From Director's Desk...

It gives me great pleasure to present the Annual Report of CSIR-National Physical Laboratory (NPL) for the year 2010-11.

The year, 2010-11, had been productive, eventful and transformational. CSIR-NPL, with the objective of carrying out R&D in Physical Sciences and related areas of Metrology, has come a long way and emerged as one of the premier institutes of research in India.

Due to ever-changing pace of development in the international scientific arena and the altered dynamics of the scientific and technological scenario caused by the accelerating pace of globalization, CSIR-NPL has to keep orienting itself from time to time to maintain its significant contribution to India's national competitiveness as well as global image. The expectation all around is to produce excellent research results as well as demonstrate their commercialization potential, develop intellectual property and standard, provide consultation and nurture human resources.

The motivation of CSIR-NPL members to work effectively to meet the new challenges had always been admirable. During the year, to have more focused approach towards our research activities, some organizational and operational changes were done. Some of the research and development activities, so far, based on core scientific disciplines, were reorganized on the basis of highly prioritized research themes. Efforts were made to develop and establish the best-in-class experimentation and instrumentation setup in priority areas of research. Several new and state-of-the-art characterization facilities were created and set up during the year. A plan was also initiated to grow and nurture high quality young researchers.

The existing seven Divisions, such as Physico-Mechanical Standards, Electrical and Electronic Standards, Engineering Materials, Electronic Materials, Materials Characterization, Radio & Atmospheric

Sciences and Superconductivity & Cryogenics have been restructured to new theme-wise Divisions, now known as (1) Physics of Energy Harvesting, (2) Materials Physics and Engineering, (3) Radio & Atmospheric Sciences, (4) Time, Frequency & Electrical Standards, (5) Quantum phenomenon & Applications and (6) Apex Level Standards & Industrial Metrology. The erstwhile Materials Characterization Division has now been reconstituted as Sophisticated & Analytical Instruments Group as a supporting unit.

CSIR-NPL being National Metrological Institute (NMI) of India and the custodian of the national standards of measurement, maintenance and up-gradation of National Standards of Measurements remained the statutory responsibility of CSIR-NPL. In addition to that, intensive R&D in frontier areas of physics was carried out under several externally funded and in-house projects. With the initiation of Network-projects programme of CSIR-NPL had been playing a crucial role in many of these projects as is reflected in the report.

The Division, Physics of Energy Harvesting created during the year, incorporating activities of the erstwhile division of Electronic and Engineering Materials, comprises activities on organic photovoltaic and light emitting devices, inorganic light emitting diodes, amorphous and crystalline silicon solar cells and a newly created activity on materials for thermoelectric devices. The activities under the CSIR projects on silicon and amorphous silicon solar cells (SIP17) and light emitting devices (NWP 25) form the core of the division. The work on the utilization of nano-crystalline silicon as a unit process in crystalline silicon solar cells was appreciated internationally. Many advanced facilities including the RIBER – Molecular Beam Epitaxy (MBE) system for growth of nitride devices, the Omicron multi-technique surface characterization system for in-situ characterization of these devices, an evaporator integrated with a glove box for the fabrication of organic electronic devices without life time limitations were setup. Looking into the future, the activities on organic photovoltaic will be supported by the INDO-UK collaborative program - Advancing the Efficiency & Production Potential of Excitonic Solar Cell (APEX) and CSIR initiative on Technology & Production for Solar Energy Utilization through Networking (TAPSUN). Projects for the development of CIGS solar cells, a-Si thin film modules and advanced c-Si solar cells will be supported by the TAPSUN and Ministry of New and Renewable Energy (MNRE) leading to a bright future for the activity of the division and significant contribution to the research activity of CSIR-NPL and the Nation.

The Division of Materials Physics and Engineering worked with the main objective of development of advanced materials, processes and technologies for designing components, devices, sensors and systems. It has a wide range of research groups, namely, Polymer and Soft Materials, Physics and Engineering of Carbon, Luminescent Materials, Multiferroics and Magnetics, Biomolecular Instrumentation, Optical Thin Films & Ceramics and Metals & Alloys. The major R & D output included development of aerospace metallic devices, nano-luminescent materials for lighting and biomedical applications, new carbon products of strategic importance such as advanced composite bipolar plates, porous conducting carbon paper for PEM fuel cell applications and a variety of biosensors. Several developmental projects such as CSIR network, sponsored, grant-in-aid, collaborative and consultancy were successfully implemented/ completed for different R&D organizations, both in the public and private sectors.

Radio & Atmospheric Sciences Division initiated a program to establish a Space Physics Laboratory at South Pole, Antarctica in collaboration with National Centre for Antarctic and Ocean Research, Goa to

observe the real time measurement of ionosphere over polar region. Two global ionospheric scintillation and total electron content monitoring (GISTM) systems are installed at both the Polar Regions (Maitri, Antarctica and Himadri, Arctic (78.55°N, 11.56°E)) to investigate the generation of polar plasma patches and ionospheric scintillations. Communication measurements and model evaluations were done at different regions in India including experiments at 2.3 GHz using WiMAX transmissions, useful in the telecom sector of the country. In the atmospheric science area, greenhouse gases (GHG) emission inventory was done for GHG emitted from fossil fuel combustion in electricity generation from coal based thermal power plants in India and emission estimates of particulate matter and trace gases from biomass fuels consumed in rural sector of Indo-Gangetic Plain. The other studies include long term changes in stratospheric water vapour, methane emission from landfills in Delhi, chemistry and sources of PM10 aerosols in the Indo-Gangetic Plain region, and stable isotopic characterization of atmospheric aerosols over India and surrounding ocean.

Time, Frequency and Electrical Standards Division covers activities such as ultra stable Atomic Frequency Sources, Physics of Cold Atoms, Precise Timing Systems, and various parameters of Electrical & Electronic Metrology. Various Primary / National Standards of Electrical and Electronic parameters are maintained by this Division. During the year, traceability of these standards was provided to industry and other laboratories through calibration. Many areas of this division were engaged in international inter-comparisons organized by international bodies like International Bureau of Weights and Measures (BIPM), Asia Pacific Metrology Programme (APMP) etc. Some bilateral comparisons were also conducted. The Calibration and Measurement Capabilities of most of the parameters in the Division are internationally accepted and appear on the BIPM website. Training programs in various parameters were organized contributing to the development of skilled man power in the field of metrology in India as well as neighbouring countries. A new facility for measurement of AC High Voltage Capacitance and Tan δ up to 200 kV at 50 Hz was established. Significant progress was made in the development of the laser cooled Cesium Fountain frequency standard during the year. The atom cloud was cooled to a few microkelvin, launched up to a meter high and the fluorescence from returning atoms after passing trough a microwave interrogation region was detected. For Indian Satellite based navigation system, CSIR-NPL in collaboration with ISRO is developing the ultra stable Rubidium (Rb) atomic frequency source to meet the overall onboard performance requirements. Two models of Rb Atomic Clocks were developed for this purpose and were handed over to ISRO for testing. Work is in progress for further improvement.

The R&D activities of the Apex Level Standards and Industrial Metrology Division included high pressure Raman studies in Dy_2O_3 and CeO_2 and experimental investigations on anomalous spectral behaviour of polychromatic light in phase singularity domain which might be used for free-space optical (FSO) links for indoor and outdoor optical communications. Other activities include design and development of a compact mixed flow relative humidity generator to generate humidity precisely within 0.1% in the range from 5% to 95% RH. Several inter-comparisons and bilateral comparisons for various parameters like mass, dimension, luminous flux, force and pressure were carried out. Four calibration measurement capabilities (CMC) in temperature parameter were published in the Appendix-C of key comparison database (KCDB) of BIPM. Several new facilities, e.g. Electro-Magnetic Acoustic Transducer System, 1MN force standard facility and the Brinell hardness primary standard facility were fully installed. The publication of draft A of the CCM sponsored International Key Comparison (CCM.

P -K13) in the pressure range 50 to 500 MPa, where only a few countries from the entire APMP region were permitted to participate, was an achievement.

In the Division, Quantum Phenomena & Applications, besides the continuation of earlier activities of Josephson voltage (JV) and Quantum Hall Resistance (QHR) standards, manganite thin films, superconducting bulk materials, photometry and spectroscopy, new initiative has been launched with a focused objective of making Josephson junctions, arrays of normal and exotic superconductors, and 2DEG quantum structures. To that effect, a new Division Quantum Phenomena & Applications was constituted where various research groups of QHR and JV standard, Superconductivity and Cryogenics, Photometry and Spectroscopy were merged. State-of-the-art fabrication facilities based on pulsed laser deposition and UHV sputtering for superconducting/magnetic thin films and CVD for growth of graphene are being established. Keeping in mind novel properties and measurements related with weak magnetic field and single photon detection, phase slip devices and 2DEG facilities at low temperatures and high magnetic fields have also been planned.

Sophisticated & Analytical Instruments Group (SAIG) comprising of four subgroups namely X-ray Analysis, Electron and Ion Microscopy, EPR & IR Spectroscopy and Analytical Chemistry remained committed to the basic characterization of materials regarding different aspects, namely, chemical composition, purity, structure (including defects) and crystallographic perfection. Besides this, study of solid surface thin film and interfaces were also undertaken along with different key materials related to semiconductors, metals and alloys, composites of various kinds, insulators, ferro-fluids, thermo-electric and magnetic, polymers and variety of nanomaterials.

There were some major installations in the SAIG during the year. In the X-ray analysis group: A PANalytical X'Pert PRO MRD High-Resolution X-ray Diffractometer (HRXRD) cum X-ray Reflectometer (XRR) system was installed for characterization of thin films and nanostructures and a Rigaku Make ZXS Primus Sequential Wavelength Dispersive Fully Automated X-ray Fluorescence Spectrometer was commissioned for elemental analysis.

The Electron and Ion Microscopy group equipped with state-of-the-art and most modern equipments such as SEM, variable pressure SEM, High Resolution TEM (HRTEM) with EDS and STEM attachments, Secondary Ion Mass Spectrometry (SIMS) and Scanning Probe Microscope (SPM), besides providing characterization facilities carried out basic research in the area of size controlled synthesis of magnetic nanoparticle and thermoelectric materials. Keeping in view the need for advanced analysis, the modes like Electric Force Microscopy and Nanolithography of SPM were made functional. The EPR & IR spectroscopy group while providing support for the EPR characterization of the materials, also developed different ferro fluids that are technologically advanced nano-magnetic materials. In Analytical Chemistry group, an Inductively Coupled Plasma–High Resolution Mass Spectrometry (ICP-HRMS) for determination of elements/metals (with atomic mass 6-250) in lower ppb level concentration in water was commissioned. R&D in Metrology in Chemistry (MiC) and Certified Reference Material (CRM) were major activities of the NWP-45 CSIR network metrology project of CSIR-NPL. Four CRMs of mono and multi elemental solutions were released during 2010-11. Besides, industries and other R&D organizations were supported by whole of this group towards improvement in their product quality.

