonde, etc. We also provide ionospheric forecasting/nowcasting to users worldwide through our space weather Regional Warning centre (RWC, NPL-India) and have consistently improved the International Reference Ionosphere (IRI) model.

Atmospheric Chemistry : Our vibrant atmospheric chemistry group is engaged in developing the Greenhouse gas (GHG) inventory from different sources, emission estimates of particulate matter (PM) and trace gases (SO_2, NO and NO_2) from biomass fuels consumed in rural sector of our country, emissions from land fills and wheat and rice crop fields etc. At the same time we also do chemical characterisation using state-of-the-art techniques and source apportionment of particulate matter (PM) and precursors at different regions in the country, including the surounding oceans, Himalayas and poles. This group also studies the atmospheric ozone (good as well as bad), its chemistry and dynamics using various models and observations.

Spectroscopy of Atmosphere : A wide range of information about the atmospheric aerosols, trace gases, solar radiation and their interactions are obtained in the division by doing spectroscopy of the atmosphere in the UV, Visible and NIR-IR spectral range. It enables the optical fand physical characterisation of the atmospheric aerosols and help in identifying the trace chemical constituents in the gas samples or in the atmospheric column. The high resolution Open-Path FTIR, micro-pulse LIDAR are the recent modern equipments that supplement the study of aerosol optical depth, vertical profile of aerosols, aerosol size distribution, scattering and absorption coefficients of aerosols, single scattering albedo (SSA), effect of aerosol shape and size on optical properties, chemical characterization, etc.

Simulation and Modeling for Atmospheric Physics : Although, mathematical modeling is an integral part of all the groups in the division, the purpose of this particular group is to assismilate the various data generated in the division through spectroscopy, chemical and physical characterisation etc. to simulate and understand the atmospheric processes. Some of the models that are currently in use include Climate Change scenario development model MAGICC; Aerosol optical model using Mie-code, Discrete Dipole Approximation (DDA) and T-matrix; Radiative Transfer models SBDART, and moderate resolution atmospheric transmission model (MODTRAN); and Regressive Photochemical and Dynamical model for atmospheric processes.

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Radio Science

Comparison of 1.8 GHz cellular outdoor measurements with AWAS electromagnetic code and conventional models over urban and suburban regions of northern India

An attempt is made to investigate the suitability of various prediction models using the 1.8 GHz cellular frequency narrowband measurements conducted in urban and suburban areas of Delhi in northern India. In total 11 base stations were utilized in the study out of which 3 stations fall in the urban category, 6 in dense urban category and 2 in suburban category. The observed signal levels converted into path loss values were compared with different models. Apart from this the major contribution of this study is the comparison of the above results with the predicted ones of AWAS electromagnetic code in the near field and far field zones. The deviations of all the methods and standard deviations are presented. Path loss exponents and break point distances have been deduced. A typical figure showing the comparison of observed path losses with that of AWAS, COST 231 Hata, ITU-R, Walfisch-Ikegami, Dmitry models is shown in figure 3.1.

An analysis of prediction errors and standard deviations showed that AWAS electromagnetic code and ITU-R methods reported good agreement and lower standard deviations compared with other methods. The advantage of using AWAS electromagnetic code is that it does not require any building information and was able to compete with other empirical methods and followed the trend of observed data in most of the cases. High path losses and large path loss variance observed at closer distances to the transmitter were not explained by the prediction methods. It seems till the break point the dominant propagation mechanism is in horizontal mode and beyond this it changes into vertical one. At close to the transmitter high path loss exponents were observed and after a certain distance at the end of the near field or beginning of far field zone path loss exponents settled to a value of 3 and remained for rest of the distances. High path loss exponents observed can make the operators to rethink on the margins provided by them and this study is useful for the design of upcoming 3G and wimax systems in these regions and similar regions.

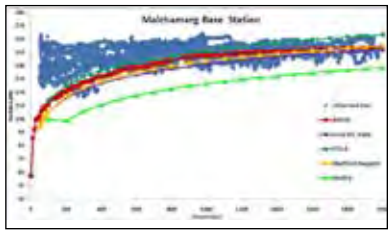


Fig. 3.1 Comparison of observed path losses

Experimental investigation of GSM 900 MHz results over northern India with AWAS electromagnetic code and other prediction models

In the above study using 10 base stations of GSM 900 MHz signals measurements conducted in Delhi and surrounding areas were validated with AWAS electromagnetic code and other prediction models. The results have been explained in terms of transitions in the near and far field zones. Path loss exponents and break point distances have been deduced. In most of the cases path loss exponent falls rapidly at distances close to transmitter and settled at values around 3 for rest of the distances. The data validated many of the Sommerfeld's propositions.

Analysis of WiMAX radio measurements and comparison with some models over dense urban western India at 2.3 GHz

An experimental campaign was conducted in the dense urban region of Mumbai using WiMAX transmissions at 2.3 GHz, for seven base stations. The observed signal levels converted into path losses were compared with the various prediction methods, namely, COST-231 Hata, ECC, SUI, ITU-R (NLOS) as well as with the least square regression method. A typical diagram showing the comparison for Ajay Amar Cooperative housing society (AAC) is shown in figure 3.2. The path loss exponents, the ME and

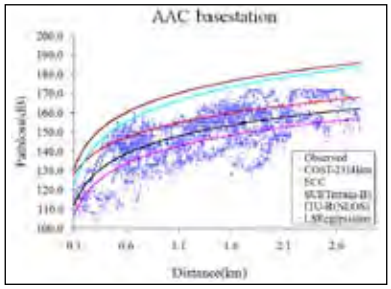


Fig. 3.2 A typical diagram showing the comparison of path loss for Ajay Amar cooperative housing society (AAC)

the SD of all the methods have been deduced and compared to measured values. The cdf values of prediction errors have also been compared. The different statistical parameters have been deduced and the best fit distribution for the cdf curves has been found. The prediction errors of the SUI and the ITU-R NLOS models are considerably higher than those of the COST-231 Hata and the ECC models. The Poisson distribution is the one that best represents the statistics of the prediction error for regression analysis and for the COST-231 Hata model, whereas the other models follow the negative binomial distribution. The COST-231 Hata and the ECC methods give a good agreement with the measured data than the other methods.

Ionospheric F2 –region variability and sudden stratospheric warmings

The low latitude ionospheric F2 –region is known to show a large day to day and hour to hour variability. Some of this variability has been related to sudden stratospheric warmings (SSWs). We therefore investigated the extent of ionospheric response to a number of stratospheric warming events using ionosonde data from six different stations in the Asian zone thus covering a broad latitudinal range (Fig 3.3). In nearly all cases, we find that ionospheric F2-region responds to stratospheric warming within a week or two

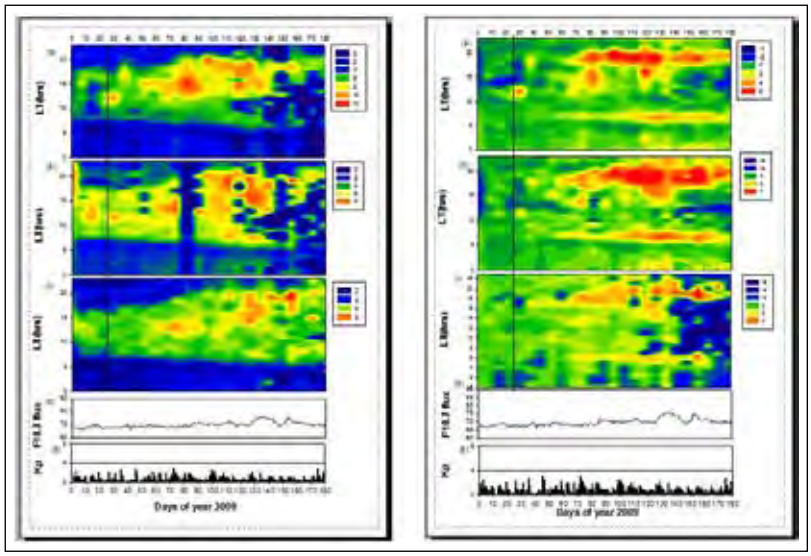


Fig 3.3. Shows the variation of F2 layer critical frequency foF2 and ΔfoF2 at Okinawa, Yamagawa and Kokubunji (Japanese stations) .

from the day of the event, with an increase in foF2 around 10 hr L.T. and a decrease around 16 hr LT at the low latitude stations. These results are in conformity with those observed with the GPS TEC data for the 2008 and 2009 SSW events and attributed to the semidiurnal changes in the vertical ion drifts. Further, it seems to us that it is difficult to quantify the changes in foF2 as well as in the response times involved in these events. While the physical mechanisms for the ionospheric variability are known, the variability observed in the ionospheric data cannot be predicted with precision.

Daytime additional F-layer stratification seen over Delhi under geomagnetic disturbed conditions:

F-layer stratification is seen at Delhi a region which is situated at the outer edge of equatorial ionization anomaly (EIA) zone. The digital ionosonde data observed over Delhi (28.6° N, 77.2° E, dip 42.44° N) during March-April, 2011 has been used to carry out the present work on F-layer stratification over Delhi (Fig. 3.4). The observational period was geomagnetically disturbed and represents the high solar activity phase of 23rd solar cycle. The additional transient cusp is frequently observed in the considered months before the noon hours; however, in this report only five prominent cases are presented. From the analysis of ionograms, it is observed that the transient additional cusp is formed between the pre-existing F1 and F2 layer; hence, named as the cusp of F1.5. Study reveals that the Traveling Atmospheric Disturbances (TADs) along with the vertical expansion of F-layer provides the necessary condition for the existence of this transient feature.

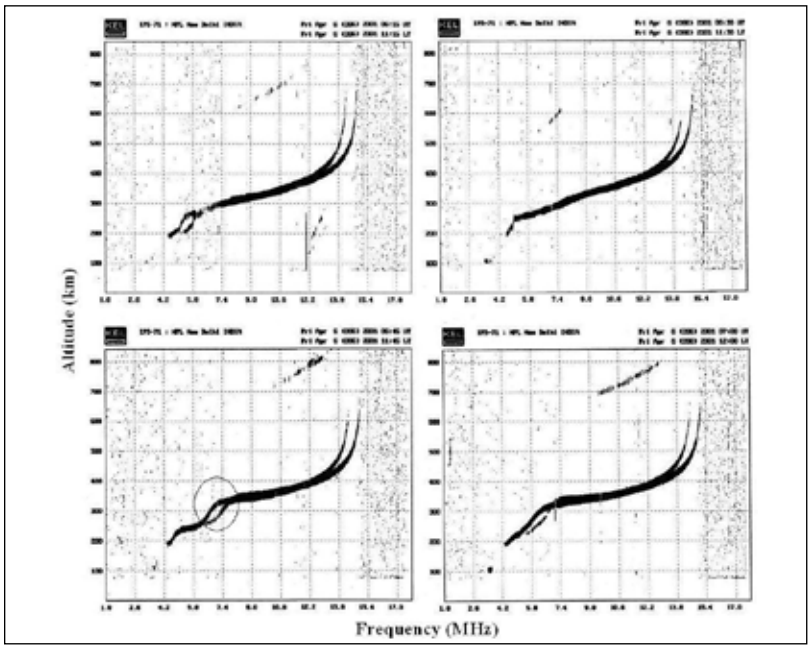


Fig. 3.4: Sequential Ionograms on April 06, 2001 shows the presence of additional cusp which is marked by the circle.

Atmospheric Chemistry

Uncertainty reduction in methane emission estimation from landfills in Delhi

In developing countries such as India, inventory estimates of methane (CH_4) emission from landfills have large uncertainties due to inadequate data availability on Municipal Solid Waste (MSW) management and CH_4 emissions factors. During the cradle to grave process, MSW passes through various stages such as sorting of recyclable and compostable materials before final disposal to landfills. These stages may change the quantity and properties of waste ultimately reaching the landfill sites, thereby influencing GHG (i.e. CH_4) emissions. An effort has been made to carry out in-situ measurements of GHG emission fluxes in Delhi's three landfills, namely (a) Ghazipur (GL), (b) Bhalswa (BL) and (c) Okhla (OL), for generation of representative CH_4 emission factors (EF) for reduction of uncertainties in the inventory estimates. The CH_4 emission estimations for Delhi's landfills, based on site specific CH_4 emission factors (EFs), are also compared with the CH_4 emission estimates developed using other available methods like the IPCC Default Method (DM), IPCC First Order Decay (FOD) and Modified Triangular Method (MTM) for each of the

three landfill sites. The time series estimations revealed that, the in-situ measurement methodology, capturing the actual CH_4 emissions, results in the lowest CH_4 emission estimates thereby indicating that the other three methodologies may be over estimating the CH_4 emissions (Fig 3.5). It is also observed that, the in-situ method yields CH_4 emission values close to FOD values in most of the cases except for the OL where organic matter as well as Degradable Organic Carbon (DOC) contents are less compared to the other two landfills. It shows that the FOD method would results in comparable values for CH_4 emission estimates with that of in-situ method if good quality MSW composition data is available.

The annual CH_4 emissions have been found to be increasing during the last decade in all the three landfills of Delhi except in OL where the recycling activities are quite strong. Methane generation trend during the first phase (i.e. from 1 to 6 years) of MTM is almost similar with the FOD but differed in second phase (i.e. from 7 to 15 years) when MTM showed higher values than the FOD values with average difference in CH_4 emissions in MTM & FOD methods is about 3 Gg in the three landfills. The estimation using in-situ methodology showed that only 10.2 Gg CH_4 is emitted from the three landfills in Delhi during 2008-09 period. The total CH_4 emission estimation for the Delhi's landfills by other methods yielded the values of 31.1 Gg by FOD, 41.1 Gg by MTM and 45.7 by DM for 2008-09 period.

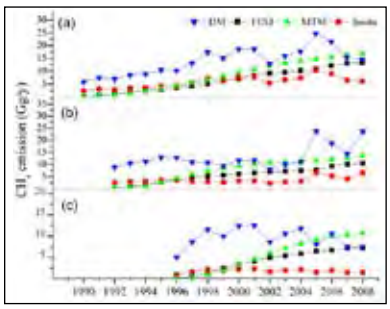
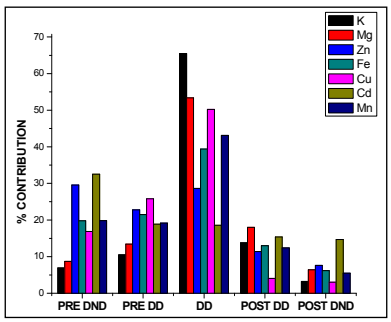


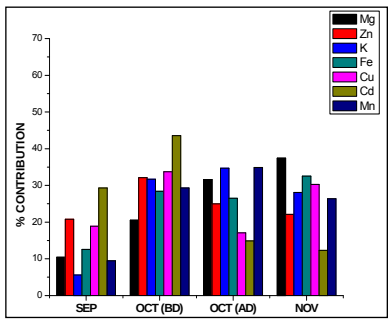
Fig. 3.5: Methane emission estimation by different methods for (a) Ghazipur (GL), (b) Bhalswa (BL) and (c) Okhla (OL).

Chemistry and sources of trace metals in PM10 aerosols over Delhi region

Figures 3.6A and B show % contribution of various metals in PM_{10} aerosols during Diwali days and normal days spread over three months respectively. Figure 1A clearly indicates a very sharp peak of all the metals except Cd on Diwali day. The highest contribution was observed for K followed by Mg, Cu, Mn, Fe, Zn and Cd respectively. This is due the reason that different salts of metals are used in the crackers and fireworks for colouring effects. These results clearly establish the role of crackers and fireworks for high levels of metal emissions and accumulation in the atmosphere during Diwali festival days. During normal days, spread over a period of three months, the levels are much lower as indicated by Figure 1B. As other sources also contribute to emissions of metals in the atmosphere like dust, industries, vehicular traffic etc., these levels are expected. Low levels of metals in September may be due to relatively clean atmosphere after monsoon. The levels of metals during October before Diwali are on little higher side which may be expected due to festival season. Mostly, people use their personal vehicles for shopping purpose. The study of these metals in the atmosphere is of serious concern as excess levels may be cause serious health effects.



(Fig-1A)



(Fig-1B)

Fig. 3.6: % contribution of various metals in PM_{10} aerosols at Delhi

Role of ambient ammonia in the formation of inorganic aerosol over Indo Gangetic Plain (IGP) of India

Mixing ratio of ambient NH_3, NO and NO_2 were measured along with particulates at urban sites

of Chandigarh, Delhi, Varanasi and Kolkata of IGP of India to study their variability and role of ambient NH_3 in the formation of aerosol. During winter (2011-12) the day time average mixing ratio of ambient NH_3 was recorded as 11.95 ± 1.36 ppb and night time as 12.11 ± 0.48 ppb at Delhi. The day night ratio of ambient NH_3 was computed as 0.79 (night time value: 48.3 ± 8.1 ppb) at Kolkata whereas 0.80 at Chandigarh (night time value: 8.1±1.1 ppb). During winter the mixing ratio of ambient NH_3 at Kolkata was recorded 3 times higher than the Delhi and Chandigarh. The higher mixing ratio of ambient NH_3 at Kolkata may be due to source strength and meteorological conditions of the observational site. Similarly, NO and NO_2 mixing ratios were also recorded higher at Kolkata than Delhi and Chandigarh. Figure 3.7 shows the monthly variation of NH_3, NO and NO_2 at Delhi. A good correlation of SO_4^{2-} and NO_3- with NH_4+ (NH_4+ vs. SO_4^{2-}, r^2 = 0.91; NH^4+ vs. NO_3-, r^2 = 0.96) and NH_3 (NH_3 vs. SO_4^{2-}, r^2 = 0.90; NH_3 vs. NO_3-, r^2 = 0.91) indicates the formation of aerosol over Delhi. More or less similar, correlations were also recorded over Chandigarh and Kolkata.

Spectroscopy of Atmosphere

First solar occultation spectra recorded at NPL using OP-FTIR, Delhi

Solar occultation spectra (total 22) of good quality have been recorded in Delhi (NPL) on

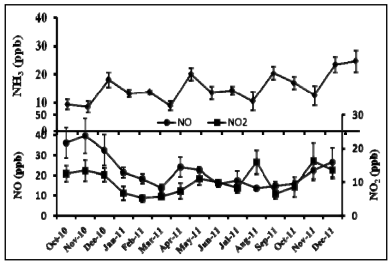


Fig. 3.7. Monthly variation of ambient NH_3, NO and NO_2 over Delhi.

March 28, 2012 with the Filter 6 (2500-3280 cm^{-1}) using Bruker 125 HR at NPL. The signal to noise ratio (SNR) and spectral resolution seem adequate for the use of these spectra to retrieve atmospheric trace gases profiles. The signatures of C_2H_6 and N_2O (troposphere) and HCl (stratosphere) are detected. The signatures of C_2H_2 (around 3250 cm^{-1}) and HCN (around 3287 cm^{-1}) are not detected probably because they are at the upper end of the filter 6 spectral domain. The quality of spectra is being checked in the other spectral domains. The priority is being given to tropospheric gases such as O_3 (filter 3: 900-1300 cm^{-1}), CO (filter 5: 2020-2500 cm^{-1}), C_2H_2 and HCN (filter 7: 3500-4150 cm^{-1}).

The first preliminary retrievals performed for the above spectra are encouraging. We have successfully retrieved realistic profiles of N_2O and C_2H_6 in the troposphere. Concerning HCl, the narrow absorption line located at 2985.9 cm^{-1} seems to have the right shape and width indicating a correct alignment of the spectrometer. Retrievals of HCl (stratospheric) and other trace gases are ongoing. The typical solar spectrum (with filter # 6) is shown in Figure 3.8.

Calibration of aerosolized NH_4 and SO_4 using FTIR spectroscopy

FTIR spectroscopy has been recognised as a potential tool for molecular fingerprinting of several key constituents of atmospheric particles. However, quantifications using this rapid and non-destructive analytical tool is highly dependent on quality of primary calibrations using engineered aerosols of known chemical composition. $(NH_4)_2SO_4$ particles were generated from a standard (known concentration) and collected on PTFE filters at varying time intervals in order

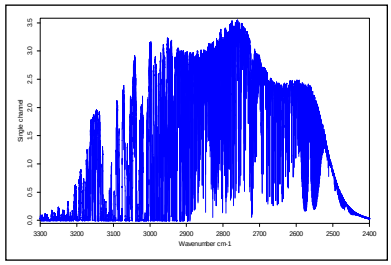


Fig. 3.8: The typical solar spectrum (with filter # 6) at Delhi

to examine the IR absorbance variations against varying amount of analyte as shown in the Figure 3.9. IR absorbance appear to show good linearity at 1420 cm^{-1} (for NH_4^+) and 1115 cm^{-1} (for SO_4^{-2}).

Daily broadband global and UV radiant fluxes at Delhi

Figure 3.10 shows the day-time (07:00 to 19:00 h) daily average variation of solar broadband

global radiation flux (G) along with the UV radiation flux (GUV) as observed on a horizontal plane during the period of measurements over Delhi. The data were recorded at every 2 min of interval and hourly values of radiation were derived by integrating the data every hour. The G and GUV radiation fluxes show similar pattern throughout the observation. The day-time daily-averaged GUV flux varied

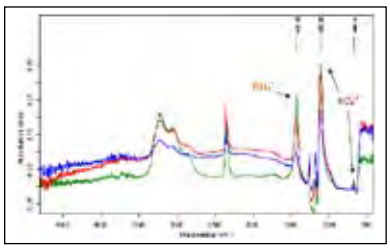


Fig. 3.9: IR absorbance variations against varying amount of analyte.

between 0.15 and 1.23 MJ m^{-2} with an average annual value of 0.67 ± 0.24 MJ m^{-2}. Similarly, the daily-averaged G varied in the range 3.36–27.02 MJ m^{-2}.

Long term spectral variation of Aerosol Optical Depth (AOD) and Angstrom parameters at Delhi

With a view to examining the seasonal, annual and inter-annual variations, the monthly mean values of spectral AODs and Angstrom parameters were estimated from the time series of the daily mean data. The contour map showing the spectral AOD variations for the entire period of study is shown in top panel of Figure 3.11a. The monthly mean values are in the range of

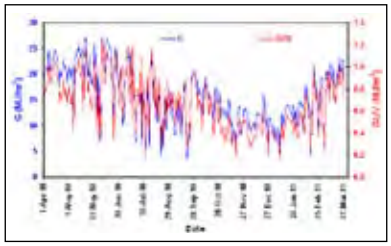


Fig. 3.10: Day-time (07:00 to 19:00 h) daily average variation of G and GUV at Delhi.

~0.25- 1.5 at 500 nm with strong seasonal/annual variations in both spectral AOD as well as in spectral gradient along with a weak but significant inter-annual variability. The seasonal changes in the spectral variation of AOD is clear from the figure with comparatively steeper spectra during winter/post monsoon season and the spectra is found to be exceptionally flat during summer followed closely by the monsoon season as the AOD at longer wavelengths are comparable to that of AOD at shorter wavelengths 500 nm. It is interesting to observe a weak decreasing trend in the spectral AODs as the year progresses from 2001 to 2011. Among the Angstrom parameters (Figure. 3.11b), the highest value of α (~1.1) is observed during January 2008 and the least value (~0.1) during July 2002. The turbidity parameter β shows similar variations as that of AOD.

Ozone standard at NPL, Delhi

The CMC for Ozone standard (SRP43) has been filed. The expanded uncertainty and the range of measurement for Ozone have been shown in the following table.

Parameter	Range	Measurement uncertainty at coverage factor (k=2; level of confidence 95%)
Ozone	(0-500) ppb	$U(x) = [(1.0)^2+(0.020x)^2]^{1/2}$ x = ozone concentration $U(x) = Q[1.0, 0.020x]$; where $Q[a,b]=[a^2+b^2]^{1/2}$

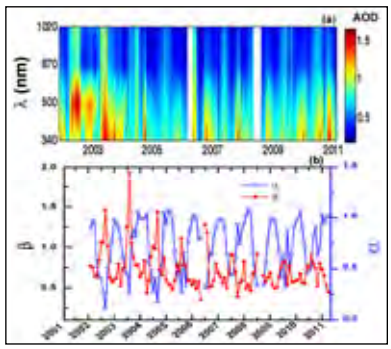


Fig. 3.11: Monthly mean pattern of spectral AOD and Angstrom parameters (a): the contour map showing the spectral variation of AOD (b) time-series of α and β

Simulation and modeling for atmospheric physics :

Modeling clearness index over Delhi

The clearness index (K_T) is defined as a ratio of the global solar radiation measured at the surface to the extraterrestrial radiation. The extraterrestrial radiation was modelled for Delhi using the various parameters. Variation of hourly K_T values during April 2010 to March 2011 is displayed in Figure 3.12. The day 1 in the x-axis corresponds to 1 April 2010. The contour clearly shows enhanced values during mid-day and highest values during the month of April 2011. The low K_T values

during the monsoon may also be noticed. From this study we have found that at Delhi during highly cloudy or overcast conditions $0 \leq KT \leq 0.15$, during partial cloudy or hazy conditions $0.15 \leq KT \leq 0.21$ and for clear sky conditions $KT > 0.21$. Further, during foggy days in winter the KT values were found lying in the range 0.12–0.18. A strong anti-correlation with correlation coefficient –0.75 is observed between AOD at 340 nm and KT indicating a decrease in KT with increasing AOD. For every unit increase in AOD, KT decreases by 0.06.

Figure 3.13 shows the frequency distribution (frequency of occurrence) and cumulative frequency for every 0.03 interval of the daily clearness index obtained during 1 April 2010 to 31 March 2011 at Delhi. It shows that during most of the year (about 50%) daily KT values lies between 0.18 and 0.24 for the annual distribution with marked peak value in the interval 0.21–0.24. About 40% of the days in the year, the daily KT values are below 0.18 and only during the remaining 10% of the days it goes beyond 0.24.

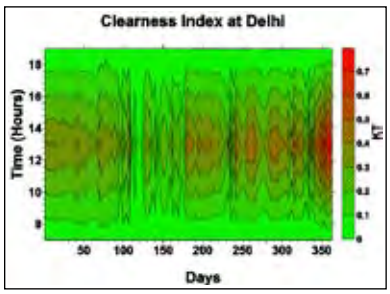


Fig. 3.12. Contour plot of clearness index (KT) during 1 April 2010 to 31 March 2011 at Delhi

F2 region response to geomagnetic disturbances across low latitude ionosphere:

The morphology of ionospheric storm has been investigated across equatorial and low latitude of Indian region. The deviation in F2 region parameters at equatorial stations Thiruvananthapuram (8.5°N, 76.8°E) and Delhi (28.6°N, 77.2°E) have been studied during five geomagnetic storm periods. The southward polarity reversal of the z component of the interplanetary magnetic field, Bz, is found to be highly correlated with the storm sudden commencement (SSC). Both positive and negative phases have been noticed during the study and it is observed that in spite of local time variation in Dst,

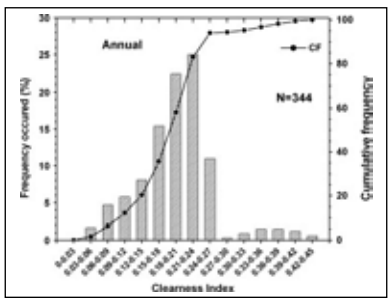


Fig. 3.13. Frequency of occurrence along with cumulative frequency of daily clearness index from April 2010 to March 2011 over Delhi.

the corresponding deviation in F layer parameter vary with the intensity of the storm as well as latitude of the observing stations (Fig 3.14). The positive storm phase over equatorial stations are found to be more frequent while the drop in ionization in most of the cases have been noticed at low latitude station of varying amplitude of deviations from the mean quiet day value. Due to disturbed electric field the simultaneous height rises have been noticed at these stations, with higher amplitude at Delhi in between 0000 to 0600 EMT. Positive deviation in foF2 is also observed across low latitude station during the storm which is attributed to daytime eastward electric field penetrating promptly from high to low latitudes. It may also be concluded that the reaction as seen at different ionospheric stations may be quiet different during the same storm depending in the station coordinates, local time of the magnetic disturbance beginning.

Phased array acoustic wind profiler

Both hardware and software modifications of the indigenously developed Phased Array Acoustic Wind Profiler have been initiated with NI LabVIEW based design with a view to upgrade the existing system to enable continuous measurement of boundary layer winds with high resolution. Data acquisition and signal processing software development in LabVIEW has been completed and tested for vertical mode and remaining work is progressing. With the ongoing modification, the wind profiler can be used to generate Integrated boundary

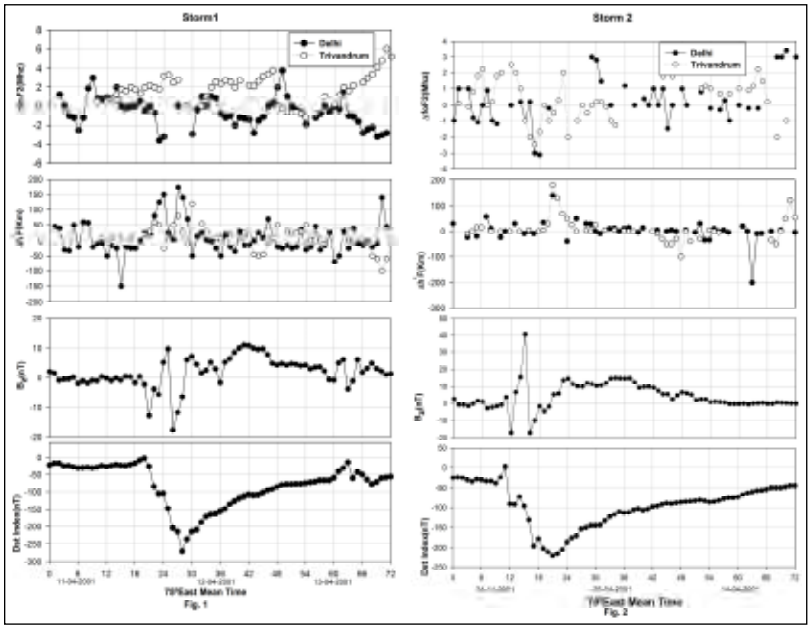
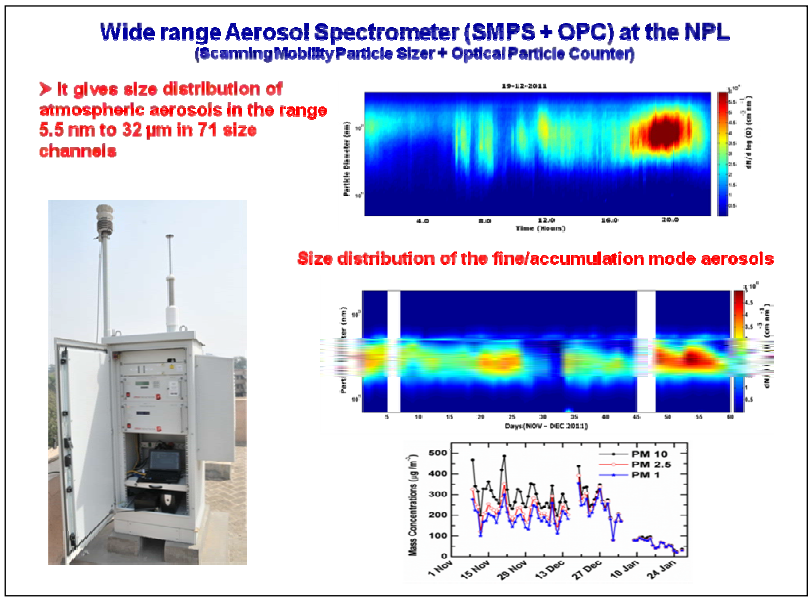


Fig.3.14 Variation of hourly values of Dst index, Bz intensity, and actual deviations of foF2, h`F from mean value of five quite days of the month during the geomagnetic storm event of 01-04/10/01 and 24-26/11/01.

layer winds (IBLW) and make it possible to study the occurrence of nocturnal low level jets (LLJ). LLJs occur over the mixing layer of the nighttime boundary layer and conditions for the occurrence of LLJs exist over the vast planes around Delhi, especially during post-monsoon and winter months, and the role of LLJs in long range transport of RSPM from far off polluting sources is something that can be investigated. Other boundary layer parameters, such as, stability class, mixing height, obukhov length, and friction velocity can also be generated.

Major facilities installed

Recently we have installed the GRIMM Wide Range Aerosol Spectrometer (Scanning Mobility Particle Sizer + Optical Particle Counter) at the NPL Terrace and the instrument has been operational since October 2011. The system measures the size distribution of the near surface aerosols varying from 5.5 nm to 32 µm in 71 size channels. The system is a unique combination of optical (optical particle counter) and electrical mobility particle sizing technologies (Scanning Mobility Particle Sizer (SMPS)). The SMPS measures the particles mostly in the nano size regime (5.5 to 250 nm) and the optical particle counter provides the size distribution of coarser particles of the order of micrometers (250 nm to 32 µm). This is a stand-alone system with an automatic sample air dehumidification and moisture extraction system along with separate air conditioning facility. In addition, the system includes meteorological sensors.




वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद
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समय और फ्रीक्वेंसी मानक

Time & Frequency Standards

समय और फ्रीक्वेंसी मानक

इस प्रभाग की मत्त्वपूर्ण गतिविधियां हैं :–

1 समय मानक का अनुरक्षण

2 अल्ट्रा स्टेबल टाइम लिंक (अति संतुलित समय योजक) के माध्यम से समय मानक का प्रसार

3 अल्ट्रा स्टेबल एटॉमिक (अति संतुलित परमाणविक) आवृत्ति मानक का विकास

4 अंशांकन सेवाएं

5 पावर बैक अप सिस्टम (विद्युत शक्ति समर्थन तंत्र) में सुधार

यह प्रभाग मुख्यतः भारतीय मानक समय के अनुरक्षण, प्रसार व अनुमार्गणीयता के लिए उत्तरदायी है। यह प्रभाग परमाणविक घड़ियों और आवृत्ति स्रोतों के लिए अंशांकन सेवाएं प्रदान करता है। इस प्रभाग की महत्त्वपूर्ण अनुसंधान एवं विकास गतिविधि सिजियम परमाणविक फाउंनटेन जैसे प्राथमिक आवृत्ति मानक का विकास करना है।

Time & Frequency Standards

The major activities of this division are:

1 Maintenance of time standard

2 Dissemination of time standard via ultra stable time links

3 Development of ultra stable atomic frequency standard

4 Calibration services

5 Improvements in Power Backup System

This division is mainly responsible for the maintenance of Indian Standard Time, its traceability and its dissemination. The division also provides calibration services for atomic clocks and frequency sources. Major R&D activity of the division is development of primary frequency standard namely cesium atomic fountain.

Dr Amitava Sen Gupta
Outstanding Scientist
Email : sengupta@nplindia.org

D 04.01 Ultrastable Atomic Frequency Sources

Dr Amitava Sen Gupta
Sh Kavindra Pant
Dr Ashish Agarwal
Dr (Ms) Poonam Arora

D 04.02 Precise Timing Systems

Ms Arundhati Chatterjee
Ms Pranalee Premdas Thorat
Sh Anil Kumar Suri

Precise Timing Systems

Maintenance of Time Standard

National Physical laboratory, India is a custodian of Indian Standard Time (IST). There are five commercially available Cs Clocks for recording of time data and one of them is designated as the reference clock NPLI. This clock is continuously traceable to BIPM through GPS network by common view GPS technique. The reference clock has been recently upgraded with a Hydrogen maser. A complete automation system for the generation of Time Scale UTC (NPLI) has been put in place and is being continually improved. The block diagram of this automatic Time scale development system is shown in figure 4.1 and actual implementation of the system at NPLI is shown in figure 4.2. Hydrogen maser is shown in figure 4.3. The plan is to generate UTC (NPLI) from several atomic clocks which are together treated as an ensemble. The phase differences of all pairs of clocks are recorded at regular intervals of time using automatic switching system (shown in figure 4.4).

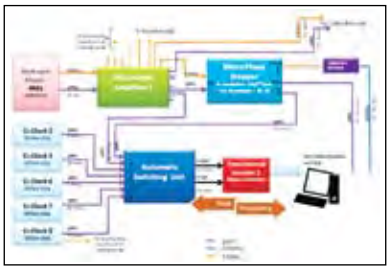


Fig. 4.1 Block Diagrammatic representation of TIME SCALE UTC(NPLI), India

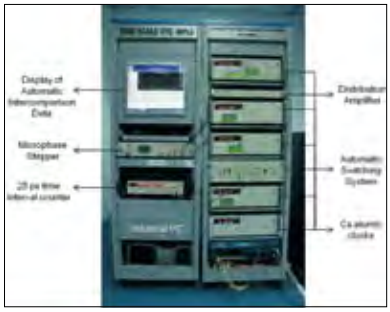


Fig. 4.2 Time scale UTC (NPLI) system

These readings are combined through an algorithm designed to generate a smoother time scale rather than taking data of an individual clock. This algorithm aims at maintaining UTC (NPLI) as close as UTC in phase and also decides the amount of phase or frequency jump to be given to a particular clock to maintain better stability and accuracy. A micro-phase stepper is generally

Fig. 4.3 Hydrogen Maser

Fig. 4.4 Automated switching system

Fig. 4.5 Micro-phase stepper

used to give these jumps (refer figure 4.5). Behaviour of various clocks is shown in figure 4.6

With introduction of Hydrogen maser the NPLI time scale has been improved by taking the reference output from Hydrogen maser instead of a Cs clock and distributing the standard output through a HROG 5 micro phase stepper to adjust the phase or freq. offset of the reference output

Clock intercomparison system is totally automatic and all the comparison data are recorded in an industrial PC. Automatic switching system (refer figure 4.4) has been indigenously developed at NPL. This system compares a pair of clock at routine intervals of time and records the data into a PC automatically which was very crucial (as a first step to) the automatic development of time scale.

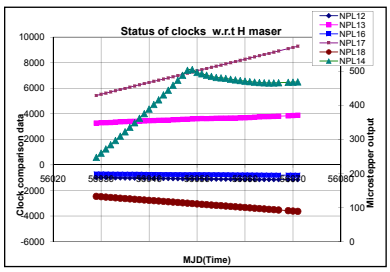


Fig. 4.6 Status of Various Clocks and H2 Maser

Dissemination of Time Standard via Ultra Stable Time Links

NPLI is contributing to BIPM, Paris using GPS network by common view method. This link of time transfer is very stable. A new system of ultra stable time transfer known as Two Way Satellite Time & frequency Transfer (TWSTFT) system is now introduced at NPLI. The set up at NPLI is shown in figure 4.7.

Figure 4.7 TWSTFT & GPS system arrangement

1. Time Transfer via GPS Network:

The reference clock of NPLI i.e. UTC (NPLI) is continuously traceable to BIPM through GPS network using common view technique. We already have two single frequency 8 channel GPS receivers, TTS2-A & TTS2-B. This being a multichannel receiver, one gets more than one solution depending upon the number of satellite tracked by the set and hence improvement in the Time Scale. The recent addition to our receiver set is from Septentrio which is not only a multichannel (24 channels) but also a dual frequency receiver.

In TTS2 receiver the ionospheric path delay is evaluated on the basis of Klobuchar model while

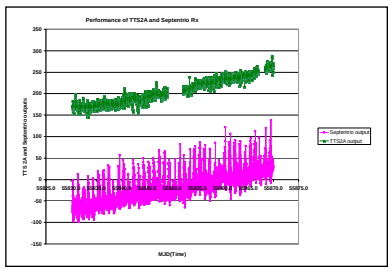


Fig. 4.8 Graph representing performance of dual frequency (Septentrio) and single frequency (TTS2A) GPS Receiver

Fig. 4.9 GPS Antenna Unit of TTS2 Rcvr and Saptentrio Rcvr System installed

the new (Septentrio) receiver actually calculates the delay by measuring the phase difference between two frequencies L1 & L2. This can be understood better using figure 4.8 below which shows the performance of dual frequency (Septentrio) and single frequency (TTS2A) GPS Receivers

As can be seen from above graph duel frequency GPS receiver has markedly improved the time scale by reducing the jitter. Antenna Unit of Receiver mounted on rooftop is shown in figure 4.9.

2. TWSTFT experiment to establish precise time link with Japan, Germany, China & Korea

Two Way Satellite Time & Frequency Transfer (TWSTFT) is a most precise technique to compare the time & frequency of two remotely located clocks. This link is established via geostationary satellite visible from both the locations of the clocks. Through TWSTFT one can compare clocks within an accuracy of one or two nanosecond with a resolution capability of sub-nanosecond. TWSTFT is operational in European and American continents. There is one operational link in APMP region also. A new proposal has been attempted to link PTB Germany and NICT Japan through AS-4 satellite which is not available now for such purpose since current year 2010.