An International Conference on "Quantum Effects in Solids of Today (I-ConQuEST)" along with "K. S. Krishnan Discussion Meeting on Frontiers in Quantum Solids (FQS 2010)" and "Indo-US Workshop on Physics & Applications of Quantum Phases in Condensed Matter" were organized during December 20-23, 2010 at CSIR-NPL. The conference, spread over 18 technical sessions, broadly covered areas like electron-electron correlations, heavy fermion systems, transport in mesoscopic systems, fractional quantum Hall effect and topological insulators. There were 40 invited talks out of which 20 talks were delivered by distinguished foreign speakers including a Noble Laureate. About 100 poster presentations were made and around 200 delegates attended the conference. This conference was of special significance to CSIR-NPL as some of the quantum phenomena were related to Quantum Metrology which is gradually replacing Conventional Metrology.

"World Metrology Day" together with "National Technology Day" was celebrated on May 20, 2010. 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. The theme emphasized on how 'measurement' influences science and stimulates innovations. This was exemplified by the distinguished speakers invited on the occasion.

A planning workshop was organized during November 24-25, 2010 in collaboration with Physikalisch Technische Bundesanstalt (PTB),Germany, under ongoing program of the South Asian Association for Regional Cooperation (SAARC)-PTB Technical Cooperation in the field of Quality Infrastructure to promote regional cooperation in the one a of Metrology. SAARC comprises eight member states -Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan, Sri Lanka and India. Participants from all the eight SAARC member countries participated in the workshop underlying the importance all governments attach to the issue of regional cooperation in Metrology.

Hon'ble Minister of Science & Technology and Vice President, CSIR, Sh. Prithviraj Chavan accompanied with Prof. Samir Brahmachari, DG, CSIR paid a goodwill visit to CSIR-NPL on 14th July, 2010. He met and interacted with senior scientists as well as addressed all the staff members. He also visited some of the important research activities and recently created state-of-art facilities. To mark the occasion, he along with DG, CSIR and some of the senior members of CSIR-NPL planted the seedlings of *Callistemonelanceolatus* in front of the CSIR-NPL main building.

CSIR-NPL was actively involved in CSIR Technofest-2010, organized by CSIR Head Quarters at Pragati Maidan. CSIR had put up impressive display of its R&D competence, technology and products developed and the societal and strategic missions undertaken. CSIR-NPL's technologies and products covered many of the themes and were displayed in pavilions namely Energy, Healthcare, Aerospace, Mining, Minerals and Materials, Engineering Infrastructure, Water, Ecology & Environment and CSIR-800. CSIR-NPL received two platinum, three Gold and four Bronze awards.

Towards human resource development, CSIR-NPL provided facilities to students from universities and other educational institutes including IITs / IASc-Bangalore, etc., for project work and training. About 102 students pursuing M.Sc., M.E./ M.Tech., M.C.A., B.E./ B.Tech. courses from various institutes underwent short and long term training. Under the Interim Academy of Scientific and Innovative Research (AcSIR), 27 students were registered for Ph.D. at CSIR-NPL. The proposal for initiating a Post Graduate Research Programme in Engineering (PGRPE) in 'Advanced Materials Physics & Engineering' at CSIR-NPL during

2011-2012, with an intake of 10 students, was drafted and sent to CSIR for approval. Thirty eight fresh research fellows were motivated to join CSIR-NPL during the year, making a total strength of 91. 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. Nine institutional visits were arranged involving schools, colleges, scientific and technical institutes which helped enhancing CSIR-NPL's visibility in the society. A one day Seminar on Advanced Materials & Quantum Metrology was organized on May 28, 2010 for NET-qualified Junior Research Fellows to give them exposure to research activities being pursued at CSIR-NPL.

The annual CSIR Programme on Youth for Leadership in Science (CPYLS) was organized during 25-26 November, 2010 and was attended by bright young students from various schools specially chosen by CSIR for this programme. This program helps motivating young talented students towards science and scientific career.

National Science day was celebrated on 28th February, 2011, in honour of Sir C. V. Raman for his legacy and discovery of the Raman Effect on this day of the year 1928. Prof. Samir K. Brahmachari, DG, CSIR was the chief guest. A poster presentation event was organized on the occasion where the work of all research fellows of CSIR-NPL was exhibited.

During the year, a total of 347 scientific and technical papers were published which included 285 papers in SCI indexed Journals and 62 papers in SCI indexed proceedings. 220 papers were presented at various national and international conferences. Ten patents were filed in India and eight were filed abroad. Seven international patents and three Indian patents filed in previous years were granted during 2010-11. Eighteen new projects (sponsored and consultancy) were undertaken and 2332 calibration reports were issued, which contributed to generation of an ECF of about 447 lakhs.

On my part, I, earnestly, acknowledge the unflinching support and team spirit of all our CSIR-NPL staff members and young researchers during the year without which much of our accomplishment would not have been possible. I also take this opportunity to acknowledge the valuable guidance, solidarity and encouragement received from CSIR Head Quarters, Research Council and Management Council from time to time which proved to be very helpful in achieving our aims. The interaction with external experts who visited CSIR-NPL on different occasions had been very rewarding.

Last, but not the least, I would also like to acknowledge the contribution of the Publication Committee Chairman, Dr. Virendra Shanker and associated team members in bringing out this report. The cooperation and special efforts of 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

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 Jawahar Lal 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, kilogramme, second, kelvin, ampere, candela, mole (mol) 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; power; impedance; attenuation and noise; microwave power; frequency; impedance; attenuation and noise.

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.


National Technology Day
&
World Metrology Day
Metrology-Measurements in Science & Technology: a Bridge to Innovation
Chief Guest: Prof. Shri Krishna Joshi
Former DG-CSIR and Honorary Professor, JNCASR
P BANERJEE
RAKESH KACK
World Metrology Day and National Technology Day Celebrations
May 20, 2010

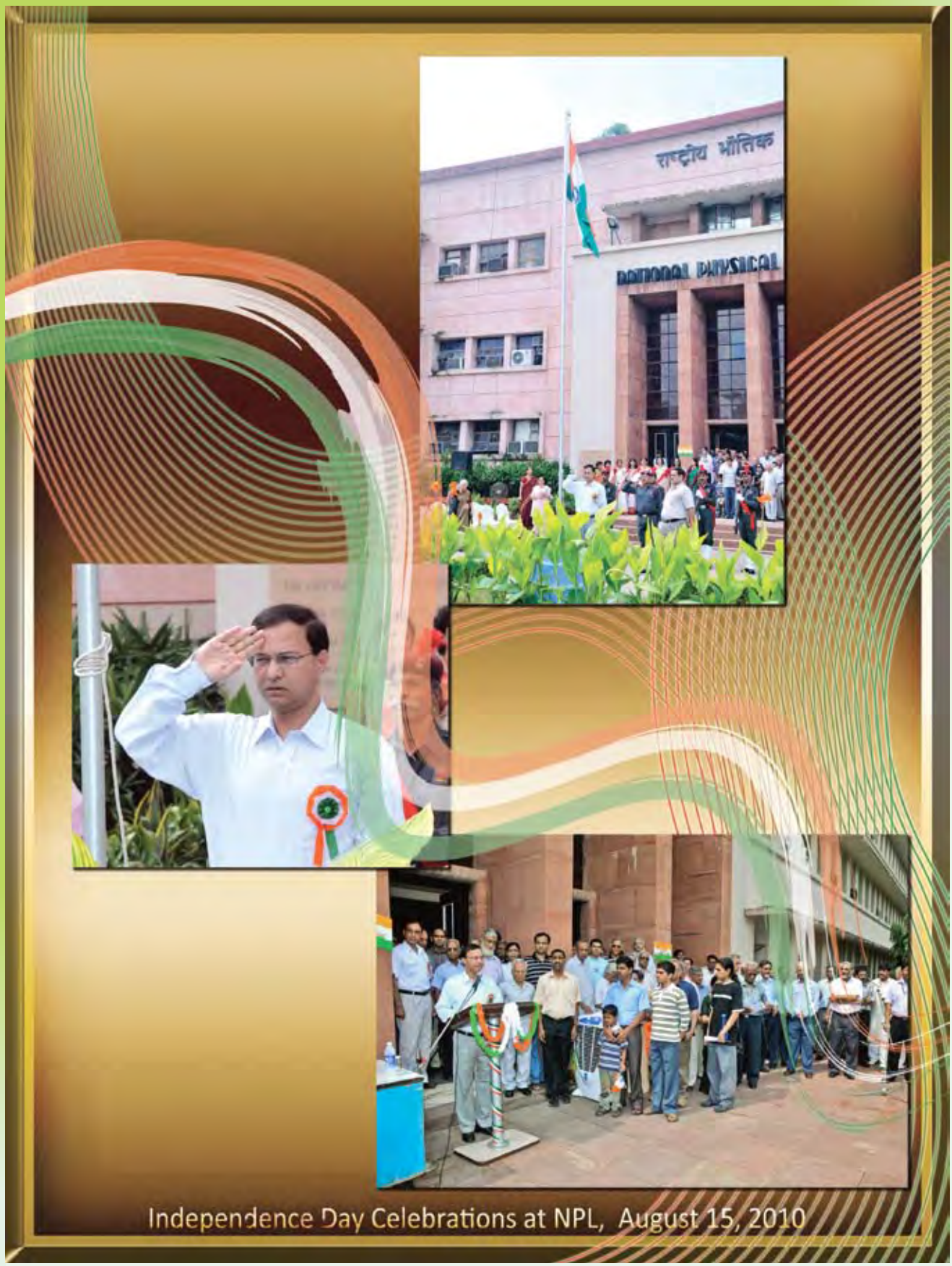

Workshop on Materials Characterization and Techniques
July 12-14, 2010


Visit of Honorable Minister of Science and Technology and Vice President CSIR Sh. Prithviraj Chavan
July 14, 2010.


Minister's Visit Continued ...


Minister's Visit Continued ...


RC - Meeting July 27, 2010

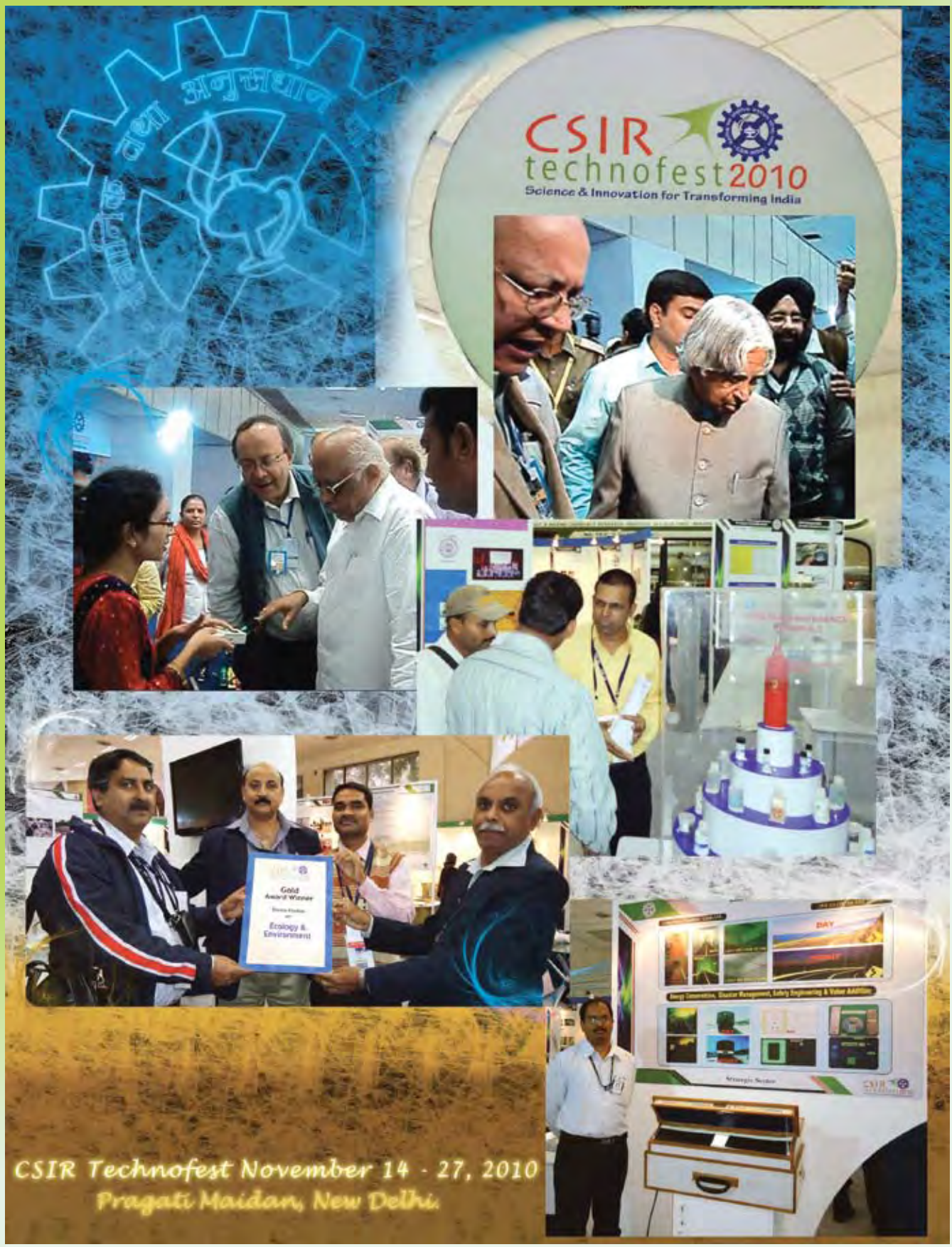


Independence Day Celebrations at NPL, August 15, 2010


CSIR Foundation
Day Celebrations
September 26, 2010


EURAMET
4th EURAMET General Assembly
25th-28th May 2010
IPQ - Lisbon
Asia Pacific Metrology Programme 2010
26th General Assembly and Related Meetings
APMP 2010
Asia Pacific Metrology Programme (APMP), November 14-20, 2010

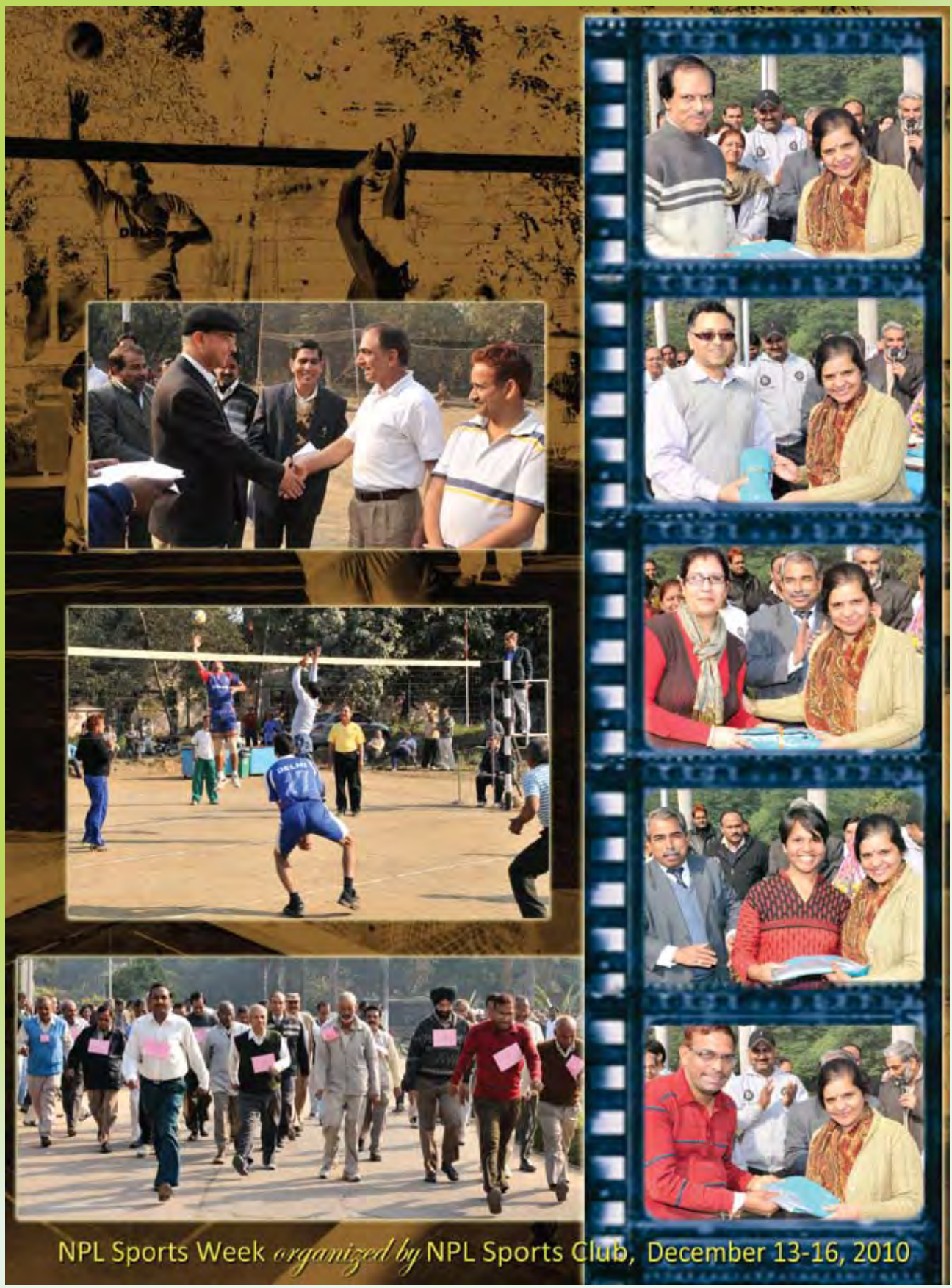
CSIR Programme for Youth Leadership in Science (CPYLS - 2010)
November 25-26, 2010

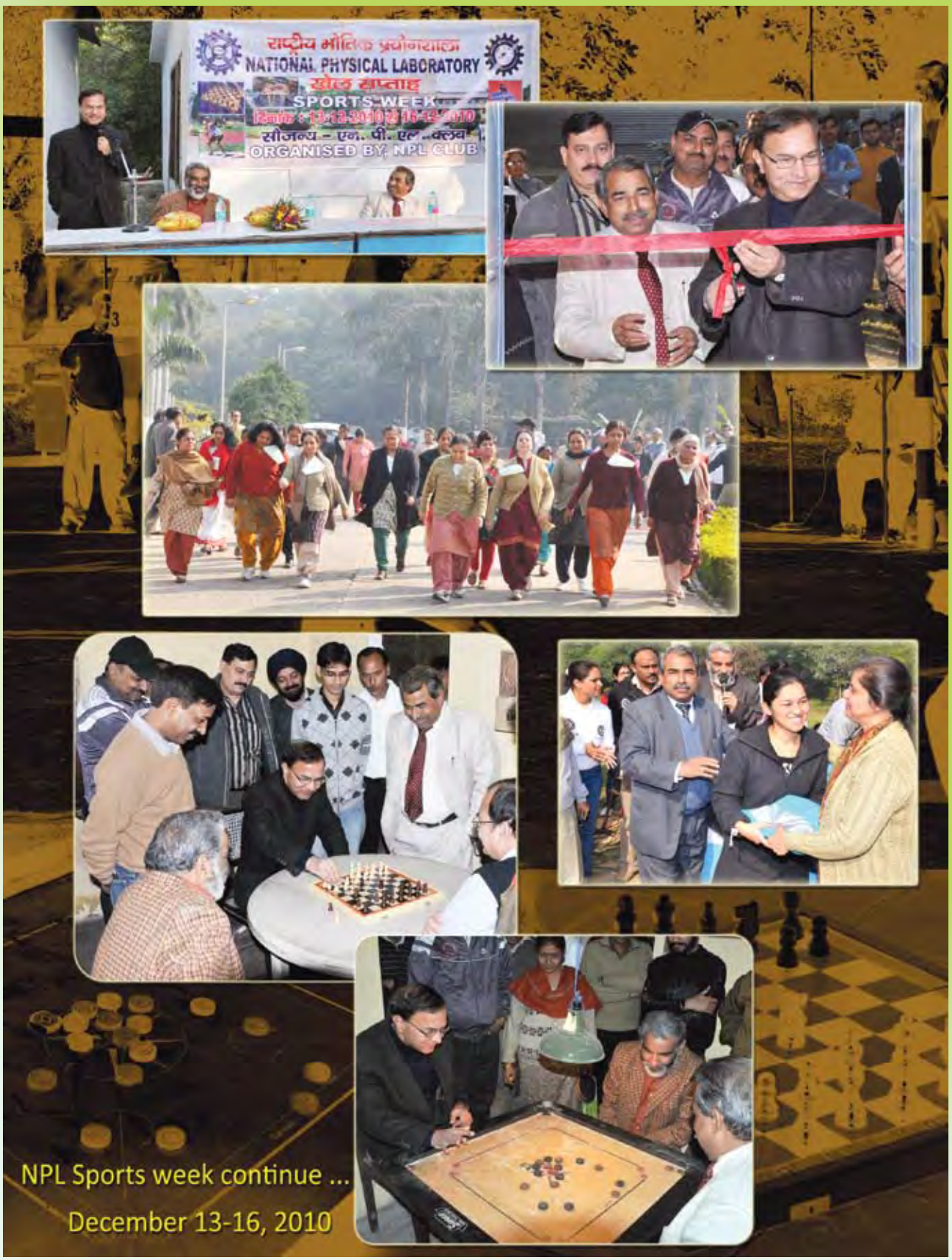

CSIR
technofest2010
Science & Innovation for Transforming India
Gold
Award Winner
Ecology &
Environment
CSIR Technofest November 14 - 27, 2010
Pragati Maidan, New Delhi.