A new scheme been worked out to link NICT and PTB through AM-2 satellite (parked at 80.2°E). NPL, India (NPLI) in has planned to enter into this network to establish a link with NICT, PTB, NIM (china), KRISS (Korea), TL(Thailand) and SU(Sudan) .

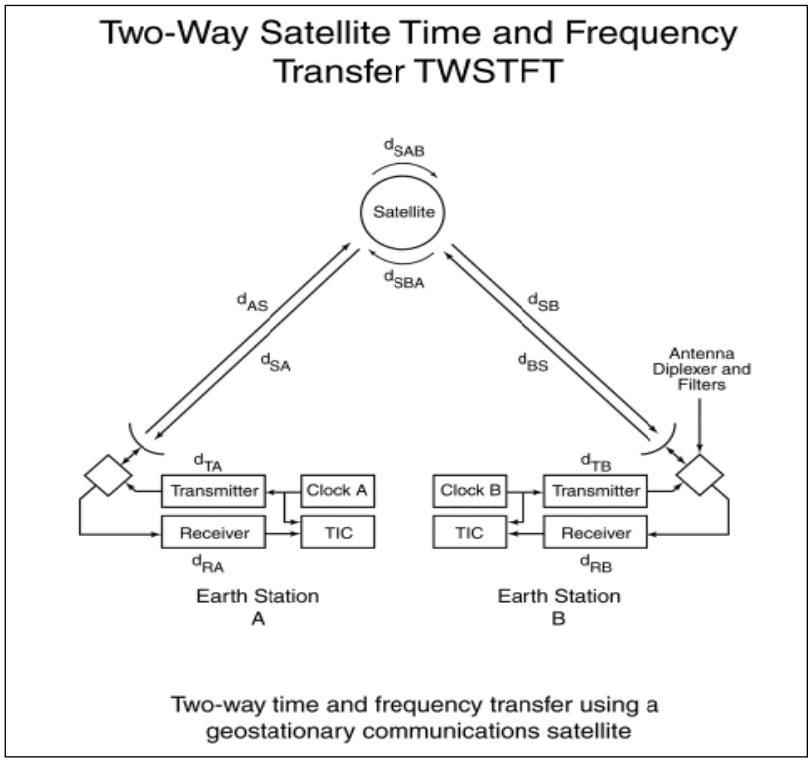


Fig. 4.10 Principal of Two Way Satellite Time & Frequency transfer System

Specifications of the TWSTFT Facility added at NPLI:

1	**SATRE TWSTFT Modem, dual receiver channel**
Spread Spectrum Capabilities	
1.1	**Number of PN Codes :** 16 predefined (20 and 10 MChip), 32 predefined (5 MChip and below)
1.2	**Signal Input :**
	Signal input : BNC (option: TNC, N)
	Reference Frequency : BNC, 5/10 MHz, + 3.. +10 dBm
	Pulse reference : 1 pps, rising slope, trigger level 0.. 4V programmable
	Impedance : 50Ω/2kΩ selectable
	Time reference : NTP (RJ45, 10 Mbit/s), serial line (RS232, ASCII codes)
1.3	**Signal Output**
	Signal output : BNC (option: TNC, N)
	Time pulses : 0..4V unloaded, impedance 50Ω
	Tx : PPS, Frame Rate, PN sequence
1.4	**Data interface**
	Physical : RS232 (19200 bps) or network (TCP, UDP)
	Contents : Delay measurements, first, second, third order regression, real time estimate, system health status, …
2	**Ku-Band VSAT Transceiver with SSPA and LNA**
2.1	**Transmit characteristics**
	Output frequency : 13.75 to 14.5 GHz, in 1.0 MHz steps
	Input frequency : 70 ± 18 MHz (compatible to SATRE Modem output)
	Input power level : -25 to -45 dBm operational
	Gain : 20 to 40 dB adjustable in the step of 1 dB
	Oscillator stability : 2×10-9/day or better
2.2	**Receive Characteristics**
	Input Frequency : 10.95 to 12.75 GHz in 1.0 MHz steps
	Output Frequency & Power : Compatible to SATRE Modem input
	Output Power adjustment : 20 dB adjustable

Remote monitoring and Control of trans-receiver (gain & frequency)	
2.3	**LNA**
	Noise Temperature : 85° K or less
	Gain option : 50 dB or more
2.4	**General Characteristics**
	Temperature : -5 to 50°C, **Humidity :** 90% RH
2.5	**General SSPA Characteristics for 20 W or more**
	Frequency Range : 13.75 to 14.5 GHz
	Power output : 20W
3	**Ku-BAND Antenna**
3.1	**Electrical Specifications**
	Antenna Size : 2.4m diameter
	Operating Frequency : Receive: 10.95 – 12.75 GHz, Transmit: 13.75– 14.50 GHz
	Mid-band Gain : Receive: ≥47.0 dBi, Transmit: ≥49 dBi
	Polarization : Linear orientable
	Trans/Receive Isolation : 80 dB with TRF
	Cross polarization discrimination : > 30 dB
	Minimum EIRP : 60 dBW
3.2	**Mechanical Specifications**
	Reflector Material : Glass Fiber Reinforced Polyster
	Antenna Optics : Prime Focus,/ One-Piece Offset Feed
	Elevation Adjustment Range : 5° to 90°, Continuous Adjustment
	Azimuth Adjustment Range : ± 45° continuous, 360° in sectors
	Mount Type : Elevation over Azimuth
	Wind Loading : Operational : 80 km/h, Survival: 200 km/h
	Operational : -5°C to 50°C
	Antenna Drive :
	Motorized controller for moving Azimuth, elevation and polarizer with display of elevation and Azimuth (0.1°) & polarization angle

Fig. 4.11 Antenna unit of TWSTFT system installed on terrace of main building of NPL

Ultrastable Atomic Frequency Sources

Development of Ultra Stable Atomic Frequency Standard :

1. Atomic Clock for Space.

For Indian Satellite based navigation system, Time and Frequency Division in collaboration with ISRO is developing a Rubidium Atomic Clock. The clock is a portable frequency standard with excellent short term frequency stability. The clock frequency is locked to the ground state of hyperfine transition frequency of Rb 87 atoms the two Design Verification models of the clock have been developed jointly by NPL and ISRO. Further joint work is in progress to develop the Engineering Thermal Model of the atomic clock. These clocks are being developed in order to provide absolute position accuracy better than 20 meters throughout India and within a region extending approximately 2,000 km around it.

The core of the atomic clock is made of a rubidium bulb and an integrated filter and absorption cell. The optical resonance radiation from the rubidium bulb is transmitted through the glass absorption cell containing Rb87 isotope in vapour state and a buffer gas at low pressure. The action of the optical resonance radiation from the rubidium bulb produces a population inversion between the hyperfine levels in ground state of Rb atoms filled in the absorption cell. NPL has taken up the development of these Rubidium Bulbs and Cells to be finally integrated to produce an indigenous Rubidium Atomic Clock. For this purpose, a rubidium filling station consisting of UHV pumps, high purity buffer gas cylinders, different kinds of gauges and glass manifold have been developed, as shown in Figure 4.12.

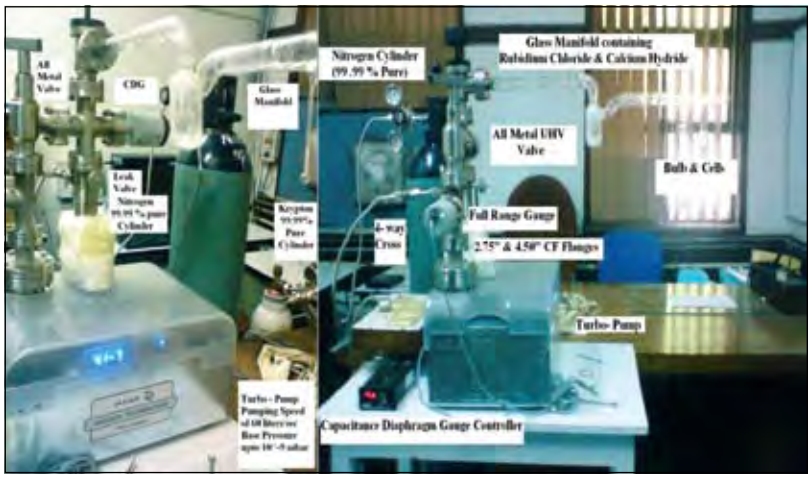


Fig. 4.12 Rubidium filling station

A UHV compatible glass manifold consisting of borosilicate glass bulbs, which will be filled with Rubidium and buffer gas atoms under vacuum, is shown in Figure 4.13. Another system is being developed for producing the Rubidium absorption cells.

2. Development of Cesium atomic fountain India-CsF1

Ramsey fringes :

The laser cooled Cesium fountain clock named India CsF1, designed and developed by T&F Division became operational in May 2011. Figure 4.14 shows the layout and assembly of the Physics package of the fountain.

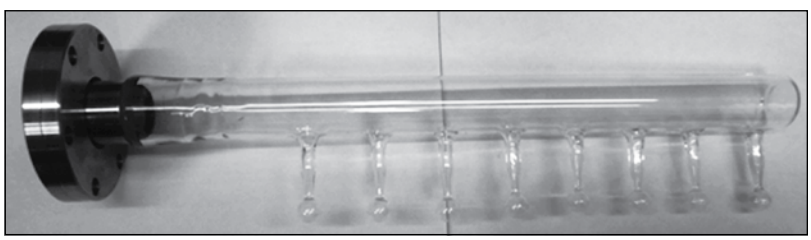


Fig. 4.13 Glass manifold consisting of bulbs

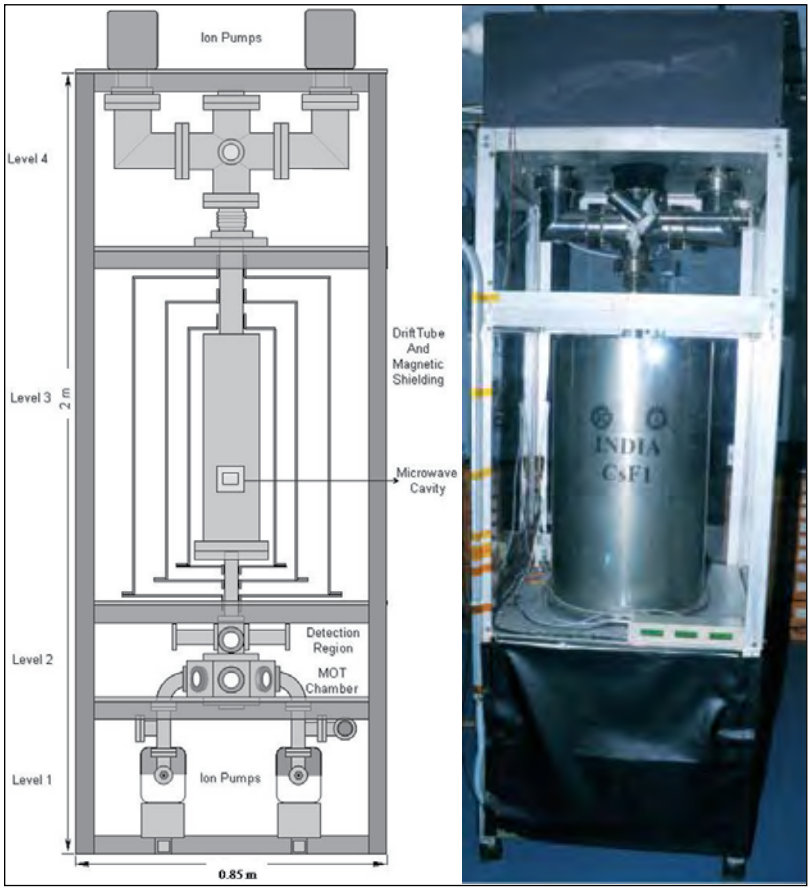


Fig. 4.14 Planned layout (left) of the physics package of the fountain and assembled fountain (right).

This clock, when operated continuously, will lose or gain one second in several million years. It will also serve as a primary frequency standard. Such an ultra precise measurement device has been developed completely in India and puts India in the elite club of 6 developed nations having such a standard.

The fountain is now fully operational and is ready for complete frequency evaluation including all systematic and statistical biases. It is now possible to trap about 10 million cesium atoms, cool them to about 6 μK temperature, launch them to about 70 cm high and to detect relatively clean return signals after interaction of atoms with the microwaves. The detected signals are collected using a National Instruments data acquisition card (DAQ). A labview program has been developed to collect the detected signals via DAQ. The signals are then processed to calculate the transition probability. The same program is used to tune the microwave synthesizer in order to obtain the Ramsey fringes. The signal to noise ratio has been considerably improved and is

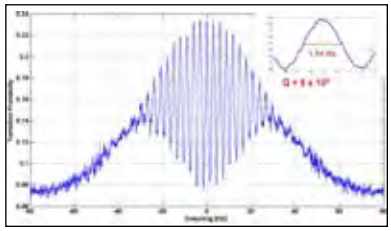


Fig. 4.15 The observed Ramsey fringes for a toss height of 65.4 cm; Ramsey Time: 325 ms. Inset: enlarged central fringe.

evident from the clock signals as shown in Figure 4.15.

Magnetic field mapping:

One of the most important frequency corrections of cesium frequency standards is the frequency shift due to the C-field. C-field is used to remove the degeneracy of the magnetic substates in cesium atoms during their interaction with the microwaves. A long solenoid coil around the central vacuum chamber produces a static magnetic field. Several compensation coils are used at the top and bottom of the vacuum chamber to create highly homogeneous magnetic field in the flight region. It is crucial to have high magnetic field homogeneity and therefore, it becomes important to monitor the magnetic field during fountain operation. In order to precisely measure the magnetic field strength, linear Zeeman frequency shift of magnetically sensitive transitions $|F, m_f \neq 0\rangle$ is measured. In practice, the position of the central fringe of $m_f = 1$ transition is monitored by launching the atoms to different toss heights (in

steps of ~ 1 cm) and a map of ν_{1-1} as a function of toss height is obtained. Using Breit-Rabi formula $\langle B \rangle$ is calculated as function of toss height. Magnetic field profile is then reconstructed by deconvolution of the average magnetic field and the ballistic time of flight as shown in Figure 4.16. The magnetic field is quite homogeneous in the atomic flight region and the measured average magnetic field strength is 104.5 nT which is very close to the value measured with a magnetometer in the drift region before the assembly of the fountain.

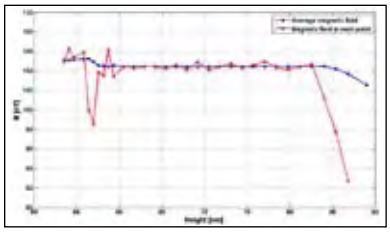


Fig. 4.16 Variation of magnetic field along the axis of the NPLI fountain. The arrow shows the position of the center of the Ramsey cavity.

Frequency stability analysis:

The interrogated microwave frequency is locked to the narrow Ramsey resonance by the frequency modulation locking method, in which the microwave is toggled between f0 $+\Delta\nu/2$ and f0 + $\Delta\nu/2$ where f0 is the microwave central frequency, and $\Delta\nu$ is the linewidth of the Ramsey fringe, at each cycle. Figure 4.17 shows the Allan deviation of the fountain frequency with the Hydrogen maser frequency.

As shown in Figure 4.17, the noise averages down as white-

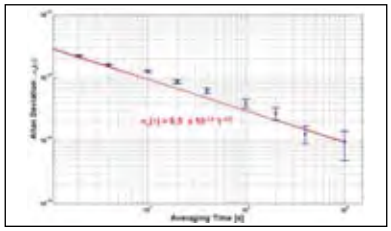


Fig. 4.17 Frequency stability of India-CsF1

frequency noise law and reaches the level $\sigma_y(\tau) = 9.5\times10^{-13}\tau^{-1/2}$. We clearly need to improve the short term stability of the fountain.

3. Development of Novel Optically-Pumped CEsium Founatin (NOVOCEF)

The objective of the project is to design and build a second Cs fountain at NPL with special design features that enable us to carefully investigate the systematic errors in order to enhance the accuracy of our frequency standard to a few parts in 10^{16} – which would be at the level of the best in the world. One special feature of the design would be to employ a novel method of optical pumping using two lasers to enhance the number of cold atoms taking part in the microwave interrogation process. It is also planned to determine accurately the frequency shifts due to (a) the so-called "cold collisions" in the atom clouds and (b) the so-called "distributed microwave cavity phase shift". The above two are the least accurately known source of systematic error budget currently.

During the first year (2011-12) of the project, the design of the optical set-up and physics package of the fountain has been finalized. Some of the electronic subsystems such as current sources, microwave synthesizer and microwave cavity have also been designed.

Calibration Services

The Calibration set up has now been modernized and the block diagram of the set up is shown in figure 4.18.

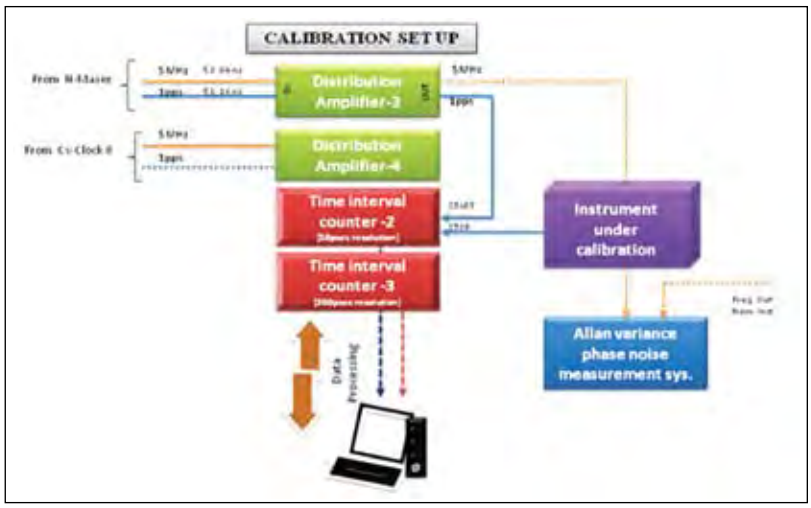


Fig. 4.18 Block diagram of calibration set up

On calibration front we have not only calibrated stop watches but a total of 19 systems including Cs clock, Rubidium Standards, GPS set and Master clock for various organizations viz ISRO, were calibrated.

Introduction of SMS alert service for our UPS system

To make the power supply system more reliable and foolproof we have installed a GPRS/GSM based SMS alert system for monitoring the mains input of each UPS. The unit consists of a GPRS Module which uses a GPRS/GSM enabled SIM card. When mains power to any UPS fails and remains off for about 15 minutes the timer output changes state and closes the respective switch of GPRS module which subsequently sends SMS alert messages to five persons. Thus in the event of failure of mains power to any or all the UPS due to tripping of MCBs, burning of change-over switch or breakdown of generator and BSES Power, timely possible corrective measures can be taken up to rectify the faults. Actual implemented system is shown in figure 4.19.

Up gradation of Power Distribution System during 2011-12

Additional UPS Purchased:

Sr. No.	UPS/ Battery	No.	Date of Installation
1	5KVA ONLINE (1+1) UPS	01	23.03.12
2	Exide Tubular Batteries - 6EL150+ for 5KVA UPS (2 sets 12V/150AH)	02 sets of 10	23.03.12
3	2KVA ONLINE UPS	02	23.03.13
4	Exide Sealed maintenance free batteries (12V/100AH, 8Nos for each UPS)	02 sets of 8	23.03.14
5	Exide Tubular Batteries - 6EL150+ (For 24V DC Supply)	04	23.03.15
6	Exide Tubular Batteries - 6EL150+ 12VX 12- 6 sets, 2 sets for each UPS.)	06 sets of 12	3.10.11- 4 sets 28.11.11- 2 sets

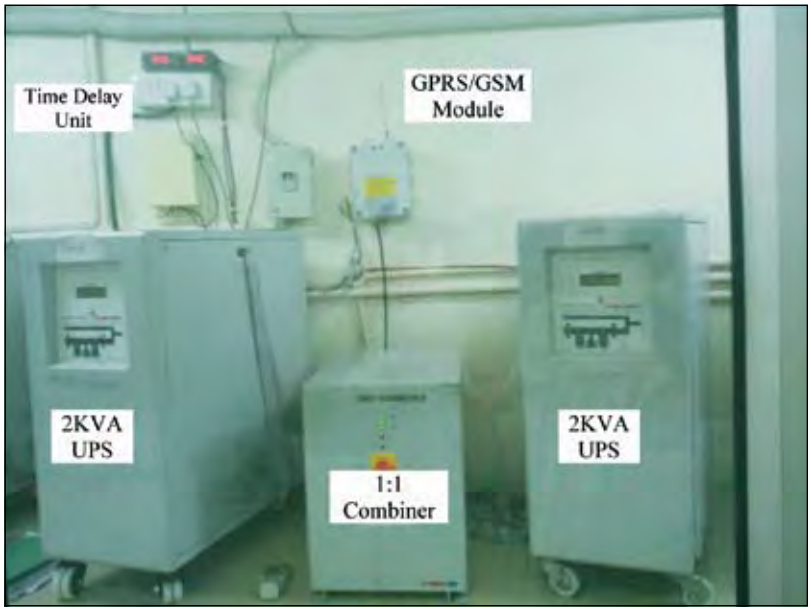


Fig. 4.19 One section of UPS room power packup with sms alert system


वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद
CSIR · INDIA ·


राष्ट्रीय भौतिक प्रयोगशाला
1
kg
· NPL - INDIA ·

शीर्ष स्तरीय मानक एवं औद्योगिक मापिकी

Apex Level Standards & Industrial Metrology

शीर्ष स्तरीय मानक एवं औद्योगिक मापिकी

शीर्ष स्तर मानक एवं औद्योगिक मापिकी विभाग में भौतिक, यांत्रिक, इलैक्ट्रिकल एवं इलैक्ट्रॉनिक्स, प्रकाशीय एवं थर्मल मापन गतिविधियों सहित 12 समूह (ग्रुप) हैं। विभाग मापन के राष्ट्रीय मानकों को स्थापित करने, उनका अनुरक्षण और उनके निरन्तर उन्नयन से संबन्धित कार्य करता है। विभाग द्वारा देश के उद्योगों और संस्थानों को उच्च स्तरीय अन्तर्राष्ट्रीय स्वीकृति प्राप्त अंशांकन सेवाएं उपलब्ध करायी जाती है और इस प्रकार उन पैरामीटरों के आधार पर किए गए मापन के अनुरेखण (ट्रेसीबिलिटी) को सुनिश्चित किया जाता है। विभाग में निम्नलिखित ग्रुप हैं :–

1. द्रव्यमान मानक
2. विमा मानक
3. ताप एवं आर्द्रता मानक
4. प्रकाशीय विकिरण मानक
5. बल एवं कठोरता मानक
6. दाब एवं निर्वात मानक
7. ध्वानिक, परा ध्वानिक, आघात और कंपन मानक
8. द्रव प्रवाह मानक
9. LF & HF प्रतिबाधा एवं डी सी मानक
10. LF & HF वोल्टेज, धारा एवं माइक्रोवेव मानक
11. AC उच्च वोल्टेज एवं उच्च धारा मानक
12. AC पावर एवं ऊर्जा मानक

इस विभाग के कई ग्रुप BIPM, APMP जैसे अन्तर्राष्ट्रीय निकायों द्वारा आयोजित अन्तरराष्ट्रीय इंटर–कंपैरिज़न में कार्यरत हैं। कुछ द्विपक्षीय कंपैरिजन भी संचालित किए जाते हैं। यह विभाग देश की अंशांकन और परीक्षण प्रयोगशालाओं को उनके मापन प्रत्याभूति (assurance) कार्यक्रम के अनुरक्षण के लिए विभिन्न पैरामीटरों में उनको प्रशिक्षण देकर और दक्षता प्रशिक्षण कार्यक्रम संचालित करके उनकी मदद कर रहा है।

Apex Level Standards and Industrial Metrology

The division constitutes of Physical, Mechanical, Electrical & Electronics, Optical and Thermal measurement activities involving twelve groups. The division is responsible to establish, maintain and continually upgrade the National Standards of measurements. Provides the apex level internationally accepted calibration services to the industry and institutions of the country and thus ensures the traceability to measurements made by these parameters. The groups are:

1 Mass Standards

2 Standards of Dimensions

3 Temperature and humidity Standards

4 Optical Radiation Standards

5 Force and Hardness Standards

6 Pressure and Vacuum Standards

7 Acoustics, Ultrasonic, Shock and Vibration Standards

8 Fluid Flow Measurements

9 LF & HF Impedance & DC Standards

10 LF & HF Voltage, Current & Microwave Standards

11 AC High Voltage and AC High Current Standards

12 AC Power & Energy Standards

Many areas of this division are engaged in international inter-comparisons organized by international bodies like BIPM, APMP etc. Some bilateral comparisons are also conducted. This group is also helping calibration and testing labs of country to maintain there measurement assurance programme by proving training and conducting proficiency testing programme in different parameters

The calibration and measurement capabilities of most of the parameters in the division are internationally accepted and appear on the BIPM website.

Dr Ashis Kumar Bandyopadhyay
Chief Scientist
Email : akband@nplindia.org

D 05.01 Mass Standards

Sh Anil Kumar
Dr Sanjeev Sinha
Sh Gautam Mandal
Sh Mahargha Baran Das

D 05.02 Standards of Dimensions

Dr K P Chaudhary
Ms Girja Moona
Sh Virendra Babu
Sh Mukesh Kumar
Sh Ravi Khanna

D 05.03 Temperature and Humidity Standards

Dr Yesh Pal Singh
Mr Dilip Dhondiram Shivagan
Sh Jagdish Kumar Gupta
Sh Gurcharanjit Singh
Sh Bhikham Singh
Sh Rasik Behari Sibal

D 05.04 Optical Radiation Standard

Dr. H.C. Kandpal
Dr Ms Ranjana Mehrotra
Sh Virendra Kumar Jaiswal
Dr Parag Sharma
Sh K N Basavaraju
Sh Sudama
Dr Bharat Kumar Yadav

D 05.05 Force and Hardness Standards

Dr Sushil Kumar Jain
Dr S Seela Kumar Titus
Sh Rajesh Kumar
Sh Harish Kumar
Sh Vikram

D 05.06 Pressure and Vaccum Standards

Dr Ashis Kumar Bandyopadhyay
Dr Pardeep Mohan
Sh D Arun Vijayakumar
Dr Sanjay Yadav
Dr Ms Nita Dilawar
Sh Om Prakash
Sh Harish Kumar
Sh Virendra Kumar Gupta

Mass Standards

Final report of APMP.M.M-K2.1 - bilateral comparison of four stainless steel mass standards (500 g, 20 g, 2 g and 100 mg) between KRISS and NPLI had published in Metrologia. The results of KRISS and NPLI were consistent with each other for all four nominal values. The NPLI results were also within the agreement of KCRV of CCM.M-K2 within their uncertainties (k = 2).

(Results were published in ***Metrologia***, 48, Tech. Suppl., 07007, 2011)

Final report on CCM key comparison of the second phase of multiples and sub-multiple of the kilogram (CCM.M-K5) has come. Twenty MMIs have been nominated to participate in this comparison in measuring.

Equivalence among participants is as follows :

See, 2 kg in figure 5.1, 200 g in figure 5.2, 50 g in figure 5.3, 1 g in figure 5.4 and 200 mg in figure 5.5.

(Results were published in ***Metrologia***, 48, Tech. Suppl., 07008, 2011)

Interim results of inter-comparison of 1 kg platinum-iridium mass standard as APMP pilot study were presented in Asia Pacific Symposium on Measurement on Mass, Force, Torque (APMF-2011). NPLI was one of the participating laboratories in this inter-comparison. This inter-comparison was carried out among 10 laboratories from January 2009 to January 2010.

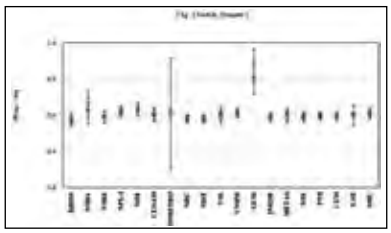


Fig. 5.1 – 2 kg

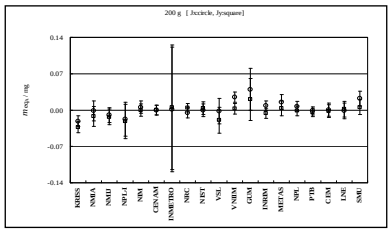


Fig. 5.2 – 200 g

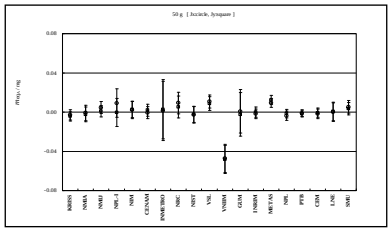


Fig. 5.3 – 50 g

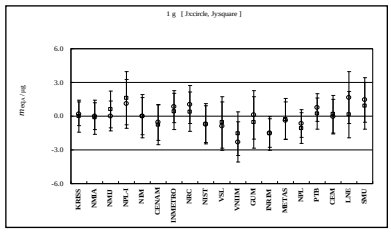


Fig. 5.4 – 1 g

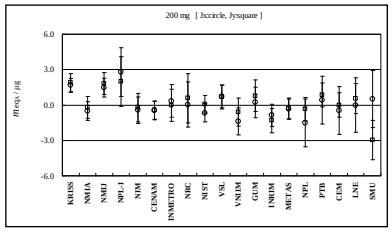


Fig. 5.5 – 200 mg

Fig. 5.6 & 5.7 : Artifacts for CCM.M-K4 inter-comparison

NPLI is one of the selected MMI who participated key comparison of 1 kg stainless steel weight (CCM.M-K4) organized by the working group of mass standard of the consultative committee for mass and related quantities (CCM).

Mass standard has unique facility of 2500 kg balance

Fig. 5.8 : 2000 L volumetric vessel

Fig. 5.9 : 525 L volumetric vessel

located at fluid flow laboratory. Carried out characterization of 225 liters, 525 litres and 2000 liters vessels on this balance.

Completed the Proficiency Testing (PT) Program on Mass measurement (No. NPL-NABL/M/1/2010) among twenty seven NABL accredited laboratories in two loops. Results are in progress.

This section has provided apex level calibration facilities for the mass, density, volume and viscosity to number of organization belong to Govt. and private sectors. We are specializing in catering for pharmaceutical industries.

The Mass Standards group is strongly supporting SAARC countries (Pakistan, Bangladesh, Nepal, Sri Lanka, Bhutan, Maldives and Afghanistan) under PTB program for the activities like inter-comparison, training, traceability etc.

Well in advance, we have submitted our National Prototype Kilogram (copy No. 57) at BIPM for re-calibration after successful planning.

Major facilities established :

AX 206 mass comparator was established in the group. This comparator is provided by M/s Mettler Toledo. Its technical features are as follows:

Maximum load	:	211 g
Readability	:	1 µg
Repeatability	:	4 µg
Linearity	:	±8 µg

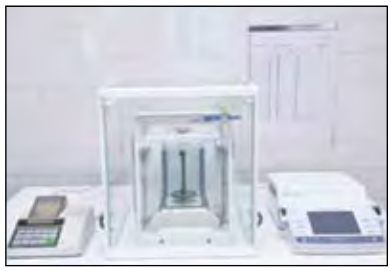


Fig. 5.10 : 200 g Mass comparator

It will enhance our technical capability with more precision.

Extraordinary research highlights:

Our 27 CMCs entered in Appendix 'C' of BIPM database on 24th May 2011. Previously we had six CMCs in Appendix 'C'. First time, viscosity with six CMCs came in Appendix 'C'. We got CMC of ±28 µg; k=2 in 1 kg, comparable to other NMIs.

Sr.No.	Country	NMI	Exp. uncertainty (k=2)
1	Australia	CSIRO	± 30 µg
2	China	NIM	± 30 µg
3	Canada	NRC	± 40 µg
4	France	BNM	± 30 µg
5	Germany	PTB	± 28 µg
6	India	NPLI	± 28 µg
7	Italy	IGMC	± 18 µg
8	Japan	NMIJ	± 50 µg
9	Korea	KRISS	± 38 µg
10	New Zealand	MSL	± 40 µg
11	Russian Federation	VNIIM	± 50 µg
12	Sweden	SP	± 70 µg
13	Switzerland	METAS	± 50 µg
14	U.K.	NPL	± 30 µg
15	U.S.A.	NIST	± 33 µg

Fig. 5.11 : International status of mass measurement at 1 kg level

First time, NPL Mass Standards took consultancy project for characterization of the weighing balances up 20 t at M/s ABB, Faridabad and completed successfully the same. M/s ABB

D 05.07 Acoustics, Ultrasonic, & Vibration Standards

Dr Ashok Kumar
Sh Mahavir Singh
Sh Naveen Garg
Sh Gurbir Singh
Ms Reeta Gupta
Dr Yudhisther Kumar Yadav

D 05.08 Fluid Flow Measurements

Sh Shiv Kumar Jaiswal
Sh Taak, Ishwar Singh

D 05.09 LF & HF Impedance & DC Standards

Sh Anil Kishore Saxena
Dr Sher Singh Rajput
Sh Ajeet Singh
Sh Rajbeer Singh
Sh M A Ansari
Sh Satish
Sh Kul Bhushan Ravat
Sh Mohammad Saleem
Sh Avdhesh Kumar Goel

D 05.10 LF & HF Voltage, Current & Microwave Standards

Sh Anil Kumar Govil
Sh Pramendra Singh Negi
Sh Saood Ahmed
Sh Bijendra Pal

D 05.11 AC High Voltage and AC High Current Standards

Sh H R Singh
Sh Sridhar Lingam

D 05.12 AC Power & Energy Standards

Sh Mukesh Kumar Mittal
Sh Joges Chandra Biswas
Sh Anoop Singh Yadav

is one of the leading flow meters manufacturing industries.

Fig. 5.12 : 300 kg weighing balance

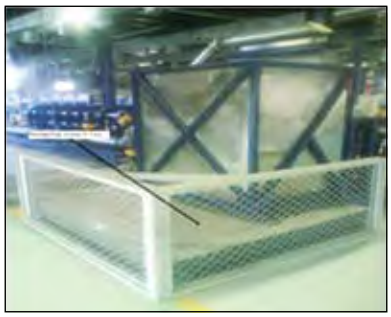


Fig. 5.13 : 3 t weighing balance

Fig. 5.14 : 20 t weighing balance

Fig. 5.15 : Characterization of 3 t weighing balance using NPL mass standards

Standards of Dimensions

1) New technique developed:

In Dimension Standard, a new method is developed to calibrate flick standard using laser interferometer. A Laser retro-reflector is fitted with a linear displacement probe. A Moore's indexing table and laser interferometer are arranged on a three dimensional Length Measuring Machine. The flick standard is aligned at the centre of index table. The flick depth is measured using laser interferometer to establish traceability through laser wavelengths. The uncertainty of measurement is improved from 170 to 60 nm .This technique will leads to obtain patent/ copyright.

Fig. 5.16 : Newly developed Flick Standard calibration facility using Laser interferometer electronic probe and UMM

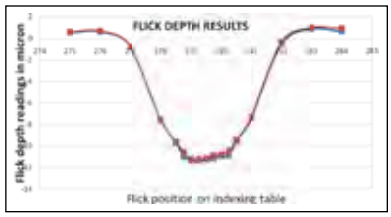


Fig. 5.17 : Measurement result of Flick Standard

2) New facility established:

A new facility for measurement of Long Gauge Blocks up to 4 meter has been established using Laser Interferometer. This newly established facility will not only serve Indian Industries but SAARC countries also.

Specification of facility:

Nominal Range : 0-4000 mm

Working Range : 0-3700 mm

Resolution : 0.01 µm

Maximum Error : 1.5 µm

Repeatability : 0.1 µm

Temperature : (20 ±1)°C

Relative Humidity : (50 ±10) %

Uncertainty of measurement : ± (0.3 µm + (L/1200)×10^{-6}), L in mm

(At k = 2 i.e. at 95% confidence level)

Laser used : He-Ne Laser (wavelength 632.8 nm)

Automatic compensation : Temperature

Humidity

Atmospheric Pressure

Photograph of facility:

Fig. 5.18 : 4 m Length measuring machine using laser interferometer

2. High precision roundness measuring machine:

Purchase order has been placed to establish the Form and Roundness Measurement Facility and this machine is expected to be commissioned in August 2012.

3. SAARC - PTB Project:

International Inter-comparison was conducted in gauge blocks and its report was submitted /presented in SAARC Co-ordination committee workshop at Dhaka, Bangladesh during March 2012 with NPL as pilot Laboratory and MUSSD, Sri Lanka as the participating Laboratory. The other SAARC countries will also participate in the International Inter-comparison of gauge Blocks as and when they will have the traceability. The final protocol has already been circulated to all the member SAARC countries.

4. Coordination of the proficiency testing program (PT - Project) under NABL sponsorship:

Coordinated proficiency testing in Pressure, Length, Mass and Temperature. In Dimension Standards, one loop of the proficiency testing has been completed for the Dial Gauges in the ranges 0-25 µm and 0 to 10 mm. The least count of the dial testers is 0.5 µm and 10 µm.

Temperature and Humidity Standards

APMP key comparisons - This year our Group has developed the experimental facilities to participate in two APMP key comparisons, one in LIGT (-40 °C to 250 °C) and the other in Pt/Pd thermocouple on Co-C eutectic fixed point (1324 °C). Set of Pt/Pd thermocouples has been received from KRISS Korea (Pilot Lab) and measurements are under process.

We are establishing the primary standard in high temperature by realizing the Silver and Copper blackbody fixed points by linear photoelectric pyrometer (LP4). The LP4 pyrometer procured from K.E. Technologies, Stuttgart, Germany has been received and will be installed very shortly. Presently two of our tungsten strip lamps are the standards for high temperature and both of these standard lamps were calibrated in PTB Germany during Feb-March 2012.

For the XIIth Five Year plan, we have formulated an innovative project entitled "*Determination of Boltzmann constant and realization of thermodynamic temperature by acoustic gas thermometry*". We are working on the preliminary experimental requirements for this project.

National collaboration with NABL

Our group was associated with NABL activities by organizing

proficiency testing programs in LIGT and TC comparison among accredited calibration laboratories in order to support quality assurance in temperature metrology. PT Programs in LIGT and TC are under process. Expertise was provided to NABL for laboratory accreditation in the field of thermal calibration. Expertise was also provided by attending the meetings of Supplementary and Core Accreditation Committees relating to thermal calibration area.

International collaboration with SAARC-PTB project in Temperature Metrology

Under the 2nd Phase of SAARC-PTB Project in metrology, Temperature & Humidity Standards is associated as one of the teams in the project. A preparatory workshop was attended during 6-8 June 2011 held and organized by MUSSD, Sri Lanka. The workshop was attended by the participants from BSTI Bangladesh, NBSM Nepal, NPL India, MUSSD Sri Lanka, Afghanistan, Bhutan and Maldives.

A 1st SAARC-PTB Coordination Meeting was held recently at BSTI, Dhaka during 13-14 June 2012. The meeting was attended by the participants from NPL India, BSTI Bangladesh, NBSM Nepal, MUSSD Sri Lanka and Bhutan. Temperature metrology is one of the areas of the above project in which the inter-laboratory comparison is to be organized by our group among the four SAARC countries (Bangladesh, Nepal, Pakistan and Sri Lanka).

Major facilities

Establishment of high temperature blackbody source

We have established the high temperature variable temperature blackbody source (Model M390 of M/s MIKRON Infrared Inc. USA) for the calibration of infrared total radiation pyrometers in the range from 600 to 3000 °C. The blackbody source has an emissivity of 0.997 and the overall uncertainty of measurement using this source is ±1.5 °C to ±7.8 °C for the calibrated range from 660 to 2700 °C. We have calibrated infrared radiation pyrometer, MINOLTA/LAND Cyclops 152, with spectral response of 0.8 to 1.1 µm on the above blackbody radiation source in the temperature range from 660 to 2700 °C with the estimated uncertainties of measurement ±1.8 °C to ±7.9 °C, as shown in Fig 5.19. The facility will be useful for comparison calibration of IR-total radiation pyrometers in the above mentioned range to the accredited laboratories, user industries and temperature metrology community in the country. The facility has been introduced in the Quality system documents as per ISO/IEC: 17025 (2005) for calibration of IR-total radiation pyrometers Calibration Procedure No. Sub-Div.#D5.03/THS/Doc.3/TTP/CP#TRP-02.