CSIR Technofest ...
CSIR-INDIA


Indo-Russian Expert Meeting
on
Preparation and Characterization of
Silicon for Photovoltaic
Applications
Indo-Russian Expert Meeting on Photovoltaic Application
November 30 - December 2, 2010


International Conference
on
Quantum Effects in Solids of Today (I-ConQuEST)
&
K. S. Krishnan Discussion Meeting on
Frontiers in Quantum Science (FQS2010)
&
I-ConQuEST-2010
NPL-INDIA
I-ConQuEST
I-ConQuEST2010 - International Conference
on Quantum Effects on Solids of Today
December 20 - 23, 2010


NPL Sports Week organized by NPL Sports Club, December 13-16, 2010


राष्ट्रीय भौतिक प्रयोगशाला
NATIONAL PHYSICAL LABORATORY
खेल सप्ताह
SPORTS WEEK
ORGANISED BY NPL CLUB
NPL Sports week continue ...
December 13-16, 2010


PUSA HORTICULTURE SHOW
26 - 27 February, 2011
NPL's Prize in Pusa Horticulture Show
and Some Glimpses of Seasonal Flowers in NPL Campus

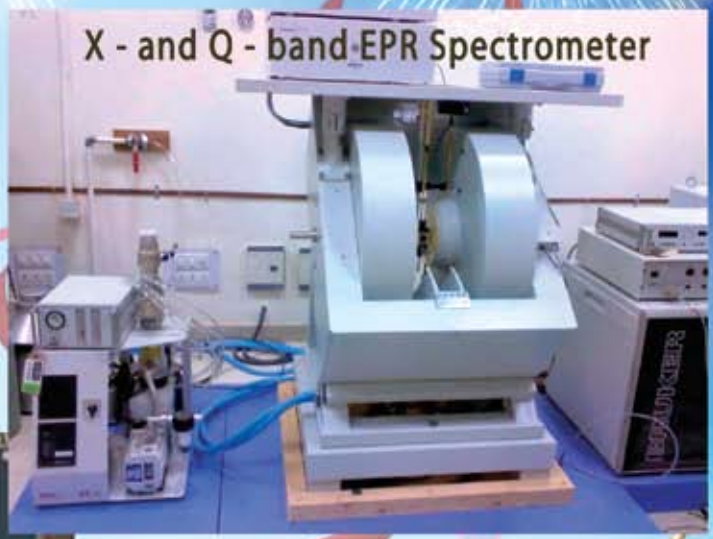

NATIONAL SCIENCE DAY
CELEBRATIONS
National Science Day Celebrations
February 28, 2011

NEW FACILITIES CREATED (2010-11)

Inductively Coupled Plasma-High Resolution Mass Spectometry

Molecular Beam Epitaxy System

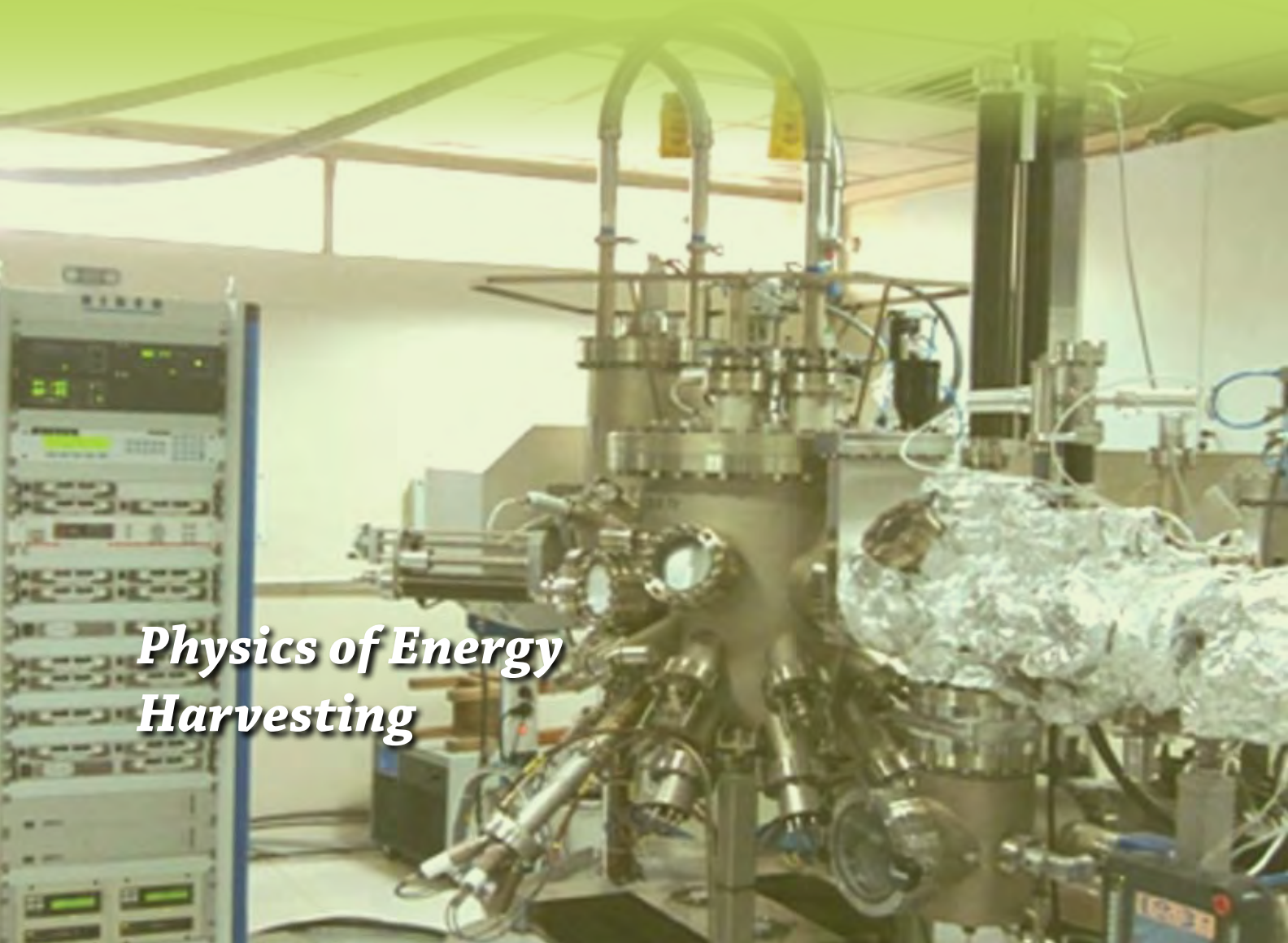
High Resolution XRD System



X - and Q - band EPR Spectrometer

Spark Plasma Sintering Unit (SPS)

ऊर्जा संचयन भौतिकी



Physics of Energy Harvesting

ऊर्जा संचयन भौतिकी

भूतपूर्व इलेक्ट्रॉनिक और इंजीनियरिंग पदार्थ प्रभाग द्वारा किए जा रहे क्रियाकलापों को शामिल करके इस वर्ष के दौरान सृजित नए प्रभाग ऊर्जा संचयन भौतिकी प्रभाग द्वारा कार्बनिक प्रकाश वोल्टीय और प्रकाश उत्सर्जी युक्तियों, अकार्बनिक प्रकाश उत्सर्जी डायोडों, रवाहीन और रवायुक्त सिलिकन सौर सेलों से संबंधित क्रियाकलापों तथा वैद्युत युक्तियों हेतु पदार्थों के संबंध में एक नवसृजित क्रियाकलाप का निष्पादन किया जा रहा है। सिलिकन और रवाहीन सिलिकन और सेलों (एसआईपी 17) और प्रकाश उत्सर्जी युक्तियों (एनडब्ल्यूपी 25) से संबंधित सीएसआईआर परियोजनाओं कें अंतर्गत क्रियाकलाप इस प्रभाग द्वारा किए जाने वाले मुख्य क्रियाकलाप हैं। वर्ष के दौरान, कार्बनिक इलेक्ट्रॉनिक युक्ति विषय पर किए गए उत्कृष्ट अनुसंधान कार्यों से संबंधित अनेक शोध पत्र अत्यधिक प्रतिष्ठित पत्र–पत्रिकाओं में प्रकाशित हुए हैं। क्रिस्टलीय सिलिकन सौर सेलों में इकाई प्रक्रम के रूप में अति सूक्ष्म क्रिस्टीय सिलिकन के उपयोग से संबंधित कार्य की विश्व भर में सराहना की गई है। नाइट्राइड युक्तियों को विकसित करने के लिए दॅ राइबर–आण्विक रश्मिपुंज अधिरोहण (एमबीई) प्रणाली, दॅ ओमिक्रोन बहु–तकनीक सतह अभिलक्षणन प्रणाली, जो इन युक्तियों के स्व–स्थाने अभिलक्षण ान हेतु प्रयुक्त होती है, उपयोगी आयु की सीमा से मुक्त कार्बनिक इलेक्ट्रॉनिक युक्तियों के संगठन हेतु एक ग्लव बॉक्स से युक्त एक वाष्पित्र सहित अनेक उन्नत सुविधाएं संस्थापित की गईं। भविष्य को ध्यान में रखते हुए, कार्बनिक प्रकाश वोल्टीय क्रियाकलापों को भारत–यूके सहयोग द्वारा शुरू किए गए कार्यक्रम – ऐक्साइटॉन युक्त सौर सेल की दक्षता और उत्पादन क्षमता को उन्नत बनाने (एपीईएक्स) तथा नेटवर्किंग के माध्यम से सौर ऊर्जा के उपयोग हेतु प्रौद्योगिकी और उत्पादन (टीएपीएसयूएन) संबंधी सीएसआईआर पहल द्वारा वित्तपोषण किया जाएगा। सीआईजीएस सौर सेलों, सिलिकन तनु परत मॉड्यूलों तथा उन्नन कार्बन–सिलिकन सौर सेलों को विकसित करने के लिए परियोजनाओं को टीएपीएसयूएन तथा नवीन एवं नवीकरणीय ऊर्जा संसाधन मंत्रालय द्वारा वित्तपोषित किया जाएगा जिससे इस प्रभाग के क्रियाकलापों का भविष्य उज्ज्वल प्रतीत होता है तथा इससे राष्ट्रीय भौतिक प्रयोगशाला के अनुसंधान क्रियाकलापों को उल्लेखनीय योगदान प्राप्त होगा एवं राष्ट्र को नई दिशा प्राप्त होगी।

Physics of Energy Harvesting

The division, Physics of Energy Harvesting has been created during the year, incorporating activities of the erstwhile division of electronic and engineering materials and comprises activities on organic photovoltaic and light emitting devices, inorganic light emitting diodes, amorphous and microcrystalline silicon solar cell and crystalline silicon solar cells and a newly created activity on materials for thermoelectric devices. The activities under the CSIR projects on silicon and amorphous silicon solar cells (SIP 17) and light emitting devices (NWP 25) 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. The work on the utilization of nano-crystalline silicon as a unit process in crystalline silicon solar cells has been appreciated internationally. Many advanced facilities including the RIBER MBE system for growth of nitride devices, the Omicron multi-technique surface characterization system for in-situ characterization of these devices, an evaporator integrated with a glove box for the fabrication of Organic electronic devices without life time limitations have been setup. Looking into the future, the activities on organic photovoltaics will be supported by the INDO-UK collaborative program APEX and CSIR initiative on TAPSUN. Projects for the development of CIGS solar cells, a-Si thin film modules and advanced c-Si solar cells will be supported by the TAPSUN and MNRE leading to a bright future for the activity of the division and significant contribution to the research activity of NPL and the nation.

I. Silicon Solar Cells Group

(a) Developed a chemical route for surface passivation for materials quality testing

Extensive studies on surface passivation were made on p-type single-crystalline silicon wafers using ethanolic solution of iodine and bromine. Minority carrier lifetime (τ_{eff}) was measured by the microwave photoconductance decay (μ-PCD) method and using a Sinton's lifetime tester. Measurements are carried out at different molar concentrations of iodine–ethanol (I–E) and bromine–ethanol (B–E) solutions to optimize the process parameters. It is found that good passivation (±5% of measured maximum lifetime) could be achieved for certain ranges of concentration, which in the case of I–E and B–E are 0.07–0.12 M and 0.05–0.07 M, respectively. The wet chemical pre-conditioning treatment on surface passivation (silicon surfaces with and without native oxide) has been found to be critical for the quality of surface passivation. The effect of bias light and passivation time was also studied. It has been established that I–E solution provides better passivation than B–E solution in terms of τ_{eff} whereas B–E solution passivation exhibits better stability in comparison with I–E solution. The important finding of the present study is that the τ_{eff} measured by the Sinton method (WCT-120) and using a Semilab system (μ-PCD, WT-2000) are comparable if injection levels are matched and the τ_{eff} has strong dependence on the injection level i.e. excess carrier density in both measurement tools.

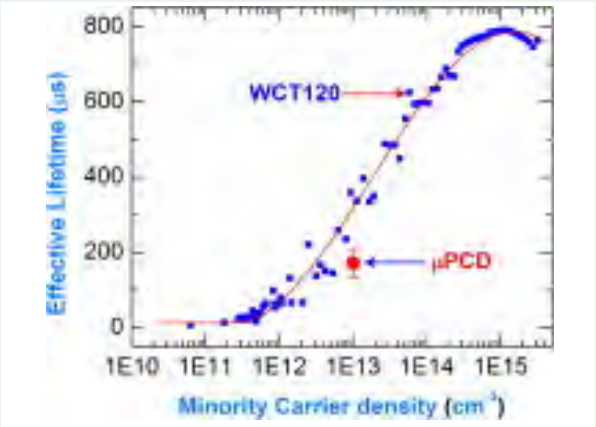


Fig. 1.1 : Effective minority carrier lifetime has strong injection level dependence as observed by the Sinton (injection level in the range 10^{11}–10^{15}) and μ-PCD (low injection level, i.e., Δn=1.2×10^{13} cm^{-3}) methods.

(b) Sol–gel derived ZnO:Al films for silicon solar cell application

Al doped zinc oxide (AZO) films were prepared by sol-gel method with varying level of Al doping. Effect of hydrogen annealing on antireflection and surface passivation properties of Al rich zinc oxide films coated on silicon wafers has been studied in 300–600 °C temperature range. After annealing of AZO coated silicon wafer in hydrogen ambient for 30 min between 400 and 600 °C the effective minority carrier lifetime τ_{eff} improved 5 fold as compared to the initial value of ~16 μs for an optimum annealing temperature at 500 °C. The annealing in air in the same temperature range did not affect the lifetime. AZO films annealed at 500 °C in hydrogen or air show high transmittance in 400–1200 nm wavelength range and are suitable as AR coatings for silicon solar cells. The hydrogen annealed AZO was applied as antireflection coating on n^+ front surface and an equally thick hydrogen annealed AZO coating on the p-back surface of an n^+-p multi crystalline silicon solar cell. Preliminary results of AZO film on silicon solar cell show improvement in cell performance parameters.

(c) Silicon nanowires based solar cells

The process for silicon nanowires based solar cells were further improved to alleviate the metal contact problems faced in silicon nanowires. Selective silicon nanowires were prepared for good ohmic metal contacts by protecting the front metal pattern of the silicon solar cells using a suitable anti-etchant coating. As a result, parasitic resistances (series and shunt) and the fill factor of the silicon nanowires based solar cells were found be comparable with that of the planar cells without silicon nanowires. With the modified silicon nanowires solar cells fabrication protocol, approximately 1% absolute improvement in efficiency was achieved.

II. A-Si:H and μc-Si Solar Cells Group

(a) R&D on Microcrystalline Silicon thin films

Doped & Undoped microcrystalline silicon films were deposited using microwave/VHF PECVD process. Dark conductivities values of 1.88x10^{-2} $\Omega^{-1}cm^{-1}$, 9.8x10^{-7} $\Omega^{-1}cm^{-1}$ & 1.2x10^{-4} $\Omega^{-1}cm^{-1}$ and photo-conductivities values of 2.3x10^{-4} $\Omega^{-1}cm^{-1}$, 1.3x10^{-4} $\Omega^{-1}cm^{-1}$ and 1.7x10^{-3} $\Omega^{-1}cm^{-1}$ were measured for p, i and n-layers of

microcrystalline silicon films, respectively. These layers are being used for making single junction solar cells. However, conductivity values of n-layer are desired to be more. We have to increase the doping concentration of phosphorus to obtain the high conductivity value of n-layer. Work in this direction is in progress.

(b) R&D on various types of diamond like carbon thin films

Diamond-like carbon (DLC) films deposited over Ni-Cr dots containing substrates exhibited a strong adhesion to the substrate. Ni-Cr metal dots improved adhesion, optical and electrical properties of DLC films with a little deterioration in their mechanical properties. In addition, nanostructured copper/hydrogenated amorphous carbon (Cu/a-C:H) multilayer films were also deposited. The analysis shows very low residual stress (below 1 GPa), moderate nanohardness (H) and elastic modulus (E) of the these nanostructured films. Further, these films were studied for their plastic deformation energy and elastic recovery. Atomic force microscopic analysis reveals the nanostructured morphology and low surface roughnesses of the resultant films. The presence of Cu in these structures have been confirmed by time of flight, secondary ion mass spectroscopy, X-ray photoelectron spectroscopy and energy dispersive X-ray analysis. Detailed Nanoindentation testing was also performed on nitrogen (N_2) incorporated diamond-like carbon (N-DLC) films. These N-DLC films were deposited using radio-frequency plasma-enhanced chemical vapour deposition technique, with varied percentage of nitrogen partial pressures of 0, 44.4, 66.6, and 76.1%. The values of nanohardness (H) and elastic modulus (E) of these films were obtained from 38 to 22 GPa and 462 to 330 GPa, respectively, as the partial pressure of N_2 increases from 0 to 76.1%. Further, these films were studied for % elastic recovery, ratio between residual displacement after load removal and displacement at maximum load (d_{res}/d_{max}), plastic deformation energy and plasticity index parameter (H/E).

(c) R&D on undoped and doped tetrahedral amorphous carbon (ta-C) and amorphous carbon thin films having embedded nanoparticles

(i) The effect of substrate bias, hydrogenation and nitrogenation on spectroscopic ellipsometric (SE) and atomic force microscopic (AFM) studies of tetrahedral amorphous carbon (ta-C) films deposited by S bend filtered cathodic vacuum arc (FCVA) process have been studied. Spectral dependence of dielectric constants obtained from SE data has been used to estimate carbon bonding ratio within few percent accuracy. The sp^3/sp^2 ratio and sp^3 content evaluated are found to be slightly larger than X-ray induced Auger emission spectroscopy (XAES) method but the trend of sp^3/sp^2 ratio and sp^3 content evaluated with the substrate bias is found to corroborate with the trend observed by XAES studies. In ta-C films, optical constants increase with substrate bias and hydrogen/nitrogen incorporation. The optical band gap (E_g) and sp^3 content increase upto – 200V substrate bias and then decrease. E_g increases with hydrogen incorporation but it is unchanged by nitrogen incorporation.

(ii) Pure (undoped) nitrogen and hydrogen incorporated amorphous carbon films have been deposited using modified arc based techniques such as cathodic jet carbon arc (CJCA) technique. These films have been characterized by variety of measurements. X-ray diffraction study reveals dominantly an amorphous nature of the film. HRTEM exhibited initially the amorphous structure but on closer examination the film was constituted of amorphous phase with the nanoparticle embedded in the amorphous matrix. A straight forward method of deconvolution of C1s peak of XPS spectra has been used to evaluate the sp^3 and sp^2 content present in a-C: N films. The surface morphology and the amorphous nature of the films examined by SEM and AFM studies indicated that the grain size and the root mean square roughness values decrease when we go from helium to nitrogen and to hydrogen gas environment. The sp^3 content, electrical conductivity and hardness values of a-C films deposited under different gaseous environments are found to increase with the change of gaseous environment from helium to nitrogen to hydrogen. a-C film deposited with embedded nanoparticles under hydrogen gas environment has the highest

sp^3 (54.6 at %), hardness (21 GPa), elastic modulus (225 GPa) and the lowest conductivity (10^{-7}ohm^{-1}cm^{-1}) whereas the film deposited under helium gas environment show the lowest sp^3 (37 at %), hardness (15 GPa), elastic modulus (190 GPa) and the highest conductivity (10^{-1}ohm^{-1}cm^{-1}).

(iii) Undoped and nitrogen doped amorphous carbon films have also been deposited using anodic jet carbon arc technique. Characterizations on these films including field emission measurement are in progress.

III. Organic and Hybrid Solar Cells Group

(a) R&D activity :

The R&D activity of group is development of organic and hybrid solar cells. Our present focus is to understand the charge carrier transport and device physics in the materials and devices. It has been found that these devices are very sensitive to ambient conditions and exhibit degradation on exposure to ambient. Organic molecules react with oxygen and moisture present in the ambient and loss their optical and electrical properties and as a result the device performance deteriorates. Apart from high efficiency, the stability and cost are other parameters which will decide the commercial viability of organic solar cells. For long term stability the complete understanding of degradation mechanism is very important. Our main focus is to understand the physics behind the degradation of organic solar cells. We are doing experiments on devices in this direction. The efficiency has been observed to degrade initially very fast and then slowly with time. Degradation of short circuit current (Jsc) has been found to be the dominant factor for degradation in efficiency. We have studied the current-voltage (J-V) characteristics time to time and are trying to understand the change in behaviour. The change in behaviour of J-V characteristics will help to understand the degradation mechanism.

(b) Major facility developed:

We have established a glove box integrated with thermal evaporator. This is an important facility to fabricate the organic devices in inert atmosphere so that the devices exhibit longer life time. The photograph of the same facility has been appended below.

Fig. 1.2 : Glove box integrated with thermal evaporator.

IV. Thermoelectric Materials Group

(a) Bi_2Te_3 Nanostructures

Bismuth telluride (Bi_2Te_3) is one of the most used materials for thermoelectric applications at ambient temperature. An improvement of thermoelectric performances through a suitable modification of electron and phonon transport mechanisms is predicted for low dimensional systems, but this requires a control of the material structure down to the nanoscale. Deposition of nanostructured thin film of bismuth telluride on oxidized silicon wafer was carried out by vaporization and condensation of bismuth telluride vapours on SiO_2 substrate. These nanostructures were characterized by XRD, SEM and TEM for structural/ microstructural features and thermoelectric properties by electrical and thermal transport measurements. Substrate and source temperature along with flow rate of carrier gas has proved to be crucial for the control of morphology and crystallinity of these nanostructures. 5N purity ingot of bismuth telluride (Bi_2Te_3 : BT) was crushed to powder and was used as a source material for the synthesis of BT nanostructures. Synthesis of bismuth telluride (Bi_2Te_3) nanostructures was carried out in a three zone horizontal tube furnace via thermal deposition (vapour-liquid-solid) process. Source material (BT powder), put in one zone with oxidized silicon wafer (SiO_2), as a substrate, was put in another adjacent zone with distance between the two maintained at 10 cm.