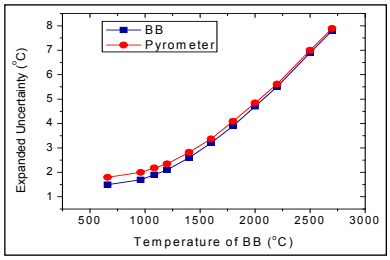


Fig. 5.19 Uncertainty for blackbody source and pyrometer.

The fixed point of Silver (961.78 °C) has been established using a new silver cell procured from HART Scientific, USA and realized by SPRT with an uncertainty of 4 mK. The fixed point is to be used for international comparisons and also to provide traceability to user industries and accredited laboratories.

The humidity standard has been upgraded with addition of a new humidity generator Model 2500 of Thunder Scientific, USA based on two pressure technique. The traceability of temperature and pressure transducers has been achieved from in-house at NPL, India. The measurements have been performed in the range of humidity from 10 % to 95 % RH & in the temperature range from 15°C to 70°C with uncertainty of ±0.3% RH & ±0.02 °C. The facility has been introduced in the Quality System Documents as per ISO/IEC: 17025(2005) as reference humidity standard for calibration of hygrometers,

Calibration procedure No.: Sub-Div.#D5.03/THS/Doc.3/HS/CP#02.

Extraordinary research highlights

We are developing the in-house fixed point realization facility for the new Co-C and Fe-C metal carbon eutectics using vertical three zone heating furnace from CARBOLITE, TZF 16/610 with bottom end closed. We have fabricated the graphite cell for Co-C from NPL workshop. For accurate realization of the fixed point, it is desired that the zone of the furnace where fixed point cell is placed should be highly stable and uniform to provide homogeneous heating to the fixed point cell. Therefore, it was required to measure the vertical thermal profile measurements of the said furnace, using a Type-S thermocouple and is shown in Fig 5.20. A stability of ±1°C has been achieved at the middle zone of about 200 mm (100 mm from center), which is adequate to place melting cell of 110 mm height.

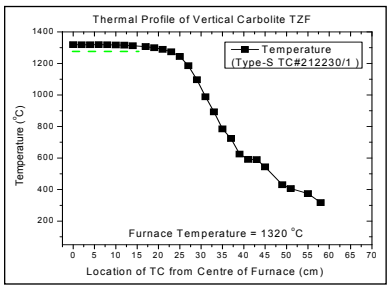


Fig. 5.20. Temperature profile of vertical furnace, TZF 16/610

Optical Radiation Standards

This section is providing world class calibration facilities for lamp and lighting industries, laboratories and institutes. The calibration facility is available for photometric parameters namely luminous intensity, luminous flux, luminance, illuminance, illuminance responsivity, color coordinates and color temperature. A number of Polystyrene films are calibrated for different pharmaceutical industries and R& D organizations using Fourier transform infrared spectrophotometer (FT-IR). FT-IR and FT-Raman Spectroscopic testing facilities are provided to various groups of NPL and outside agencies. A significant mount as ECF is generated through these calibration activities.

The scales for illuminance and illuminance responsivity are maintained through luminous intensity standard and standard illuminance meters, (which have cosine corrected V(λ) matched silicon photodiode). The illuminance meters are also traceable to international standards. Absolute scales of luminous flux are prepared using a Gonio-photometer. The traceability of luminance comes from the luminous flux scales and the scales of colour temperature and colour coordinates are measured through luminous intensity standard lamps.

Spectral switching is now a well-known phenomenon. Recently, its potential applications have been explored for information encoding and transmission in free-space. In our recent work, we demonstrated a novel type scheme to encode and process information at multiple levels through spectral switching. A new

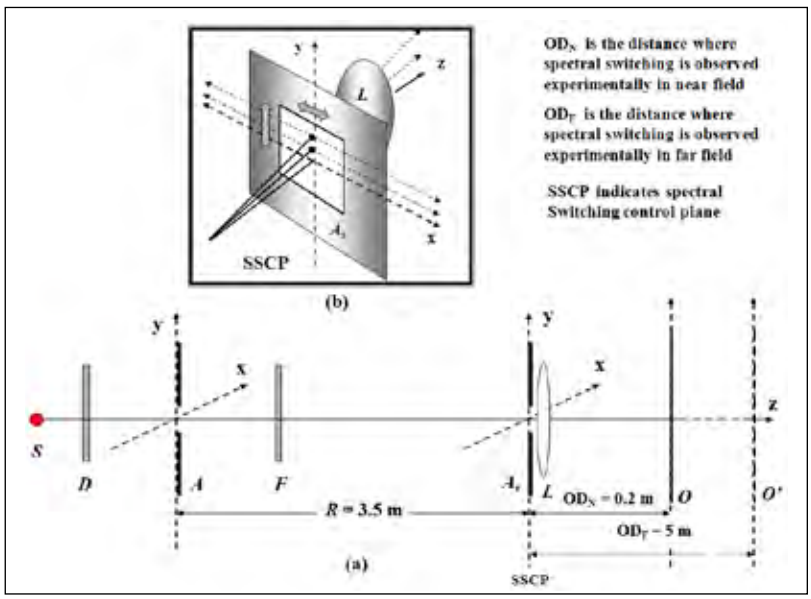


Fig. 5.21. Schematic diagram of the experimental set up for optical switching.

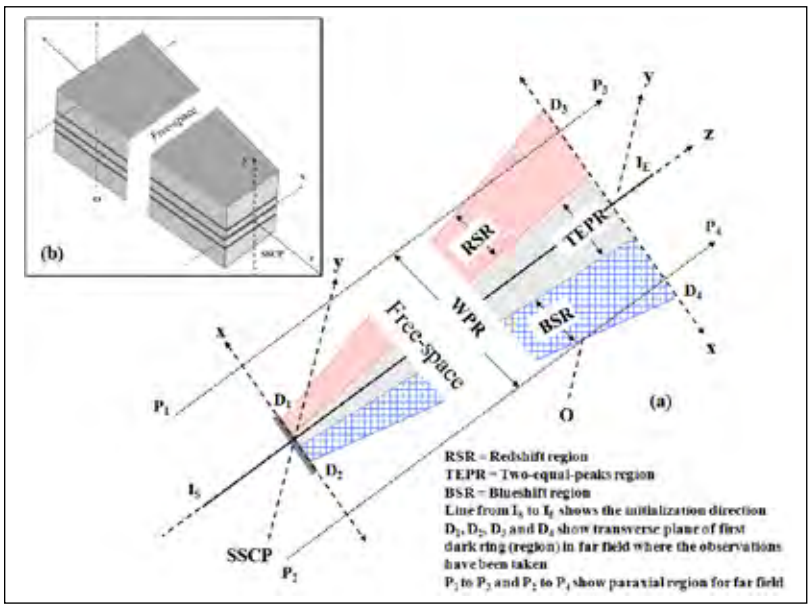


Fig. 5.22. Spectral switching based FSO link

technique was also proposed to establish multiple parallel free-space optical (FSO) links using a single critical direction in phase singularity domain of diffracted polychromatic light. These are contrived ideas on the basis of theoretical and experimental studies carried out so far on spectral switching. The study might find potential application in the field of FSO interconnects and FSO communication. Fig. 5.21 shows the schematics of experimental setup while Fig. 5.22 illustrates the logic behind the spectral switching based FSO link.

Force and Hardness Standards

In recent years the group has established new force and hardness standard facilities with a view to provide to the users the national traceability in measurement of these parameters with lower uncertainty and international compatibility. The new force standard machine (GTM make) of capacity 1 MN commissioned and established with CMCs showing equivalence with PTB, Germany, was introduced as the national standard of force into the quality management system for force calibration. With the availability of this facility, option has been made available to the users to get the calibration of their lower uncertainty class force instruments such as class '00' up to 1 MN following the latest international standards ISO 376-2011. Further, the new force standard was used to recalibrate all the force transfer standards which in turn were used to calibrate/determine the CMC of the secondary standard force machines, so that the users get traceability of calibration of their force devices against the new national standard having lower uncertainty (± 0.002% up to 100 kN and ± 0.009% up to 1000 kN).

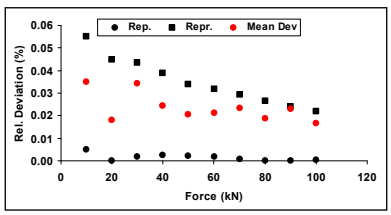


Fig. 5.23. The relative repeatability, reproducibility and mean value deviation of force transfer standard output in 100 kN comparator machine

The existing 50 kN dead weight primary standard (Morehouse Instruments make) was compared with the new force standard machine to establish its equivalence. It was shown that the force values realized by the two machines have normalized error less than unity. The new 100 kN force comparator machine, designed and fabricated earlier to explore the feasibility of developing a force calibrator in this range, was evaluated for its CMC from 10 to 100 kN using the NPL force transfer standards. Its expanded uncertainty was evaluated to be within 0.05% (Fig. 5.23). Further work to improve its performance for stability in force application is in progress.

The force calibration facility for 2000 kN was upgraded using a 2.1 MN build-up system in the hydraulic force machine. The individual force transducers of the build-up system were

calibrated in the 1 MN force standard (GTM) and the curve fit of their calibrated output were used to determine the reference equation of the build-up system. The expanded uncertainty of the hydraulic force machine with the build-up system was evaluated using a class '00' 3 MN force transducer as 0.05%. This facility has been put into operation to provide to users the calibration of their 2000 kN force transducers.

In-house comparison of torque standards

A comparison of the NPL primary and secondary torque machines, as a supported lever machine and as an unsupported lever torque machine respectively, was carried out with a view to study the bending effect of the lever in the unsupported case. The bending effect due to the unsupported lever appears as an asymmetric deviation in the transducer output when mounted at different angular positions around its axis (Fig. 5.24). Taking into account the bending effect, the secondary torque machine was shown to agree in the realized torque values with the primary standard machine within its claimed uncertainty of 0.05% (k=2).

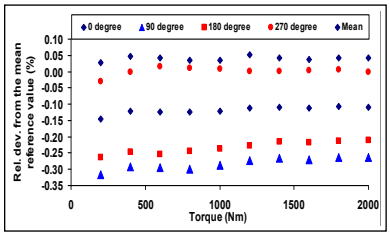


Fig. 5.24. The sending effect due to the unsupported lever in the torque standard machine.

Key comparison in Rockwell Hardness A and B

Draft B of the APMP key comparison in Rockwell Hardness scales HRA and HRB, carried out by NPL during 2010-11, was received from the pilot laboratory, NIMT, Thailand. The key comparison measurement results of NPL(I) are within the claimed CMC values of the HRA and HRB scales, which is reflected in normalized error between the HRA and HRB values of the NPL(I) and the key comparison reference values as shown in the Fig.5.25.

The group is engaged in a major way in providing support to industry and other user organizations in calibration of their reference devices, providing training, etc. About 450 calibration reports in force, hardness and torque parameters were issued to different users during the year. The ECF realized was approximately Rs 50 lakh. Force calibration as per the latest international standards ISO 376-2011 and ASTM E74-2006 have also been accepted to meet demand from user organizations.

Major facilities established

The hardness calibration facility was augmented by adding secondary hardness standard machines of Brinell, Rockwell (including superficial Rockwell), Vickers and micro-

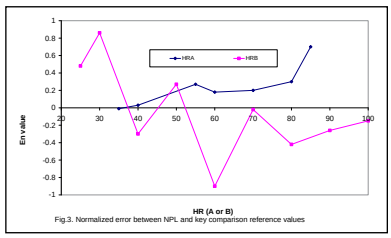


Fig. 5.25. Normalized error between NPL and key comparison reference values

Vickers hardness (Fig. 5.26) to the existing primary hardness standard machines so as maintain in-house traceability of hardness calibration machines, which shall be used to provide the necessary traceability in hardness scale to the users. The secondary hardness machines conform to the requirement of the international standard ISO 6507 – 3 for calibration of standard hardness blocks. The work to establish the CMC of the secondary hardness machines is in progress.

Fig. 5.26. Secondary hardness standardizing machines for Rockwell, Vickers and Brinell scales

Pressure and Vacuum Standards

The pneumatic pressure standards lab provides traceability in pneumatic pressure range from 0.4 to 400 bar. The measurements made are world class and traceable to the

international standards. The primary as well as the secondary standards dead weight testers which are characterized against each other as well as are traceable through a continuous chain of overlapping pressures to the ultrasonic interferometer manometer. The latter is the low pressure primary standard of the Vacuum Standards. The secondary standards provide traceability to Indian industries through calibration services.

In addition to the above mentioned activities, the group is also engaged in research into the behaviour of rare earth sesquioxides under high pressures and a number of papers have been published in international reputed journals. The group also collaborates with groups within and outside NPL for Raman characterization of strategic materials. This work is being carried out as a part of a DST sponsored project.

A proficiency testing program in pneumatic pressure range up to 50 bar was also completed in which seven labs all over India participated. This program was started in November 2010 and was completed in October 2011

In continuation of our research on high pressure behaviour of rare earth oxides, data analysis was completed for Ho_2O_3 and Yb_2O_3 and the results have been communicated for publication. Er_2O_3, Tb_4O_7, and PrO_2 were also studied under high pressures. The detailed analysis of results is underway.

PrO_2 which is found to be cubic at ambient, was seen to undergo a phase transition to the orthorhombic type, and the phase transition was observed at 33.9 GPa at room temperature (Fig. 5.27).

In addition, finite element simulations were also carried out on our 20 MPa piston cylinder assembly using ANSYS package as a part of an M.Tech. project and excellent agreement between the experimental and simulated results were achieved. The effective area, the distortion coefficient and the strain profiles were simulated and gap profiles obtained.

A 500 MPa controlled clearance piston gauge (CCPG) type primary pressure standard has been characterized with its parameters traceable to NPLI primary standards of mass and length that offer the potential for reduced uncertainties. The system is basically consisting of three parts: (i) a pressure generation device, (ii) an automatic weight loading / unloading unit, and (iii) a controlled clearance piston cylinder assembly having nominal diameter of 3.5 mm. The diameter of the piston measured with the help of NPLI Reference Standard Reference Gauge Blocks within the measurement uncertainty of + 0.07 mm (k = 2), is 3.56777 mm. The inner and outer diameters of the cylinder measured by Precision 3D Coordinate Measuring Machine within the uncertainty limit + (0.5 + L / 900) mm (k = 2), are 3.7668 mm and 26.0222 mm, respectively. The piston is in floating position when it is located 3.4 mm above its rest position in the cylinder. The total engagement length is 18.9 mm. We have carried out

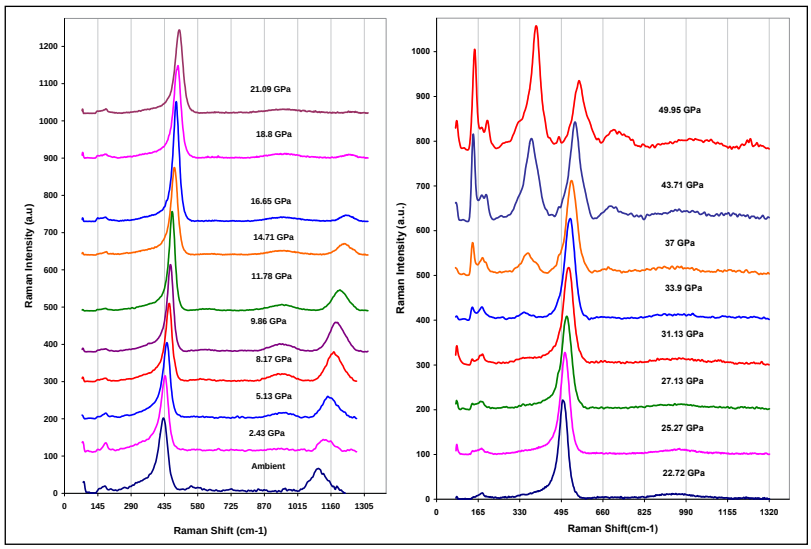


Fig. 5.27. Raman spectra of PrO_2 at increasing pressures

experiments to obtain results of piston fall rate measurements at different applied loads (50, 100, 150, 200, 250, 300, 350, 400, 450 and 500) MPa at varied jacket pressures from 50 % to 100 % (up to 200 % for lower pressures) of applied pressure. We evaluate the uncertainties in the effective area and pressure based on the Heydemann-Welch model. The linear behaviour of piston fall rate based on this model agrees well with the present pressure standard. However, at high pressures around 500 MPa slight non linearity appears. The cube root of the fall rate was plotted as a function of applied pj and extrapolating the linear portion of the curve to zero fall rate [Fig. 5.28(a)], which provided us the values of pz for different loads. From the pz at different loads, the zero clearance between the piston and cylinder was determined [Fig. 5.28(b)]. The cylinder deformation coefficient (d) [Fig. 5.28(c)] is determined by cross floating the CCPG against a secondary pressure standard of known effective area.

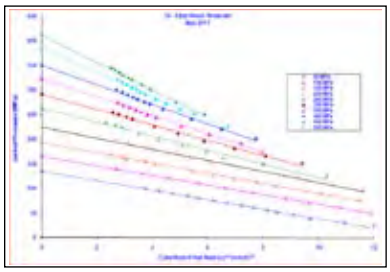


Fig. 5.28 (a): Fall rate $(v)^{1/3}$ as a function of *pj* at 10 different measured pressures up to 500 MPa and

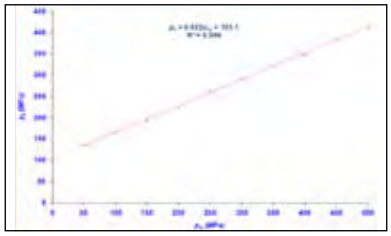


Fig. 5.28 (b): Fall rate $(v)^{1/3}$ as a function of *pj* at 10 different measured pressures up to 500 MPa

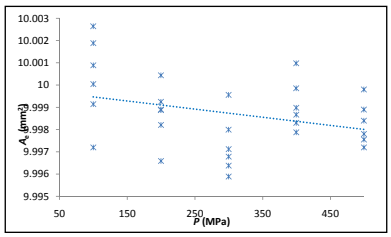


Fig. 5.28 (c): Change in effective area at 5 different loads as a function of *pj*

2. Participation in APMP. M.P. K13

The NPLI is participating in this comparison, identified as APMP.M.P-K13 by BIPM and APMP, is being piloted by NMIJ, Japan. The objective of the project is to compare the performance of hydraulic pressure standards in participating institutes, in the pressure range 50 to 500 MPa in gauge mode to essentially support the objective evidence for high pressure CMCs of the participating institutes. The results of this comparison will also be linked to the corresponding CCM key comparison, CCM.P-K13. The number of participating institute is 13 including the pilot institute. These institutes are NMIJ/ AIST, Japan; NPLI, India; NML/ SIRIM, Malaysia; NMC/A*STAR, Singapore; NIM, Thailand; NMIA, Australia; NIM, China; CMS/ ITRI, Chinese Taipei; KIM-LIPI, Indonesia; NIS, Egypt; KazInMetr, Kazakhstan; NBSM, Nepal; KRISS, Korea. The comparison started during November, 2010 and is expected to be completed during December, 2012. In this comparison, a piston-cylinder assembly of 2 mm^2 nominal effective area is being circulated as the transfer standard (TS). It is built in hydraulic pressure balance PG7302 equipped with a mass loading bell, a mass set, all parts having been manufactured by Fluke Corporation, DH Instruments Division, USA. The NPLI has completed the measurements and submitted their results to pilot laboratory during period under report. The evaluation of measurement results is under process.

3. Establishment of new Hydraulic Pressure Standards

A new controlled clearance type piston-cylinder assembly to measure hydraulic pressure up to 100 MPa has been procured (Fig. 5.29). The system is being charaterised which would enable us to trace our secondary standards to primary pressure standard up to 100 MPa within improved relative measurement uncertainty of 35 x 10^{-6} at k = 2 in pressure measurements. Also established a secondary reentrant type piston cylinder assembly to give services to Indian industries up to 20 MPa. Two digital reference pressure

Fig. 5.29: Controlled Clearance Piston Gauge (CCPG) type Primary Pressure Standard and Reference Pressure Monitors (RPMs)

monitors (RPMs) have also been procured in the range 100 MPa and 200 MPa, respectively (Fig. 5.29). These RPMs will be used to calibrate low accuracy industrial gauges and also monitoring jacket and line pressure in our experiments.

4. Studies on industrial pressure balances

The studies on stability of effective area were carried out on industrial pressure balances (PBs) which were characterized at NPL. The first industrial PB studied was Ruska Model 2485 530D, procured during 2004 (manufacturer supplied data) being used in Delhi, a northern part of India. It was first calibrated during 2007 and recently during 2011. Therefore, the stability data of the effective area was available for the period of 7 years for the analysis. The plots showing the stability of effective area (Ae) as a function of applied pressure (p) are depicted in Fig. 5.30 (a). As expected, the similar trends of the effective area (Ae) is observed during all these years except some drift in the values between 2009 and 2011. The data obtained during 2009 is much closer to the values reported by the manufacturer during 2004. When 2009 data is compared with manufacturer data of 2004, it is found that the values of 2009 are slightly higher up to 60 MPa and lower beyond that pressure. It is evident form the plots that there is no unidirectional drift in the values to assign some correction factors.

Therefore, it was considered appropriate to plot the average of all these values and determine the deviations from the average values for each year's data as shown in Fig. 5.30(b). It is clearly evident form Fig. 5.30(b) that 2004, 2009 and 2011 data are well within 20 x 10^{-6}, 14 x 10^{-6} and 28 x 10^{-6}, respectively form the average values which is in excellent agreement with the estimated measurement uncertainty of this gauge as 72 x 10^{-6} at a coverage factor of k = 2. There is an agreement of 20 x 10^{-6} between 2004 and 2009 data while it is 45 x 10^{-6} in case of 2009 and 2011 data. It is mentioned here that these agreement values are the worst case values, generally obtained at the lowest pressure point of 5 MPa which is 5 % of the full scale pressure due to obvious reason that best performance of any PB is obtained in between (10-100) % of full scale pressure. Therefore, it is concluded from these studies that the gauge under test remained very stable during all these years and is properly handled by the operators.

Further studies were carried out on the two other PBs, one being used at the extreme southern part of India and another extreme eastern part of India. These two PBs studied were the identical Ruska Model 2485-5586 as previously described in Figs. 5.30(a) and (b) but slightly

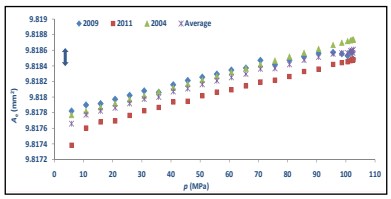


Fig. 5.30(a): Stability of the effective area

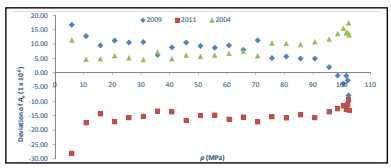


Fig. 5.30(b): Deviations of effective area from average value

varying dimensions of piston cylinder assemblies. The motive behind studying identical PBs was to investigate the behaviour of effective area when used at different locations, organizations and operators. The behaviours of effective area for these PBs alongwith average effective area of previously described PB are shown in Fig. 5.30 (c). Interestingly, the similar trends of effective areas were observed for all the 3 three locations. It is observed that there is a small change in the short term stability but the change is prominent in case of long term stability. However, such changes are well within the estimated measurement uncertainty of the instrument. The reported maximum difference in the effective areas is less than 180 x 10^{-6}, 140 x 10^{-6} and 60 x 10^{-6}, between PBs of Chennai and Guwahati, Chennai and Delhi and Delhi and Guwahati, respectively due to obvious reasons of varying form geometry of the piston cylinder assemblies. It is concluded from the studies that all the PBs remained very stable within their estimated measurement uncertainties. Compilation of such data creates the history of the instrument's usage which would be helpful for the users to decide the frequency of their next calibrations.

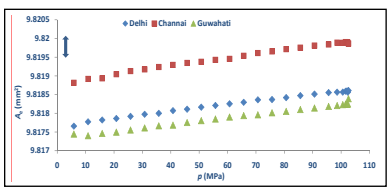


Fig. 5.30(c): Effective area of PB of a same model used at three different locations

Acoustics, Ultrasonic, Shock and Vibration Standards

The theoretical computational for sound transmission loss (TL) have computed by developing software through Statistical Energy Analysis approach. The program is written in Visual Basic (VB) and the coding. Some of the aspects of Statistical Energy modeling procedures adopted in developing the program are explained subsequently. Figures 5.31 and 5.32 show the comparison for 12 mm thick gypsum board panel with cavity and panel with insulation. With cavity the sound reduction index at low frequencies is higher.

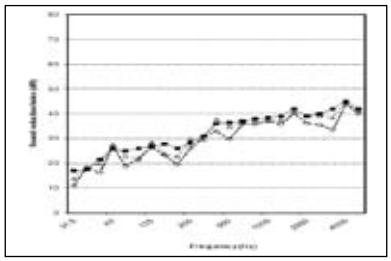


Figure 5.31. Comparison of predicted (----) and measured (----): sound reduction index of 12 mm thick gypsum panel with 25mm cavity. Experimental [■], SEA [Δ] and Odeon [◇]

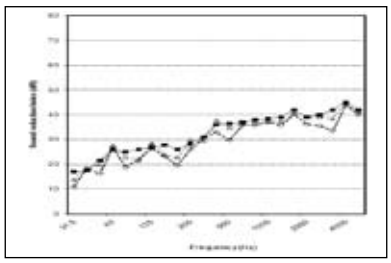


Figure 5.32. Comparison of predicted (----) and measured (----): sound reduction index of 12 mm thick gypsum board panel with 25mm cavity and absorptive material. Experimental [■], SEA [Δ] and Odeon [◇]

The AUV Section organized the one day workshop on 'Noise and Vibration Control (WNVC-2012) on January 27, 2012.

Advancement in Vibration and Acoustic Metrology

The new facility of primary vibration calibration standard in extended frequency range of 0.1 Hz to 20 kHz had been established last year. Although this facility, being a commercial system, yet there are numerous investigations carried out for improvement in the signal processing part especially the non-linearity's arising in Homodyne interferometer and drift compensation in charge amplifier at low frequencies. The ongoing investigations have been fruitful in analysis of the behaviour of shakers at high frequencies and certain deviations at 20 kHz have been observed, which are validated by FEM investigations for understanding the vibration modes excited especially in low and high frequencies.

The new microphone calibration standard facility using insert voltage technique was also established this year for the calibration of acoustic calibrators and microphones, which has reduced the uncertainty in calibration to a level at par with other NMIs of APMP region.

Inclusion of NPLI Vibration CMCs in KCDB website & Successful completion of Peer Review in October, 2011

The CMCs for vibration have been appended in KCDB website in January, 2012. The section had successfully got peer-reviewed in October, 2011 and 36 CMC were approved by Technical and Quality expert in field of Acoustics, Vibration and Ultrasonic.

Results of APMP.AUV.A-S1 comparison

The recent APMP.AUV.A-S1 comparison for multifunction acoustic calibrator (B&K 4226) initiated in 2009 with NIMT, Thailand as pilot laboratory and 13 participating laboratories validated NPLI CMCs for sound pressure level determination of multifunction acoustic calibrator (Fig.5.33). The maximum deviation in sound pressure level determination by NPLI in comparison to NMI Japan was 0.12 dB at 16 kHz while 0.19 dB at 8 kHz as compared to NMI Australia which lies within the domains of the uncertainty

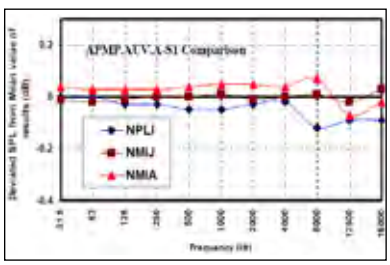


Fig. 5.33. Deviated sound pressure level from mean value of amalgamated results in APMP.AUV.A-S1 comparison at 94 dB

value realized for multifunction calibrators calibration.

Bilateral Inter-comparison

Bilateral inter-comparison of Ultrasonic power measurement between NIST, USA and NPL India was carried out. Artefact designed and developed by NIST received by NPL. Measurement taken at three different frequencies in the range of 2 to 15 MHz for each frequencies at three different in put voltage, 10 sets of observations carried out following the procedure in the protocol. Results were sent to Dr. Fick, NIST. As per statement of Dr. Fick results were very encouraging and comparison shows variation with in uncertainty limits of NIST even without taking the attenuation correction.

International PEER Review of Primary Standard of Ultrasonic Power Measurement

NPL maintains Primary Standard of ultrasonic power using radiation force balance, developed indigenously in the laboratory. The Lab participated in the international Peer Review during 8-10, Nov. 2011. For this purpose, the radiation force balance was modified for providing variation of distance between the transducer face and float. It allowed uplift of water tank by an arrangement designed and developed for smooth functioning of vertical motion of tank and for a precision measurement of separation in 0.01 mm.

EMAT System : The EMAT (Electromagnetic Acoustic Transducer) system, designed and developed at NPL (Fig. 5.34, 5.35) was tried on aluminium sample to study the effect of external force for evaluation of residual stress measurement. Measurement of velocity by EMAT could be done with a precision of 0.1 m/s. Samples were exerted force in the range from 20 to 500 kN using the UTM machine of Force Standards at NPL.

The EMAT system has also been used to evaluate variation in wall thickness of a pipe with a precision of 0.1 micron.

Fig. 5.34 Snapshot Showing the entire setup

Fig. 5.35 EMAT applied on 3cm thick aluminum alloy

Ultrasonic object detection system

To help the divers operating in deep sea, the transmitter and receiver parts of the object detection system have been

developed was tested in Chennai NIOT tank. The system worked well up to a range of 25 meters.

Research Highlights

Appreciable deviation in microphone calibration by Reciprocity technique and calibration by actuator technique was investigated for working standard microphones. The actuator response is compared with the pressure response measured on a reciprocity set up for a one-inch B&K 4144 (S. No. 1304815) microphone (Fig 5.36). The actuator response deviates from the pressure response because the radiation impedance loads the front of the diaphragm. If this impedance could be significantly reduced during the calibration, then the actuator could be used to measure accurately the pressure response.

Establishment of new Secondary Microphone Calibration facility

The secondary microphone calibration standard of NPL was commissioned in October this year. The system is capable of calibrating the microphones and acoustic calibrators as per IEC 60942. The system has been procured from B&K, Denmark. (Fig 5.37)

Fig. 5.37 Secondary Sound Standard

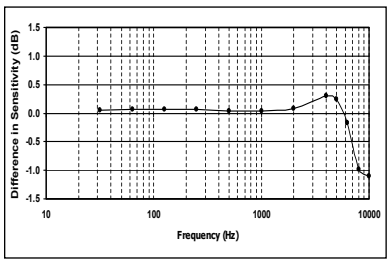


Fig. 5.36 Comparison of actuator response with pressure response observed in reciprocity set up for B&K 4144 microphone

Fluid Flow Measurements

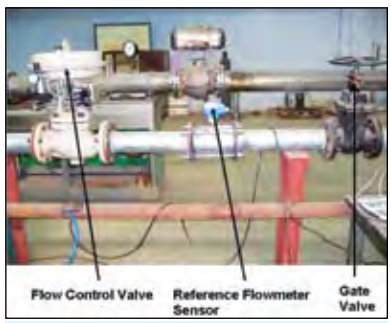
The Fluid Flow Measurement Standards group has the mandate to provide apex level testing and calibration services for the different types of domestic and industrial water flowmeters. The group has a Water Flow Calibration Facility (i.e. Primary Standard of Flow) comprising of two Test Rigs of sizes DN50 and DN200 for calibration of different types of water flowmeter as per ISO 4185 standard. The facility has the problems related to its traceability and also it has become obsolete now. Therefore, upgradation of this facility using latest instrumentation and controls has been planned to make it operational and traceable and also of NMI level.

The group also has a Water Meter Testing Facility (i.e. Secondary Standard of Flow), for testing of domestic/ industrial water meters of sizes 15 mm to 50 mm as per IS 779, IS 6784 and ISO 4064 standards. The quality system has been implemented in the Water Meter Testing Facility. During this period, total 06 test reports were issued and an ECF of Rs. 4,32,369/- was generated for NPL.

The renovation work of the Fluid Flow Laboratory is almost finished. It took about 1½ years to complete.

Major facilities to be established

Presently, a Water Flow Calibration Standard (i.e. Primary Standard of Flow) of size DN100 is being developed in technical collaboration with M/s. Bharti Automation Pvt. Ltd., New Delhi. The different parts of this system have been installed and integrated. Now automation



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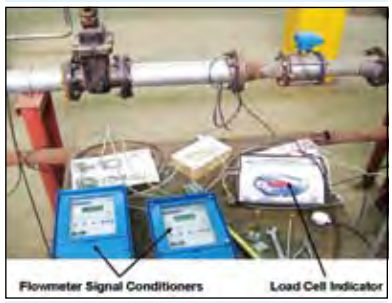

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Fig. 5.38. Photographs showing different part of a new Water Flow Calibration Standard

Division 5

work of this prototype system is in progress. Our development work was severely affected due to renovation of our laboratory. Figure 5.38 shows the photograph of this new system.

LF & HF Impedance & DC Standards

This activity is maintaining the LF & HF impedance standards, DC standards and DC High Voltage standards.

LF & HF Impedance Standard: This activity is maintaining the primary standards of capacitance, inductance and ac resistance. Value to the 10 pF capacitor is assigned through primary standard, calculable cross capacitor, with an uncertainty of 0.6 ppm using precision ac bridges. Scale of capacitance is build up from 10 pF to 1 F using transformer ratio bridges. The unit of inductance, Henry, is realized from capacitance and resistance using Maxwell-Wien bridge. Value to 100 μH to 10 H is assigned through this bridge. The unit of ac resistance, Ohm, is also realized from capacitance, using Quadrature Bridge and other precision ac bridges at 1kΩ. The scale of resistance from 1 Ω to 1 MΩ builds up with Kelvin double arms ac bridge. Precision reference airlines are being used as primary standards of HF impedance in frequency range of 10 kHz to 250 MHz.

DC standards: This activity is maintaining National Standards of DC voltage, DC current and DC resistance. The apex level calibration facilities have been provided to the ERTLs, ETDCs, Defence and other government organizations for dissemination of traceability.

DC High Voltage Standards: This group is providing calibration facility for High Voltage DC equipments ie. DC High Voltage probe, DC High Voltage divider, DC High Voltage Power Supplies and DC Volt meter, upto 100 kV. Primary standard of DC High Voltage is the Resistive Divider, which is traceble to Josephson Voltage Standard.

An automation program using LabVIEW for the study of Standard Inductor

This group has recently developed measurement automation program for the study of standard inductor over the required temperature range using LabVIEW Platform. This measurement automation program simultaneously controls LCR Meter and Air Bath. The high precision LCR Meter has superior measurement stability and air bath has the temperature stability of ± 0.03 °C over 24 hours, which provides a stable environment for the study of standard inductors.

Measurements have been taken for Standard Inductors of nominal values of 10 mH and 100 mH using the measurement automation. It is observed that air bath is providing very stable temperature for the study of standard inductor over the temperature range as shown in the Fig. 5.39. The inductance and resistance have been measured at different frequencies and plotted simultaneously for 10 mH as shown in Figs. 5.40 & 5.41.

Measurement automation program is providing the excellent platform for the study of standard inductor with better estimation of uncertainty parameters. Measurement automation also improves the reliability and efficiency of measurements.

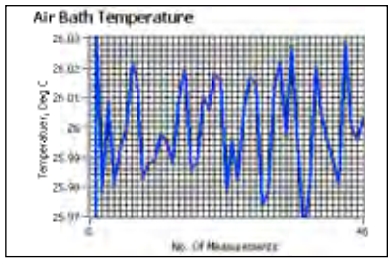


Fig. 5.39. Temperature stability of air bath

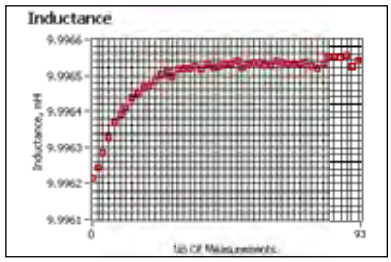


Fig. 5.40. Inductance of 10 mH at 1 kHz

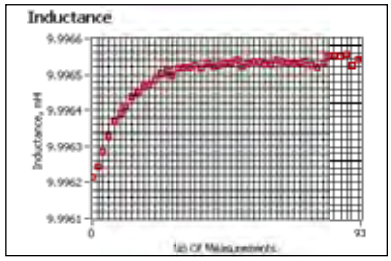


Fig. 5.41. Resistance of 10 mH at 1 kHz & 20 Hz

Bilateral comparison of low dc current with KRISS, Korea

This group is carrying out a bilateral comparison with KRISS, Korea for low dc current under Asia Pacific Metrology Programme (P1-APMP.EM. S-11). NPL is pilot lab for this comparison. Under this comparison, the measurements were carried out for low dc currents of 1 pA, 10 pA and 100 pA at NPL. The measurement setup consists of the calibrated Calibrator (as voltage source-traceable to JVS), Standard resistor (traceable to QHR) and electrometer (as current meter), all connected in series. Standard resistor of 1 GΩ and 100 GΩ were used, suitable voltage was taken from the calibrator to obtain the current of 1 pA, 10 pA and 100 pA. The artefact (electrometer) was then hand carried to KRISS and measurements were taken for about a week. The measurement setup at KRISS comprises of linear voltage ramp generator of 10 mV/s charging a capacitor and measuring the charging current. In this set-up, the non-linearity of a capacitor located in the integrator circuit is compensated by an analog feedback network. The diminution of the voltage slope was carried out by a Kelvin Varley divider. In order to calculate the generated current, the voltage output of the divider was measured by a high precision digital voltmeter (DVM), which was triggered by a precision external time base. The reference frequency of 10 MHz of the time base was monitored by a frequency counter. Using air capacitors in the range of 1 to 1000 pF, the set up can generate 100aA to 100 pA. The reading of the DUT (electrometer) was recorded simultaneously with the output of the DVM by a computer. The ramping sequence was controlled by a computer through a relay controller via an optocoupler, which was used for galvanic isolation between the computer and ramp generator. All instruments were calibrated against KRISS Standards for the units of volt, capacitance and time/frequency.

Repeat measurements are being carried out at NPL as per the technical protocol. After measurements, the report will be sent to APMP for approval.

APMP Inter-comparison of 6½ Digit Precision Multimeter

This group alongwith LF, HF Voltage, current and Microwave Standards group is coordinating inter-comparison of 6½ Digit Multimeter (DMM) under Asia Pacific Metrology Programme (P1-APMP.EM-S8). For the first time, NPL is the Pilot laboratory for this inter-comparison, in which 16 countries are participating. The participating countries are Australia, Hong Kong, Sri Lanka, Kazakhstan, Egypt, South Africa, Thailand, New Papua Guinea, Vietnam, Jordan, Mangolia, Philippines, Malaysia, Indonesia, Syria and India.

The comparison will take about two years time for completion.

The measurement parameters are given in Table 1.

The DC measurements are taken by this group and ac measurements by LF, HF Voltage, current and Microwave standards group.

Out of 16 countries, only 8 countries are covered under ATA Carnet System. The inter-comparison is being carried out in two circulation schemes for countries covered under ATA Carnet system and for countries not covered under ATA Carnet system. Both circulation schemes have two loops.

Table 1

Parameter	Nominal value
DC Voltage	100 mV, 1 V, 10 V, –10 V, 100 V and 1000 V
DC Current	10 mA and 1 A
DC Resistance	100 Ω, 1 kΩ and 10 kΩ (using 4-wire)
AC Voltage	100 mV, 1 V, 10 V, 100 V and 700 V at 40 Hz and 1 kHz
AC Current	10 mA and 1 A at 40 Hz and 1 kHz

First loop of the countries covered under ATA Carnet for Australia, South Africa and Mangolia was completed during May to Nov, 2011. Similarly, the first loop for for countries not covered under ATA Carnet system (i.e. Vietnam, Philipines, Papua New Guinea, Indonesia) is also in progress.

The second loop for countries covered under ATA Carnet started in Jan 2012 and is progressing as per the schedule.

Comparative study of temperature influence on thick film and wire wound precision HV resistive divider.

The study focused to determination of temperature influence of thick film and wire wound High voltage resistive divider. The deviation in resistance value depends upon the material used in resistance, type of construction and its coefficients. The temperature coefficient play vital role in calibration. The construction of HV divider reduces the temperature coefficient minimum by choosing some resistance with positive and other negative temperature coefficient. When these resistances are arranged in series, the total resistance changes for lower than that of individual but influenced with the working temperature of HV divider.

The study of deviation due to environment temperature from 20 to 30°C of Thick film divider and Wire wound divider up to 100 kV dc under stable condition of source traceable from National Standard. The nominal scale factor of both dividers are 10000:1, the comparative study investigate the influence of temperature in wire wound resistive divider is 5 ppm /°C where as thick film resistive divider have 1 ppm /°C

Comparative study of voltage dependence and self heating in precision HV resistive divider

The study focused to determination of voltage dependence of precision high voltage divider and self heating of HV resistance. High voltage resistive divider is a Primary Standard of DC High Voltage measurements. The traceability of HV measurements is directly related to divider's traceability, to scale the voltage from Josephson voltage standard, which is primary standard of DC voltage. The change in effective resistance ratio with voltage depends upon self heating of resistance, electrostatic stress and leakage current. The design of divider and precision source minimize the above factor. The relative ratio change due to high voltage of HV divider in both positive and negative polarity is about 0.1 ppm /kV.

LF & HF Voltage, Current and Microwave Standards:

The activity has the responsibility for the establishment, maintenance, updating the Primary Standards and calibration facilities for the LF& HF Voltage, Current, Microwave Power, Attenuation and Impedance parameters, which are compatible to International Standards through continuous research and development. We are providing national traceability in the above parameters through apex level calibration to ISRO, DRDO, Naval Dockyard, Air Force, BEL, STQC labs, regional laboratories and the other user organizations. We regularly participate in international and bilateral comparisons (BIPM, APMP, EURAMAT) to establish a close degree of equivalence in measurements among the participating NMIs.

Traceability of the Low Frequency Voltage at 2 V, 10 Hz to 1 MHz and Current Standard at 5 mA, 40 Hz to 10 kHz have been re-established from the recently procured Multijunction Thermal Converter (MJTC). The established standards have better uncertainty ranging from 5 ppm to 20 ppm and will be used to calibrate the transfer standards of the user organizations. We have participated in a EURAMAT Intercomparison for Low Frequency Voltage recently and the results are at par with the well established NMIs are very close to the reference line as shown in the Fig. 5.42.

An APMP Intercomparison P1-APMP.EM-S8 of 6½ digit DMM is being piloted by NPLI. Sixteen countries had participated.

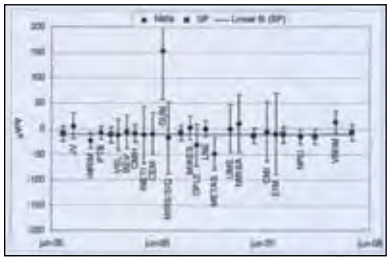


Fig. 5.42. EURAMAT Intercomparison

We had provided an exclusive training in Low frequency voltage and current to Mr. Joe Panga from NISIT, (NMI) of Papua New Guinea in June 2011 at NPLI.

Broadband attenuation measurement facility based on the procured attenuator & signal calibrator system (8852/ VM7) has been established. It will be used for the calibration of coaxial fixed & variable step attenuators in the frequency range from 10 MHz to 18 GHz. The complete measurement setup and the results are shown in Fig. 5.43 & Fig. 5.44.

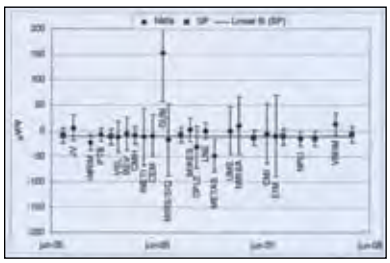


Fig. 5.43. Attenuation measurement system

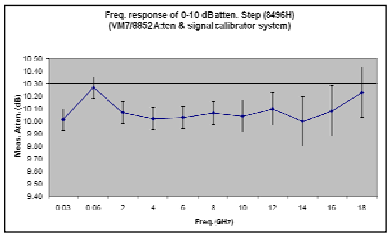


Fig. 5.44. Frequency response of attenuator

Fig. 5.45. NPLI Technology Award 2011

Saood Ahmad, Bijendra Pal and A. K. Govil (Team – NPLI), have been awarded NPLI Technology Award 2011 comprising of Certificate & Cash Prize for the R&D invention based on Software Development for the Advancement in Measurements, which was registered by Copyright Office, Govt. of India for their contributions and innovation in the field of Electrical Metrology (Fig. 5.45). The developed softwares are of great use in calibration and maintaining the traceability chain of reference and transfer standards of LF & HF Voltage, Current and Microwave power. The award was presented during the National Technology Day Celebrations on 20 May, 2011 held at NPLI, New Delhi, India. Dr. Srikumar Banerjee, Chairman, Atomic Energy Commission & Secretary Department of Atomic Energy, Govt. of India, who was the Chief Guest at the said function, presented the awards.

This group has established a Vector network analyzer (VNA) based measurement facility in the frequency range of 1 MHz to 2 GHz for the characterization of RF power reference standards, power sensors and power mounts. We are working on establishing the in house measurement traceability for the one port broadband S-parameter measurements of VNA, from Dimensional Metrology and DC Resistance Standard. The measurement setup and the calibration kit are shown in Fig. 5.46 & Fig. 5.47. The established traceability will be used in assigning the VSWR/ reflection coefficient measurement and estimating

Fig. 5.46. VNA calibration (Airline)

Fig. 5.47. Calibration kit of VNA

the mismatch uncertainty for the microwave power measurement.

NPLI had piloted an APMP supplementary comparison for reflection coefficient magnitude and phase on coaxial a few years back. The Draft A report on the APMP supplementary comparison (P1-APMP.EM.RF-S3), Reflection coefficient magnitude and phase on coaxial have been prepared, compiled and submitted to APMP TCEM chair: Dr. Ilya Budovsky. The report was presented by him to all CCEM members presented at CCEM, BIPM meeting, Paris- France in March 2011. Subsequently, Draft A report have been circulated among the participating NMIs for their comments/suggestions. Inputs and the feedback received from the participants have been incorporated in Draft A report. Preparation for the Draft B report will follow after the final approval from TCEM Chair.

AC High Voltage & High Current Standards

This section is maintaining National Standards for AC High Voltage and High Current Ratios at power frequencies (50Hz) by using Reference Standard High Voltage Ratio Measuring System and Reference Standard Current Transformers. Accordingly calibration services were provided for the calibration of Current Transformers, Current Transformer Testing Sets, Clamp Meters, CT Burdens, Voltage Transformers, Voltage Transformer Testing Sets, HV Probes, Electrostatic Voltmeters (ESVMs), HV Break Down Test Sets and Voltage Transformer Burdens etc. As many as 69 calibration certificates were issued to the electrical manufacturers and utilities in the country.

The National Standard of AC High Current Ratio Measuring System up to 5000A/1A, 5A is shown in Fig. 5.48.

The National Standard of AC High Voltage Ratio up to 100 kV/100 V comprising of the Compressed Gas Capacitor, Air Capacitor & the Electronic Voltage Divider (EVD) is shown in Fig. 5.49.

Establishment of the National Standard for AC High Voltage Capacitance and Tangent Delta Measurement at NPL

AC High Voltage & High Current Standards have established the National Standards for the calibration and measurement of AC High Voltage Capacitance and Tan δ upto 200 kV at 50 Hz (Fig. 5.50). This will also provide the measurement traceability to kV Meters, High Voltage Dividers, BDV Testers upto 200 kV. With the help of this facility insulation level of test objects like transformers, bushings and cables etc. can be measured with a high degree of accuracy.

Fig. 5.48 The National Standard of AC High Current Ratio Measuring System up to 5000A/1A, 5A.

Fig. 5.49 National Standards for AC High Voltage

Fig. 5.50 calibration and measurement of AC High Voltage Capacitance and Tan δ upto 200 kV at 50 Hz.

Fig. 5.51 Calibration of reference standard against Primary Power Calibration System

The ranges of the measurements of C & Tan δ are as follows:-

Applied Voltage & Frequency	Parameters	Ranges	Accuracy
5 V – 200 kV/50 Hz	HV Capacitance Tan δ	≥0.01 pF 0 – 100	± 0.02% ± 0.001%

National Standard for AC High Voltage Capacitance and Tan δ

- **Extraordinary Research Highlights**

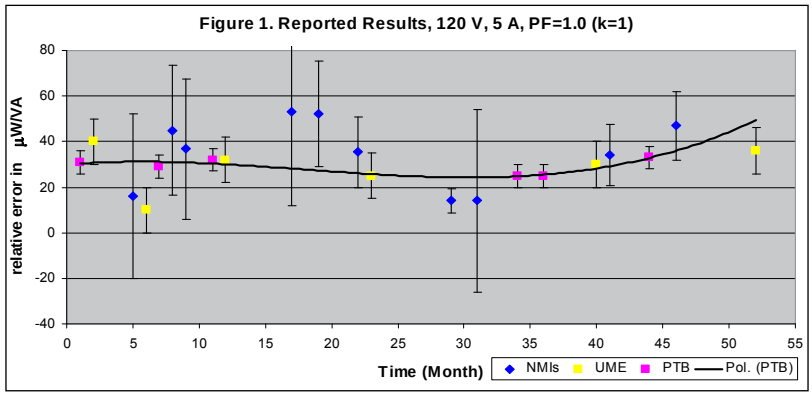
Making use of the expertise and experiences available with the division, an innovative idea of using the recently installed C and Tan delta facility as kV meter for measurement of voltages as high as up to 200 kV has been implemented in addition to the C and Tan delta measurement and calibration services. This idea has added a new dimension in our measurement capability by adding one more parameter of AC high voltage measurement services from existing 100 kV to 200 kV for High Voltage Sources, kV Meters and High Voltage probes. This has been made possible by the induction of C and Tan Delta high precision measuring system.

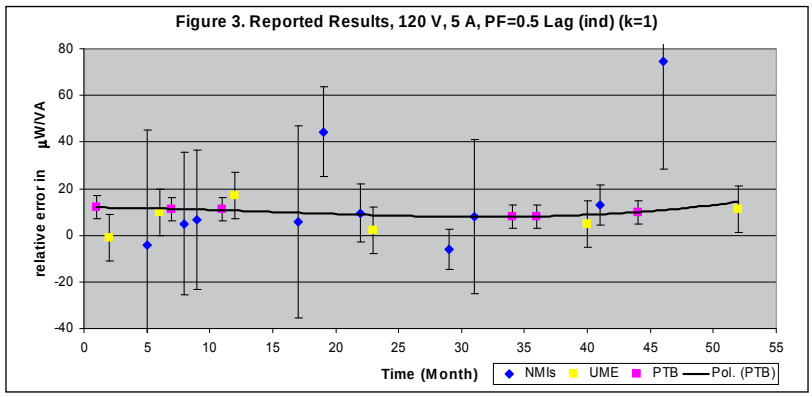
AC Power and Energy

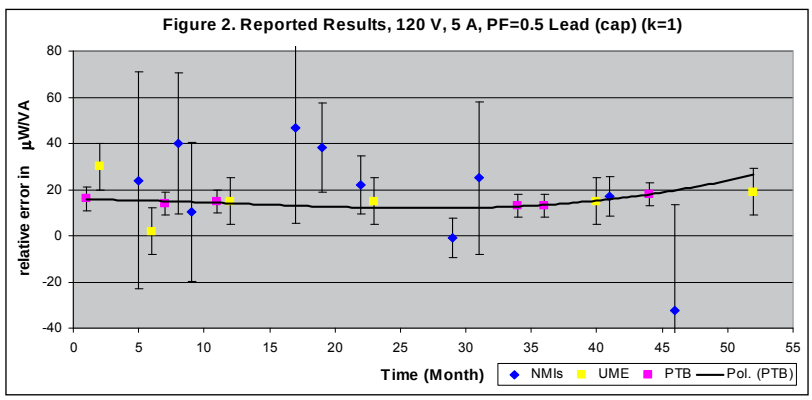
PPCS primary power calibration system as shown in fig. 5.51, has been established traceable to DC voltage, resistance and time. We have calibrated our 3 phase and 1 phase reference standard against this PPCS.The uncertainties are established to within 30 ppm with respect to apparent power.

The uncertainties claimed in peer review in 2009 have been published in JCRB of BIPM. Minimum value is 70 ppm for active power, 90 ppm for rective power and 80 ppm for apparent power.

Final report of Key comparison EURAMET.EM-K5.1, EURAMET Project 687 "comparison of 50/60 Hz power" has been published in KCDB. Pilot lab was UMM Turkey. We had taken part on normal test points , 120 V/5 A, PF = 1, 0.5i/c and 0i/c, so at additional no power points: 120 V/0 A, 0 V/5 A & 0 V/0 A for DC offsets and for DC reference voltage measurement. Our results at every point are very close to the pilot laboratory. The results at 120 V/ 5 A, PF = 1, 0.5 i/c are given in Fig. 1,2,3 below:







(NPLI is at 31st month)

ECF earned during the financial year 2011-12 is 28 lakhs with 157 calibration & test reports

क्वान्टम परिघटना एवं अनुप्रयोग

Quantum Phenomena and Applications

क्वान्टम परिघटना एवं अनुप्रयोग

राष्ट्रीय भौतिक प्रयोगशाला में 10 वोल्ट के स्तर पर प्रोग्रामनीय जोसेफसन वोल्टता मानक संस्थापित किया गया है, जो कि एन आई एस टी, संयुक्त राज्य अमेरिका के सहयोग से प्राप्त हुआ है। इससे भारत में "वोल्ट" के मात्रक के मानक हेतु अंतर्राष्ट्रीय स्तर के अनुरूप आधार निर्मित हुआ है।

क्वान्टम कैंडेला (cd), जो ज्योति तीव्रता का SI आधार मात्रक है, को स्थापित करने के लिए फोटोन की गणनीय संख्या के संदर्भ में प्रयास किया जा रहा है। एस पी डी सी प्रक्रम का प्रयोग करके फोटोन गणन संसूचकों की निरपेक्ष संसूचन दक्षता हेतु दो फोटोन सह–संबंध गुणों को प्रयोग में लाया जा सकता है।

T (निरपेक्ष ताप) = 1.8 से 400 K (केल्विन) तक तथा B = 1 से 7 T में प्रचालनात्मक एक SQUID आधारित परिशुद्ध मैग्नोमीटर (एम पी एम एस) सुविधा संस्थापित की गई। एक हीलियम–क्रायोस्टैट, अति चालन चुम्बक (0–7 T) का प्रयोग करके एक पूर्णतः स्वचालित मैग्नेटो ट्रांसपोर्ट व्यवस्था, परिवर्ती ताप इन्सर्ट (4.2 – 300 K) तथा प्रयोगशाला दृश्य सॉफ्टवेयर (लैब व्यू सॉफ्टवेयर) विकसित किया गया। बुनियादी अभिकल्प समीकरणों का प्रयोग करके स्पंदित चुम्बक का एक प्रयोगशाला आद्यप्ररूप अभिकल्पित किया गया तथा उसका 1 T फील्ड हेतु परीक्षण किया गया।

$MgCNi_3$ (Tc = 7.5 K) तथा Bi_3 Ni (Tc) = 4.3 K) में अति चालकता जो Ni लौह चुम्बकत्व की घनिष्ठ समीपता में घटित होता है, का विस्तार से अध्ययन किया गया। मल्टी बैंड निक्टाइड यौगिक जैसेकि अति चालक Nd, SmFeAs O/F तथा घनिष्ठ रूप से संबंधित चुम्बकीय RECoAsO का अन्वेषण किया गया। (Eu/Y) Ru - 1222 चुम्बकीय अति चालक में लौह चुम्बकत्व से प्रचक्रित काँच (spin glass) की उत्पत्ति को दर्शाया गया, जिसके फलस्वरूप इन अंतर्निहित प्रणालियों में अति चालकता की उपस्थिति प्रदर्शित हुई। सिन्टरित ऑक्सिनिकटाइड LaO_{1-x} F_x FeAs अति चालक में दुर्बल सहलग्नता आचरण का अन्वेषण किया गया।

$LaTiO_3$/ $SrTiO_3$, $LaAlO_3$/ $SrTiO_3$ विषम संरचनाओं में ऑक्साइड इंटरफेसों का प्रापण संभव हुआ है तथा उनमें ताप में परिवर्तन करके या चुम्बकीय अथवा वैद्युत क्षेत्रों का प्रयोग करके वाहक घनत्व तथा इलेक्ट्रॉनिक प्रावस्थाओं को समस्वरित करने की संभावना का अध्ययन किया गया।

चुम्बकीय टनल जंक्शनों (MTJ), चुम्बकीय वलय व्यूहों के संविरचन तथा अभिलक्षणन तथा अति चालक फिल्मों एवं नैनो संविरचित अति चालकों में क्वान्टम प्रावस्था स्लिप प्रक्रमों पर उनके प्रभाव से संबंधित क्षेत्र में सक्रिय अनुसंधान कार्यों को आरंभ किया गया।

एक संयोजित केंद्रित आयन किरण पुंज सूक्ष्मदर्शी संस्थापित किया गया और उसे सक्रिय बनाया गया जिसमें बहु प्रकार्यात्मक सुविधाएं हैं जैसेकि उच्च वियोजन प्रतिबिंबन, स्थानीकृत मिलिंग तथा धातु या रोधी पदार्थों का निक्षेपण, जटिल प्रतिरूप लेखन हेतु ई–किरण पुंज लिथोग्राफी, तात्विक तथा क्रिस्टलीय अभिलक्षणन आदि। प्रारंभिक स्तर पर नैनो युक्तियों का संविरचन आरंभ किया गया है।

Quantum Phenomena and Applications

Programmable Josephson Voltage Standard at 10 V level has been installed at NPL with the support of NIST, USA. This forms the basis for standard of the unit of 'Volt' in India at par with the international level.

Strides have been made, in terms of the countable number of photons for establishing quantum candela (cd), which is SI base unit of luminous intensity. Two photon correlation properties can be used for absolute detection efficiency of photon counting detectors using SPDC process.

A SQUID based precision magnetometer (MPMS) facility, operational in T=1.8 to 400 K and B = 0 to 7 T, was established. A fully automized magneto transport setup, using a He-cryostat, superconducting magnet (0-7 T), variable temperature insert (4.2 - 300 K) and LabView software was developed. Following basic design equations, a laboratory prototype of pulsed magnet was designed and tested for 1T field.

Superconductivity in $MgCNi_3$ (Tc = 7.5K) and Bi_3Ni (Tc = 4.3K), that occurs in close vicinity of Ni ferromagnetism, were studied in detail. The multiband pnictide compounds like superconducting Nd,SmFeAsO/F and closely related magnetic RECoAsO were investigated. The ferromagnetism in (Eu/Y)Ru-1222 magnetic superconductor was shown to convert to spin glass, that then allows the existence of superconductivity in this intriguing systems. Weak link behaviour in sintered oxypnictide $LaO_{1-x}F_xFeAs$ superconductor was investigated.

Oxide interfaces were realized in $LaTiO_3/SrTiO_3$, $LaAlO_3/SrTiO_3$ heterostructures and the possibility of tuning the carrier density and electronic phases by changing temperature or by applying magnetic or electric fields were studied in them.

Active research was initiated in fabrication and characterization of Magnetic Tunnel Junctions (MTJs), Magnetic Ring Arrays and their influence on superconducting films and Quantum phase slip processes in nanostructured superconductors.

A combined focused ion beam microscope was installed and made active, which has multifunctional facility such as high resolution imaging, localized milling and metal or insulator deposition, e-beam lithography for complex pattern writing, elemental and crystallographic characterizations. Fabrication of nanodevices at preliminary level has strated.

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D 06.01 Josephson Junctions and Single Electron Tunneling Physics
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D 06.02 Quantum Transport in Thin Film Heterostructures
Dr. Vijay Kumar Gumber
Dr Hari Krishna Singh
Dr (Ms) Anjana Dogra

D 06.03 Nanoscale Measurements
Dr (Ms) Rina Sharma
Dr Vijay Kr. Toutam
Dr Ashok Kumar
Ms Usha Kiran

D 06.04 Quantum Optics and Photon Physics
Dr Hem Chandra Kandpal
Sh Virendra Kumar Jaiswal

D 06.05 Superconductivity : Materials and Dissipation Physics
Dr Ms P L Upadhyay
Dr Anurag Gupta
Sh Rajendra Singh Meena
Dr Sudhir Husale
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D 06.06 Electronics & Instrumentation Cell
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Ms Poonam Sethi Bist

Programmable Josephson Voltage Standard

Recently Programmable Josephson Voltage Standard at 10 V level has been installed at NPL (Fig. 6.1) with the support of NIST, USA. The heart of the system is the Josephson chip fabricated at NIST, Boulder, USA. The salient features of the chip are:

- The non-hysteretic Josephson tunnel junctions which are made of Nb electrodes and Nb_xSi_{1-x} barriers.
- The 10 V chip contains a total of 256,116 Josephson junctions organised in stacks of three junctions and distributed into 32 microwave coplanar waveguide lines.

The PJVS system is based on 'Quantum Phenomena' (Josephson Effect) given by the relation

$$2eVn = nhf$$

Where n= 0, ± 1, ± 2, ± 3, ---;

Vn = quantized voltage;

f = frequency of irradiation;

h = Planck's constant;

e = electron charge

This forms the basis for standard of the unit of 'Volt' in India at par to the international level.

The uncertainty in measurement of Zener Reference Standards is ± 350 nV at k = 2 (inclusive of noise of a typical Zener) at 10V level as per the ISO/IEC 17025:2005.

Quantum Transport in Thin Film Hetreostructures

$MgCNi_3$ - We report synthesis, structural, magnetic, specific heat and Density Functional Theory (DFT) studies on $MgCNi_3$ superconductor. Polycrystalline $MgCNi_3$ samples are synthesized

Fig. 6.1 : Photograph of the 'Programmable Josephson Voltage Standard' (PJVS) at 10 Volt at NPL-India

through standard solid state reaction route and found to crystallize in cubic perovskite structure with space group *Pm3m*, without any detectable trace of Ni impurity. Both *AC* and *DC* magnetization exhibited superconducting transition (T_c) at around 7.25 K. The lower critical field (H_{c1}) and irreversibility field (H_{irr}) are around 140 Oe and 11 kOe respectively at 2 K. The upper critical field (H_{c2}) being determined from in-field *AC* susceptibility measurements is 11.6 kOe and 91.70 kOe with 50% and 90% diamagnetism criteria respectively. Heat capacity (C_p) measurements are carried out under applied field of up to 140 kOe and down to 2 K. The Sommerfeld constant (γ) and Debye temperature (Θ_D) as determined from low temperature fitting of $C_p(T)$ data to Sommerfeld-Debye model are 36.13 mJ/mole-K^2 and 263.13 K respectively, see (Fig.6.2). The Bardeen-Cooper-Schrieffer (BCS) parameter ($2\Delta/K_BT_c$) is around 3.62, suggesting $MgCNi_3$ to be an intermediate coupled BCS superconductor with value λ = 0.69. Although the DFT calculations exhibited the compound to be non-magnetic but with spin fluctuations, the experimental isothermal magnetization *MH* loops at 20, 50, 100, 200 and 300 K showed some ferromagnetic nature in this compound with coercive field (H_c) of around 50 Oe at 20 K. The Ni^{3d} states play dominant roles near the Fermi levels and there is strong hybridization between Ni^{3d} and C^{2p} states. It seems that $MgCNi_3$ is superconducting in close proximity of ferromagnetism.

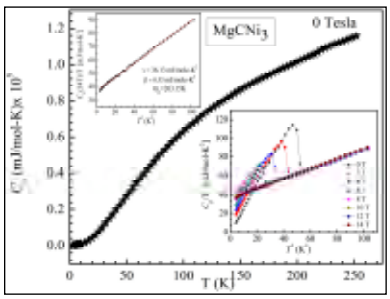

Fig. 6.2: Heat Capacity vs Temperature C*p* *(T)* plot of $MgCNi_3$ in temperature range of 2-250 K without applied magnetic field. Inset 'a' shows linear fitting of Cp/T *vs* T^2 – 140 kOe curve (normal state). Inset 'b' shows Cp/T *vs* T^2 plots in magnetic fields 0 to 140 kOe. **[J. Appl. Phys.111, 033907 (2012)]**

Bi_3Ni **-** We report the experimental and theoretical study on magnetic nature of Bi_3Ni system. The structure is found to be orthorhombic (*Pnma*) with lattice parameters a = 8.879Å b = 4.0998Å and c = 4.099Å. The title compound is synthesized via a solid state reaction route by quartz vacuum encapsulation of 5N purity stoichiometric ingredients of Ni and Bi. The superconducting transition temperature is found to be 4.1 K as confirmed from magnetization and specific heat measurements. The lower critical field (H_{c1}) and irreversibility field (H_{irr}) are around 150 and 3000 Oe respectively at 2 K. Upper critical field (Hc_2) as determined from in field (up to 4 Tesla) ac susceptibility is found to be around 2 Tesla at 2 K. The normal state specific heat is fitted using Sommerfeld-Debye equation $C(T) = \gamma T + \beta T^3 + \delta T^5$ and the parameters obtained are γ = 11.08 mJ/mol-K^2, β = 3.73 mJ/mol-K^4 and δ = 0.0140 mJ/mol-K^6. The calculated electronic density of states (*DOS*) at Fermi level $N(E_F)$ and Debye temperature Θ_D are 4.697 states/eV per formula unit and 127.7 K respectively. We also estimated the value of electron phonon coupling constant (λ) to be 1.23, which when substituted in MacMillan equation gives T_c = 4.5K. *DFT* based calculations for experimentally determined lattice parameters show that Ni in this compound is non-magnetic and ferromagnetic interactions seem to play no role. The Stoner condition $I*N(E_F)$ = 0.136 per Ni atom also indicates that system cannot have any ferromagnetism, see Fig. 6.3.

EuRu-1222 **-** We report *DC* magnetization, detailed systematic linear and nonlinear

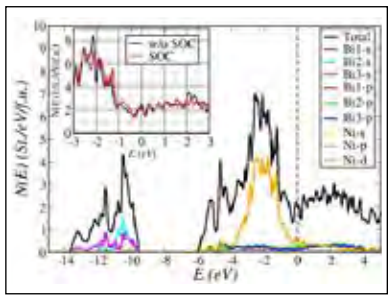

Fig. 6.3 Calculated electronic density of states (*DOS*) for the fully relaxed structure Bi_3Ni, inset shows the *DOS* with and without SOC around Fermi level. **[Sup. Sci. Tech. 24, 085002 (2011)]**

Division 6

AC magnetic susceptibility and transport for a single phase $RuSr_2Eu_{1.4}Ce_{0.6}Cu_2O_{10-\delta}$ (EuRu-1222) magneto-superconductor. The studied sample is synthesized through standard solid state reaction route, which is crystallized in single phase tetragonal structure with space group *I4/mmm*. DC magnetic susceptibility measurements revealed that the studied EuRu-1222 is a magneto-superconductor with Ru spins ordering at around 110 K and superconductivity in the Cu-O_2 planes below ≈ 30 K, see Fig. 6.4. Temperature dependence of AC susceptibility with different frequency and amplitude variations confirms spin-glass behaviour with cluster ferromagnetism of the system. Change in the cusp position with frequency follows the *Vogel-Fulcher law*, which is commonly accepted feature for a spin-glass (SG) system with ferromagnetic clusters. The third harmonic of AC susceptibility (χ_3) shows that the system undergoes a spin glass transition below 80 K. Superconducting transition temperature (T_c) onset and ρ = 0 are seen at around 30 and 18 K without any applied field and the same decreases to 10 and 2 K under 130 kOe applied field. Also low fields isothermal (*MH*) suggests that ferromagnetic clusters are embedded in spin-glass (SG) matrix. The magnetization vs. applied field (*MH*) loops exhibited ferromagnetic (*FM*) like behaviour with rather small coercive fields. Detailed AC magnetic susceptibility measurements are carried out to unearth the short range magnetic correlations. These results support the spin-glass (SG) formation followed by ferromagnetic clustering effects at low temperatures. Our detailed magnetization and magneto transport results will undoubtedly contribute to current understanding of the complex magnetism of the EuRu-1222 system.

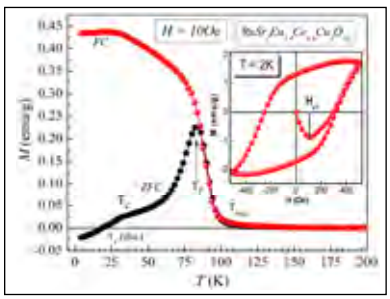

Figure 6.4: *ZFC* and *FC DC* magnetization plots for $RuSr_2Eu_{1.4}Ce_{0.6}Cu_2O_{10-\delta}$ measured in the applied magnetic field, H = 10Oe. Inset shows the M vs. H plot at temperature 2K in the range of -500 Oe ≤ H ≤ +500 Oe. **[J. Appl. Phys.111, 043926 (2011)]**

RECoPO (RE = La, Nd & Sm): We report the electrical, magneto transport and specific heat of the layered polycrystalline RECoPO (RE = La, Nd and Sm) samples. These compounds are iso-structural to recently discovered superconductor LaFeAs(O/F). Bulk polycrystalline samples are synthesized by solid state reaction route in an evacuated sealed quartz tube. All these compounds are crystallized in a tetragonal structure with space group *P4/nmm*. Cobalt in these compounds is in itinerant state with its paramagnetic moment above 1.4 μ_B and the same orders ferromagnetically (*FM*) with saturation moment of around 0.20 μ_B below say 80K. Though, LaCoPO shows single paramagnetic (*PM*) to ferromagnetic (*FM*) transition near 35 K, the NdCoPO (Fig.6.5) and SmCoPO exhibit successive *PM-FM-AFM* transitions. Both *FM* and *AFM* transition temperatures vary with applied fields. Although the itinerant ferromagnetism occurs with small saturation moment, typical anti-ferromagnetic (*AFM*) transitions (T_{N1}, T_{N2}) are observed at 60 K and 14 K for Nd and 70 K and 40 K for Sm. This *FM-AFM* transition of Co spins in NdCoPO and SmCoPO is both field and temperature dependent. The Magneto-transport of NdCoPO and SmCoPO distinctly follows their successive *PM-FM-AFM* transitions. It is clear that Sm/Nd (4f) interacts with the Co (3d) in first time synthesized Sm/NdCoPO.

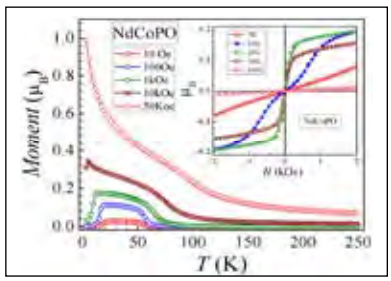

Fig. 6.5 Magnetization (*M*) versus temperature (*T*) for NdCoPO at different fields. Insets show the isothermal magnetization *M(H)* plots of the compounds at various temperatures. **[J. Appl. Phys.111, 103913 (2011)]**.

Focused ion beam microscope : A nanodevice laboratory

"In order to explore and understand electronic, magnetic and photonic properties of new novel materials, in particular superconducting thin films, nanowires and carbon nanotubes, we fabricated nanostructures/ nanodevices by using state of the art lithography tools such as focused ion beam microscope or ebeam lithography. Successful creation of these nanodevices gives access to many novel experiments to investigate the quantum phenomena".

Fig. 6.6 A focused ion beam microscope

Pulsed Laser Deposition (PLD) Laboratory

A multi user facility has been established in the year 2011 – 2012 for the deposition of variety of thin film materials. This unique lab facilitates researchers with multidirectional activities in some of the never saturated fields namely; manganites, both high Tc cuprate and normal metal superconductors, nitrides, multiferroics, chalcogenides semiconductors for their exotic nature and also due to the possibility of their tailored made artificial structures which are promising candidates for the next generation device applications.

The Pulsed laser lab is equipped with Two 50 Hz KrF excimer lasers (Energy ~ 700 mJ, λ = 248 nm), 5 PLD chambers. Chambers are equipped with substrate heater with PID controlled operating temperature of up to 850°C; gas manifold - provision for independent gas (inert and/ or reactive) regulation; fully automated target carrousel for mounting 6 numbers of 1 inch dia. targets for multilayer deposition; programmable target raster and rotating mechanism; interfacing facility with excimer laser for synchronized operation. Together with PLD chamber, magnetron sputtering and thermal evaporation facilities are also integrated to one of the cluster. This system provides in-situ sample transfer facility; load lock chamber for sample loading and shadow mask mounting. DC and RF Sputtering chambers are equipped with variable distance UHV compatible sputtering sources for 2 inch dia. targets; and 1000 Watt DC & 600 Watt RF power supplies for multilayer deposition.

Quantum Optics and Photon Physics

The unified theory of coherence and polarization first proposed by Wolf connects the spatial coherence with the polarization property of light and also shows that change in the spatial coherence of the light on propagation not only changes the spectrum but also the polarization properties of the light fields. Thus a relationship

Fig. 6.7 Pulsed Laser Deposition (PLD) Laboratory

between the electric cross-spectral density matrix and the generalized Stokes parameters, which are two-point parameters, was established. This was possible only by treating components of electric fields as vector quantities. As a consequence of these studies a very important law termed as electromagnetic spectral interference law governing the usual Stokes parameters with the generalized Stokes parameters was also proposed for the first time by Setala et al. Very recently for the first time, by using polarizers and half wave retarders in widely separated beams, in a modified version of the Young's interferometer, the electric cross-spectral density matrix and the generalized Stokes parameters were realized experimentally and the electromagnetic interference law was also verified by us. These two-point parameters have found various applications in polarization studies and also in polarization metrology of thermal sources.

Entanglement of two or more spatially distant particles has applications both in fundamental and applied research. In a two-photon system, a pair of photons is generated in certain physical process called parametric down conversion. Recently it was found that under certain conditions thermal light or classically correlated light mimics the properties of entangled photon pairs. The use of spatial correlation to carry information using pseudo-thermal light radiation in the second-order intensity correlation measurements was explored to study the classical subwavelength interference effect and also ghost or coincidence imaging. This is a technique for generating an image of an object with photons that do not directly interact with the object. Experiments were performed at near field and far field to study the influence of various parameters on the quality and the resolution of the reconstructed image.

A complete understanding of the underlying physical phenomena of drug cytotoxicity is vital necessity for the rational design of drug therapy regimens. Lack of details on discerning binding behaviour of anticancer drugs and structure of their DNA complexes remains central problem in antitumor drug development. To address issues related to DNA interaction mechanisms of different anticancer drugs, we applied different spectroscopic and molecular docking studies. Amsacrine and its derivatives, which share a common anilinoacridine chromophore in their structure, form one of the major groups of chemotherapeutics used to treat a wide range of malignancies ranging from solid tumors to leukemia and lymphoma of adults but albeit several studies, DNA binding behaviour of amsacrine is not clear. We utilized FTIR, FT-Raman circular dichroism and UV-Visible spectroscopic techniques in combination with in silico studies to understand the interaction mechanism of amsacrine with DNA. Our results suggest that amsacrine has weak to intermediate type of intercalative properties. It intercalates more between AT base pairs compared to GC pairs. This intercalation widens the distance between two DNA strands. Perturbation of B-DNA conformation at amsacrine binding sites is also observed. No major B- to A-DNA transition occurs at any concentration of amsacrine used in the experiments. These local changes induced by amsacrine binding with DNA could be recognized by topoisomerase II enzyme and hence may help in formation and subsequent stabilization of ternary complexes, which ultimately renders cytotoxic efficacy of the drug.

Fourier transform infrared spectroscopy (FTIR) is potentially a powerful analytical method for identifying the spectral properties of biological tissues. It is a fast and reliable tool for distinguishing between normal and cancerous tissues without the need for laborious sampling procedures. Normal and

malignant breast tissue samples from hundred patients of different age group were collected from Max superspecialty hospital, New Delhi and analyzed using Fourier transform infrared spectroscopy. Samples were obtained from the organs removed during surgery and then classified on the basis of histopathological examinations. To characterize differences between the normal and cancerous tissue, specific regions of the spectra were analyzed to study variations in the levels of metabolites. The malignant tissue showed appreciable biochemical deviations from their normal forebears in all the cases. We were able to mark some important IR marker peaks, which are present only in either normal or cancerous tissue. Various infrared intensity ratios, which are related to, the biochemical condition of a cell was calculated. These infrared ratios are indicative of metabolic state of a cell.

A number of polystyrene films were calibrated for different pharmaceutical industries and R&D organizations using Fourier transform infrared spectrophotometer. Further FT-IR and FT-Raman Spectroscopic testing facilities were provided to various groups of NPL and outside agencies. Apart from this, night vision cameras received from various industries were calibrated against the blackbody.

Phase singularity or screw dislocations are common throughout in optical physics. Because of their specific spatial structure and associated orbital angular momentum, they find variety of applications namely, optical trapping of atoms, optical tweezers, optical spanners, micro-machining and optical communication. Apart from the mechanical control over micro-particles, recently they have found applications in quantum computation and quantum information processing. Despite of having variety of applications of phase singular optical fields, their vector dependent physical properties are still a field for exploration. We demonstrate that vortex beams, along with other states of polarization, carry pairs of polarization entangled photons which are basic requirement in various processes, such as quantum information processing and quantum teleportation.

We study polarization of phase singular optical beams and the changes in coherence when a fundamental mode from an intensity stabilized laser is transformed into phase singular beam. Stokes vector and coherency matrix approach is adopted to quantify changes in diffracted orders of the computer generated hologram containing optical vortices. Coherency matrices were evaluated for vortices of several topological charges for different state of polarization. Matrix elements of the coherency matrices are used to quantify degree of coherence and to evaluate the effective phase difference between the field components to quantify coherence. We observe the similar profile for all the diffracted orders for given state of polarization of incident beam, confirming classical nature of coherence in vortex beams. Inadvertently, the same coherence nature for the central order and vortices indicates that the spin angular momentum and orbital angular momentum of photons are not coupled in this process.

Study of light-induced processes in biological photoreceptors is interesting and important as well, for both basic and applied research, as the photoresponse of these molecules is optimized by nature itself through centuries of evolution. Among large variety of photosensitive biomolecules, rhodopsin proteins seem to be most attractive, as they are basis for vision processes and some part of photosynthesis in nature. Realization of photonic devices with biological molecules will also provide the ground for green photonics.

Theoretical analyses of laser induced nonlinear absorption processes in rhodopsin protein molecules have been performed. The results validate the feasibility of all-optical switching operation 'Switching light with light', in

these protein molecules in very simple pump-probe geometry. The performance of the switch in terms of contrast has been enhanced by optimizing the concentration of molecules and signal wavelength. Nonlinear transmission characteristics of some newly synthesized organic molecular photochromic systems were also analyzed.

Superconductivity: Materials and Dissipation Physics

A fully automized magneto transport setup was developed for RT and IV characterization of superconducting samples in a temperature range T = 4.2 - 300 K and in magnetic field B = 0 - 7 T. A N_2 jacketed He cryostat, 7 Tesla magnet and variable temperature insert (VTI) were assembled to carry out the measurements. An exhaustive software based on LabVIEW was developed to automize the setup completely. The setup and the software were tested on a NbN superconducting thin film sample.

Extremely high magnetic fields from 30 - 90 T have been possible with pulsed magnet technique. Taking a reference of Tallahassee coil of 250 kJ, a pulsed magnet was worked out to produce 50 T field for 10 ms at 77 K. To begin with, following the basic design equations, a laboratory prototype of pulsed magnet was designed and tested for 1T.

Samples of oxypnictide compound $LaO_{1-x}F_xFeAs$, with x = 0.15 and 0.2 were studied by XRD and HRTEM, as well as resistivity $\rho(T)$, magnetization M(B) and microwave modulated absorption (MMA) response between 4.2 – 300 K and applied fields B = 0 - 8 T. With change in x, both the superconducting and magnetic behaviour of the samples show an interesting pattern. The "magnetic anomaly" at T~130 K, observed in M(T) for x = 0, instead of getting totally suppressed shows a tendency to reappear in x = 0.2 sample. The superconducting transitions as measured by $\rho(T)$ at B = 0 are found broad for both x = 0.15 and 0.2 samples with transition widths ~ 2.5 and 6 K, respectively. The slope dB_{c2}/dT (where B_{c2} is upper critical field) determined by resistive onsets, for x = 0.15 and 0.2 samples, has values ~ -7.5 and -3.5 T/K, respectively. The superconducting state characteristics as reflected by $\rho(T, B)$, M(T), magnetic Jc(B) and MMA response are typical of the presence of weakly linked inter-grain regions in both the samples. Our HRTEM images of x = 0.15 sample show a presence of high angle (~ 43°) grain boundaries, that are well known to limit the J_c in cuprate-based high T_c bulk materials.