Table 1.1

S.No	Deposition time (hr)	Diameter (nm)	Length (µm)
1.	2	125	2.06
2.	4	125	3.12
3.	6	470	16.25

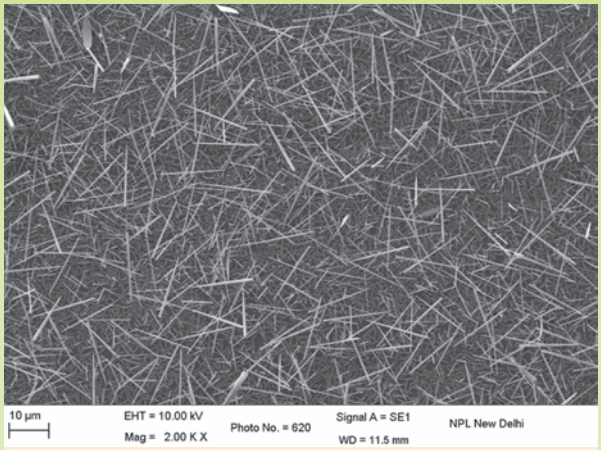


Fig. 1.3 SEM Micrograph of $B_{12}Te_3$ nano wire

Optimization of process parameters (such as temps. of source material and substrate, flow rate of carrier gas Ar and deposition time) was done gradually. The table 1.1 shows the variation of nano rod length and diameter with deposition time keeping flow rate and distance constant. To characterize the morphology of the samples, scanning electron microscope (SEM) images were taken which showed that nanostructures were hollow from inside suggesting nanorods have been formed. The diameter of the nanorods ranges from ~ 500-100 nm with micron size lengths (as shown in table) therefore the average aspect ratio was found out to be 95-98. XRD data confirms the presence of Bi_2Te_3 phase. A typical SEM image for 6 hr 25 sccm Ar flow is shown above.

(b) Rare Earth Doped $SrTiO_3$

Conventional high performance thermoelectric materials ($ZT \geq 1$) are almost all intermetallic compounds such as Bi_2Te_3 alloys, filled skutterudites, half-Heusler compounds, etc., but have limitation that they are easily decomposed or oxidized at high temperatures in air. Recently, oxide thermoelectric materials have attracted attention because of their chemical stability at high temperatures, low toxicity and with the possibility of improving ZT by material tailoring. Among them, a typical transition metal perovskite-oxide $SrTiO_3$ has attracted considerable research interest because the electron doped $SrTiO_3$ has relatively high mobility and large effective mass, which results in high electrical conductivity as well as large negative Seebeck value. Okuda et al (Phys. Rev B, 63, 113104, 2001) observed large power factor of 3.6 x 10^{-3} W.m.K^{-2} in $Sr_{1-x}La_xTiO_3$ ($0 \leq x \leq 1$) single crystal. Recently Okinaka et al. (Scripta Materialia 63, 407, 2010) have observed the maximum ZT of 0.22 at 800 K in $Sr_{0.92}La_{0.08}TiO_3$ bulk sample and further synthesized the $Sr_{0.95}(Sm/Gd/Dy/Y)_{0.05}TiO_3$ series by combustion synthesis with post-spark plasma sintering to study the sintering effect on TE properties. Keeping the possibility of doping at La site in $Sr_{1-x}La_xTiO_3$ (SLTO) we doped the La-site with Sm and Gd (weighty rare earth having maximum 4f electron may leads to improve ZT) in $Sr_{0.92}La_{0.08-x}Sm_xTiO_3$ (Sm; x=0.02, 0.04, 0.06) and $Sr_{0.92}La_{0.08-x}Gd_xTiO_3$ (Gd; x=0.02, 0.04, 0.06) to study the effect of dopant on the TE properties to have max. ZT. The Sm (Xe-4f6 6s2) and Gd (Xe-4f7 5d1 6s2) doped $Sr_{0.92}La_{0.08}TiO_3$ (SLTO) series have been synthesized by standard solid state reaction route. Polycrystalline samples of Sm-SLTO and Gd-SLTO have been prepared from high purity (4N) oxides of Sr, La, Sm, Gd and Ti.

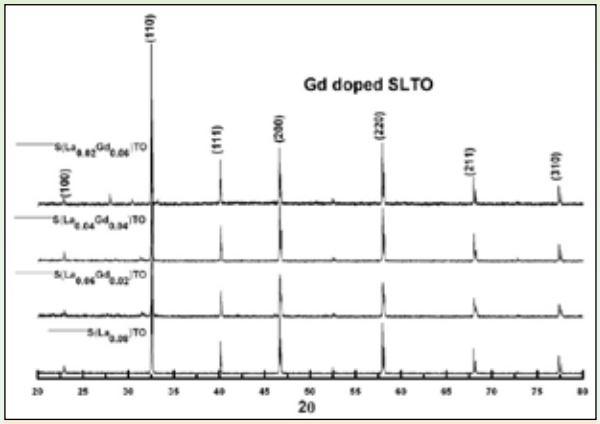


Fig. 1.4 X-ray diffraction patterns of Gd doped SLTO

Desired stiochiometry amount of respective oxides have been weighed, mixed thoroughly and calcined at ~900ºC to 1200 ºC with several intermediate grinding for 48 hrs. After that obtained black precursor have been sintered at ~ 1400 ºC for ~ 6-12 hrs. These as synthesized samples were characterized by X-ray diffraction for phase purity and SEM for surface microstructure. The XRD analysis (shown for Gd doped SLTO) reveals that all samples are single phasic with perovskite structure and peaks are well indexed with JCPDS file No # 84-0444). All the diffraction peaks for the samples correspond well to those of $SrTiO_3$ without any detectable second phase(s),

which suggests that La^{3+} and Gd^{3+} ions completely enter the $SrTiO_3$ lattice to form a single perovskite phase. These samples will be further characterized for electrical and thermal transport properties to evaluate the ZT.

V. Organic and Inorganic LEDs Group

(a) Development of White Organic Light Emitting Diodes

Organic light emitting diodes (OLEDs) are quite promising for next generation of flat panel displays. Tang and VanSlyke(1987) demonstrated the first thin film electroluminescence (EL) devices. Out of the various types of OLEDs, under development, white organic light emitting diodes (WOLEDs) have attracted special attention owning to their potential applications in light signs, general lighting and back lights for LCD displays. A straightforward method for obtaining white light emission with small molecules is to combine electroluminophores which emits two complementary colours, for example blue and yellow. The co-evaporation process allows, to a certain extent, a control of the emitted radiation colour via different evaporation rates of the blue and yellow emitters. However, it remains technologically difficult to control the doping concentration and deposition process accurately. The colour can also be controlled in multilayered devices by varying the applied voltage, thus shifting the electron-hole recombination zone. The colour purity and other performance such as luminescence and current density were still affected even by the careful modification of doping concentration and deposition conditions. Multilayer structures composed of emitting and charge transport layers efficiently confine charge carriers and molecular excitons. OLED characteristics are largely affected by the chemical and physical interaction at organic/organic interfaces in OLEDs.

We have demonstrated a WOLED by inserting a thin buffer layer of red dye layer in hole transport layer with a blue emitting material Zn(hpb)2. We have compared the colour coordinates and luminous efficiencies of the devices with DCM and rubrene used as a thin buffer.

An interaction of organic materials at interface forms a charge transfer excited-state complex, which is known as exciplex. The exciplexes are formed between two different molecules, such as an electron-donating molecule and an electron-accepting molecule, in which one of them is in an excited state and the other is in a ground state. In the OLEDs, there is a high possibility that exciplex formation occurs at the ETL/EML or HTL/EML interfaces, because HTL and electron transport layer (ETL) usually have an electron-donating and an electron-accepting nature, respectively.

We have observed the formation of exciplexes at the HTL/EML interface. The ultra-thin dye layer was placed at various positions from the HTL/EML interface, which acts as a probe to detect the position of exciplexes. The maximum energy transfer was obtained from host to the guest molecule at the interface. Also by varying the position of dye layer from the HTL/EML interface, the energy transfer from host to dye molecule was controlled and at the optimum distance of 10 nm white light emission was obtained due to emission from both exciplexes as well as dye molecule, because of an incomplete energy transfer.

The OLEDs were fabricated on Indium-Tin-Oxide (ITO) (anode) coated glass substrates with a sheet resistance of 20Ω/□. Thickness of ITO was 120 nm. ITO coated glass substrates were patterned and cleaned using deionised water, acetone, trichloroethylene and isopropyl alcohol sequentially for 20 min using an ultrasonic bath and dried in vacuum oven. Prior to organic film deposition ITO surface was treated with oxygen plasma for 5 min to increase ITO work function .Organic layers were then deposited onto glass substrates under high vacuum (4×10^{-6} torr) at a deposition rate of 0.4Å/s. Thickness of the deposited layers were measured in situ by a quartz crystal thickness monitor. Three OLEDs A, B and C were fabricated. The device structure for devices A and B were ITO(120nm)/ α-NPD (xnm)/ DCM(1nm)/ α-NPD (ynm)/ Zn(hpb)2(50nm) / BCP(6nm)/ Alq3(28nm) / LiF(1nm) /Al(150nm). The values of x and y were 26.5nm, 27.5nm and 8.5nm, 7.5nm for devices A and B respectively. The third device C having the structure ITO(12nm)/ α-NPD (27.5nm)/ Rubrene (1nm)/ α-NPD (7.5nm)/ Zn(hpb)2 (50nm) / BCP (6nm)/ Alq3 (28nm) / LiF (1nm) /Al (150nm) was fabricated. Schematic diagram of device is shown in Fig.1.5. Here $Zn(hpb)_2$

was used as emissive layer, DCM and Rubrene as buffer layers, Tris (8-hydroxyquinoline) aluminium (Alq3) (Sigma Aldrich) and N,N'-Di-[(1-naphthalenyl)-N,N'-diphenyl]-(1-1'-biphenyl)-4,4'-diamine(α-NPD)(Sigma Aldrich) were used as the electron and hole transporting layers respectively. Lithium Floride (LiF)/Aluminium (Al) and ITO has been used as cathode and anode respectively. The size of each pixel was 5mm×5mm. Photoluminescence was studied using a Fluorolog (Jobin Yvon – Horiba, model-3-11) spectrofluorometer at room temperature. Electroluminescence spectrum has been measured with a high resolution spectrometer (ocean optics HR-2000 CG UV-NIR). The current density-voltage-luminescence (J-V-L) characteristics have been measured with a luminance meter (LMT-1009) interfaced with a Keithley 2400 programmable current-voltage digital source meter. All the measurements were carried out at room temperature under ambient conditions.

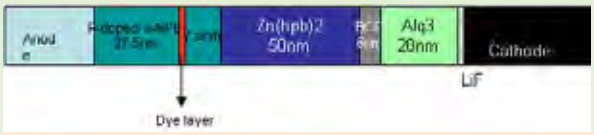


Fig. 1.5: Schematic diagram of device

Photoluminescence (PL) spectrum of thin films of Zn(hpb)2 and DCM deposited on fused silica substrate were measured and the results are shown in Fig.1.6. PL spectrum of Zn(hpb)2 shows broad features with a broad peak centered around 478nm and DCM shows peak at 571nm. The combined PL spectrum of the two materials cover almost the entire visible spectrum and hence these materials have been used to fabricate WOLEDs.

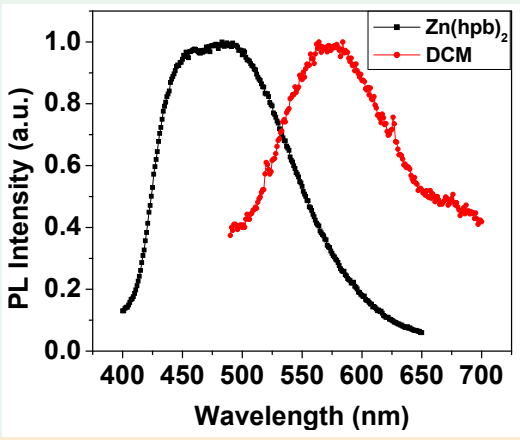


Fig.1.6 Photoluminescence spectrum of Zn(hpb)2 and DCM.