Major facilities established:

During last year (2011-2012), we have installed a focused ion beam microscope (Fig. 6.6) (Zeiss_Auriga 39-71). This is a unique microscope, can be used for high resolution imaging, localized metal or insulator deposition, elemental analysis, micromanipulation of objects, localized milling / circuit modifications. Our potential results demonstrate the functioning of this facility and subsequently show that we can fabricate nanodevices from 1D or 2D materials, nanolayers or nanowires. Moreover this facility can be used as a micro- and nano-machining tool at the nanoscale and we believe that this will boost the nanofabrication activity at NPL and hence the nanodevice research. Following are the important devices fabricated by using above mentioned facility.

1. Solar Energy project: Nanodevice fabrication of quantum wells:

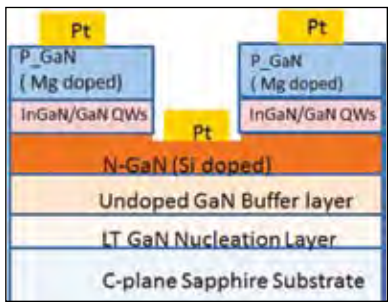

Fig. 6.8 A. Epitaxial layers

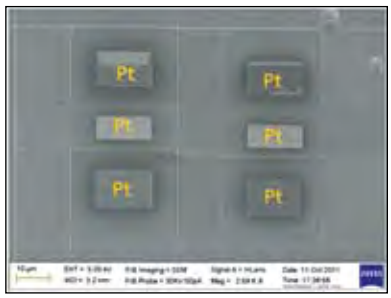

Fig. 6.8 B. FIB fabricated device for transport stud

Here we mainly used FIB milling and platinum (Pt) metal deposition techniques to fabricate these devices as shown in the Fig. 6.8A&B. Goal of this project is to measure transport properties through quantum wells formed by ~ 30 nm thick layers of InGaN/ GaN layers which is shown in Fig 6.8A.

2. Nanodevice Fabrication of Te nanowires/ nanotubes:

Here we show the fabrication of nanodevices from 1D materials. First chemically synthesized tellurium nanowires were dispersed on the substrate (Fig 6.9A). We used coarse Au metal deposition (shadow mask technique) to make metal contacts. First nanowires were localized by using FESEM, further nanowires were connected to gold pads by localized platinum deposition, and finally FIB milling was used to remove unwanted connections. Devices are made and ready for the transport measurement study (Fig 6.9B).

Fig. 6.9 A. Tellurium nanowires

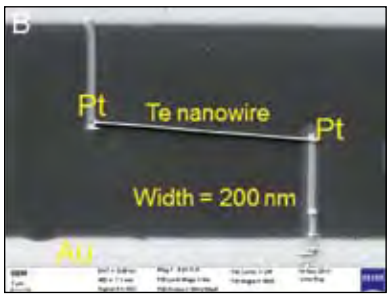

Fig. 6.9 B. FIB fabricated Tellurium

3. Graphene based nanodevices:

High quality junctions between nanomaterial and metal contacts are very crucial in the creation of high –performance transistors. As far FIB made contacts are concerned, as yet detail measurements of contact resistance have not been studied. Here we have made platinum metal contacts, using FIB metal deposition technique, on the mechanically exfoliated graphene layers (Fig 6.10A). Fabrication challenge of this project is to localize single layer of graphene using FESEM and make accurate metal contacts at the nanoscale without damaging the single layer of graphene (Fig 6.10B).

Fig. 6.10 A. Graphene layers

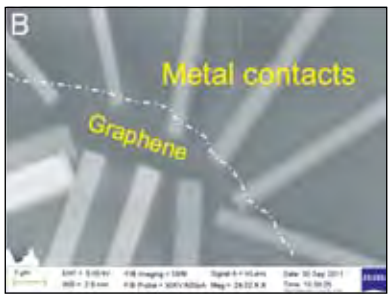

Fig. 6.10 B. FIB fabricated Graphene

4. Topological insulators based nanodevices:

Spin–orbit coupling in topological insulators leads to the formation of surface states that are topologically protected from scattering, insensitive to scattering by impurities. These materials may provide new routes to generating novel phases and particles, possibly finding uses in spintronics and quantum computing (RefJoel E. Moore, Nature, 464, 194-198, 2010.). Here first we fabricated a nanowire / nanoribbon (45 nm in width) of topological insulator Bi_2Te_3 from the mechanically exfoliated flake. We used FIB for milling and platinum deposition for making four metal contacts as shown in the Fig. 6.11 A&B.

Fig. 6.11 A&B. FIB fabricated bismuth telluride nanoribbon device

SQUID based magnetometer (MPMS) facility

A SQUID based magnetometer (MPMS) facility has been established. It can measure very precisely magnetization with an accuracy better than 1E-6 emu in temperature range 1.8 to 400 K and magnetic field range 0 to 7 Tesla. There are other features also like precise ac- susceptibility (0.01 to 1000 Hz), electrical transport and higher temperature attachment.

Accepted Project:

Indo-French Project on "Two dimensionalelectrongasphysics in oxide heterostructures"

(i) From Indian side

Principal Investigator: Dr. Anjana Dogra, Scientist, NPL

Co-Principal Investigator: Prof. R. C. Budhani, Director, NPL

(ii) From French side:

Principal Investigator: Prof. Jerome Lesueur, LPEM, France,

Co-Principal Investigator: Dr. Nicolas Bergeal, LPEM, France

❍

परिष्कृत और विश्लेषणात्मक उपकरण

Sophisticated and Analytical Instruments

परिष्कृत और विश्लेषणात्मक उपकरण

पदार्थ, जो अनुसंधान तथा अनुप्रयोगों हेतु सभी आधुनिक प्रौद्योगिकियों के संरचनात्मक घटक हैं, कड़ी विनिर्दिष्टियों के अनुरूप होने चाहिए। पदार्थ का संघटन, शुद्धता संरचना तथा क्रिस्टलीय पूर्णता पदार्थ के गुणों को नियंत्रित करने वाले बुनियादी अभिलक्षण हैं। अभिलक्षणन पदार्थ की सभी तीनों अवस्थाओं अर्थात ठोस अवस्था, द्रव अवस्था और गैसीय अवस्था से संबंधित है। इन कार्यों को करने के लिए अपेक्षित विशेषज्ञता अत्यधिक उन्नत है तथा इसके लिए आवश्यक सुविधाएं अत्यधिक परिष्कृत हैं।

राष्ट्रीय भौतिक प्रयोगशाला में स्थित परिष्कृत और विश्लेषणात्मक उपकरण प्रभाग पदार्थ की अकारिकी, रासायनिक संघटन, शुद्धता, संरचना (त्रुटियों सहित), क्रिस्टलीय पूर्णता से संबंधित अभिलक्षणों को ज्ञात करने एवं ठोस पृष्ठीय तनु परतों तथा अंतरापृष्ठों के अध्ययन हेतु उच्च कोटि की सुविधाओं से युक्त है। यह इस प्रयोगशाला में उपलब्ध कराई गई एक मुख्य सुविधा है।

एक उल्लेखनीय तथ्य यह है कि इन सुविधाओं के अनुरक्षण तथा विकास के कार्य में जुड़े वैज्ञानिक न केवल संगठन के अन्य प्रभागों को ये अभिलक्षणन सुविधाएं उपलब्ध करा रहे हैं बल्कि वे उन्नत क्षेत्रों में अपने स्वयं के अनुसंधान कार्यों में भी काफी सक्रियता से जुटे हुए हैं जिसके कारण यह प्रभाग इस क्षेत्र में हुई नवीनतम प्रगतियों से अवगत बना रहता है तथा साथ ही नई जानकारियों के सृजन में भी अपना महत्त्वपूर्ण योगदान देता है। इस प्रभाग में एक्स–किरण विश्लेषण, इलेक्ट्रॉन तथा आयन सूक्ष्मदर्शी, ई पी आर तथा आई आर स्पेक्ट्रमविज्ञान एवं विश्लेषणात्मक रसायन विज्ञान के क्षेत्र में कार्य कर रहे समर्पित समूह शामिल हैं।

Sophisticated and Analytical Instruments

Materials, the building blocks of all modern technologies for research as well as for applications have to conform to strict specifications. Basic material characteristics which control material properties are composition, purity structure and crystallographic perfection. Characterization is concerned with all the three phases mainly solid, liquid and gases. The expertise needed to carry out these tasks is very advanced and the facilities required are very sophisticated.

The Sophisticated and Analytical Instuments Division at NPL houses high quality facilities for characterization of materials for morphology, chemical composition, purity, structure (including defects), crystallographic perfection and the study of solid surface thin films and interfaces. This is the central facility for the laboratory

It is worth mentioning that scientist involved in the maintenance and development of such facilities are not only providing these characterization facilities to other groups of the organization but are very actively engaged in their own research programe in advanced areas thus enabling the group to remain close to the latest development in the field and to contribute towards generation of knowledge.

The division comprises of dedicated groups working in the field of X-Ray Analysis, Electron and Ion Microscopy, EPR and IR Spectroscopy and Analytical Chemistry.

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Director
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D 07.02 Electron & Ion Microscopy

Dr Sukhvir Singh
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D 07.04 Analytical Chemistry

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Dr (Ms) Daya Soni
Sh Niranjan Singh
Sh Rajiv Kumar Saxena
Ms Abha Bhatnagar
Dr Khem Singh

Crystal Growth and X-ray Analysis

Growth and Characterization of strategic and technologically important single crystals and thin films/LED structures.

Well-characterized single crystals, thin films or thin film based nanostructures are the building blocks of most of the advanced technologies of the modern science. Several important technologies like microelectronics, optoelectronics, communication, computers, photonics, lasers, information science, biosensors, radiation detection, nuclear science etc. require these well-ordered materials. Because of the stringent properties of modern devices the structure, purity and crystalline perfection are to be evaluated very accurately. X-ray methods have been well proven for these studies because of their non-destructive and convenient nature with good accuracy. The result obtained from the X-ray method is a statistical average of many ensembles as X-ray penetrates several microns into the specimen. At NPL we have established XRF for purity, powder XRD for structure assessment and for perfection we have variety of X-ray techniques like high-resolution X-ray diffraction (HRXRD), grazing incidence X-ray diffraction GI-XRD, X-ray reflection (XRR) and diffuse X-ray scattering (DXS). Characterization of single crystals by HRXRD includes the real knowledge about the arrangement of atoms/ molecules/ions including the dopants and their effect on the perfection, macroscopic defects like dislocations, structural grain boundaries, microscopic defects like point defects and their aggregates, crystallographic orientation of the surfaces, determination of radius of curvature of crystallographic planes. HRXRD is also very useful for characterizing epitaxial films to determine the film thickness, lattice mismatch, composition, depth profile, crystalline perfection of interfaces/substrates etc. which control the device performance characteristics like band gap energy, quantum effects, optical, electrical and electronic transportation.

Variety of MOCVD and MBE grown GaN based solid state light emitting diode structures at CEERI Pilani and at NPL have

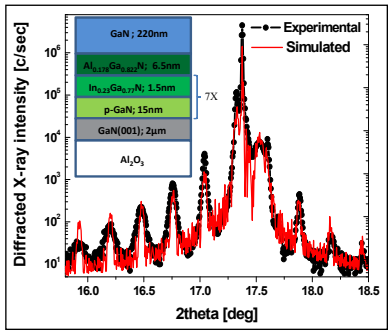


Fig.7.1 HRXRD studies on GaN based LED structure elucidating the quality (good fit) and various structural parameters and composition.

been characterized with required theoretical simulations.

The ever-increasing application of semiconductor-based electronics creates an enormous demand for high quality semiconducting crystals. Other applications like sensors and high energy radiation detectors demand ferroelectric, piezoelectric and oxide single crystals. Due to the unlimited capacity of data storage, processing and communication, nonlinear optical (NLO) crystals are expected to play a major role in photonics. Even in the upcoming nanotechnology, single crystals act as strong and reliable base, e.g. in the development of quantum wells and quantum dots. In view of these important applications, NPL is fully engaged in the growth of technologically important single crystals like Fe and Zn doped $LiNbO_3$, BSO, LC-added Benzophenone etc by Czochralski method and variety of nonlinear optical organic and semi-organic NLO crystals [Cr-doped ZTS, LHN, L-alanine doped KDP, Mn-doped L-alanine, Glycine Phosphite, trans-stilbene, ZnSe nanoparticles, etc.] by solution growth methods. Doping in NLO crystals are specially targeted to engineer the desired properties for tailor made applications.

In this financial year along with collaborators, this group has achieved a remarkable and record R&D output, which is published in 47 SCI journals with high impact factors (five papers have IF > 3 and average IF~2). A few of these well published investigations are described briefly in the following.

- Zinc Selenide (ZnSe) nanoparticles were synthesized by a microwave irradiation technique at 2.8 GHz using 7N purity Zn and Se powder in stoichiometric ratio as the starting materials. The crystallite size was calculated using Scherer's formula and found to be ~ 35 nm. The fluorescence study shows that the material is highly fluorescent. The broad emission peak at 401 nm (3.1 eV) has been observed in the fluorescence spectra and this value is highly blue shifted towards the lower wavelength from the bulk value, which shows confinement effect.
- A study of the effect of Cr^{3+} doping in zinc tris(thiourea) sulfate (ZTS, a well known nonlinear optical material) single crystals on crystalline perfection and optical properties was carried out. HRXRD analysis revealed that chromium doping lead to creation of vacancies in the single crystal that contributed to increase in the optical band gap. The doped crystals exhibited higher linear refractive indices than the pure crystals. The optical dielectric constant (), the extinction coefficient (k), the average single-oscillator energy for electronic transitions (Eo) and the oscillator strength (Ed) were evaluated and significant changes were observed in these parameters due to the Cr^{3+} doping (J. Appl. Cryst. 44 (2011)1054-1061, IF=3.8).
- The remarkable enhancement of the crystalline perfection of benzophenone (BP) crystals induced by liquid crystal (LC) doping has been investigated, and has in turn led to better optical properties. HRXRD demonstrates the elimination of structural defects due the high alignment capability of LCs which is observed for the first time. The LC-doped crystal exhibits higher optical transparency over its entire transparent region. The optical polarizing behaviour of the doped BP crystal is also improved (J. Appl. Cryst. (2011). 44, 839-845, IF=3.8).
- Benzil single crystals have been grown by the modified vertical Bridgman technique using the double wall ampoule with nanotranslation for the

first time. The crystals were characterized by HRXRD, FTIR, UV-Vis-NIR, PL studies. Studies show that the grown benzil crystals cutoff wavelength is around 434 nm. The second harmonic conversion efficiency of the grown benzil was determined. (Cryst. Eng. Comm, 13 (2011) 4018; IF=4.1).

- The effect of variety of dopants: transition metals (Cr, Mn, Co, Ni, Zn, Mg, Cd), rare-earth metals (Ce, Nd, La), dyes (rhodamine B, malachite green, fluorescein) and an amino acid (l-proline) dopants in good quality and optically transparent single crystals were characterized and studied the accommodating capabilities of in a typical ferroelectric glycine phosphite (GPI) crystals were studied by HRXRD (J. Appl. Cryst. (2011), 44, 313–318; IF=3.8).
- Structural analysis by XRD of zinc oxide samples for confirmation of crystalline phases and estimation of crystallite sizes in intrinsic, PVP capped, doped and composites samples were carried out. (J. of Colloid and Interface Science, 369, 40-45, 2012).
- Quantitative XRF analysis of CNTs-Al matrix composites was carried out. The weight % of carbon (corresponding to CNTs) determined by XRF was almost equivalent to that observed by TGA.

Pure and Zn-doped (1 mol%) $LiNbO_3$ single crystals have been grown successfully by the Czochralski technique with desired crystalline perfection. The Zn doping in crystals has demonstrated an enhancement in optical transparency over the entire visible and near-infrared wavelength range and optical band gap. The prism coupler, refractive indices and birefringence measurements infer that the doped crystal is suitable for photorefractive applications in the ultraviolet wavelength region. The evaluated Li concentration by Raman and UV, as well as birefringence depicts that the grown crystals are congruent in nature with a slight deviation from stoichiometry. (*Cryst. Eng. Comm*, 14 (2012)3297–3305, I.F=4.1)

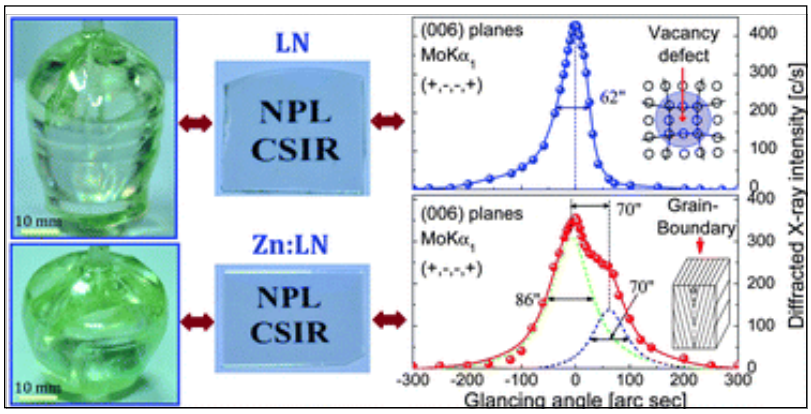


Fig.7.2: Pure and Zn-doped Lithium niobate single crystals (left) grown by CZ-method along with their HRXRD rocking curves.

AcSIR

The Division is also actively involved in AcSIR. A Course # NPL-603 entitled "Materials Characterization Techniques" for the First Batch of PGRPE on Advanced Materials Physics & Engineering is successfully taught with six practical. The theme of the course is "An advanced level introduction on characterization techniques for the analysis of composition, purity and structure including defects, surface and interface analysis." The course contains twelve X-ray related techniques and 12 other techniques along with their basic theory and analysis of the results.

Scientific Support and R&D Collaborations: The group is actively involved in providing scientific support to various groups of NPL and various outside laboratories through R&D collaborations by characterizing variety of samples by in-house developed multi-crystal X-ray diffractometer, Bruker AXS

D8 Advance Powder X-ray Diffractometer and the recently established XRF and HRXRD cum XRR systems. Samples have been characterized for purity including phase analysis, structure and perfection for various projects at NPL including the CSIR network projects NWP-025 and NWP-045 on materials development/metrology. No. of samples characterized to various NPL groups and collaborators: (i) by multi-crystal HRXRD: ~ 160, MRD system ~ 300, Powder XRD: ~700, XRF~150 whose notional cost is around Rs. 40 lakhs/-.

The major important technical achievements are:

1. A newly procured Vickers Micro- hardness tester has been installed successfully to characterize single crystals.

Electron & Ion Microscopy

The electron microscopes (HRTEM and SEM), Scanning Probe Microscopy (SPM) and Time of Light Secondary Ion Mass Spectrometry (TOF-SIMS) in the NPL are available to researchers to provide high-resolution images and microanalysis. The SEM lab has two SEMS, a LEO 440 SEM provides imaging with resolution of 3.5 nm SCI mode and of 5.5 nm in BEI mode. EVO MA 10, a variable pressure SEM provides images with resolution of 3.0 nm in SEI mode and 5 nm in BSE mode. It is equipped with SE, BSD, STEM and IR chamberscope.

NPL has a state of art FEG high resolution transmission electron microscope, FEI-Tecnai F30 G^2 STWIN. It has a point resolution of 0.205 nm and line resolution of 0.144 nm. The facility also has a STEM and EDAX attachment with resolution of 0.17 nm 136 eV respectively. Besides the single tilt and double tilt holder there is a special holder for in-situ high temperature measurements studies from 30^0 to 100^0C. Analysis of different types of samples in the form of thin films and powders prepared by various techniques are routinely conducted using the microscopes for their particles shape, size, distribution of particles, phase identification. The sample preparation laboratory for bulk samples has the whole range instruments for cutting, polishing, dimpling and Ion milling of samples and make them electron transparent.

Major areas where the group has contributed

1. Three Principal Scientists were actively involved in AcSIR. A Course # NPL-603 entitled "Materials Characterization Techniques" for the First Batch of PGRPE on Advanced Materials Physics & Engineering is successfully taught with six practicals on advanced characterization techniques.
2. **A US Patent for the removal of As and Cr from water- US 2011/0220577 A1**

   A Process removal of As and Cr from contaminated water using zinc peroxide nanoparticles comprising treating the contaminated water. At present there is no effective medicine available which can treat disease, caused by arsenic and chromium. Hence the requirement of As and Cr free water is urgently required.
3. A process to coat nano-copper on self sintering carbon material by electroless method and development of carbon – copper composite there from.- **Ref No. 011NF2011- An Indian patent under process**

   Nano particles of size 20-100 nm of copper were coated on coal tar pitch based self sintering green coke (GC) powder by electroless method which were after hydrogenation moulded and carbonized to 800°C to obtained the car-copper composites and were characterized for physical, mechanical and electrical properties
4. Morphological characterization of atmospheric ambient particles in the ganges (Kanpur): Preparation of database for aerosol optical/radiative properties estimation **(in collaboration with IIT, Kanpur).**

5. The effect of dust particles on the microwave signal attenuation is being studied by accounting particulate morphological (shape and size) parameters. As the Indian desert is the source of huge amount of mineral dust load in the atmosphere, samples have been collected from **Rajasthan from various altitude (hills) for the first time**

6. Development of bismuth telluride based thermoelectric composites reinforced with the MWCNT and BNNT to improve the figure of merit- under thermoelectric project of NPL in order to use these materials for energy conversion at high efficiency. Growth and characterization of single crystals of Bi_2Te_3, Bi_2Se_3 and BiSbTe in collaboration with Crystal Growth & X ray Analysis group in order to improve the figure of merit ZT of the materials

34 research papers in SCI journals have been published and more than 2000 samples of NPL R&D groups and outside organizations have been characterized by SEM, EDS, TEM, HRTEM, SPM and SIMS techniques.

An amount of Rs. 3.05 lacs was realized as test fee from industries and other institutes etc,

A detailed microstructural features associated with the Bi_2Te_3 thin films deposited at 300, 373 and 473 K have been investigated by using high resolution transmission electron microscopy (HRTEM) technique. TEM micrograph as shown in figure 7.3(a) reveals the formation of uniform film with presence of randomly oriented fine crystallites of polyhedral shape having particle size between 15nm to 36 nm. Selected area electron diffraction pattern (SAEDP) as shown in the inset of the micrograph revealed the polycrystalline nature of the film. On detailed analysis of the diffraction rings indicated the formation of single phase Bi_2Te_3. Reflection of weak intensity rings in the SAEDP is due to the presence of very fine particles. High resolution image recorded under HRTEM is as shown in figure 7.3b which depicts the interplaner spacing of two grains as 3.22A and 2.41A corresponding to the plane (015) and (1010) respectively of rhombhohedral structure of Bi_2Te_3 (JCPDS file no 82-0358). Area marked as A in the micrograph reveals the presence of moiré fringes which may be due to the development of stress/strains during the synthesis of the thin films and also due to the overlap of tiny nanocrystals.

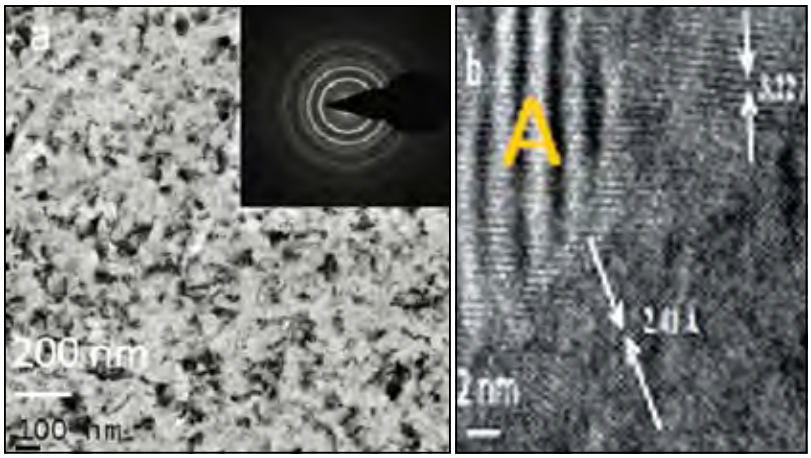


Fig.7.3 TEM micrograph and high resolution lattice image of Bi_2Te_3 thin films deposited at 300K

Thin film deposition temperature was further raised to 473K in order have thermodynamically stable phase of the Bi_2Te_3 in thin films. Fig. 7.4(a&b) represents the TEM and HRTEM micrographs of the thin films deposited at 473 K. It is revealed from the micrograph that grain size has further increased with polycrystalline nature of the film as depicted in the inset of the TEM image. High resolution image figure 7.4(b) depicts the presence of plane (015) and (110) respectively of rhombhohedral structure of Bi_2Te_3 (JCPDS file no 82-0358). All these thin films were

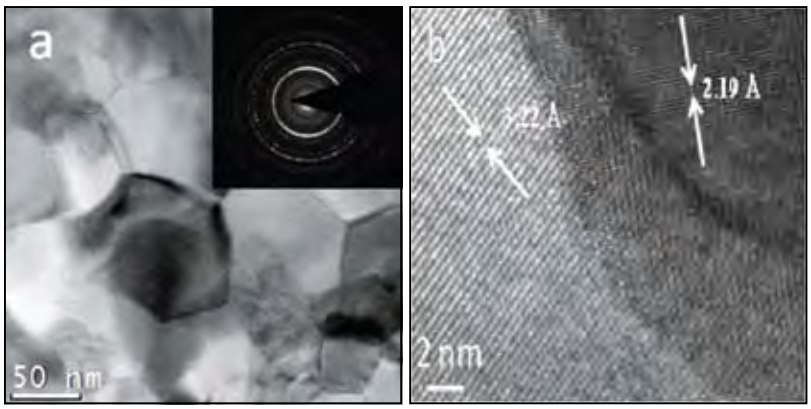


Fig.7.4 TEM micrograph and high resolution lattice image of Bi_2Te_3 thin films deposited at 473K

uniform, dense, having network of randomly oriented particles. Inset in fig 7.4(a) shows the corresponding SAEDP of Bi_2Te_3. In generals, it is observed that particles size increases with increase in the deposition temperature.

Scanning Probe Microscope

Scanning Probe Microscope (SPM) is one of the fast growing techniques for the study of surface properties of thin films. It is the central facility of NPL and is extensively used by different R & D Groups of Laboratory for the surface characterization in the field of Thin Film Technology. It includes Atomic Force Microscopy (AFM) and Scanning Tunnelling Microscopy (STM). NPL has Multimode-V (NS-V) which has other advanced mode techniques i.e. Magnetic Force Microscopy (MFM) (used for measuring spatial variation of magnetic forces over the sample), Electric Force Microscopy (EFM) (used for measuring electric field gradient above the sample) & Nanolithography (one of the nanoscale technology for the fabrication of nanometer scale structures and devices).

In 2011-12 total 320 samples were studied under SPM to see morphological effects like particle size, roughness and other magnetic & electrical properties for variety of materials like polymers and their composites, biological samples, CNTs, ZnO, TiO_2 nanoparticles, graphene oxide & graphene sheets, magnetic material thin films etc. Scanner calibration was done twice in the above said period. Few of the images obtained through AFM are shown below:

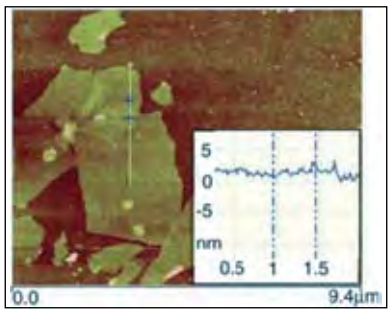


Fig.7.5. AFM image of grapheme sheets on Si(100) (Result published in Materials Today)

Time of Flight Secondary Ion Mass Spectrometry (TOF-SIMS)

Secondary ion mass spectrometry (SIMS) is a surface analytical technique used to determine the composition of the materials, where bombardment of a sample surface with a primary ion beam followed by mass spectrometry of the emitted secondary ions constitutes secondary ion mass spectrometry (SIMS).

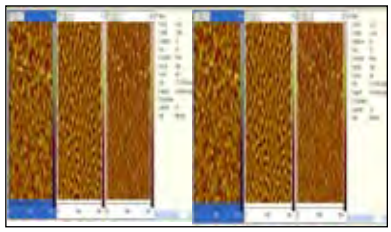


Fig.7.6. Normal Phase and MFM

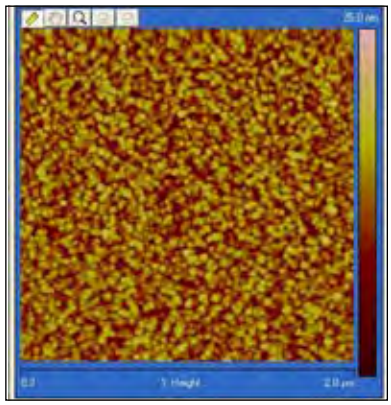


Fig.7.7. NbN deposited by sputtering with average roughness ~2.3 nm

In Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS), a pulsed beam of primary ions focus onto a sample surface that produces secondary ions in a sputtering process. These secondary ions are then accelerated into a "flight tube" and their mass is determined by measuring the exact time at

Fig. 7.8 TOF–SIMS at NPL

which they reach the detector (i.e. time-of-flight). Lighter mass reach the detector faster than the heavier one. The next pulse of primary ions cannot start until the secondary ions of the first pulse have cleared the analyzer. Otherwise the slower heavy ions of the first pulse are overtaken by the faster light ions of the second pulse. The TOF–SIMS available in NPL is shown in the above figure 7.8. The three modes of operation available are, Surface spectroscopy, Chemical imaging and Depth profiling. The visualization of 3D sample structures is possible by combining spectral, imaging and depth information. The composition, shape and position of features and defects can be visualized. Varieties of samples (Si and Organic solar cells, DLC, Oxide heterostructures, LEDs, Nanophosphors etc.) from various groups of NPL were

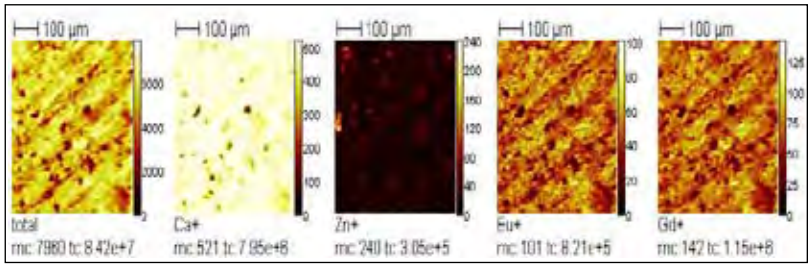


Fig. 7.9(a). Chemical imaging of $Gd_2CaZnO_5:Eu^{3+}$

analyzed using TOF-SIMS during this reporting year. Some of the results are shown below.

Fig. 7.9(a) shows the chemical imaging of $Gd_2CaZnO_5:Eu^{3+}$, where the intensity of Ca is highest compared to the other elements. From the intensity distribution of Eu & Gd, it says both the elements are distributed uniformly. The homogeneity of these two elements is confirmed by colour overlay shown in Fig. 7.9(b).

Fig. 10 shows the depth profile of N–DLC film deposited on a Si substrate. The intensity of C, H and N varies with depth and decreases at the interface where the intensity of Si goes up and moves constantly throughout the substrate

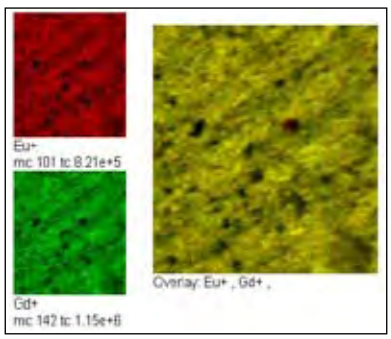


Fig. 7.9(b). Colour overlay of Eu & Gd

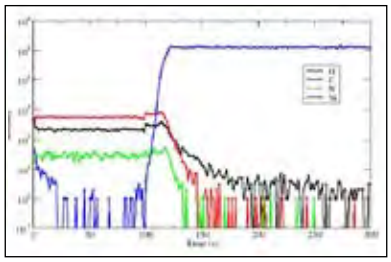


Fig. 7.10. Depth profile of N–DLC/S

Infrared and Raman Spectroscopy

Study of crystallographic structural transformations and the determination of lattice parameters in Si and Ge using IR reflectance measurements have been carried out. IR methods are generally employed for the determinations of various types of vibrations between atoms (group frequencies) and lattice vibrations of the molecule based on symmetry or point groups. However, for the first time, IR reflectance techniques have been used to study crystallographic structural transformations and for the determination of lattice parameters in Si and Ge. IR studies have also provided information's regarding the mass of crystal lattice (mass of atoms in space or Bravais lattice) and number of unit cells which are generally not provided by prevalent X-ray diffraction methods; developed by Laue and Braggs a century

ago. Also, lattice masses of Si and Ge crystals (determined from IR studies) are proportional to masses of their respective unit cells (obtained from X-ray studies) and IR d spacing at near normal incidence (10°). **Reviewer of the International SCI specialized top journal of area "Acta Crystallographica A" has agreed with the key result and has commented "This paper alludes to some possibly interesting approaches to the study of structural transformations and the determination of lattice parameters in Si and Ge using IR reflectance measurements.** The paper been completely rewritten incorporating all the reviewer's comments and suggessions and is ready for the resubmission shortly.

Infrared, Raman and XRD diffraction studies on nano crystalline silicon have revealed that there is complete agreement between results Infrared and Raman studies. This has shown that size of nano crystal play an very important role in determining the crystalline and amorphous states. The smaller crystals has crystalline state whereas larger crystals has amorphous state. IR angular results of specular reflectance and regular transmission have shown astonishing results having complete agreement between reported X-Ray diffraction. This work is available in souvinor of below mentioned international SCI conference

EPR Spectroscopy

R & D Activities

In recent years, ferrofluids have emerged as an active area of research due to their enhanced thermal, rheological and magnetic properties over the base fluids. These fluids move as whole in the direction of applied magnetic field and offer an excellent property for sensor & actuators, Thus making them very attractive in variety of applications like sensors, biomedical, energy and magnetic data storage, etc. During this period, we have prepared magnetic nanoparticles of Fe_3O_4, $CoFe_2O_4$, Gd^{3+} doped $Ni_xZn_{1-x}Fe_2O_4$ and investigated their physical properties like structural, morphological, rheological and magnetic by XRD, FTIR, SEM, HRTEM, AFM, VSM, Magnetorheometer and EPR spectroscopic techniques. These investigations have helped us in developing stable and suitable ferrofluid for device based applications. Some of the results of our investigations are as follows:

Induced size effects of Gd^{3+} ions doping on structural and magnetic properties of Ni-Zn Ferrite nanoparticles

Gd^{3+} ions substituted $Ni_{0.5}Zn_{0.5}Gd_xFe_{2-x}O_4$ (where x = 0.1,0.2,0.3) ferrite nanoparticles in the size range from 15 to 25 nm were prepared by chemical method. The effect of Gd^{3+} ions in spinel structure in correlation to structural and magnetic properties has been studied in detail using XRD, HRTEM and EPR techniques. A detailed high resolution transmission electron microscopy experiments were performed to reveal the nano – scaled features of Gd^{3+} doped Ni – Zn ferrite system in real and reciprocal space. It was noted that the addition of Gd^{3+} (0.1, 0.2 and 0.3 wt.%) leads to increase in the size of the Ni – Zn ferrite nanoparticles. These nanoparticles are random in shape with normally facetted morphology with sharp edges and vertices (Fig. (a), (b) & (c)). The average size of the particles

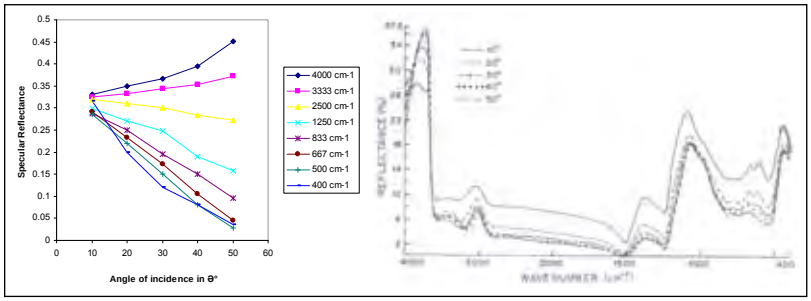
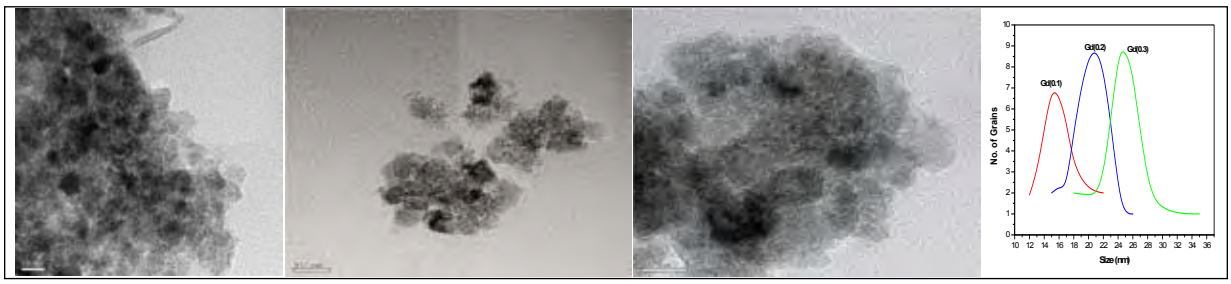


Fig. 7.11 (a) IR Specular Reflectance of one surface polished Si verses angle of incidence, Θ°at various wavenumber (cm^{-1}). (b) Angular FT-IR reflection spectra of Nano crystalline Si film on glass.

Division 7

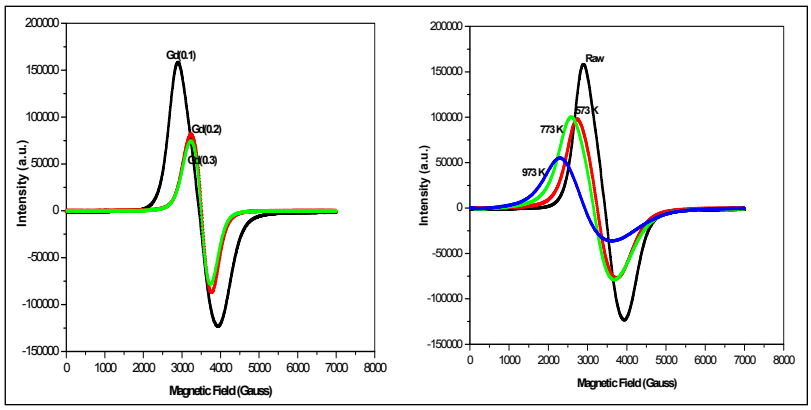


(a) (b) (c) (d)

Fig. 7.12 HRTEM images of nanoparticles: (a) $Ni_{0.5}Zn_{0.5}Gd_{0.1}Fe_{1.9}O_4$ (b) $Ni_{0.5}Zn_{0.5}Gd_{0.2}Fe_{1.8}O_4$ (c) $Ni_{0.5}Zn_{0.5}Gd_xFe_{2-x}O_4$ (where x = 0.1, 0.2, 0.3) and (d) corresponding size distribution curve for nanoparticles.

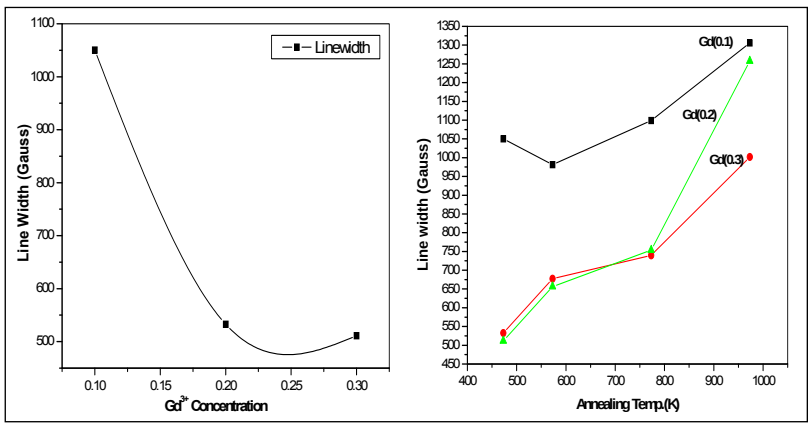
was noted about 15, 21 and 25 nm for $Ni_{0.5}Zn_{0.5}Gd_{0.1}Fe_{1.9}O_4$, $Ni_{0.5}Zn_{0.5}Gd_{0.2}Fe_{1.8}O_4$ and $Ni_{0.5}Zn_{0.5}Gd_{0.3}Fe_{1.7}O_4$ respectively (Fig. 7.12).

EPR spectra confirm the ferromagnetic behaviour of these nanoparticles due to higher order of dipolar-dipolar interaction. On increasing Gd^{3+} ions concentrations in sample the narrowing of signal is observed that explains the increase in super exchange interaction i.e. movement of electron among Gd^{3+}-O-Fe^{3+} in the core group and the spin biasing in the glass layer. The decrease in g value and increase in relaxation time is correlated with increase in particle size as the Gd^{3+} ions concentration increases in Ni-Zn ferrite nanoparticles.



(a) (b)

Fig. 7.13. EPR spectra (a) Gd^{3+}: $Ni_{0.5}Zn_{0.5}Gd_xFe_{2-x}O_4$ (where x = 0.1, 0.2, 0.3) ferrite nanoparticles and (b) $Ni_{0.5}Zn_{0.5}Gd_{0.1}Fe_{1.9}O_4$ annealed at different temperatures.



(a) (b)

Fig. 7.14 Variation of linewidth with (a) Gd^{3+} conc. And (b) at different annealing temperatures

Major Facilities Established

1. **Electron Nuclear Double Resonance Spectrometer (ENDOR) accessory to the existing X- band EPR spectrometer**

ENDOR Specifications:

- Frequency range: 1 to 100 MHz
- Frequency modulation with amplitude upto 1 MHz
- RF Amplifier: 1-100 MHz, 100 W
- RF Attenuator: 60 dB maxium. Attenuation, 1 dB step
- X-band EPR/ENDOR resonator
- ENDOR software package
- Operating mode: FM ENDOR

ENDOR Resonator

EPR Spectrometer with ENDOR

2. **Rheo-microscopy attachment to the existing Magneto-rheometer**

Rheo-optics Rheo-microscope Microscope

Make: Anton Paar, Model H-PTD200/GL

Specifications of Rheo-microscope attachment for existing Mangeto-rheometer

- Light microscopy simultaneous to rheological measurements
- Universal temperature control for optical systems based on Peltier- (-20 to 200°C)
- Modular open design of microscope with standard optical components
- CCD Camera, microscope lens and light source are exchangeable
- Lens magnification: 50x
- Measuring systems made of glass to avoid reflection
- Microscope can also be used as stand-alone system

Image recording and display

- Rheometer software controls both rheometer and CCD camera
- Automated image/ video recording during measurement
- Direct assignment of images and videos to rheological data

Analytical Chemistry

The mandate/mission

Analytical Chemistry group focuses on the Metrology in Chemistry (MiC) and Certified Reference Materials (CRM) activities for SI 'mole', to help provide traceability at apex level in country, through a nationwide network of MiC partners, under CSIR network project 'Advances in Metrology'. It involves building capacity & quality system and participation in CCQM & APMP international key-comparisons and help establish international collaborations in MiC with PTB Germany. Its mission is helping showcase CSIR-NPL & partners chemical metrology services in equivalence with international NMIs; interaction and close cooperation with national (BIS, NABL, QCI, CPCB, IMD, ICAR, MoEF, ISRO-GBP and Universities) & international (BIPM-CCQM-APMP, CITAC, ISO, PTB/BAM Germany, NIST USA etc) stakeholders for dissemination of SI traceability, quality data and spreading MiC awareness/ education. The group has been working for chemical analysis need for challenges in NPL & in MiC & CRM activities with its tremendous scope, the activity is touching all aspects of life like environment, drinking water, food security, health, energy, trade, societal sectors and international trade.

Besides metrology the group has R&D work in the feed of aerosol metrology, second national communication (NATCOM-SNC): Greenhouse gases emission factor development & inventory in waste sector and provides QA/QC support to all national teams for various sectors.

Proficiency testing (PT) schemes for iron ore/ coal with NML Jamshedpur and pesticide solutions with IITR Lucknow were carried out for Indian testing labs. MiC activities international peer were successfully done for the CMCs of elemental solutions. CRMs and primary ozone calibration facility for ambient ozone UV-absorption based measurement systems. These services are now open to users. Key R&D activities are;

1. CRM preparation of elemental solutions

Five new elemental aqueous certified reference materials i.e. Bharatiya Nirdeshak Dravyas (BNDs/ or CRMs) namely Pb (50 mg/kg and 100 mg/kg), Cr (110 mg/kg), Ca (100 mg/kg) and SO_4 (50 mg/kg) were prepared and certified according to quality management system based on ISO/IEC-17025 and Guide 34/35. Certified values are assigned by gravimetric primary method (traceable to SI through CSIR-NPLI mass).

2. Quality System and International Peer-review on CRM activity

Quality management system (ISO/IEC-17025) in aqueous elemental solution analytical capability after their preparation (as per ISO Guide 34/35) under inorganic analysis CRM activity has been implemented. An international peer-review on elemental aqueous solution (CRM) preparation activity was successfully completed for 13 No. CMCs (Table-7.1) during February 21-23, 2012 by the technical expert from BAM Germany.

Table 7.1: Brief information about elemental aqueous CRMs

BND ID	Matrix	Analyte/ elements	Certified value (in mg/kg)
BND 20.100.01	Mono-elemental aqueous solution	Ca	100
BND 401.04	Mono-elemental aqueous solution	Cr	0.83
BND 405.01	Mono-elemental aqueous solution	Cr	4.80
BND 24.110.01	Mono-elemental aqueous solution	Cr	109.60

BND 2401.01	Multi-elemental aqueous solution	Fe, Cu, Zn	0.81, 0.89, 0.83
BND 2301.01	Multi-elemental aqueous solution	Pb, Cd, Ni	0.89, 0.91, 0.81
BND 2305.01	Multi-elemental aqueous solution	Pb, Cd, Ni	4.88, 4.78, 4.82
BND 82.50.01	Mono-elemental aqueous solution	Pb	49.98
BND 82.100.01	Mono-elemental aqueous solution	Pb	102.8
BND 2101.01	Mono-elemental aqueous solution	K	0.84
BND 2105.01	Mono-elemental aqueous solution	K	4.67
BND 501.01	Mono-elemental aqueous solution	Ag	0.82
BND 505.01	Mono-elemental aqueous solution	Ag	4.8

3. Participation in International Inter-comparison studies

(i) Participation in inorganic and gas analysis areas for three international inter-comparison studies was done (Table-7.2) i.e. for Fe, Cd, Zn, and As elementals in herb/ seafood and for CO_2 in nitrogen.

Table 7.2: International inter-comparison participation by NPLI

Inter-comparison	Matrix	Analyte/ component	Technique used
APMP.QM-P18	Herb	Cd and Zn	F-AAS
APMP.QM-S5	Seafood (shrimp)	As, Fe, Zn Cd,	GF-AAS F-AAs ICP-HRMS
EURAMET-1166	Nitrogen	CO_2	GC-FID / Gravimetric

(ii) Participation in aerosol or nanoparticles size measurements international inter comparison participation was done under VAMAS project (TWA 34: Project 3 "techniques for characterizing the morphology of airborne nanoparticles") using the SMPS system, and following the protocol as shown in Figure 7.15. Measurements of particle size in the supplied suspension (PSL 80nm) were to be 78.02±2.80 nm (at k = 2). A typical AIM software data view from these SMPS measurements (n = 10) is shown in Figure 7.16.

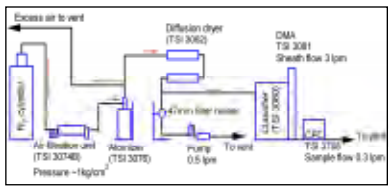


Fig. 7.15. Setup for SMPS analysis

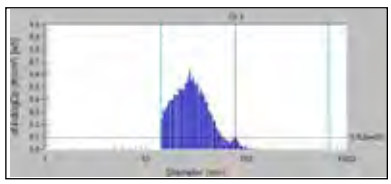


Fig. 7.16 A view of size distribution measurement of PSL 80 nm sample using SMPS

Major facilities established during the year 2011-12

(i) GC-PDHID System

The Gas Chromatograph (GC) with Pulsed Discharge Helium Ionization Detector (PDHID) is

Fig. 7.17 GC-PDHID system for trace gas analysis

a non-destructive and highly sensitive gas analyzer system. Its response to organic compounds is linear over five orders of magnitude with minimum detectable levels (MDLs) in the low picogram (pg) range. Response to fixed gases is with MDLs in the low parts per billion (ppb) ranges. It is being used for gas impurity analysis of the constituent gases for gas metrology activity.

(ii) Cylinder Evacuation System

Vacuum system for pressure vessel evacuation has been procured from PTB Germany, under the PTB-NPL MiC technical cooperation during 22-30 March 2012. The system is being used for the evacuation and blending/ preparation of gas standard mixtures. This evacuation system can be attached to maximum 4 No. of gas cylinders.

Fig. 7.18. Vacuum system for pressure vessel evacuation

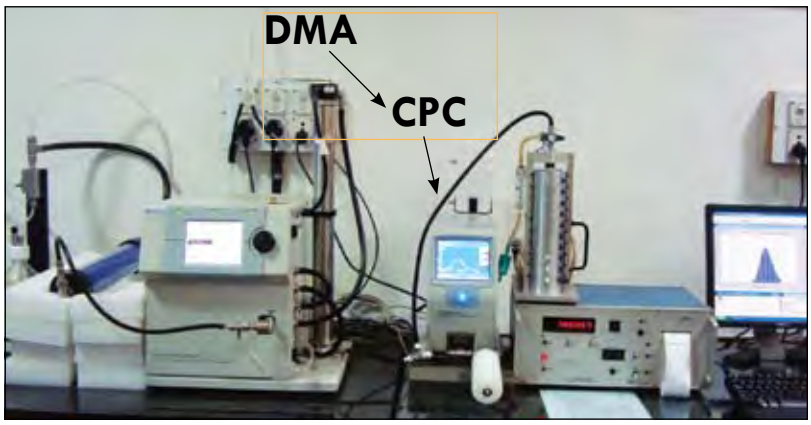


Fig. 7.19 Scanning mobility particle sizer (SMPS) setup

(iii) Scanning Mobility Particle Sizer (SMPS)

SMPS is a combination of Differential Mobility Analyzer (DMA) and condensation particle counter (CPC). In this system (Fig. 7.19), the DMA segregates particles depending on their electrical mobility followed by the particle number concentration measured by CPC based on the scattering of light. The particle size range and number concentration, which can be determined is 10-800 nm and $4x10^5$ particle/cm^3 respectively.

Highlights of R&D on Aerosol research

Tracing of aerosol sources is an important task helpful for making control strategy, and for climate change study. Open waste burning has been believed to be a considerable source of aerosols in several mega cities in India and China. To better understand this source contribution in New

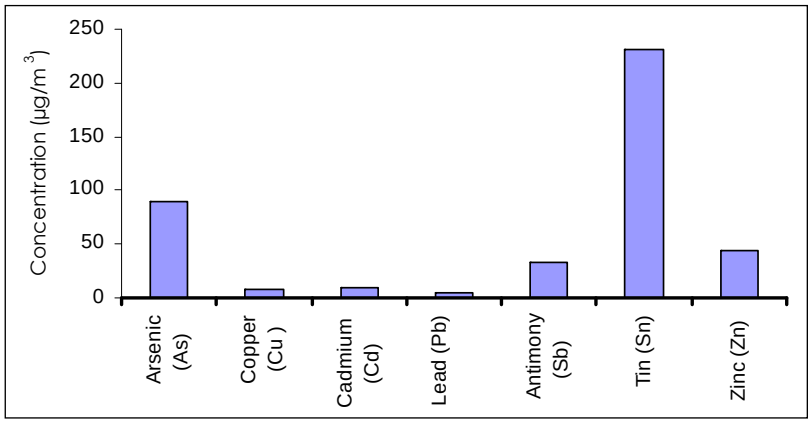


Fig. 7.20 Metal concentration in a typical waste-buring aerosol sample filter

Delhi aerosols, samplings were conducted at landfill site of Okhla and in its proximity (within 1 km). Aerosol filter samples were acid digested and analyzed using inductively coupled plasma – high resolution mass spectrometry (ICP-HRMS) for trace metal signatures in particles. The metals, e.g, Sn, Sb and As those are found almost negligible in remote aerosols, are maximized in these garbage burning aerosols (Fig. 7.20). Preliminary studies of isotopic ratios of these metals suggested that these metals, especially Sn can be used as marker for tracing the open waste burning sources of aerosols in New Delhi.

Formation of secondary aerosols particles and their subsequent growth in atmosphere is largely due to gas-to-particle conversion. Understanding of effects of secondary aerosols on climate and health are more complex as their distribution and fraction in aerosol mass are highly uncertain. Measurement of frequency of these nucleation events can help to better constrain the secondary aerosols distribution, and hence aerosol effects. Scanning mobility particle sizer (SMPS) has been used to observe such nucleation and growth events in winter-2011. One of the results is shown in Figure 7.21 in the form of a plot between size (mode peak diameter of the size distribution) versus time on 4th November 2011, from 10:38h to 15:02h. Study suggests that polluted air of the mega city like New Delhi is much susceptible for such events where major sources of aerosols reported are vehicular emission and biofuel - biomass burnings. Long-term measurements of aerosol distribution and trace gases would further help to better model the distribution of secondary aerosols.

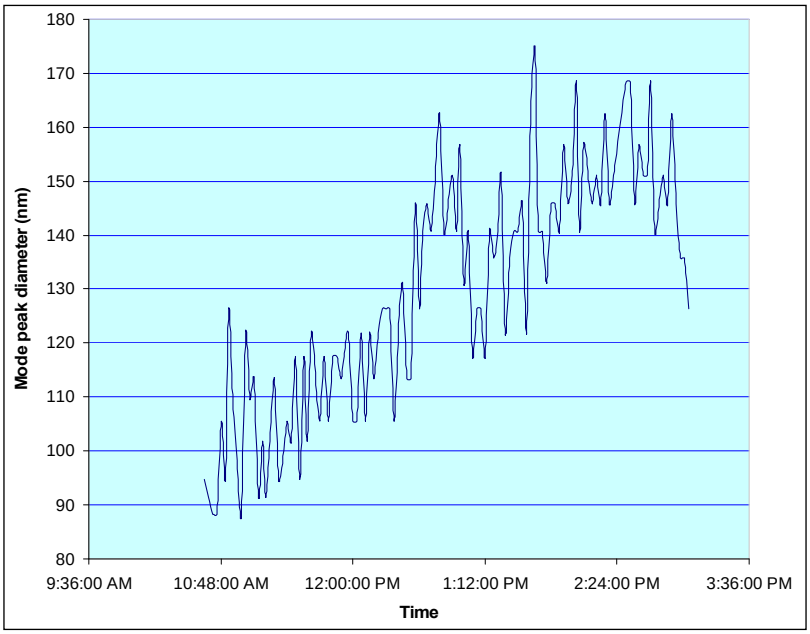


Fig. 7.21 Particle nucleation and subsequent growth observed in New Delhi using SMPS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CSIR · INDIA ·


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वैज्ञानिक एवं प्रशासनिक सहायक सेवाएं

Scientific and Administrative Support Services

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Sh V D Arora
Sh Ashok Kumar
Mrs Anita Sharma

Industrial Liaison Group
Dr (Ms) Jyoti Lata Pandey

Human Resource Development Group
Dr Rajeev Chopra

International Science and Technology Affairs Group
Sh S K Sharma
Dr V K Gumber
Sh Ashwani Kumar Suri

Knowledge Resource Centre
Sh N K Wadhwa
Sh Abhishek Sharma
Sh Jagdish Prasad
Sh Rajpal Zamaji Walke
Ms Neetu Chandra

Workshop
Dr R K Kotnala
Sh Ravi Khanna
Sh P Srinivasan
Sh Jai Pal Singh
Sh Amar Singh

Computation & Network Facility
Dr Ravi Mehrotra
Mr Ashish Ranjan
Ms Deepti Chaddha
Mr Nitin Sharma
Ms Anjali Sharma
Mr Trilok Bhardwaj
Mr Kanwaljit Singh
Mr Vijay Sharma

Quality Management System
Dr Rakesh Kumar Garg

Planning, Monitoring and Evaluation Group (PME)

Contract R & D Projects, as Sponsored, Collaborative and Grant-in-Aid Projects are undertaken by the Laboratory with funding from External Agencies. Before submission of the project proposals to the outside agencies they are evaluated by the Group based on various criteria and conditions. Monitoring and developing of complete database for report generation on projects are done and project files are created and maintained. Similarly Major Laboratory Projects and other In-house Projects funded by CSIR & NPL, undertaken in NPL, are also monitored. Fund allocation and processing of indents is an important activity undertaken by this group. The report on completed projects and refund of unspent balance to the funding agencies at the end of project are made by the group.

PME prepares Annual Plan and Five Year Plan for NPL. It organizes Research Council meetings and coordinates the Management Council meetings, organized by administration. Time to time PME disseminates information on projects, performance reports and ECF reports to CSIR. PME is also involved in monitoring of Networking Projects. PME developed manpower data and maintains staff positions and disseminates the information to various authorities. The group also maintains and regulates the appointments of project staff under various externally funded projects.

PME has the additional responsibility of getting feedback on degree of customer satisfaction in a prescribed format from funding agencies who are funding the different contract research projects in NPL. The process is done at the end of each project. This function has been initiated by CSIR under the supervision of Customer Satisfaction Evaluation Unit (CSEU) at CSIR Headquarter, Rafi Marg, New Delhi – 110 001. The feed-back received from the funding agencies are sent to CSEU, CSIR.

PME prepares many types of reports on Manpower in different formats as required from time-to-time and also does different type of Analysis for manpower planning of the laboratory.

Publication of Annual Report is another important activity of PME. On receiving inputs from various Divisions & other concerned groups, Text and Apendices of Annual Report are compiled, corrected and published in the form of Annual Report each year.

Industrial Liaison Group (ILG)

The Industrial Liaison Group (ILG) is responsible for the commercialization of research

and knowledge developed by the NPL scientists and researchers. Our focus is to foster and develop collaborative work environments between researchers, industry partners and funding agencies. We want to ensure that the relationships created through the commercialization of a technology continue to add value for all partners; leading to ongoing research projects for the inventor and the industry partner and to the commercialization of complementary technologies.

In addition, this group also undertakes consultancy, technical services and dissemination of science and knowledge base. This group is responsible for all matters connected with business development. It also helps in organizing "Technology" Day and "World Metrology Day" function where all licensees are invited to interact and deliberate with concerned PI of the technology. It also helps in organizing "Open Day" function, wherein few thousand school and college students with their teachers are invited to see the various scientific and technical activities at NPL. This group further carries out the dissemination of science through publication in CSIR news and in CSIR annual report, business and industrial magazines and their websites and through advertisements in news papers, conferences, symposiums, various other events and their souvenirs and also through participation in exhibitions. Processing of applications for the awards pertaining to technology or consultancy services is rendered. This group also undertakes distribution of royalty, premia and intellectual fee pertaining to consultancy, technical services and technology know transferred. It further updates industries, licensees and scientists for any CSIR/DST entrepreneurship/ funding schemes for applying for awards/projects. It updates scientists about scientific and technical exhibition, events. It acts as bridge in resolving scientific and technical issues raised by industries/clients for providing them solution through technical and consultancy services. This group also takes care in the management of S & T outputs with other funding agencies viz. DST, CSIR, NRDC, AIMA, CDC, FICCI, etc. This group interacts with FICCI and loads technology inventions at their website for wider exposure, collaborative work, market search and entrepreneurship demand. During the year, the ECG-PC based plug-in device received best technology award among technologies screened by CSIR. The USB based PC plugin ECG monitoring device which provides high quality ECG records is extremely cost effective. The group disseminated Knowledegebase / Technology during India-Africa Exhibition held in Vigyan Bhawan Taj Palace and at 99th Indian Science held during January 3 -7 2012 at Bhubaneswar.It Extended support to M/s Imax Media Pvt Ltd, New Delhi and Vigyan Prasar, who made documentary film on footage of Dr. K S Krishnan. This film was well appreciated by jury.

This group has initiated its efforts in setting-up an Incubation Center and possible knowledge alliance with Sensor Technology Pvt. Ltd., Moser Baer Photovoltaic Limited, Prabhatam Radisafe Limited, New Delhi, Reinste Nano Ventures Pvt. Ltd, Noida, Jyoti Cero Composite, Jamshedpur, ONGC energy center, Dehradun, GTC Technologies, Houston USA in the area of carbon composite, energy, sensor electronics, solar energy biological instrumentation water purification, EMI shielding, radiation safety etc. A certificate for setting-up of NPL Technology Innovation Center (NTIC) under Sec-25 company act will be issued during early 2012-13 as informed by registrar of Companies during 2011-12.

Human Resource Development Group (HRDG)

The Human Resource Development (HRD) Group of NPL is a constituent group of SASD 8 and represents a central group of the laboratory providing a wide range of HRD services. It undertakes several activities in various areas of core competence of the lab and also related to the research scholars.

The group is involved in various activities, such as, Organisation of Industrial Training in Metrology/ Standards, Placement and support to Research Scholars, Training for M.Tech./MCA/M.Sc. students from all over the country, Institutional Visits, Deputation of NPL staff members to attend conferences, etc. The basic object behind these activities is to make the Human Resource better informed, knowledgeable and highly skilled & trained so that it can prove to be more competitive, productive and useful to the society and the country.

International Science and Technology Affairs Group (ISTAG)

International Scientific Collaborations is rising to enhance the quality of research. ISTAG group facilitates the visits of scientific and technical personal of the laboratory. It advises the scientists to participate in International Conferences, seminars and summer schools. It helps the scientists to get prestigious international fellowships. This group also advises the scientists to avail bilateral exchange programme. It also organizes the visit of foreign delegations at NPL. International experts are invited to give talks and lectures at NPL. The scientific staff is motivated to avail sabbatical leave/study leave. Arranging training programmes for international candidates is also the job of this group. International collaborative projects, bilateral exchange programme and MoU are also handled by this group.

Knowledge Resource Centre (KRC)

NPL Knowledge Resource Center (KRC) has been providing library and information support to scientists for R & D pursuits.

Over the years, it has developed a rich collection of scholarly books and journals for the purpose, especially in the field of physics and related sciences.

During the current year, KRC subscribed to 93 scholarly journals (*72 foreign journals and 21 Indian journals*) and added 561 books, out of which 286 were S&T books, 275 were Hindi books. KRC serves the NPL community with services like Reprographic service, Electronic Document Delivery service, Inter Library Loan service, Reference service, Literature Search service etc.

NPL-KRC offers online access to more than 6000+ full text journals under the e-consortium project of NKRC (CSIR+DST). The project facilitates access to electronic content from various publishers such as Elsevier, Springer, AIP (American Institute of Physics), APS (American Physical Society), AGU (American Geophysical Union), Wiley - Blackwell, Oxford University Press, Royal Society of Chemistry, American Chemical Society etc as well as the archives of few publishers on concession rates.

KRC is also providing access to intranet edition of Indian Standards.

The shift in technology achieved with the installation of improved routers helped in attracting the R & D personnel in large number to make use of NPL-KRC and leads to optimize the use of the subscribed/ entitled e-resource as well as internet resources.

On continuous basis, KRC maintains its site on the NPL intranet to provide latest information on its activities such as additions to its collection, current subscribed journals, new journals received during the week, links to electronic libraries, publishing houses, and papers published by NPL researchers.

NPL-KRC also maintains NPL website (http://www.nplindia.org) on Internet to inform others about the activities of NPL such as its role towards the society, thrust area of research, facilities, services and achievements.

Further, to improve the quality, speed and effectiveness of services, KRC has completed the second phase of the automation task i.e. retro-conversion of books. With this, end users of KRC would avail the value added services associated with the NPL-KRC Information System (NKIS).

In the direction of providing

free worldwide access to the intellectual outputs of NPL in form of journals articles, research papers, conference papers, technical reports, preprints, and other scholarly communication and also to support the concept of open access initiative, NPL-KRC has established its Institutional Repository (IR@NPL) http://npl.csircentral.net/

NPL-KRC has moved its steps towards digitization in order to preserve the valuable information available in the print format. For the same MoU between NPL and Indian Institute of Information Technology (IIIT) Allahabad has been signed as a formality to enter into a UDL (Universal Digital Library) Project, a strictly non-commercial project, funded by Ministry of Communication and Information Technology, Govt. of India, New Delhi. Till date, more than two lakhs pages have been digitized under this project.

Central Workshop & Glass Technology Unit

Central Workshop has successfully completed 863 jobs related to R & D and maintenance work costing approximately Rs. 1.9819 crore (Rs. One crore ninety eight lac nineteen thousands) only. The jobs included designing , drawing, fabrication and development of various components required by the several scientists for their activities. Most of them are highly sophisticated components related to various R & D works.

In the Glass Technology Unit, we completed 120 jobs of different sections in N.P.L. It included the sealing of quartz ampoules, making of reactors B-45, Bubbler B24, distillation plant, condenser, covering of filaments in quartz tubes and electro chemical cells.

Due to good preventive maintenance, most of the machines in work shop are in good working condition.

Computation & Network Facility (CNF)

IT Infrastructure

The CNF strives to continuously upgrade the IT infrastructure at NPL, to keep up with ever increasing demand for IT facilities, and at the same time ensure reliable and secure operations. The NPL Data Centre houses various servers and security devices with redundant internet connectivity which are continuously monitored and dynamically reconfigured for maintaining efficient and secure services. Currently, the servers performing cirtical operations include Mail, Web, DHCP, DNS, Intranet, Anti-virus, Computation, Database, and Backup. The security devices include antivirus solutions and a Unified Threat Management system(UTM) consisting of a multi-level firewall and anti-spam solutions.

A Gigabit fiber optics based backbone now connects all buildings on campus providing LAN connectivity to approximately a thousand computers. A new leased line connectivity with NKN (National Knowledge Network) has been established raising the internet bandwidth from 12Mbps to 1Gbps. Apart from this, CNF continues to provide IT hardware and software support to end-users.

A 128-core computational cluster has been established, which provides high performance computing facility to NPL research community. An enterprise level hardware facility like Storage Area Network (SAN) is being setup.

Inhouse Software Development

The CNF has been developing automated processes using open source technologies to create conducive and transparent environment for day to day tasks for both researchers and administration.

A web based Instrument Booking System (e-IBS) has been developed and deployed to efficiently manage various sophisticated and analytical instruments at NPL. The features include calendar availability and online reservation of the instruments, automatic email notifications and management of instruments. Access to various functionalities of the system is as according to defined roles.

A web based application system for Gp (IV) recruitment, developed earlier has been

enhanced to include automatic generation of synopsis sheet for screening of candidates, to speed up the recruitment cycle.

Currently, the process for deputation of NPL staff members to attend conferences/similar events is being automated.

Automation of Library processes has been completed. This facility is now online for the end-users.

R&D activities:

Under the DST sponsored project entitled "Innovative Product Development Centre", the Linux based software for operating the compact, low cost, PC-plugin 12-lead ECG device has been ported to the Windows platform. The Windows based software has enhanced features and has been packaged in the form of a product.

An ultra low cost brain oximeter, which measures the oxygen content of the blood flowing in the brain non-invasively has been developed and successfully tested in the laboratory.

Quality Management System

- To establish the international acceptability of the calibration & measurement capabilities of NPL worldwide;
- To give users reliable quantitative information on the comparability of national metrology services;
- To provide the technical basis for wider agreements negotiated for international trade, commerce and regulatory affairs.

This group maintains Quality System in NPL, based on the international standard IS/ISO/IEC 17025:2005, in the area of Test and Calibration. All the test/calibration areas of NPLI are periodically audited to confirm the continued compliance to the international standard.

Due to reorganization of different Groups of NPL, the Quality Manual was revised last year. Accordingly, the different activities were guided to revise their document manuals.

The QMS group coordinated the Peer reviews of four activities namely, Acoustic, Vibration & Ultrasonics, Ozone standards, Magnetic Standards and Inorganic solutions under Chemical Metrology. Out of these, three peer reviews was done for first time. This group helped all these activities to implement the quality system and for preparation of the peer review.

A delegation from NPL participated in APMP General Assembly and related meetings held in Japan. Laboratory Report of NPL was prepared and submitted to APMP in its General Body meeting. The QMS annual report was also submitted in APMP QS TC meeting.

A special training course on "Quality Management System – Laboratory Management, Need for Calibration / Accreditation as per IS/ISO/IEC-17025" was conducted during January 30 – February 01, 2012 for the staff of Department of Legal Metrology. About 30 participants from different states attended the course.

Team Members:

Dr. R. K. Garg, Quality Manager

Mr. A. K. Saxena, Dy. Quality Manager

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राजभाषा कार्यान्वयन

Rajbhasha Unit

'सौर ऊर्जा अनुप्रयोगों के लिए पदार्थों और साधनों में वर्तमान प्रगति' पर राष्ट्रीय संगोष्ठी – 2011

पुरातन काल से ही मानव सौर ऊर्जा का विविध प्रकार से उपयोग करता आ रहा है। अनन्त काल से सूर्य मानव, पृथ्वी एवं ब्रह्माण्ड के लिए अनवरत ऊर्जा का स्रोत रहा है। हमारी भारत भूमि पर प्रतिवर्ष 250–300 दिन 4.7 kWh/m^2 सौर विकिरण प्राप्त होता है। संकीर्ण होते जीवाश्म (fossil) ईंधन और उससे जनित प्रदूषण के कारण विश्व का वैज्ञानिक समुदाय सौर ऊर्जा के समुचित उपयोग हेतु प्रयासरत है। राष्ट्रीय भौतिक प्रयोगशाला के वैज्ञानिक सौर ऊर्जा के अथाह प्रभाव से अवगत रहे हैं और विगत 30 वर्षों से भी अधिक समय से सौर ऊर्जा के विभिन्न प्रकार से उपयोग हेतु शोध कार्य कर रहे हैं। इस क्षेत्र में क्रिस्टलीय सिलिकन, अक्रिस्टलीय तनुपरत सिलिकन, कैडमियम टेल्युराइड सल्फाइड सौर सैल, सौर पैनल तथा सौर उष्मा से बनी युक्तियों (devices) पर शोध कार्य में प्रयोगशाला देश में अग्रणी रही है और इसने अनेक प्रौद्योगिकी हस्तांतरित की हैं।

राष्ट्रीय भौतिक प्रयोगशाला में 1–2 सितंबर, 2011 को 'सौर ऊर्जा अनुप्रयोगों के लिए पदार्थों और साधनों में वर्तमान प्रगति' विषय पर राजभाषा हिन्दी में दो दिवसीय राष्ट्रीय संगोष्ठी का आयोजन किया गया। संगोष्ठी में सौर ऊर्जा के समुचित उपयोग हेतु देश भर के अन्य संस्थानों में संलग्न वैज्ञानिकों एवं शोध कर्त्ताओं को आपस में विचार विमर्श करने और अपने अनुभवों के आदान–प्रदान के लिए आमंत्रित किया गया। इस संगोष्ठी के उद्घाटन समारोह में श्री दीपक गुप्ता, सचिव (एम.एन.आर.ई.), भारत सरकार के मुख्य अतिथि थे। प्रो. एस. के. जोशी, पूर्व महानिदेशक, सी.एस.आई.आर. ने समारोह की अध्यक्षता की। उद्घाटन समारोह का मुख्य अभिभाषण प्रो. बी. एम. अरोड़ा, भारतीय प्रौद्योगिकी संस्थान, मुम्बई ने दिया।

संगोष्ठी का शुभारंभ प्रो. रमेश चन्द्र बुधानी, निदेशक, राष्ट्रीय भौतिक प्रयोगशाला के स्वागत भाषण से हुआ। निदेशक महोदय ने मुख्य अतिथि श्री दीपक गुप्ता, प्रो. एस. के. जोशी, प्रो. बी.एम. अरोड़ा एवं सभागार में उपस्थित वैज्ञानिक समुदाय का अभिनन्दन करते हुए एन.पी.एल. में सौर ऊर्जा के क्षेत्रों में हो रहे शोध कार्यों के बारे में बताया। राष्ट्रीय संगोष्ठी के उद्घाटन समारोह के अवसर पर श्री दीपक गुप्ता ने सौर ऊर्जा के महत्त्व तथा भारत सरकार के प्रयास के अन्तर्गत जवाहर लाल नेहरु सोलर मिशन का उल्लेख किया। प्रो. जोशी, पूर्व महानिदेशक सी.एस.आई.आर., ने सौर ऊर्जा के क्षेत्र में एन.पी.एल. की पूर्व उपलब्धियों की सराहना की तथा आशा व्यक्त की कि आगे आने वाले समय में भी अत्यन्त महत्त्वपूर्ण शोध कार्य किए जाएंगे। प्रो. बी.एम. अरोड़ा ने ''भारत में विद्युत उत्पादन हेतु सौर ऊर्जा : अर्द्धचालक रुट'' पर अपना मुख्य अभिभाषण दिया। आपने अपने अभिभाषण में आर एंड डी. समूहों और शैक्षणिक संस्थानों के समक्ष आने वाली चुनौतियों पर प्रकाश डालते हुए क्रिस्टलीय और बहुक्रिस्टलीय सिलिकॉन पर आधारित सौर सैल का उल्लेख किया।

संगोष्ठी में मुख्यतः पाँच सत्र थे :–

(i) **सोलर थर्मल एंड कंसन्ट्रेटिड फोटो वोल्टिक**

(ii) **क्रिस्टलीय सिलिकॉन सोलर सैल्स,**

(iii) **तनु परत सोलर सैल्स**

(iv) **तनु परत एवं अन्य सोलर सैल्स**

(v) **आर्गेनिक सोलर सैल्स**

संगोष्ठी में 13 आमंत्रित वार्त्ताएं, 2 मौखिक प्रस्तुतिकरण एवं 27 पेपर प्रस्तुत किए गए। हिन्दी में आयोजित यह दो दिवसीय राष्ट्रीय संगोष्ठी भारत की

राष्ट्रीय संगोष्ठी का शुभारंभ करते हुए प्रो. रमेश चन्द्र बुधानी, निदेशक, राष्ट्रीय भौतिक प्रयोगशाला

कार्यशाला में व्याख्यान देते हुए, श्रीमती भावना गुगलानी

स्वच्छ एवं हरित ऊर्जा आवश्यकताओं एवं अनवरत ऊर्जा आपूर्ति के लिए अत्यंत प्रासंगिक रही।

कार्यशाला

प्रयोगशाला के सभी वैज्ञानिकों/ तकनीकी अधिकारियों/ अधिकारियों एवं स्टाफ सदस्यों के लिए दिनांक 14 दिसंबर 2011 को ''छुट्टी यात्रा रियायत (LTC) एवं सामान्य भविष्य निधि (GPF)'' विषय पर एक दिवसीय कार्यशाला का आयोजन किया गया। कार्यशाला का शुभारंभ श्री टी.वी. जोशुवा, प्रशासन नियंत्रक महोदय ने किया। श्रीमती भावना गुगलानी, अनुभाग अधिकारी ने कार्यशाला में उपस्थित स्टाफ सदस्यों को उक्त विषयों पर अद्यतन जानकारी प्रदान की एवं एल.टी.सी. तथा सामान्य भविष्य निधि पर भारत सरकार के नियमों का स्पष्ट उल्लेख करते हुए उपस्थित श्रोताओं के प्रश्नों का भी समाधान किया। इस कार्यशाला में प्रयोगशाला के वैज्ञानिकों/तकनीकी अधिकारियों एवं स्टाफ सदस्यों ने उत्साहपूर्वक भाग लिया। इस प्रकार यह कार्यशाला अपने उद्देश्य में पूर्णतः सफल रही।

हिन्दी पखवाड़ा

राजभाषा विभाग, गृह मंत्राालय की हिन्दी पखवाड़ा संबन्धी व्यवस्थाओं को ध्यान में रखते हुए प्रयोगशाला में दिनांक 1.9.2011 से 14.9.2011 तक हिन्दी पखवाड़ा मनाया गया। प्रयोगशाला के वैज्ञानिकों/ अधिकारियों/स्टाफ सदस्यों को अपना अधिक से अधिक कार्य हिन्दी में करने के लिए प्रोत्साहित करने के उद्देश्य से हिन्दी पखवाड़ा के दौरान विभिन्न प्रतियोगिताओं का आयोजन किया गया। जिसका विवरण निम्न प्रकार से है:

दिनाँक 10.08.2011 को हिन्दी टिप्पण एवं आलेखन प्रतियोगिता (डेस्क प्रतियोगिता), 16.08.2011 को निबंध प्रतियोगिता, 18. 08.2011 को साइंस क्विज प्रतियोगिता, 26.08.2011 को टंकण प्रतियोगिता, 05. 09.2011 को वर्ष के दौरान हिन्दी में किया गया अधिकतम कार्य एवं हिन्दी डिक्टेशन प्रतियोगिताओं का आयोजन किया गया। दिनांक 07.09.2011 को प्रयोगशाला के आडिटोरियम में काव्य पाठ प्रतियोगिता का आयोजन किया गया जिसमें सुप्रसिद्ध हास्य कवि श्री 'बागी चाचा' को आमंत्रित किया गया। हिन्दी पखवाड़ा के दौरान आयोजित की गई प्रतियोगिताओं में प्रयोगशाला के स्टाफ सदस्यों ने उत्साह पूर्वक भाग लिया व अत्यधिक रुचि प्रदर्शित की।

हिन्दी पखवाड़ा समापन समारोह का आयोजन दिनाँक 14 सितंबर, 2011 को प्रयोगशाला के ऑडिटोरियम में किया गया। डॉ. ए. सेनगुप्ता कार्यकारी निदेशक महोदय ने कार्यक्रम का शुभारंभ किया। इस अवसर पर उन्होंने प्रयोगशाला के स्टाफ सदस्यों को हिन्दी में अधिक से अधिक कार्य करने के लिए प्रेरित करते हुए अपना संदेश दिया। इस अवसर पर गैस्ट लैक्चर देने के लिए डा. दुर्गादत्त ओझा, वरिष्ठ वैज्ञानिक, ग्राउण्ड वाटर डिपार्टमेंट, जोधपुर को आमंत्रित किया गया था। डॉ. दुर्गादत्त ओझा ने हिन्दी दिवस के अवसर पर प्रयोगशाला के सभागार में उपस्थित स्टाफ सदस्यों को दैनिक सरकारी कामकाज में हिन्दी का इस्तेमाल करने के लिए प्रेरित व प्रोत्साहित करते हुए कहा कि हम सभी को हिन्दी में काम करने में झिझक महसूस नहीं होनी चाहिए और अपना अधिक से अधिक कार्य हिन्दी में करना चाहिए। डा. ओझा ने **"विज्ञान और प्रशासन में हिन्दी की उपादेयता"** विषय

हिन्दी दिवस समारोह कार्यक्रम का शुभारंभ करते हुए डॉ. ए सेनगुप्ता, कार्यकारी निदेशक, एन.पी.एल.