Figure 1.7 shows the schematic energy level diagram of device structure used in this study. The distance of buffer layer DCM from $Zn(hpb)_2$ layer was variable. In these devices holes were injected from ITO electrode and electrons from Al electrode.

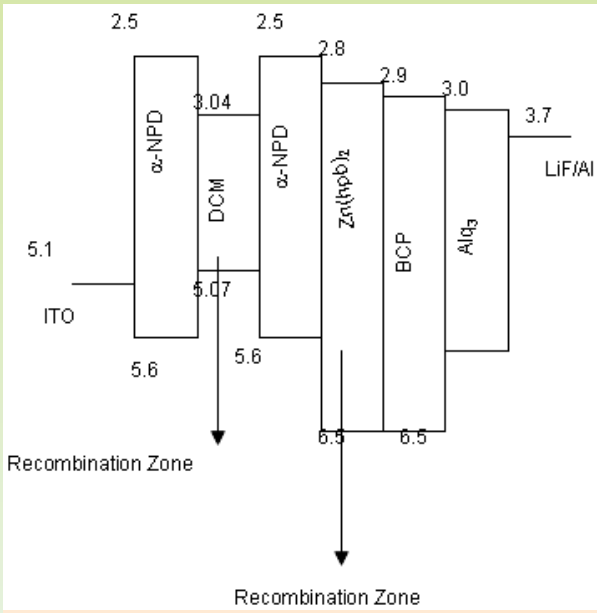


Fig.1.7 Schematic energy level diagram of device structure.

There are two recombination zones, one is DCM layer and other is Zn(hpb)2 layer. From energy level diagram, it can be seen that the barrier for electrons at each interface is quite less (~0.1 eV) except at DCM/ α-NPD interface , where it is 0.54 eV.

Therefore, this causes the trapping of electrons inside the DCM layer. Distance of DCM layer from Zn(hpb)2 layer is variable. The distance of DCM layer from Zn(hpb)2 layer and barrier for holes at DCM/α-NPD interface are deciding the recombination zone in OLED.

Figure 1.8 shows the Electroluminescence (EL) spectrum of devices A, B and C. Curves a and b of Fig.1.8 show EL spectrum of the devices with DCM layer placed at a distance of 8.5 nm and 7.5 nm respectively from Zn(hpb)2 layer. From Fig.1.8, it has been observed that the holes, flowing from ITO electrode, were getting trapped in DCM layer due to the barrier (0.53eV) at DCM/α-NPD interface. Further, the holes crossing this barrier have to travel a variable distance in α-NPD layer before recombining in Zn(hpb)2 layer. Thus the contribution of the recombination inside DCM layer is dominant. From the curve 'a' and 'b', we can see that by decreasing the

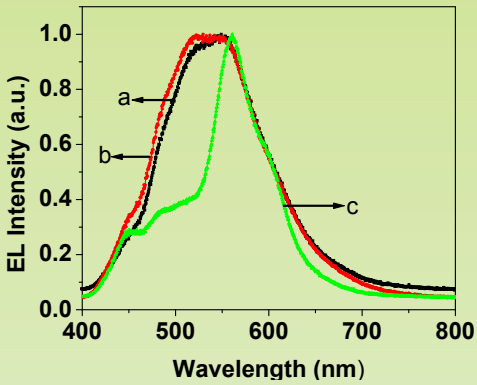


Fig.1.8 Electroluminescence spectrum of devices A, B, C shown by curves a, b, c respectively.

distance of DCM layer from Zn(hpb)2 the contribution of recombination in Zn(hpb)2 has been increased. The measured CIE coordinates for device A and B were (0.33, 0.47) and (0.33, 0.45) respectively. Further to improve white light emission DCM has been replaced by rubrene dye whose HOMO and LUMO values are 3.2eV and 5.4eV respectively. The HOMO value (5.4eV) of rubrene causes a less barrier (0.2eV) at rubrene/α-NPD interface. As a result the contribution of recombination in Zn(hpb)2 layer has been increased significantly. Measured CIE coordinates for device C were (0.33, 0.39).

Fig. 1.9 shows the VL characteristics of devices A, B and C. Maximum luminescence of 4,300Cd/m^2 has been achieved for device C.

We have also demonstrated a WOLED by stacking of three layers having red, green and blue emission. BCzVBi doped CBP, Ir(ppy)$_3$ doped CBP and Ir(btp)$_2$ acac doped CBP have been used as blue, green, red emissive layers respectively. WOLEDs with the structure ITO(120nm)/Doped α-NPD (35nm)/ BCZVBi doped CBP(20nm)/ Ir(ppy)3 doped CBP(4nm)/ Ir(acac) doped CBP (12.5nm)/Balq (30nm)/LiF(1nm)/ Al(150nm) have been fabricated. Schematic diagram of the device is shown in Fig.1.10.

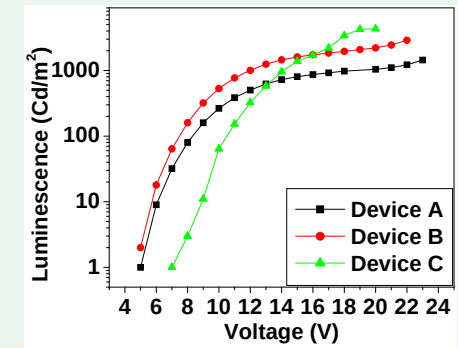


Fig.1.9 Voltage-Luminescence (V-L) characteristics of device A, B, C.

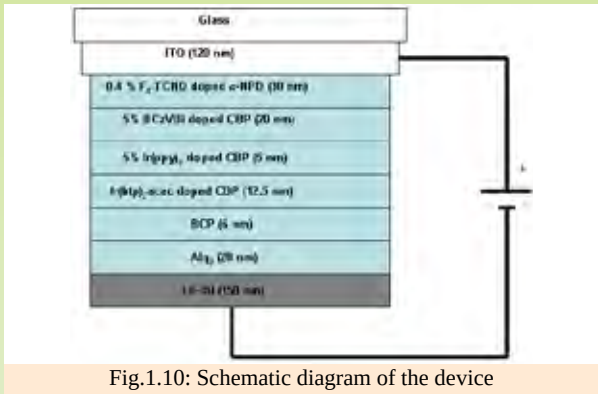


Fig.1.10: Schematic diagram of the device

Figure 1.11 shows the Electroluminescence (EL) spectrum of devices. The concentration of red phosphorescent material in CBP has been varied (0.5, 0.65 and 0.75 wt%) to optimize the CIE coordinates. The measured CIE coordinate for device with 0.75wt% concentration of Ir(btp)$_2$ acac in CBP are (0.32, 0.32) at 6V and the device shows maximum luminescence of 24,000Cd/m^2 (at 19V) (Fig.1.12).

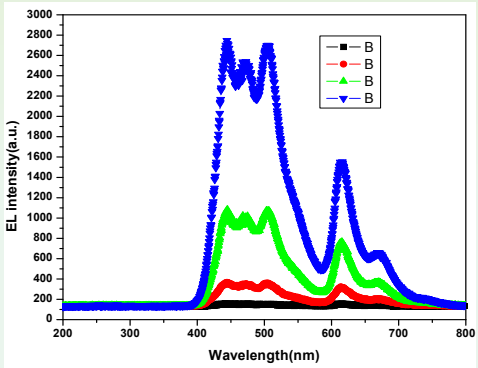


Fig.1.11: Electroluminescence spectrum of device with 0.75wt% Ir(btp)$_2$ acac in CBP

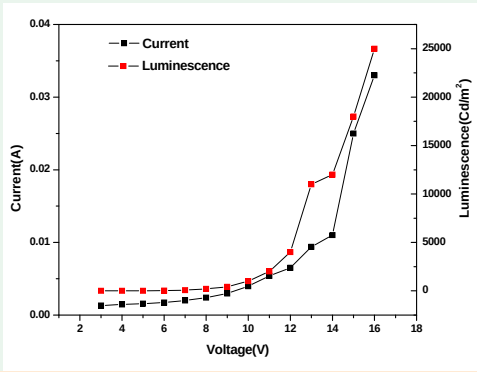


Fig.1.12: IVL spectrum of stacked layer device

(b) Inorganic LEDs (Indium & Gallium based Materials)

Kinetically controlled growth of metals (Indium & Gallium) on high index silicon surfaces has been performed and various metal induced superstructural phases were obtained. The formation of crystalline III-nitride (Indium nitride, Gallium nitride) epitaxial layers on high index silicon surfaces by N_2^+ ions has also been carried out. Extensive X-ray Photoelectron studies have been carried out on ZnO and Graphene based nanostructures.

(c) Major Facilities

Fig. 1.13 Multi Probe Surface analysis system

Multi Probe surface analysis system (Omicron) has been installed (Nov 2010) to analyze surface elemental composition, distribution and bonding information, electronic structure conduction/valence surface & interface states, adsorbate & surface structures. The system consist of X-ray Photoelectron spectroscopy (monochromatic AlKa, non-monochromatic MgKa, AlKa sources), Ultraviolet Photoelectron Spectroscopy (He Source), Ion Scattering Spectroscopy, Scanning Tunneling Microscopy, Atomic Force Microscopy (contact & non contact mode), Auger Electron Spectroscopy, Low Energy Electron Diffraction & Temperature Programmed Desorption techniques.

Three chamber nitrogen RF Plasma assisted Molecular Beam Epitaxy (Riber, France) for growth of III-nitride heterostructures on 3 inch wafer (or smaller samples). The MBE machine contain Knudsen cells of Ga, In, Al, Mg, Sb, Si, Bi with N- plasma source. The epitaxial growth information can be achieved by in-situ reflection high energy electron diffraction (RHEED). This MBE is operated under the vacuum of $3x10^{-11}$ Torr.