पर अपने बहुमूल्य विचारों को श्रोताओं के समक्ष प्रस्तुत किया। समारोह के अन्त में प्रतियोगिताओं में भाग लेने वाले विजेता प्रतिभागियों को कार्यकारी निदेशक महोदय ने पुरस्कार प्रदान किये।

व्याख्यान

प्रयोगशाला में पिछले कई वर्षों से राजभाषा हिन्दी के प्रयोग को बढ़ावा देने के उद्देश्य से प्रशासन के साथ–साथ विज्ञान एवं तकनीकी क्षेत्रों में भी हिन्दी के प्रचार–प्रसार हेतु समय–समय पर विज्ञान विषयों पर विशिष्ट व्याख्यानों का आयोजन किया जा रहा है। इसी क्रम में प्रयोगशाला के वैज्ञानिकों के लिए 26 जुलाई, 2011 को एक व्याख्यान का आयोजन किया गया। व्याख्यान देने के लिए जामिया–मिल्लिया इस्लामिया

व्याख्यान देते हुए, प्रो. एम.ए. वहाब

यूनिवर्सिटी के भौतिकी विभाग के प्रमुख प्रो. एम. ए. वहाब को विशेष रूप से आमंत्रित किया गया। प्रो. वहाब ने **"दो नए स्पेस लेटिसेस की आवश्यकता"** (Necessity of two new space lattices) विषय पर अपना व्याख्यान प्रस्तुत किया। प्रो. वहाब ने उपस्थित वैज्ञानिकों को उक्त विषय पर किए जा रहे शोध कार्यों के बारे में विस्तार से जानकारी प्रदान की।

APPENDIX - 1

Publications by NPL Researchers in SCI Indexed Journals During April 2011 to March 2012

1. Abdullah, M. M.; Khan, M. A.; Bhagavannarayana, G.; and Wahab, M. A. "Structural and Dielectric Studies of Pure and Mn Doped GaSe." Science of Advanced Materials 3 (Apr 2011): 239-244.
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APPENDIX - 2

PATENTS
(01.04.2011 – 31.03.2012)
Patents Filed in India

Sr. No	Title	Prov. Filing Date	Application No.	Inventors
1	Indelible Ink Formulations for Instantaneous Skin Marking	14/02/2011	0361del2011	Rajinder Kumar Sharma, Sukhwant Singh Bawa
2	New Indelible Ink Formulations for Spontaneous Skin Marking	14/02/2011	0362del2011	Bawa Sukhwant Singh, Sharma Rajinder Kumar
3	Development of Specific Method to Identify Inorganic Phosphate (Used as an Adulterant) in Milk	03/06/2011	1582del2011	Ajit Kumar Sarkar, Niranjan Singh, RC Sharma
4	Lithium Metal Quinolates and Process for Preparation Thereof as Good Emitting, Interface Materials as Well as N-Type Dopent for Organic Electronic Devices	21/06/2011	1746del2011	Kamalasanan M.N., Srivastava Ritu, Amit Kumar, Ishwar Singh, Dhawan S.K., Bawa S.S.
5	An Improved Process for Joining of Tubes of Oxide High Temperature Superconductors with Improved Superconducting Properties	21/06/2011	1748del2011	Gursharan Kaur Padam, Narinder Kumar Arora, Ramesh Kumar Sethi, Shrikant Narayan Ekbote
6	Light Weight High Electromagnetic Interference (Emi) Shielding Material Based on Carbon Nanotubes Reinforced Polymer Composites	24/06/2011	1793Del2011	Singh Bhanu Pratap, Garg Parveen, Pande Shailaja, Mathur Rakesh Behari, Saini Parveen, Dhawan Sundeep Kumar

Patents Filed Abroad

Sr No	Title	Country	Comp. Filing Date	Application No.	Inventors
1	An Improved Process to Deposit Diamond Like Carbon as Protective Coating on Inner Surface of Bottles	US	11/08/2011	13/201210	Kumar Sushil, Dixit Prakash Narain, Rauthan Chandra Mohan Singh
2	An Improved Process to Deposit Diamond Like Carbon as Protective Coating on Inner Surface of Bottles	JP	17/08/2011	2011550662	Kumar Sushil, Dixit Prakash Narain, Rauthan Chandra Mohan Singh

Sr No	Title	Country	Comp. Filing Date	Application No.	Inventors
3	An Improved Process to Deposit Diamond Like Carbon as Protective Coating on Inner Surface of Bottles	EP	18/08/2011	10704976.9	Kumar Sushil, Dixit Prakash Narain, Rauthan Chandra Mohan Singh
4	An Improved Process to Deposit Diamond Like Carbon as Protective Coating on Inner Surface of Bottles	KR	30/08/2011	10-2011-7020190	Kumar Sushil, Dixit Prakash Narain, Rauthan Chandra Mohan Singh
5	A Long Duration Optical Memory Device Based on Deformed Helix Ferroelectric Liquid Crystal Material and a Method for The Development Thereof	KR	26/10/2011	2011-7025406	Jai Prakash, Ajay Kumar, Choudhary Amit, Malik Anu, Coondoo Indrani, Biradar Ashok Manikrao
6	Improved Version of Teleclock Receiver Utilizing Mobile Telephone Network	GCC	09/01/2012	16564	Banerjee Parameswar, Thorat Pranalee Premdas, Suri Anil Kumar
7	Nucleic Acid Primers and Probe For Detection of Neisseria Gonorrhoeae	AP	27/01/2012	Ap/P/2012/006092	Sood Seema, Rachna Verma, Singh Renu, Gajjala Sumana, Manju Bala, Sumantaray Jyotish Chandra, Pandey Manoj Kumar, Malhotra Bansi Dhar
8	Nucleic Acid Primers and Probe For Detection of Neisseria Gonorrhoeae	UG	27/01/2012	Ap/P/2012/006092	Sood Seema, Rachna Verma, Singh Renu, Gajjala Sumana, Manju Bala, Sumantaray Jyotish Chandra, Pandey Manoj Kumar, Malhotra Bansi Dhar
9	Nucleic Acid Primers and Probe for Detection of Neisseria Gonorrhoeae	KE	27/01/2012	Ap/P/2012/006092	Sood Seema, Rachna Verma, Singh Renu, Gajjala Sumana, Manju Bala, Sumantaray Jyotish Chandra, Pandey Manoj Kumar, Malhotra Bansi Dhar
10	Nucleic Acid Primers and Probe for Detection of Neisseria Gonorrhoeae	MW	27/01/2012	Ap/P/2012/006092	Sood Seema, Rachna Verma, Singh Renu, Gajjala Sumana, Manju Bala, Sumantaray Jyotish Chandra, Pandey Manoj Kumar, Malhotra Bansi Dhar

Patents Granted in India

Sr No	Title	Gtant Date	Patent No.	Inventors
1	A Novel Iron-Poly[3-Octylthiophene] (Fe-P3ot) Nanocomposite Material and a Process for the Preparation Thereof	24/08/2011	248779	Ramadhar Singh, Jitendra Kumar
2	A Process for Manufacturing Nano-Structured Zinc Oxide Tetrapods	30/11/2011	250037	Srivastava Avanish Kumar, Sood Kedar Nath, Lal Kasturi, Kishore Ram
3	A Process for the Peparation of Nanomaterial	30/11/2011	250578	Harish Chander
4	A Process for the Preparation of a Low Contact Resistance Contact on a High Transition Temperature Super - Conductors	02/03/2012	251241	Shrikant Ekbote, Gurusharan Kaur Padam, Narendra Kumar Arora, Mukul Sharma, Ramesh Sethi, Mrinal Kanti Banerjee
5	A Single Step Process for the Preparation of HIgh Density Carbon-Carbon Composite Material	02/03/2012	251233	Bahl Om Prakash, Mathur Raesh Behari, Dhami Tersem Lal, Chauhan Sippy Kalra

Patents Granted Abroad

S. No	Title	Country	Grant Date	Patent No.	Inventors
1	An Improved Process Based on the Sol-Gel Technique for the Preparation of $CeTi_2O_6$ Powder	GB	06/04/2011	2114826	Amita Verma, S.A. Agnihotry
2	An Improved Process Based on the Sol-Gel Technique for the Preparation of $CeTi_2O_6$ Powder	FR	06/04/2011	2114826	Amita Verma, S.A. Agnihotry
3	An Improved Process Based on the Sol-Gel Technique for the Preparation of $CeTi_2O_6$ Powder	EP	06/04/2011	2114826	Amita Verma, S.A. Agnihotry
4	Monoclinic $CeTi_2O_6$ Thin Film and a Sol-Gel Process for the Preparation Thereof	CN	01/06/2011	ZI200680053857.3	Verma Amita, Agnihotry Suhasini Avinash, Bakhshi Ashok Kumar
5	Process for the Simultaneous and Selective Preparation of Single-Walled and Multi-Walled Carbon Nanotubes	US	07/06/2011	7955663	RB Mathur, Chottey Lal, TL Dhami, BP Singh, AK Gupta
6	Improved Process for the Development of High Temperature Superconducting Bulk Current Leads	DE	07/07/2011	112006003792	SN Ekbote, GK Padam, NK Arora, Mukul Sharma, Ramesh Sethi, MK Banerjee

APPENDIX - 3

Technologies Marketed
Knowledgebase generated and transferred

Title of the technology	Date of Transfer	Name of Licensee
Carbon Composite Half Rings	20.05.2011	M/s Jyoti Cero Composite, Jamshedpur, Bihar

Technology Transfer Event

APPENDIX - 4

R & D Collaborations

Collaborating Institute	Research Area
CSIR-CCMB, Hydrabad	Development of biocompatible substrates with titanium oxide film coating under suitable conditions and additives.
NABL, New Delhi	Assessment of calibration laboratories and Organizing the Proficiency Testing program among the NABL accredited laboratories.
PTB Institute, Germany	To coordinate international inter-comparison in temperature metrology among SAARC countries under SAARC-PTB Project
Bharti Automation Pvt. Ltd., New Delhi	Water flow measurement
MAX Super Specialty Hospital, New Delhi	Tumor Diagnosis
Collaborative Academic Project between C.G.C., NPL and Phys. Dept., Anna University, Chennai –CAP-14 (PI)	Crystal Growth and Characterization
Collaborative Academic Project between C.G.C., NPL and Crystal Growth Centre, SNN College of Engg., Chennai, CAP-18 (PI)	Crystal Growth and Characterization
Collaborative Academic Project between C.G.C., NPL and Physics Department, Jamia Millia Islamia, CAP-24. (PI)	Crystal Growth and Characterization
Institute of Experimental Physics, Academy of Science, Kosice, Slovak	Nanomagnetic fluids
CSIR-NML, Jamshedpur	Ferrofluid
CSIR-CEERI, Pilani	Ferrofluid
Bhavnagar University, Bhavnagar	Ferrofluid
Thapar University, Patiala	Aerosol & Health/MiC Education
JNU, New Delhi	Aerosol Chemistry/MiC Education
Hokkaido University, Sapporo, Japan	Aerosol Chemistry
PTB Braunschweig/BAM Berlin	Metrology in Chemistry

APPENDIX - 5

Sponsored/Supported R & D Projects

₹ (in Lakhs)

Sr. No.	Title of the Project	Agency/Client	Amount Received
1	Morphological study of polar region ionosphere with special emphasis on space weather events	Department of Space (DOS), Bangalore	25.73
2	A study of adaptive spherical lens using nematic liquid crystal for defence applications	DRDO, New Delhi Directorate of Extramural Research & Intellectual Property Rights (ER&IPR),	11.10
3	Preparation of energy sector GHG Emission Inventory and assessment of heat stress vulnerability under future climate change scenarios in India	CSIR, CCMMCS, Centre for Mathematical Modelling and Computer Simulation, NAL Belur campus, Bangalore	6.37
4	Preparation and characterization of silicon for solar energy applications	Department of Science & Technology (DST), New Delhi	30.16
5	Development of gold micro-electrode array with nanometer size opening for use in biosensor at physiological conditions	Department of Biotechnology (DBT), New Delhi	3.75
6	Advancing the Efficiency and Procuction Potential of Excitonic Solar Cells (APEX)	DST, New Delhi	185.00
7	Development of continuous nanofibers by electro-spining	DST, New Delhi	15.00
8	Band gap engineering of nanophosphors for use in energy saving lighting applications	DST, New Delhi	13.90
9	Superconductivity of pure and doped FeAs and FeSe systems (Under Fast Track Scheme for Young Scientists)	DST, New Delhi	7.10
10	Recommended standard practices in the field of static force, pressure & torque metrology (under USERS Scheme)	DST, New Delhi	3.45
11	J C Bose National Fellowship	DST, New Delhi	13.60
12	Ramanna Fellowship	DST, New Delhi	13.40
13	Development of hybird electroluminescent materials and low power driven lamps (Women Scientist Scheme)	DST, New Delhi	2.50
14	A novel way to reduce platinum metal loading in a carbon nano-composite electrode to produce low cost-high efficiency commercialy viable Polymer Electroyte Membrane (PEM) fuel cells	DST, New Delhi	12.00
Total			343.06

APPENDIX - 6

Consultancy Projects 2011-12

₹ (In lakhs)

Sr. No.	Project Code	Client	Title	Contract Value	Amount Received 2011-12
NEW & COMPLETED					
1.	CNP110132	ABB Limited, 32, NIT, Faridabad	Weighing scale validation project	4.33	3.90
2.	CNP110232	Electronics Regional Test Laboratory (North), New Delhi	Metrological characterization of a dual range piston gauge	3.26	3.26
3.	CNP110332	Electronics Test and Development Centre, Guwahati	Determination of metrological parameters of hydraulic and pneumatic dead weight testers	5.40	5.40
OLD & COMPLETED					
1.	CNP070332	CSIO, Chandigarh	Quality system implementation in geoseismic and medical instrumentation in accordance with ISO/IEC 17025 : 2005	0.00	0.00
2.	CNP070432	Regional Research Standards Laboratory (RRSL), Guwahati	Setting up of torque standard machine at RRSL, Guwahati	14.29	0.00
3.	CNP070532	RRSL, Faridabad	Design, fabrication and installation of primary torque measurement machine at RRSL, Faridabad	31.00	0.00
4.	CNP070932	RRSL, Bangalore	Design, develop and fabricate torque primary standards from 2 Nm-200Nm within uncertainty of 0.05 %	31.00	6.14
5.	CNP071032	RRSL, Bangalore	Design, erection and commissioning of dead weight force machine at RRSL, Bangalore	101.25	0.00
6.	CNP071132	RRSL, Ahmedabad	Design, primary and secondary torque measuring facility at RRSL, Ahmedabad	14.29	2.83
7.	CNP071232	RRSL, Bhubaneswar	Supply of one number of secondary torque measurement facility at RRSL, Bhubaneswar	14.29	0.00
8.	CNP080232	RRSL, Ahmedabad	Design, develop & fabricate secondary force standards upto 50 kN by comparison of 0.05 %	22.29	11.14

Sr. No.	Project Code	Client	Title	Contract Value	Amount Received 2011-12
9.	CNP080332	RRSL, Bhubaneswar	Design, develop & fabricate secondary force standards upto 50 kN by comparison of 0.05 %	22.29	0.00
10.	CNP080432	RRSL, Guwahati	Design, develop & fabricate secondary force standards upto 50 kN by comparison of 0.05 %	22.29	11.14
11.	CNP080632	RRSL, Faridabad	Design, develop & fabricate secondary force standards upto 50 kN by comparison of 0.05 %	22.29	0.00
12.	CNP090332	Raipur Tar Product, Raipur, Chhattisgarh, MP	General consultancy relating to reduction of QI from high QI coal tar pitch	0.98	0.00
13.	CNP100132	SIMCO Calibration Laboratory, Hyderabad	Guidance in Implementing of quality system dimensional parameters as per ISO 17025	1.37	0.00
14.	CNP100532	Rajesh & Rajesh Std Lab, Konark Apartment, Kon-Village, Mumbai-Pune Road, Tal Panvel, Dist. Raigad	Set-up of laboratory of mass measurement for NABL accreditation	2.49	0.00
CONTINUING					
1.	CNP070832	Aeronautical Development Agency (ADA), Bangalore	Certification of reference blocks of various materials as per 1,2mm FBH standards of ASTM E 127-PV3/PV5 (59/704)	9.36	0.00
			TOTAL	**322.47**	**43.81**

APPENDIX - 7

Earning from Calibration & Testing

₹ (in Lakhs)

Apex Level Standards & Metrology			
Sub-division No.	Sub-division Name	Charges or Actual Amount Received (inclusive of All Taxes)	No. of Reports
D5.01	Mass Standards	86.74	383
D5.02	Standards of Dimension	46.86	309
D5.03	Temperature & Humidity Standards	31.00	101
D5.04	Optical Radiation Standards	54.48	363
D5.05	Force & Hardness Standards	52.97	393
D5.06	Pressure & Vacuum Standards	29.39	92
D5.07	Acoustics, Ultrasonics, Shock and Vibration Standards	17.23	122
D5.08	Fluid Flow Measurement Standards	4.80	9
D5.09	LF & HF Impedance & DC Standards	17.63	117
D5.10	LF & HF Voltage, Current & Microwave Standards	9.42	30
D5.11	AC High Voltage & AC High Current Standards	29.23	59
D5.12	AC Power & Energy Standards	26.56	140
	Total (A)	**406.31**	**2118**

Time and Frequency			
Sub-division No.	Sub-division Name	Charges or Actual Amount Received, inclusive of All Taxes	No. of Reports
D4.03	Precise Timing Systems	3.32	13
	Total (B)	**3.32**	**13**

Materials Physics & Engineering.			
Sub-division No.	Sub-division Name	Charges or Actual Amount Received, inclusive of All Taxes	No. of Reports
D2.01	Polymer & Soft Material	–	–
D2.02	Physics & Engineering of Carbon	1.19	9
D2.04	Multiferroics and Magnetics	3.11	26
D2.06	Metals & Alloys	1.52	13
D2.07	Piezoelectric Sensors & Actuators	0.00	0
	TOTAL (C)	**5.82**	**48**

Physics of Energy Harvesting			
Sub-division No.	Sub-division Name	Charges or Actual Amount Received, inclusive of All Taxes	No. of Reports
D1.06	Optical Thin Films & Ceramics	0.27	4
	Total (D)	**0.27**	**4**

Sophisticated & Analytical Instruments			
Sub-division No.	Sub-division Name	Charges or Actual Amount Received, inclusive of All Taxes	No. of Reports
SD7.01.01	X-Ray Analysis	0.09	2
SD7.01.02	Electron & Ion Microscopy	01.43	11
SD7.01.03	EPR IR Spectroscopy	0.13	2
SD7.01.04	Analytical Chemistry	7.57	44
D6.02	QHR Standard	0.28	1
	Total (E)	**9.50**	**60**

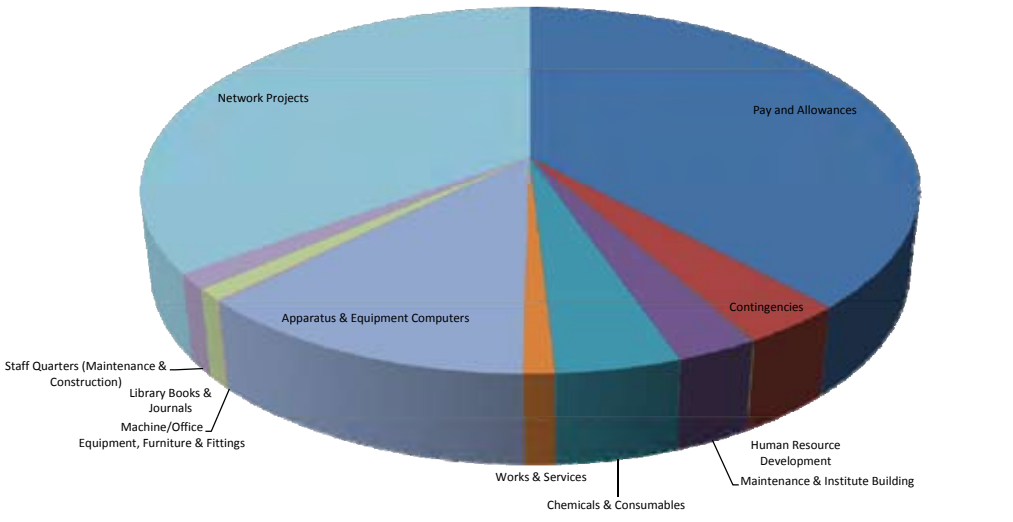
Summary			
Sub-division No.	Sub-division Name	Charges or Actual Amount Received, inclusive of All Taxes	No. of Reports
D 1	Physics of Energy Harvesting	0.27	4
D 2	Materials Physics & Engineering.	5.82	48
D 4	Time and Frequency	3.32	13
D 5	Apex Level Standards & Industrial Metrology	406.31	2118
SASD 7	Sophisticated & Analytical Instruments	9.50	60
	Grand Total	**425.22**	**2243**
Notional Cases		**135.86**	**392**

APPENDIX - 8

Annual Expenditure 2011-12

₹ (in Lakhs)

Sr. No.	Budget Heads	Grant	LRF	Total
1	Pay and Allowances	4434.047	29.292	4463.339
2	Contingencies	403.85	22.335	426.185
3	Human Resource Development	2.934	–	2.934
4	Maintenance & Institute Building	250.001	87.744	337.745
5	Chemicals & Consumables	450.993	59.206	510.199
6	Works & Services	129.554	–	129.554
7	Apparatus & Equipment/Computers	1370	47.066	1417.066
8	Machine/Office Equipment, Furniture & Fittings	8	4.127	12.127
9	Library Books & Journals	115	8.439	123.439
10	Staff Quarters (Maintenance & Construction)	101.673	59.206	160.879
11	Network Projects	4104.118	–	4104.118
	Total	**11370.17**	**317.415**	**11687.585**



APPENDIX - 9

Recognitions, Honours and Awards

- CSIR-NPL team led by Dr. Ravi Mehrotra has won the DST-Lockheed Martin Gold Medal 2012 at the Innovators' Competition under the India Innovation Growth Program. The award is for NPL's innovative ECG device technology and its potential to benefit the society. The award comprises a gold medal, a certificate and a cash prize of one lakh rupees. The competition had 800 entries and the top thirty innovations covering a broad spectrum of areas have been awarded.

- DAE-SRC Outstanding Research Investigator Award – Dr. V.P.S. Awana

- National Metallurgists Day (NMD)-Metallurgist of the Year Award 2011, Instituted by the Ministry of Steel, Government of India, under the category of Metal Sciences : Dr. Avanish Srivastava.

- The Scientific Committee of International Geosphere-Biosphere Programme (IGBP) and the International Commission for Atmospheric Chemistry and Global Pollution (iCACGP) have invited Dr. C. Sharma to become a member of the Scientific Steering Committee for their International Global Atmospheric Chemistry (IGAC) Project for the period of 1 January 2012 to 31 December 2014.

- Dr. MVSN Prasad Awarded Fellowship of the Institution of Electronics and Telecom Engineers

- Dr. Mahavir Singh : Chairman, Delhi Chapter of Acoustical Society of India (ASI)

- Horticulture Department received awards for more than 130 entries, including several first, in a flower show organized by the Agriculture Institute-Pusa for the NCR region.

APPENDIX - 11

Ph. D awards based on the research work done at NPL

Sr. No.	Title	Awardee	University/Institute	Guide(s)
1	Synthesis and Optoelectronic Characterization of some Metal Complexes	Dr. Amit Kumar	MDU, Rohtak	Prof. Ishwar Singh (MDU) Dr. Ritu Srivastava (NPL)
2	Study of optical and electrical properties of doped Organic Semiconductors	Ms. Gayatri Chauhan (Submitted)	BHU, Varanasi	Prof. P.C. Srivastava (BHU) Dr. M.N. Kamalasanan (NPL)
3	Structural, dielectric and photonic studies on certain types of liquid crystals	Mr. Gautam Singh	Indian Institute of Technology, Delhi	Dr. A.M. Biradar (NPL) Dr. G.V. Prakash (IIT Delhi)
4	Synthesis of ZnO based Nanophosphors for Applications in Solid State Light Emitting Devices	K. Jayanthi	Jamia Millia Islamia, Delhi	Santa Chawla, (NPL) Z.H. Khan, (JMI)
5	Novel nano and bulk phosphors for solar spectrum modification to improve solar cell performance	Atif F. Khan	IIT, Delhi	Santa Chawla (NPL) V. Dutta (IIT, Delhi)
6	Synthesis and Characterization of conducting polymer for sensing applications	Tarushee Ahuja	Delhi University	Dr. Rajesh (NPL) Dr. D. Kumar (DU)
7	Study of methane emission from paddy fields of Karnal: A GIS based approach	Vandana Gupta	J.N.U., New Delhi	Prabhat K. Gupta (NPL) Dr. Krishan Kumar (JNU)
8	Physico-chemical characterization of aerosols and precursor gases in and around Delhi	Khem Singh	J.M.I. New Delhi	Prabhat K. Gupta (NPL) Prof. Z.H. Khan (JMI)

APPENDIX - 12

HUMAN RESOURCE DEVELOPMENT GROUP

The Human Resource Development (HRD) Group of NPL is a constituent group of SASD 8 and represents a central group of the laboratory providing a wide range of HRD services. It undertakes several activities in various areas of core competence of the lab and also related to the research scholars.

The group is involved in various activities, such as, Organisation of Industrial Training in Metrology/ Standards, Pacement and support to Research Scholars, Training for M.Tech./MCA/M.Sc. students from all over the country, Institutional Visits, Deputation of NPL staff members to attend conferences, etc. The basic object behind these activities is to make the Human Resource better informed, knowledgeable and highly skilled & trained so that it can prove to be more competitive, productive and useful to the society and the country.

The various activities of the Group are as follows:

1. Organisation of Industrial Training Courses

Organisation of Training Courses on various physical parameters in the area of Metrology/Standards, as well as on other specialized topics is an important activity of the HRD Group. These courses are primarily meant for the personnel belonging to various industries, Testing & Calibration laboratories and other S&T organisations. However, the NPL staff members are also encouraged to attend these courses, wherever found fit.

The Training Courses consist of theory lectures on various scientific & technical aspects of the training course, followed by practical demonstration and hands-on training on the related instruments/ apparatus/machines.

Four (04) Training Courses on different subjects were organised by NPL during the period from 1st April 2011 to 31st March 2012, the details of which are as follows :

1. Training on Calibration of Digital Multimeter, 23 May-03 June 2011

   This programme were specially designed for Mr. Joe Panga, Senior Metrologist from National Institute of Standards & Industrial Technology, Papua New Guinea.

2. Training Course on Mass Metrology, 23-26 August 2011

   This course was attended by 22 participants, including 02 participants from NPL.

3. Training Course on Force, Torque & Hardness Measurements, 13-15 December 2011

   This course was attended by the 12 participants.

4. Training Course on Quality Management System, 30 Jan-1 Feb 2012

   This course was specially designed for the Legal Metrology Officers, 22 officers attended.

This activity led to an ECF generation of Rs. 13.38 Lacs.

2. Placement, Ph.D. Registration and other Support to Research Fellows

One of the most prominent activities of the NPL is to provide help and support to Research Fellows (JRFs/ SRFs), starting from the time they join NPL till the time they leave NPL. This includes their placement in a suitable Division/Group and helping them in getting hostel accommodation, if required. This also includes their Ph.D. registration, assessment for continuance/ upgradation, deputation to attend conferences, etc. Sometimes, the help to the Research Fellows starts even before they join NPL. This refers to the cases wherein they are invited and inspired to join NPL for their Ph.D. programme.

During the period from 1st April 2011 to 31st March 2012, 29 research fellows (JRFs/SRFs) were inspired to join NPL, resulting in a total strength of Research Fellows (JRFs+SRFs) in NPL to be 96 as on 31.03.2012.

3. Organization of Institutional Visits to NPL

Organization of institutional visits involving students/ teachers/faculty members/personnel belonging to schools/colleges/universities/technical institutes/S&T

organisations is an important activity of the NPL. The basic objective is to provide the visitors a glimpse of the NPL activities and achievements, and thus enhance visibility of NPL in the society.

During the period from 1st April 2011 to 31st March 2012, eleven (11) institutional visits were organised by NPL, which involved around 200 persons and included prestigious institutions like, IIT Delhi , National Institute of Technology, Kurukshetra , Rajdhani College, New Delhi, Indian Institute of Legal Metrology, Ranchi, Vasant Vally School, New Delhi etc.

4. Organisation of Students' Training at NPL

NPL provides Training to students pursuing M.Sc./M. Tech./MCA, or their equivalent degree programmes, from different educational institutions spread all across the country, in the areas of research activities being carried out at NPL. The basic objective is to provide the students a feel and importance of the various activities, as well as to motivate them towards scientific research as the career.

During the period from 1st April 2011 to 31st March 2012, 126 students were provided training oriented towards the fulfillment of their academic degree requirements in different areas of research under the guidance of senior scientists.

This activity led to an ECF generation of Rs. 4.40 lacs.

5. Dissemination of HRD-related Information to NPL Staff Members

Dissemination of HRD-related information to the NPL staff members is another important task performed by the HRD Group. The information generally refers to conferences/symposia/workshops, or DST, HRDC (Ghaziabad) or other such organisations, or awards instituted by various agencies.

More than 200 different types of HRD related papers were displayed at 4-5 prominent places of the laboratory each, during the year 2012-13.

6. Deputation of NPL Staff Members to Attend Conferences/Similar Events

NPL encourages and supports its staff members, including JRFs, SRFs, PAs, RIs, RAs, SRAs, etc., to attend and present papers at national/international conferences/symposia/seminars/workshops, organised by different agencies in areas relevant to research activities being carried out at NPL. This is primarily meant to enable the staff members to put forward their views and research results before the leading national/international experts and interact with them on the latest developments in their research areas.

During the period from 1st April 2011 to 31st March 2012, 224 cases of NPL scientists and other staff members including research scholars, were nominated to participate in various conferences/ similar events and different Training Courses held across the country.

7. AcSIR and PGRPE related Activities

All activities related to PGRPE programme for Advanced Material Physics & Engineering including Admission, Classes (theory/ tutorial/ practical), Examinations and Evaluation of PGRPE & AcSIR-Ph.D. students are handled by the HRD Group in consultation with the Coordinator.

Other Prominent Activities

I. CSIR Foundation Day Celebrations

The CSIR Foundation Day was celebrated by the concerted efforts put in by all the members of the Organizing Committee and the Academic Committee. On 26th Sept., 2011, a function was organised in the NPL auditorium. Dr. N Ratnasree, Director, Nehru Planetarium, New Delhi was the Chief Guest, who delivered the CSIR Foundation Day Lecture, entitled "From Guest Stars to a Cosmic Lighthouse: The Story of Supernovae and Pulsars". The cultural programme, including a skit & songs, was also organised by the NPL Ladies Club, staff & students of NPL. The prizes for the various competitions were distributed. Prof. R.C. Budhani, Director, NPL, gave away the mementoes to staff members who had completed 25 years of service and shawl & mementoes to those who had retired during last one year. Studentship Awards to children of NPL staff members, including scholarships instituted by the NPL Former Scientists' Forum, were also presented by Dr. Ratnasree amid loud applause.

As a part of the CSIR Foundation Day Celebrations, an Open Day was also observed by NPL on 28th Sept. for school & college students as well as general public. One Thousand Eight Hundred and Sixty One (1861) visitors including school/college students and teachers from 29 schools and 20 colleges as well as general public participated in this event. A total of 34 exhibits were placed on display and visit to various R & D groups for participants was organized through seven different routes, escorted by volunteers from NPL. The smiles on the young faces won the hearts and minds of the NPL staff members, who were busy attending to Open Day Activities since morning. The happy enthusiasm of the school children made the entire Open Day programme a big success.

II. Organisation of National Science Day Function

In honour of Sir C.V. Raman for his legacy and discovery of the Raman Effect on February 28, 1928, the National Science Day 2012 was celebrated at NPL on 28th Feb, 2012, in coordination with the Academic Committee. Prof. Kehar Singh, Formerly Professor, IIT Delhi, Honorary Distinguished Research Professor, ITM University, Gurgaon, was the chief guest of the function. A Poster Presentation Symposium involving the presentation of the work by the research fellows of NPL was organised at NPL. The main function started in the forenoon at NPL auditorium with the remarks by the Director NPL, Prof. R.C. Budhani. Prof. Kehar Singh delivered the inaugural address namely "Security Holograms". Prof. Kehar Singh along with DNPL & senior scientists, also visited all of the posters and had a lively interaction with the students.

To recognize and encourage the students for their research work, 05 best poster awards were awarded to the students by Prof. Kehar Singh.

APPENDIX - 13

IMPORTANT CONFERENCES, SYMPOSIA, WORKSHOPS AND EVENTS

Date	Conferences, Symposium, Workshops and Events
13 May, 2011	National Instrument Seminar
20 May ,2011	World Metrology Day and National technology Day
25 May, 2011	Hindi Workshop on Happiness Index and the Ancient Science of Meditation
01 June, 2011	53rd Research Council Meeting
14 July, 2011	CFCT Training Programme
15 July, 2011	PGRPE Selection committee Meeting
20 July, 2011	Task Force Review Meeting
26 July, 2011	Scientific conference in Hindi
18 August, 2011	Hindi Quiz Competition
23 August, 2011	Training Programme on Mass Metrology
01 September, 2011	Hindi National Seminar on Recent Development in Material Devices for Solar Energy Application
14 September, 2011	Hindi Pakhwada Samapan
15 September, 2011	DST Steering Committee Meeting
26 September, 2011	CSIR Foundation day celebration
08 November, 2011	PTB Meeting on Collaboration on Solar Cell
16 November, 2011	Workshop on uncertainty in Measurement, optical profiler and low level D.C. Resistance and current measurement for Nano metrology
13 December,2011	Training Programme on Force, Torque and Hardness
14 December, 2011	Hindi Unit Meeting
24 December, 2011	Nano Science Advisory Group meeting
24 December, 2011	Research Council Meeting
12 January, 2012	National Conference of Ministry of Environment And Forest
30 January, 2012	Training Course on Quality Management System
28 January, 2012	National Science Day Celebration
05 March, 2012	Training Programme on Scientists' Presentation
05 March, 2012	Training Programme on Legal Metrology
13 March, 2012	Hindi Workshop on CSIR Purchase

APPENDIX - 14

CSIR-NPL Colloquium Series

S.No.	Date	Name of the Visitor	Affiliation	Title of the talk
1	April 8, 2011	Dr. S. M. Yusuf,	BARC, Mumbai	Magnetic Ordering in Low Dimensional Spin Systems
2	May 5, 2011	Dr. G Rajalakshmi,	TIFR, Mumbai	Probing Fundamental Interactions with Laser-Cooled Atoms and Optical Interferometers
3	June 13, 2011	Dr. M. Saidur Rahaman,	LANL, USA	Probing the time variation of Fine Structure Constant Alpha (a) in Yb system
4	July 5, 2011	Dr. Subhadeep De,	JQI, NIST, MU, USA	Facility to produce ultra-cold degenerate Bose and Fermi gases
5	July 7, 2011	Prof Srinivas Sridhar,	NU, USA	Nanoplatforms for Nanomedicine
6	July 29, 2011	Professor Krishna Shenai,	TU, USU, USA	Rugged Electrical Power Switching in Semiconductors
7	August 8, 2011	Dr. Hirendra Nath Ghosh,	BARC, Mumbai	Femtosecond Interfacial electron Transfer Dynamics in Dye/Quantum Dot Sensitized Solar Cell
8	September 16, 2011	Prof. S M Shivaprasad,	JNCASR, Bangalore	Towards super-efficient Solar Cells and Light Emitting Diodes
9	September 23, 2011	Dr. P. K. Gupta,	RRCAT, Indore	Biomedical applications of Lasers
10	December 13, 2011	Vandna Gokhroo,	TIFR, Mumbai	Sub-Doppler deep-cooled bosonic and fermionic isotopes of potassium in a compact 2D+ - 3D MOT set-up
11	December 15, 2011	Michael Kazda,	PTB, Germany	Time and Frequency in a Nutshell
12	December 19, 2011	Professor Kannan M. Krishnan,	WU, Seattle, USA	Nanomagnetism: Directions and opportunities in science and technology
13	December 27, 2011	Prof. Ashutosh Sharma,	IIT, Kanpur	Self-organized Mesoscale Fabrication in Soft Materials
14	January 6, 2012	Prof. Devki N. Talwar,	IUP, Indiana, USA	Dilute nitride semiconductors – from physics to technology
15	January 20, 2012	Dr Devendra Sadana,	IBM, NY, USA	PV Technologies for $1/Watt : Challenges & Opportunities
16	March 16, 2012	Dr Samuel P. Benz,	NIST, Boulder, Colorado, USA	Fabrication and Precision Voltage Measurements with Josephson Devices at NIST

APPENDIX - 15

Invited Talks and Lectures by CSIR-NPL Scientists

S No	Speaker's Name	Topic	Event and Venue
1.	Dr. PK Singh	Applications of Nanotechnology to Photovoltaic: Approaches and Challenges	Indo-Norwegian Workshop on Solar Energy Materials and Applications: International Conference on Advanced Materials December 13-16, 2011, Coimbatore
2.	Dr. PK Singh	Application of Nano-Technology in Wafer-based Silicon Solar Cells	International Conference on Nanoscience and Nanotechnology, Coimbatore Institute of Technology, July 6-8, 2011, Coimbatore
3.	Dr. Vandana	Test and Calibration Procedures for Solar Cells	International Conference on Advanced Materials ICAM-2011, Coimbatore
4.	Dr. Govind	III-Nitride Materials for Efficient Energy Generation & Utilization	National Conference On Recent Trends In Materials Science and Nano Structure (Rtmsns-12), January 3-4, 2012, Rudrapur
5.	Dr. Mahesh Kumar	Metal-Silicon Surfaces and interfaces	IOP Bhubaneswar, Colloquium talk
6.	Dr. Mahesh Kumar	The Glimpses of Surface Science: From Atoms to Devices	University of Delhi Hindu College Teachers Day Celebration
7	Dr. M.N. Kamalasanan	Organic Semiconductors and its Applications	International Conference on Optics: OPTICS'11, National Institute of Technology, May 23-25, 2011, Calicut
8	Dr. M.N. Kamalasanan	Development of Organic-Inorganic Hybrid Devices for Energy Saving and Generation	2nd Indo-Italian Workshop on Electrochemistry for FUTURE ENERGY SOLUTIONS, Department of Chemistry University of Delhi Nov 30-Dec 1, 2011
9	Dr. Ritu Srivastava	Fabrication of Hybrid Organic-Inorganic LED Device using Quantum Dots as an active Emissive Layer	National Symposium on Recent Advances in Nanoscience, Engineering & Technology at ABV- Indian Institute of Information Technology & Managment, Gwalior, India Nov. 19-20, 2011
10	Dr. Virendra Shanker	Recent Initiatives on Phosphor R&D at CSIR-NPL	International Conference on Luminescence and its Applications (ICLA-2012), held at IICT, Hyderabad, during Feb. 7-10, 2012.
11	Dr. Santa Chawla	Rare Earth Doped Light Emitters	Brain storming session on 'Fiber Lasers and related technology', RRCAT, Indore, 5th Sept., 2011 Nanomeasure – 2011, NGM College, Pollachi, September 15-16, 2011.
12	Dr. Santa Chawla	Luminescence Spectroscopy of Quantum Dots and Nanoparticles	International Conference on Luminescence and its Applications (ICLA-2012), held at IICT, Hyderabad, during Feb. 7-10, 2012.
13	Dr. D. Haranath	Advances in Novel Phosphor/ Nanophosphor System for High-Resolution X-Ray Real-Time Imaging	Emerging Trends in Nanoscience and Nanotechnology held at NYSS College of Engineering and Research, Nagpur during Dec. 20-21, 2011

S No	Speaker's Name	Topic	Event and Venue
14	Dr. D. Haranath	Recent Advances in Nanophosphors for Photonic Applications	National Workshop on Nanoscience and Nanotechnology (NWNSNT-2012) held at Raipur during March 12, 2012
15	Dr. D. Haranath	Nanotechnology and its Enthralling Applications	IV th National Conference on Nanomaterials and Nanotechnology (NATCON NAMTECH IV -2011), held at Physics Department, Lucknow University during December 21-23 , 2011.
16	Dr. Bipin Kumar Gupta	Advanced Luminescent Nanomaterials for Strategic Applications in Forthcoming Nanotechnology	Special Chemistry Seminar, held at Department of Chemistry, The City College of New York, USA, during May 25-26, 2011.
17	Dr. Bipin Kumar Gupta	Luminescent Materials for Strategic Applications	Special Seminar on Nanomaterials, held at Hydrogen Energy Centre, Department of Physics, Banaras Hindu University, Varanasi, on March 6, 2012.
18	Dr. Bipin Kumar Gupta	Advanced Bifunctional Luminescent Nanomaterials for Strategic Applications in Forthcoming Nanotechnology	Sectional Seminar on Optical Properties of Exotic Carbon at Department of Mechanical Engineering and Material Science, Rice University, Houston, Texas , USA, on December 13, 2011
19	Dr. Bipin Kumar Gupta	Investigations on the Luminescent Properties of Graphene & Carbon nanotubes for Opto-electronic Device Applications	National Conference on Advance Materials in Industries, Feb. 10 - 11, 2012, Israel
20	S.R. Dhakate	Carbon wondrous material from Charcoal to Graphene: Industrial Applications	Yusuf College of Arts, Science and Commerce, Jogeshwari (east) Mumbai.
21	S.R. Dhakate	Synthesis of electrospun continuous nanofibers and its applications for air and water filtration	International conference on recent developments in Environmental impact assessment and Integrated approach for carbon management-solutions, technology development and pollution abatement, NEERI, Nagpur, March 28-30, 2012.
22	Dr. C. Sharma	Atmospheric Chemistry: Some Issues of Importance for Climate Change and Air Quality	UGC-SAP Workshop on Environmental Chemistry held on September 10, 2011 at D.E.I. (Deemed University), Agra.
23	Dr. C. Sharma	Problems in Meso-Scale Estimation of N_2 Emissions from River Basins in India	Brain Storming Workshop on 'Backward Integration of Nitrogen in Major Indian River Systems' held during March 02-03, 2012 at NASC, New Delhi.
24	Dr. M V S N Prasad	Measurement of Path Loss in Urban and Suburban Environments Over Various Regions of India and the Associated Modeling Studies	IEEE international conference on Applied Electromagnetics, Dec. 18-22, 2011, Kolkata
25	Y.P. Singh	Basic Concepts and Recent Trends in Temperature Metrology	2nd National Conference on Advances in Metrology, AdMet- 2012, February 6-8, 2012, ARAI, Pune.

S No	Speaker's Name	Topic	Event and Venue
26	Dr. S.K.Jain	Developments in Force/ Torque Sensors and Metrology	Indo-French Seminar on Sensors Technologies, March 1-4, 2012, I.I.T. Delhi
27	Dr. Sanjay Yadav	Pressure Balances: Theory, Practice, Calibration and Measurement	National Council for Cement and Building Materials (NCCBM), August 26, 2011 Ballabhgarh, Haryana
28	Dr. Sanjay Yadav	Principle of Pressure Measurement and Pressure Standards	NPL, New Delhi during Legal Metrology Officer's Visit, March 6, 2012, NPL
29	Dr. Mahavir Singh	Sound Transmission of a New Designed Lightweight Partition	National Symposium on Acoustics (NSA-2012), Bundelkhand University, Jhansi
30	Dr. Yudhisther Kumar	Ultrasonic Power Measurement and its Importance in Industry	National Symposium on Acoustics (NSA-2011), November 17-19, 2011, Jhansi
31	Dr. Yudhisther Kumar	Ultrasonic Non-destructive Testing and Evaluation of Materials	Two Day Workshop on Current Perspectives in Advance Material Sciences, Pt. NRS Govt. College, Rohtak, February 8-9, 2012
32	Dr. H.C. Kandpal	Strides Towards Classical to Quantum Candela	International Conference on advancement in metrology (AdMet- 2012), Feb. 6-8, 2012, Pune, India
33	Dr. H.C. Kandpal	Role of Surface Plasmons in Modulating Spectral and Coherence Properties	XXXVI OSI Symposium on Frontiers in Optics and Photonics (FOP11), IIT Delhi, Dec. 3-5, 2011
34	Dr. V.N. Ojha	Quality Management System 'ISO 17025'	A training programme on 'Competency Development for Technical Officers' at CSIR-The Human Resource Development Centre, Ghaziabad June 20-24, 2011
35	Dr. V.N. Ojha	Quality Management Systems 'ISO 9000'	A training programme on 'Competency Development for Technical Officers' at CSIR-The Human Resource Development Centre, Ghaziabad June 20-24, 2011
36	Dr. V.N. Ojha	Need for Nanometrology	Workshop on Uncertainty in Measurement, Optical Profiler & Low level DC Resistance & Current Measurements, November 16-18, 2011 at NPL, New Delhi. (under Nanometrology Project)
37	Dr. V.N. Ojha	Evaluation and Expression of Uncertainty in Measurements	Workshop on Uncertainty in Measurement, Optical Profiler & Low level DC Resistance & Current Measurements, November 16-18, 2011 at NPL, New Delhi. (under Nanometrology Project)
38	Dr. V.N. Ojha	Low Level Voltage Measurements	Workshop on Uncertainty in Measurement, Optical Profiler & Low level DC Resistance & Current Measurements, November 16-18, 2011 at NPL, New Delhi. (under Nanometrology Project)
39	Dr. V.N. Ojha	Quality Management System 'ISO 17025'	A training programme on 'Competency Development for Technical Officers' from 28 Nov-02 Dec, 2011 at CSIR-The Human Resource Development Centre, Ghaziabad.

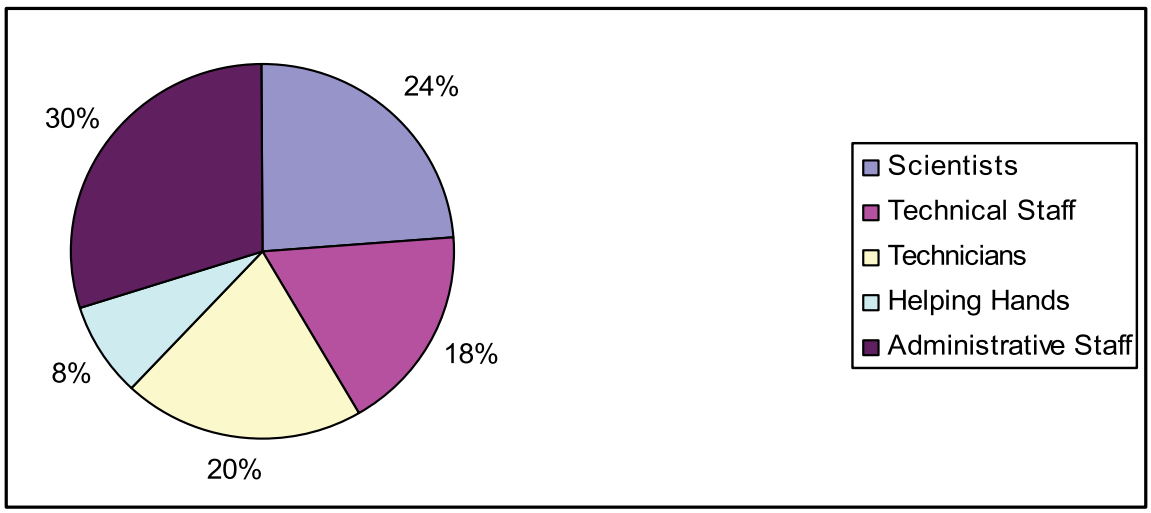
S No	Speaker's Name	Topic	Event and Venue
40	Dr. V.N. Ojha	Quality Management Systems 'ISO 9000'	A training programme on 'Competency Development for Technical Officers' from 28 Nov-02 Dec, 2011 at CSIR-The Human Resource Development Centre, Ghaziabad.
41	Dr. V.N. Ojha	Quantum Electrical, Nanoelectrical and Nanodimensional Metrology at NPL-I	Invited Talk at 'Quantum Electronics and Photonics Division' of NIST, Boulder, USA on January 17, 2012.
42	Dr. Anjana Dogra	Refresher Course in Physics (RC-239)-I	UGC-Academic Staff College, Himachal Pradesh University, Shimla, August 4-5, 2011
43	Dr. Anjana Dogra	Refresher Course in Physics (RC-239)-II	UGC-Academic Staff College, Himachal Pradesh University, Shimla, August 4-5, 2011
44	Dr. Ranjana Mehrotra	Biomedical Plasmonics	AdMet 12, PUNE
45	Dr. Ranjana Mehrotra	IR Spectroscopy & Applications	Biomedical Instrumentation Programme, CSIO, New Delhi, March 29, 2012
46	Dr. G. Bhagavannarayana	Crystal Growth: A Subject of Study and Research	Inaugural address delivered in the Inaugural function of a newly established lab "Crystal Growth and Nanosynthesis Research Center" on April 6, 2011
47	Dr. G. Bhagavannarayana	Crystal Growth and Evaluation of Structure and Perfection by X-ray Methods	Phys. Deptt., Government College (A), Rajahmundry, Andhra Pradesh on April 6, 2011 on the day of Inauguration of a new R&D lab "Crystal Growth and Nanosynthesis Research Center" on April 6, 2011
48	Dr. G. Bhagavannarayana	Advanced Materials Characterization: Role of X-rays	Physics Dept., Government College (A), Rajahmundry, Andhra Pradesh during Nov. 24-25, 2011.
49	Dr. G. Bhagavannarayana	Characterization of Epitaxial Films and their Nano-Scale Device Structures by High- Resolution XRD, GII- XRD and RSM Techniques	International Conference on Advanced Materials (ICAM 2011) held at Dept. of Phys., PSG College of Technology, Coimbatore during Dec. 12-16, 2011.
50	Dr. G. Bhagavannarayana	An Overview on X-Ray Characterization Techniques for Purity, Composition, Structure and Perfection including Defects & Interfaces	National Conference on Recent Advances in Materials and Technology (NCRAMAT – 2012) held at Phys. Dept., Sathyabama University held during Jan. 6 - 7, 2012.
51	Dr. G. Bhagavannarayana	Recent Advances in Materials & Technology	Plenary talk delivered at National Conference on Recent Advances in Materials and Technology (NCRAMAT – 2012) held at Phys. Dept., Sathyabama University held during Jan. 6 - 7, 2012
52	Dr. G. Bhagavannarayana	Evaluation of Purity, Structure and Perfection of Advanced Materials by Advanced X-Ray Techniques	DAE-BNRS National Symposium (NLS-20) held at Crystal Growth Center, Anna University, Chennai during Jan. 9-12, 2012.
53	Dr. G. Bhagavannarayana	Enhancement of NLO properties in single crystals due to additives/ dopants/ annealing and their correlation with crystalline perfection	A special Invited talk delivered at Presidency College, Chennai on Jan. 11, 2012.

S No	Speaker's Name	Topic	Event and Venue
54	Dr. G. Bhagavannarayana	Advanced Materials Characterization Techniques by X-Rays: An Overview	Invited talk delivered at Phys. Dept., Sree Subbaraya and Narayana College, Narasaraopeta, Guntur (DT), Andhra Pradesh, on Jan. 25, 2012
55	Dr. G. Bhagavannarayana	Crystal Growth and X-ray Characterization – An Overview	National Conference on Recent Advanced Materials" held during Jan. 27 & 28, 2012 at Department of Physics, Sir C.R. Reddy (Autonomous) College, Eluru, Andhra Pradesh.
56	Dr. G. Bhagavannarayana	Recent Advanced Materials	National Conference on Recent Advanced Materials" held during Jan. 27 & 28, 2012 at Department of Physics, Sir C.R. Reddy (Autonomous) College, Eluru, Andhra Pradesh.
57	Dr. G. Bhagavannarayana	Crystal Growth and X-ray Characterization – An Overview	DAE-BRNS National Laser Symposium (NLS-20) held at Anna University, Chennai during Jan. 9-12, 2012 at crystal growth centre
58	Dr. G. Bhagavannarayana	Enhancement of NLO Properties in Single Crystals due to Additives/ Dopants/ Annealing and their Correlation with Crystalline Perfection	International Conference on Nanomaterials and Nanotechnology (ICNANO-2011),held at University of Delhi, Delhi during December 18-21, 2011
59	Dr. Rashmi	X-ray Fluorescence Spectrometry for Characterization of Materials Applications of X-ray Fluorescence Spectrometry in Materials Characterization	Frontiers in Nanoscience, Nanotechnology and Their Applications (NanoSciTech 2012), held at Punjab University, Chandigarh during February 15-18, 2012
60	Dr. N. Vijayan	Growth of Highly Perfection Single Crystals by Different Methods for Technological Applications	National Seminar on Challenges and Emerging Trends in Physics (Intercollegiate meet on PHUSIS) during Feb. 23-24, 2012 held at Dept. of Physics, Dhanalakshmi Srinivasan college of Arts & Science for Women, Perambalur, Tamil Nadu.
61	Dr. S.G. Aggarwal	Overlooking Aerosol Metrology: A Big Hole in Atmospheric Aerosol Measurement Studies	7th Asian Aerosol Conference, Xi'an, China, August 17-20, 2011
62	Dr. S.G. Aggarwal	Chemical Indicators of Source Contributions in Indian Cities	Workshop on vehicular air pollution and its impact on human health (jointly organized by MoEF, CPCB, EPCA, ICCT), Indian Habitat Centre, New Delhi, India, September 1-2, 2011
63	Dr. S.G. Aggarwal	Metrology Matters more than Tightening of Vehicle Emission Regulations and Air Quality Standards	National Conference on Advances in Metrology (AdMet-2012), Pune, India, February 6-8, 2012
64	Dr. S.G. Aggarwal	Status and Challenges in Aerosol Metrology	Divisional Seminar of NPL, March 12, 2012

APPENDIX - 16

HUMAN RESOURCE
As on March 31, 2012

GROUP IV		**GROUP II**	**Sub-Total :**	**153**
Director	1			
Outstanding Scientist	1			
Chief Scientist	26	**GROUP I**	**Sub-Total :**	**61**
Sr. Principal Scientist	33			
Principal Scientist	25	ADMN-A		8
Sr. Scientist	31	ADMN-B		76
Scientist	48	ADMN-C		34
Jr. Scientist	15	ADMN-C (Cafeteria Staff)		8
Sub-Total :	**180**	ADMN-D		93
		ADMN-D (Cafeteria Staff)		7
GROUP III			**Sub-Total :**	**226**
Principal Technical Officer	8		**GRAND TOTAL :**	**756**
Supt. Engg. & Asst. Engg.	4			
Sr. Technical Officer (3)	29			
Sr. Technical Officer (2)	17			
Sr. Technical Officer (1)	6			
Technical Officer	12			
Tech Asstt Gr III(2)	6			
Tech Asstt Gr III(1)	54			
Sub-Total :	**136**			



SCIENTISTS AND OFFICERS AS ON 31.03.2012

DIRECTOR
Prof R C Budhani

PHYSICS OF ENERGY HARVESTING
Head : Dr S T Lakshmikumar

Name	Designation
Dr S T Lakshmikumar	Chief Scientist
Dr Suresh Chand	Chief Scientist
Dr Parakram Kumar Singh	Chief Scientist
Dr Omvir Singh Panwar	Chief Scientist
Dr Abdul Mobin	Sr Principal Scientist
Dr S M Shivaprasad	Sr Principal Scientist
Dr (Ms) Kiran Jain	Sr Principal Scientist
Mr C M S Rauthan	Sr Principal Scientist
Dr K M K Srivatsa	Sr Principal Scientist
Mr Sudhanshu Dwivedi	Principal Scientist
Dr T D Senguttuvan	Principal Scientist
Dr Jeya Kumar Ramanujam	Principal Scientist
Dr Shailesh Narayan Sharma	Sr Scientist
Dr Sushil Kumar	Sr Scientist
Dr Amish G Joshi	Sr Scientist
Dr Govind	Sr Scientist
Dr (Ms) Ritu Srivastava	Sr Scientist
Mr Chockalingam Sreekumar	Scientist
Mr Kamlesh Patel	Scientist
Dr Vinay Gupta	Scientist
Ms Vandana	Scientist
Dr Senthil Kumar	Scientist
Mr Pankaj Kumar	Scientist
Dr Mahesh Kumar	Scientist
Mr Sanjay Kumar Srivastava	Scientist
Dr Prabir Pal	Scientist
Dr Preetam Singh	Scientist
Dr Sunil Singh Kushvaha	Scientist
Dr Ajay Kumar Shukla	Scientist
Dr Chandra Kant Suman	Scientist
Dr S Sudhakar	Scientist
Dr Rajiv Kr. Singh	Jr Scientist
Dr Praveen Kumar Siwach	Jr Scientist
Mr Tarun Kumar Chakraborty	Principal Technical Officer
Mr Mukul Sharma	Sr. Technical Officer (3)

Name	Designation
Dr Gauri Datt Sharma	Sr. Technical Officer (3)
Dr V K Hans	Sr. Technical Officer (3)
Mr Murari Lal Sharma	Sr. Technical Officer (3)
Mr Jagdish Chand	Sr. Technical Officer (2)

MATERIAL PHYSICS AND ENGINEERING

Head : Dr R B Mathur

Name	Designation
Dr Rakesh Behari Mathur	Chief Scientist
Dr Virendra Shanker	Chief Scientist
Dr Ashok Manikrao Biradar	Chief Scientist
Mr Subodh Kumar Singhal	Chief Scientist
Dr R K Kotnala	Chief Scientist
Dr Sunil Kumar Singhal	Chief Scientist
Dr Krishan Kumar Saini	Sr Principal Scientist
Dr S K Dhawan	Sr Principal Scientist
Dr (Ms) Santa Chawla	Sr Principal Scientist
Dr Ajay Dhar	Sr Principal Scientist
Mr Sanjay Rangnate Dhakate	Principal Scientist
Dr Narinder Kumar Arora	Principal Scientist
Dr Rajesh	Sr Scientist
Dr (Ms) Gurusharan Kaur Padam	Sr Scientist
Dr Divi Haranath	Sr Scientist
Mr Vipin Jain	Sr Scientist
Dr Aloysius R P	Sr Scientist
Dr (Ms) G Sumana Gajala	Sr Scientist
Dr Dinesh Kumar Misra	Sr Scientist
Dr Nirmalya Karar	Scientist
Mr Bhanu Pratap Singh	Scientist
Mr Parveen Saini	Scientist
Dr (Ms) Nidhi Singh	Scientist
Dr Ved Varun Agrawal	Scientist
Mr Bathula Sivaiah	Scientist
Mr M Saravanan	Scientist
Dr Gounda Abdul Basheed	Scientist
Dr Bipin Kumar Gupta	Jr Scientist
Ms Priyanka Heda Maheshwari	Jr Scientist
Dr (Ms) Saroj Kumari	Jr Scientist
Mr Rajiv Sikand	Principal Technical Officer
Mr Pinaki Ranjan Sen Gupta	Sr. Technical Officer (3)
Mr Chander Kant	Sr. Technical Officer (3)

Name	Designation
Mr Rakesh Khanna	Sr. Technical Officer (2)
Mr Rajesh Kumar Seth	Sr. Technical Officer (2)
Mr Vinod Kumar Tanwar	Technical Officer
Mr Manoj Kumar Pandey	Technical Officer

RADIO AND ATMOSPHERIC SCIENCES

Head : Dr B C Arya

Name	Designation
Dr Bhuwan Chandra Arya	Chief Scientist
Dr M V S N Prasad	Chief Scientist
Mr Pattamatta Subrahmanyam	Sr Principal Scientist
Mr H K Maini	Sr Principal Scientist
Mr Thomas John	Sr Principal Scientist
Dr (Ms) Meena Jain	Sr Principal Scientist
Dr Chhemendra Sharma	Principal Scientist
Mr Randhir Singh Tanwar	Principal Scientist
Dr Tuhin Mandal	Principal Scientist
Dr Sachidanand Singh	Principal Scientist
Dr (Ms) Monika Kulshreshta	Sr Scientist
Dr Arun Kumar Upadhayaya	Scientist
Mr Rupesh M Das	Scientist
Mr Sumit Kumar Mishra	Scientist
Dr Rajesh Agnihotri	Scientist
Dr Kirti Soni	Jr Scientist
Dr Sudhir Kumar Sharma	Jr Scientist
Mr Arun Kumar Ghoghar	Sr. Technical Officer (3)
Mr Shambhu Nath	Sr. Technical Officer (3)
Ms Shiv Kumari Bhatia	Sr. Technical Officer (3)
Ms Beena Gupta	Sr. Technical Officer (3)
Mr Vinod Kumar Sharma	Sr. Technical Officer (3)
Mr Man Mohan Gupta	Sr. Technical Officer (3)
Mr Alok Mukherjee	Technical Officer

TIME AND FREQUENCY STANDARDS

Head : Dr A Sengupta

Name	Designation
Dr Amitava Sen Gupta	Outstanding Scientist
Mr Kavindra Pant	Sr Principal Scientist
Ms Arundhati Chatterjee	Principal Scientist
Dr Ashish Agarwal	Sr Scientist
Dr (Ms) Poonam Arora	Scientist

Name	Designation
Ms Pranalee Premdas Thorat	Jr Scientist
Mr Anil Kumar Suri	Principal Technical Officer

APEX LEVEL STANDARDS AND INDUSTRIAL METROLOGY

Head : Dr A K Bandhyopadhyay

Name	Designation
Dr Ashis Kumar Bandyopadhyay	Chief Scientist
Dr Ashok Kumar	Chief Scientist
Dr Hem Chandra Kandpal	Chief Scientist
Dr Sushil Kumar Jain	Chief Scientist
Dr Pardeep Mohan	Chief Scientist
Mr Anil Kumar Govil	Chief Scientist
Mr Mukesh Kumar Mittal	Chief Scientist
Dr K P Chaudhary	Chief Scientist
Dr Yesh Pal Singh	Chief Scientist
Mr Anil Kishore Saxena	Chief Scientist
Mr Anil Kumar	Sr Principal Scientist
Dr Sher Singh Rajput	Sr Principal Scientist
Mr H R Singh	Sr Principal Scientist
Dr (Ms) Ranjana Mehrotra	Sr Principal Scientist
Mr Pramendra Singh Negi	Sr Principal Scientist
Mr Joges Chandra Biswas	Principal Scientist
Mr Mahavir Singh	Principal Scientist
Mr D Arun Vijayakumar	Principal Scientist
Mr Ajeet Singh	Principal Scientist
Dr Sanjay Yadav	Principal Scientist
Dr (Ms) Nita Dilawar	Principal Scientist
Dr Sanjeev Sinha	Principal Scientist
Dr S Seela Kumar Titus	Principal Scientist
Mr Rajbeer Singh	Sr Scientist
Mr M A Ansari	Sr Scientist
Mr Rajesh Kumar	Sr Scientist
Mr Shiv Kumar Jaiswal	Sr Scientist
Mr Saood Ahmed	Sr Scientist
Mr Gautam Mandal	Sr Scientist
Mr Naveen Garg	Scientist
Mr Dilip Dhondiram Shivagan	Scientist
Dr Parag Sharma	Scientist
Mr Harish Kumar	Scientist
Ms Girja Moona	Jr Scientist
Mr Satish	Jr Scientist
Mr Virendra Babu	Principal Technical Officer

Name	Designation
Mr Jagdish Kumar Gupta	Principal Technical Officer
Mr Gurbir Singh	Principal Technical Officer
Ms Reeta Gupta	Sr. Technical Officer (3)
Dr Yudhisther Kumar Yadav	Sr. Technical Officer (3)
Mr Kul Bhushan Ravat	Sr. Technical Officer (3)
Mr Gurcharanjit Singh	Sr. Technical Officer (3)
Mr Mohammad Saleem	Sr. Technical Officer (3)
Mr Ishwar Singh Taak	Sr. Technical Officer (3)
Mr Avdhesh Kumar Goel	Sr. Technical Officer (2)
Mr Bhikham Singh	Sr. Technical Officer (2)
Mr Mukesh Kumar	Sr. Technical Officer (2)
Mr Om Prakash	Sr. Technical Officer (2)
Mr K N Basavaraju	Sr. Technical Officer (2)
Mr Bijendra Pal	Sr. Technical Officer (2)
Mr Sudama	Sr. Technical Officer (2)
Mr Mahargha Baran Das	Sr. Technical Officer (1)
Dr Bharat Kumar Yadav	Sr. Technical Officer (1)
Mr Harish Kumar	Sr. Technical Officer (1)
Mr Sridhar Lingam	Technical Officer
Mr Rasik Behari Sibal	Technical Officer
Mr Virendra Kumar Gupta	Technical Officer
Mr Anoop Singh Yadav	Technical Officer
Mr Vikram	Technical Officer

QUANTUM PHENOMENA AND APPLICATIONS

Head : Dr H C Kandpal

Name	Designation
Dr H C Kandpal	Sr. Chief Scientist
Dr Vijay Narain Ojha	Chief Scientist
Dr Tushya Kumar Saxena	Sr Principal Scientist
Dr (Ms) P L Upadhyay	Sr Principal Scientist
Dr. Vijay Kumar Gumber	Sr Principal Scientist
Dr (Ms) Rina Sharma	Principal Scientist
Dr Anurag Gupta	Principal Scientist
Dr Hari Krishna Singh	Sr Scientist
Dr Veerpal Singh Awana	Sr Scientist
Ms Manju Singh	Sr Scientist
Mr Virendra Kumar Jaiswal	Scientist
Mr Rajendra Singh Meena	Scientist
Dr (Ms) Anjana Dogra	Scientist
Ms Priyanka Jain	Scientist
Dr Sudhir Husale	Scientist

Name	Designation
Dr Rajib Kr. Rakshit	Scientist
Dr Vijay Kr. Toutam	Scientist
Dr Ashok Kumar	Jr Scientist
Ms Santhya Malikar Patel	Jr Scientist
Ms Usha Kiran	Sr. Technical Officer (1)
Ms Poonam Sethi Bist	Technical Officer

ADMINISTRATION

Head : Mr T V Joshua

Name	Designation
Mr T V Joshua	COA
Ms Veena Jain	Admn. Ofcr
Ms Manju	Hindi Officer
Mr Jay Narayan Upadhyay	Hindi Officer
Mr Jagan Nath Prasad	Sr. Technical Officer (3)
Mr Jokhan Ram	Sr. Technical Officer (2)
Mr Vikram Singh	S O(G)
Ms Bhawna Guglani	S O(G)
Mr Anil Kumar	S O(G)
Mr S K Yadav	S O(G)
Mr Hari Narain Meena	SO(G)
Mr A K Handa	SO(G)
Mr Mange Ram	PS
Ms Paramjit Kaur	PS
Mr Amar Singh	PS
Mr Ram Gopal Meena	PS
Ms Saroj Gandhi	PS

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Head : Mr S K Mehta

Name	Designation
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Mr Sudipto Chaterjee	F&AO
Mr Ajay Kumar	S O (F&A)
Mr S K Thakur	S O (F&A)
Ms Kavita Bellani	S O (F&A)
Mr R P Meena	S O (F&A)

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Head : Mr Mukesh Khanna

Name	Designation
Mr Mukesh Khanna	SPO

Name	Designation
Mr Kuldeep Kaushik	SPO
Mr Bhag Singh	S O (str & pur)
Mr Viney Kumar Sharma	S O (str & pur)
Mr Jai Singh	S O (str & pur)

WORKS AND SERVICES

Head : Dr J C Sharma

Name	Designation
Dr Jugdish Chandra Sharma	Sr Principal Scientist
Mr S K Kushwaha	Sr. Supt. Engnr.(Civil)
Mr K P S Yadav	Sr. Supt. Engnr.(Elect)
Mr Deepak Bansal	Sr. Technical Officer (3)
Mr Mohan Chandra Singh	Sr. Technical Officer (3)
Mr Gurdeep Singh Lamba	Sr. Technical Officer (2)
Mr Anand Kumar Mishra	Asstt. Exe.Engineer (Civil)
Mr Rambir Singh	Asstt. Engineer

WORKSHOP

Head : R K Kotnala

Name	Designation
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Mr Ravi Khanna	Principal Technical Officer
Mr Jai Pal Singh	Sr. Technical Officer (2)
Mr Amar Singh	Sr. Technical Officer (1)

COMPUTATION AND NETWORK FACILITY

Head : Dr Ravi Mehrotra

Name	Designation
Dr Ravi Mehrotra	Chief Scientist
Mr Ashish Ranjan	Sr Scientist
Ms Deepti Chaddha	Scientist
Mr Nitin Sharma	Scientist
Ms Anjali Sharma	Scientist
Mr Trilok Bhardwaj	Jr Scientist
Mr Kanwaljit Singh	Sr. Technical Officer (2)
Mr Vijay Sharma	Sr. Technical Officer (2)

DIRECTORATE

Head : Prof. R C Budhani

Name	Designation
Prof R C Budhani	Director

Name	Designation
Dr Godavarthi Bhagavannarayana	Chief Scientist
Mr Prabhat Kumar Gupta	Chief Scientist
Dr Rakesh Kumar Garg	Sr Principal Scientist
Mr T Raghavendra	Sr Principal Scientist
Dr (Ms) Rashmi	Sr Principal Scientist
Dr Rajendra Prasad Pant	Sr Principal Scientist
Dr Devinder Gupta	Sr Principal Scientist
Dr Sukhvir Singh	Principal Scientist
Dr (Ms) Renu Pasricha	Principal Scientist
Dr Avanish K Srivastava	Principal Scientist
Dr Jiji Thomas Joseph Pulikkotil	Principal Scientist
Dr Kamlesh Kumar Maurya	Sr Scientist
Ms Santosh Singh	Sr Scientist
Dr Nahar Singh	Sr Scientist
Dr (Ms) Prabha Johri	Sr Scientist
Dr Shankar Gopal Aggarwal	Sr Scientist
Dr Surendra Pal Singh	Scientist
Dr Narayanaswamy Vijayan	Scientist
Dr (Ms) Sushree Swarupa Tripathy	Scientist
Dr (Ms) Daya Soni	Scientist
Dr Vidya Nand Singh	Scientist
Dr Manas kumar Dalai	Jr Scientist
Mr Niranjan Singh	Principal Technical Officer
Mr V D Arora	Sr. Technical Officer (3)
Dr (Ms) Manju Arora	Sr. Technical Officer (3)
Mr Kedar Nath Sood	Sr. Technical Officer (3)
Mr Rajiv Kumar Saxena	Sr. Technical Officer (3)
Mr Ashok Kumar	Sr. Technical Officer (3)
Ms Abha Bhatnagar	Sr. Technical Officer (2)
Ms Anita Sharma	Technical Officer
Dr Khem Singh	Technical Officer

INTELLECTUAL PROPERTY AND HUMAN RESOURCE

Head : Dr Virendra Shanker

Name	Designation
Dr Rajeev Chopra	Sr Principal Scientist
Dr (Ms) Jyoti Lata Pandey	Sr Principal Scientist
Dr D P Bhatt	Sr Principal Scientist
Mr Ganga Prasad	Sr Principal Scientist
Ms Indra Tiwari	Sr Principal Scientist
Mr N K Wadhwa	Principal Scientist

Name	Designation
Ms Anuradha Sengar	Sr Scientist
Dr R G Mathur	Scientist
Mr Abhishek Sharma	Jr Scientist
Mr Jagdish Prasad	Sr. Technical Officer (3)
Mr Ashwani Kumar Suri	Sr. Technical Officer (3)
Mr V K Ojha	Sr. Technical Officer (3)
Ms Shashi Lekha Bhatnagar	Sr. Technical Officer (2)
Mr Rajpal Zamaji Walke	Sr. Technical Officer (1)
Ms Neetu Chandra	Technical Officer
Dr P Prathap	Scientist

Retired Persons

Ms Kanchan Bala, Ass(F&A) Grade II (ACP3)
Dr Gopal Bhatia, Scientist G
Dr P Banerjee, Scientist G
Dr Sita Ram Gupta, Scientist G
Dr Ms Meenakshi Kar, Scientist F
Mr Roshan Lal, Record Keeper
Mr R P Bhatnagar, Sr. Technician (2)
Mr Indra Singh Rawat, Asstt (G) Grade -1
Ms Basanti Devi, Karya Sahayak (ACP1)
Mr T Gangadharan, Asstt (G) Grade -1
Dr Desh Raj Sharma, Scientist G
Mr Raj Kumar, Sr. Technician (2)
Ms Sushila Issrani, Asst. (G) Grade II (ACP3)
Mr S Uma Maheshwar Rao, Scientist F
Mr Murari Lal Sharma, Lab Assistant
Mr S B Samanta, Principal Technical Officer
Mr Dharam Prakash, Sr. Technician (1)
Mr Rattan Lal (Kundara), Sr. Technician (2)
Mr K L Nagarwal, Sr. Technician (2)
Ms Nirmal Pasricha, Asstt (G) Grade -1
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Mr M P Singh, Principal Scientist
Dr Hari Kishan, Chief Scientist
Mr Ramesh Chandra Anandani, Sr Principal Scientist
Dr M N Kamalasanan, Chief Scientist
Mr Sri Krishan, Lab Assistant
Mr Omkar Sharma, Chief Scientist
Mr Ravi Kumar Chatwal, Principal Technical Officer
Mr Amar Singh Vats, Sr. Technician (2)
Mr Vinod Kumar, Sr. Technician (2)

Obituaries

Mr Harihar Mehto, Sr. Technician (2)
Mr Dharam Vir Singh, Sr. Technician (1)
Mr Kandhai, Lab Assistant
Mr Naseem Mohammad, Karya Sahayak
Mr Anand Singh , Karya Sahayak

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Dr C P Sharma, Emeritus Sci.
Dr Harish Chandra, Emeritus Sci.
Dr S K Aggarwal, Emeritus Sci.
Dr S K Haldar, Emeritus Sci.
Dr S L Jain, Emeritus Sci.
Dr S N Singh, Emeritus Sci.
Dr Subhash Chandra, Emeritus Sci.
Dr U N Sinha, Emeritus Sci.
Mr S C Garg, Emeritus Sci.
Dr B R Chakraborty, Emeritus Sci.
Dr S K Sarkar, Emeritus Sci.
Dr S K Gupta, Emeritus Sci.
Dr V Mohanan, Emeritus Sci.
Dr Hari Kishan, Emeritus Sci.
Dr K K Mahajan, INSA Honorary Sci
Dr Krishan Lal, INSA Sr. Sci.
Dr Preeti Bijlani, Part time Medical Officer

Dr S K Joshi, Platinum Jub. Emr. Sci
Dr Gopal Bhatia, Project Adviser
Mr R C Anandani, Project Adviser
Dr O P Bahl, Project Adviser / Co-ordinator
Dr Vikram Soni, Research Sci C
Dr (Ms) Sangeeta Sahoo, Scientist Fellow
Dr. (Ms) Shubhra Kala, Scientist Fellow
Dr Prasun Ganguly, Scientist Fellow - CSIR Nehru Science PDR Fellowship
Dr Manju Dhakad, Scientist Fellow - CSIR Nehru Science PDR Fellowship
Dr Avneesh Anshul, Scientist Fellow - CSIR Nehru Science PDR Fellowship
Dr Rahul Singhal, Scientist Fellow - CSIR Nehru Science PDR Fellowship

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Mr Vijay Kumar, JRF (DST)
Ms Chanchal Gupta, JRF (NPL) Project
Ms Renchu Scaria, JRF (UGC)
Ms Harjeet Kaur, JRF(CSIR)
Ms Pratibha Goel, JRF(CSIR)
Ms Stuti Joshi, JRF(CSIR)
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Mr Shishir Tripathi, JRF(CSIR)
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Mr Shashank Tripathi, JRF(CSIR)
Mr Raman M, JRF(CSIR)
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Dr Pratima R Solanki, P.I.
Dr K K Jain, P.I. (user scheme)
Dr R P singhal, P.I. (user scheme)
Mr Bhaskar Gahtori, P.I. Young Scientist
Dr Shilaja Pande, P.I.(WOS-A)
Ms Sonal, P.I.(WOS-A)
Ms Munu Borah, P.I.(WOS-A)
Ms Deepika Yadav, Quick Hire Scientist (Trainee)
Mr Dilip Kumar Kaushik, Quick Hire Scientist (Trainee)
Mr Aswin V., Quick Hire Scientist (Trainee)
Mr Vattikonda Bharath, Quick Hire Scientist (Trainee)
Mr Anuj Krishna, Quick Hire Scientist (Trainee)
Mr Ratneshwar Thakur, Quick Hire Scientist (Trainee)
Mr Satyendra Kumar Pandey, Quick Hire Scientist (Trainee)
Mr Achu Chandran, Quick Hire Scientist (Trainee)
Mr Dibyajyoti Mohanty, Quick Hire Scientist (Trainee)
Ms Indu Elizabeth, Quick Hire Scientist (Trainee)
Ms Indrani Coondoo, RA
Ms Kavita Sharma, RA
Ms. Taranuum Bano, RA
Dr (Ms) Jyoti Shah, RA
Dr. (Ms) Parul Singh, RA
Ms Nirmal Prabhakar, RA
Dr Jitender Gaur, RA
Ms Ranoo Bhargav, Res. Intern
Ms Anubha Sharma, Res. Intern
Ms Gunjan Mittal, Res. Intern
Ms Poonam Yadav, Res. Intern
Ms Anupam Shakya, Res. Intern
Mr Pradeep kumar Pandey, Res. Intern
Ms Rajni Porwal, Res. Intern
Ms Sucheta Juneja, Res. Intern
Mr Aishik Acharya, Sr. Project Fellow
Dr (Ms) Punita Singh, Sr. Res. Assoc.

Dr (Ms) Suman, Sr. Res. Assoc.
Dr Ashok Kumar, Sr. Res. Assoc.
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Mr Ranjit Kumar, SRF (CSIR)
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Ms Jhuma Gope, SRF (CSIR)
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Mr Vinod Kumar Chahar, SRF (CSIR)
Mr Satya Kumar Kushwaha, SRF (CSIR)
Ms Arpita Vajpayee, SRF (CSIR-UGC)
Ms Hema Bhandari, SRF (CSIR-UGC)
Mr Ravi Kant Prashad , SRF (CSIR-UGC)
Mr Umesh kumar, SRF (CSIR-UGC)
Mr Deepak Kumar Jangir, SRF (ICMR)
Mr Veeresh Kumar, SRF (UGC)
Mr Anoop Kumar S, SRF (UGC)
Mr Tilak Joshi, SRF (UGC-NPL)
Mr Ajay Kumar, SRF (UGC-NPL)
Mr Ajay Shankar, SRF(CSIR)
Mr Manish Verma, SRF(CSIR)
Mr Sandeep Kumar, SRF(CSIR)
Mr Saurabh Srivastava, SRF(CSIR)
Ms Nidhi Puri, SRF(CSIR)
Mr Kirandeep Singh, SRF(CSIR)
Mr Amit Kumar Chauhan, SRF(CSIR)
Ms Aditya Sharma, SRF(CSIR)
Ms Aneeta Kharkwal, SRF(CSIR)
Mr Kajal Kumar Dey, SRF(CSIR)
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Mr Sandeep Kumar Pundir, SRF(CSIR)
Mr Surjeet Kumar Mishra, SRF(CSIR)
Mr Manoj Kumar Srivastava, SRF(CSIR)
Mr Amit Kumar, SRF(CSIR)
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Dr Razi Ahmad, SRF(CSIR)
Mr Md Azahar Ali, SRF(CSIR)
Mr Md Taukheer Khan, SRF(CSIR)
Ms Anu Malik, SRF(CSIR)
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Mr Purushottam Bhawre, SRF(NPL)
Ms Rachna Sharma, SRF(UGC)
Mr Jitendra Gangwar, SRF(UGC)
Ms Priyanka Tyagi, SRF-CSIR
Ms Ruchi Singh, SRF-CSIR, NPL(Project)
Ms Sonika, SRF-DBT
Ms Gunjan Tyagi, SRF-ICMR, NPL
Mr Anil Kumar, SRF-MNRE
Ms Monika Mishra, SRF-MNRE
Ms Daisy Verma, SRF-NPL (Project)
Mr Dharam Pal Singh, SRF-RGN
Ms Arti Rani, SRF-RGN
Mr Rahul Tripathi, SRF-UGC

APPENDIX-17

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(01.04.2010 - 31.03.2013)

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Chairman
Division of Physical and Mathematical Sciences
Dept of Physics
Indian Institute of Science
BANGALORE - 560 012

02 **Prof Shyam Lal** ... . Member
Head (External)
Space and Atmospheric Science Division
Physical Research Laboratory (PRL)
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03 **Prof Ashutosh Sharma** .. .. Member
Dept. of Chemical Engineering
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(IIT) Kanpur
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04 **Dr M J Zarabi** .... Member
C – 28
Pamposh Enclave
NEW DELHI - 110 048

05 **Dr C S Sundar** .... Member
Director
Materials Science Group
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KALPAKKAM - 603 102

06 **Prof E V Sampath Kumaran** .... Member
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07 **Dr Praveer Asthana** .... Member
Mission Director (Nano Mission) (Agency Representative)
Department of Science and Technology (DST)
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08 **Dr Pawan Kapur** .... Member
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09 **Prof Indranil Manna** .... Member
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10 **Dr Chandra Shekhar** .... Member
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11 **Dr Sudeep Kumar** .... Member
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12 **Prof R C Budhani** .... Member
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13 **Sh T Raghavendra** .. ..Non-Member
Head, Planning Monitoring & Evaluation Group Secretary
National Physical Laboratory
Dr K S Krishnan Marg
NEW DELHI - 110 012

Members of the Management Council of CSIR-NPL
(01.01.2010 to 31.12.2011)

01.	Prof. R.C. Budhani, Director	...	...	...	Chairman
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03.	Dr. (Ms) Nita Dilawar, Gr IV(3)	...	...	...	Member
04.	Dr. Ajay Dhar, Gr IV(5)	...	...	...	Member
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06.	Sh. Ravi Khanna, Gr.III(7)	...	...	...	Member
07.	Shri T. Raghavendra, Head, PME	...	...	...	Member
08.	Sh. S.K. Mehta, CFA	...	...	...	Member
09.	Dr. S. Gangopadhyay, Director, CRRI	...	...	...	Member
10.	Sh. T.V. Joshua, COA	...	...	...	Member Secretary