Fig. 1.14 MBE System

वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद्
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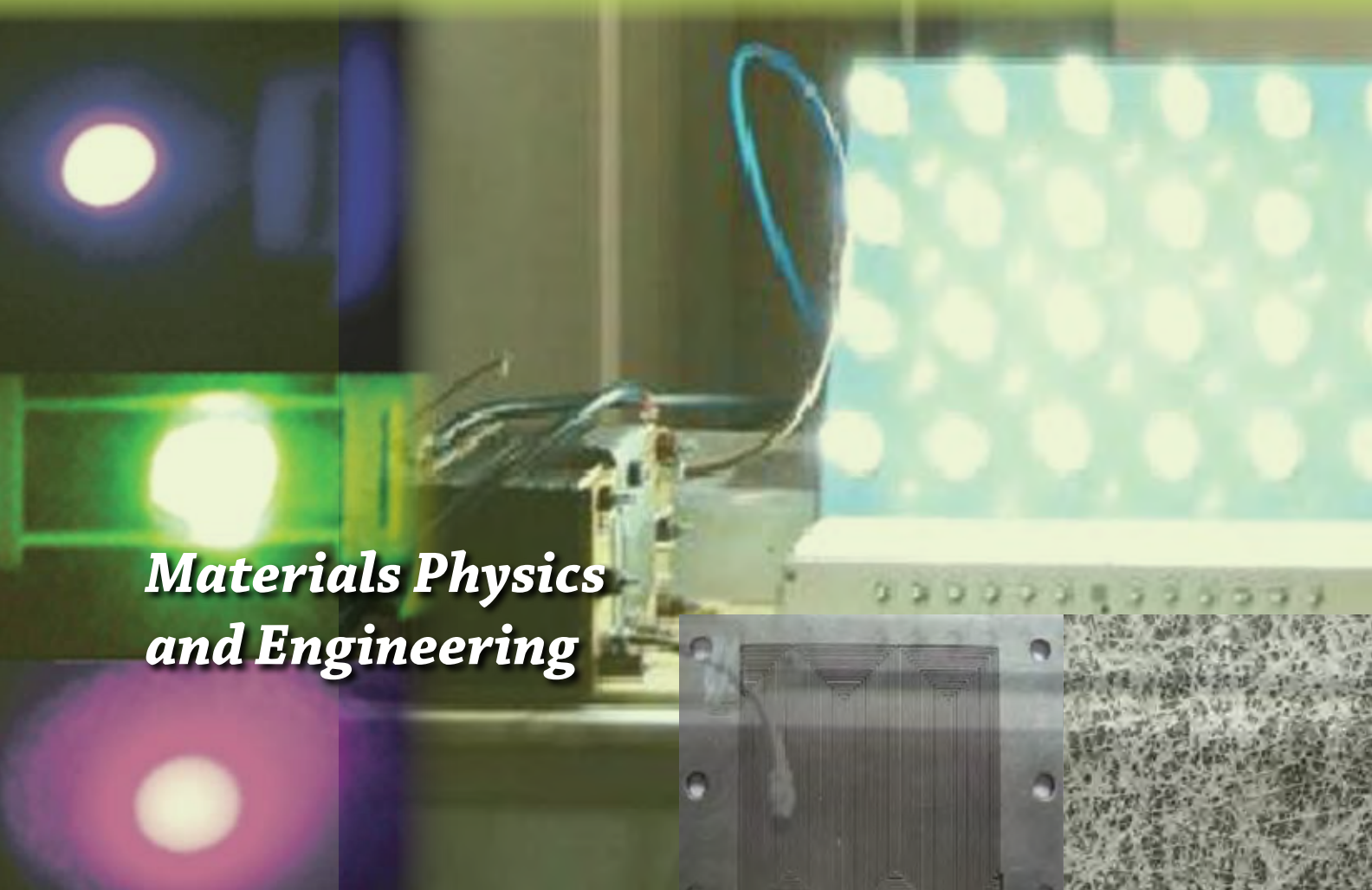
पदार्थ भौतिकी एवं इंजीनियरिंग



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।

प्रकाशीय तनु परत और सिरैमिक्स

यह समूह जिंक ऑक्साइड की अति सूक्ष्म संरचनाओं और इसके एकल क्रिस्टलीय परतों, तथा टिटैनिया अति सूक्ष्म संरचनाओं के संश्लेषण के कार्य में संलग्न रहा। इस समूह द्वारा तापीय वाष्पीकरण तकनीक द्वारा विभिन्न प्रकार के जिंक ऑक्साइड की अति सूक्ष्म

संरचनाओं तथा प्लाज्मा सहाय्य एम ओ सी बी डी द्वारा टिटेनिया अति सूक्ष्म संरचनाओं का संश्लेषण किया गया। एक्स टी डी, पी एल, एस ई एम/ई डी एक्स, टी ई एम का प्रयोग करके इन अति सूक्ष्म संरचनाओं का व्यापक अभिलक्षण निर्धारित किया गया। जिंक ऑक्साइड को विकसित करने के लिए टेम्पलेट के रूप में सिलिकन पर एकल क्रिस्टल जिंक ऑक्साइड परत को विकसित किया गया और इस प्रकार 800 आर्क सेकंड के रूप में एक्स आर डी का एफ डब्ल्यू एच एम तैयार किया गया और इसमें आगे और सुधार लाने की प्रक्रिया जारी है। यह समूह उच्च ताप पर निक्षेपण हेतु मौजूदा प्लाज्मा आधारित एम ओ सी वी डी, कण क्षेपण प्रणालियों के उन्नयन के कार्य में संलग्न 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.

Optical Thin Film & Ceramics

This group was involved on the synthesis of ZnO nanostructures and its single crystalline films, and titania nanostructures. Different ZnO nanostructures were synthesized by thermal evaporation technique, and titania nano structures by plasma assisted MOCVD. The detailed characterizations of these nanostructures were carried out using XTD, PL, SEM/EDX, TEM. Single crystal ZnO film

was grown on silicon as template for ZnO growth, and achieved the FWHM of XRD as 800 are see and further improvements are underway. The group has undertaken the up gradation of the existing plasma based MOCVD, sputtering systems to carry out the depositions at high temperatures.

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.

I. Polymeric and Soft Material Section

Ferroelectric liquid crystals

The introduction of ferroelectricity in liquid crystal (LC) materials has attracted a great deal of interest from researchers around the world. Ferroelectric liquid crystals (FLCs) have been found to be more advantageous than nematic LCs due to their good optical contrast, low threshold voltage, and faster electro-optical response. Some boundary conditions have been imposed to make FLC cells to achieve bistable switching, which led to an important discovery of surface-stabilized FLCs (SSFLCs). The discovery of the deformed helix FLCs (DHFLCs) has ruled out the constraint on the cell thickness as the optical bistability is independent of the cell thickness in these materials. DHFLCs have many applications in display devices because of their low driving voltage, gray scale generation capability, easily achievable alignment, fast response, etc. The averaged optical indicatrix of the helical structure in DHFLCs has been found to depend almost linearly on the applied electric field and, hence, these materials are enriched with the gray scale generation capability. The bistability in DHFLCs arose due to the fact that the modulated planar LC conformation hinders the helix formation in DHFLC layers. In DHFLCs, a low field causes only a deformation of the helix, whereas a larger field unwinds the helix and provides a quasibistable switching. The phenomenon of bistability and memory effect in DHFLC has been undertaken by our group at NPL.

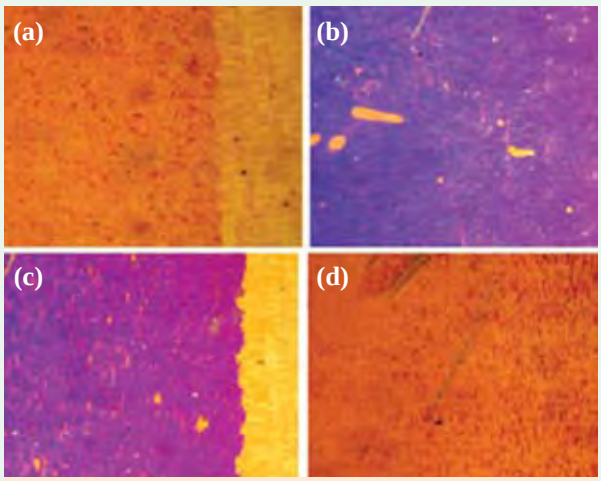


Fig. 2.1: Optical micrographs of DHFLC material at (a) 0 V, (b) 8 V, (c) after 80 h of removal of bias, and (d) scattering state achieved upon applying low voltage and high-frequency ac field.

Figure 2.1(a) shows the optical micrograph of the material when no bias was applied across the cell and it was called scattering state. A completely switched state of the cell was achieved by the application of 8 V bias as shown in Figure 2.1(b). Figure 2.1(c) shows that the memory was retained for 80 h after the removal of bias. Once the cell switches, it tends to remain in that state for a long time (for many days). The memory state in DHFLC samples was switched back forcibly to the original state (scattered state) upon application of a sinusoidal field of low amplitude (1 V) and high frequency (around 50 Hz), which is shown in Figure 2.1(d).

The occurrence of memory effect has also been confirmed by taking the optical response of the material as shown in Figure 2.2. The optical transmission changes from maximum to minimum as the applied field reverses its polarity, and there is almost no change when the applied field attains its 0 V state, which confirms the memory effect.

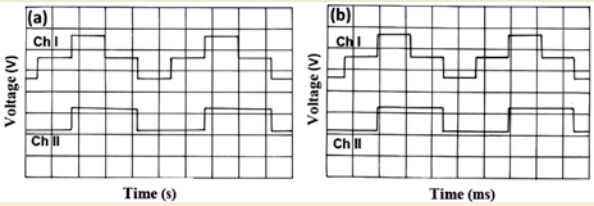


Fig. 2.2: Optical response of DHFLC sample at frequencies of (a) 200 mHz [Ch I-10 V/div, Ch II-0.02 V/div, Time-1 s/div] and (b) 10 Hz [Ch I-10 V/div, Ch II-0.02 V/div, Time-20 ms/div].

It has been predicted that the higher value of rotational viscosity is one of the reasons for the long-lasting memory effect. However, the mechanism of the memory effect in DHFLC materials is rather unclear and leaves further space for LC researchers to think in this direction.

Electrochemical impidimetric technique for the detection of cardiac biomarkers

C-reactive protein (CRP) and Myoglobin proteins are being extensively used as diagnostic markers of acute myocardial infarction (AMI). As a cardiac biomarker, myoglobin is used in conjunction with troponin to help diagnose or rule out a heart attack in human blood. New biochemical diagnostic methods for AMI are being investigated in response to the requirement for superior diagnostic accuracy and rapidity, and for improvements in the management of patients with chest discomfort. High sensitivity and selectivity nature of the recognition

between antigen (Ag) and antibody (Ab) makes the immunoassays very useful in widespread applications in environmental monitoring, processing quality control and clinical diagnosis. The concept of direct label-free immunosensors has advantages with respect to speed and simplicity in which the immune interaction between antibody and antigen is directly monitored.

Due to small size of 17.8 kDa of Myoglobin, a non-enzymatic cardiac protein, it is released into plasma in a significant amount within 3 hrs of the onset of AMI while the plasma concentrations usually return to normal within 24 hrs. Normal serum myoglobin levels range from 30 to 90 ng/ml. After 1 hour of the onset of myocardial infarction, serum myoglobin level can elevate to 200 ng/ml or even higher. During the peak hour, myoglobin level can be as high as 900 ng/ml.

Recently, we report a protein immobilized self-assembled monolayer (SAM) of gold nanoparticles (GNPs) on indium-tin-oxide (ITO) coated glass plate. The protein-antibody, Mb-Ab, was covalently immobilized over the self-assembly of GNPs through a mixed SAM of 11-mercaptoundecanoic acid (MUA) and 3-mercapto propionic acid (MPA) via carbodiimide coupling reaction using N-(3-dimethylaminopropyl)-N'-ethyl carbodiimide (EDC) and N-Hydroxy Succinamide (NHS). The whole assembly was constructed on 0.25 cm^2 area of ITO-glass plate (Mb-Ab/MUA-MPA/GNPs/APTES/ITO-glass) and an impedimetric study was carried out for its application in myoglobin detection (Fig. 2.3). This prototype assembly was characterized by scanning electron microscopy, atomic force microscopy and electrochemical techniques. The modified electrode showed an increased electron-transfer resistance on coupling with protein antigen, Mb-Ag, in the presence of a redox probe $[Fe(CN)_6]^{3-/4-}$ (Fig. 2.4).

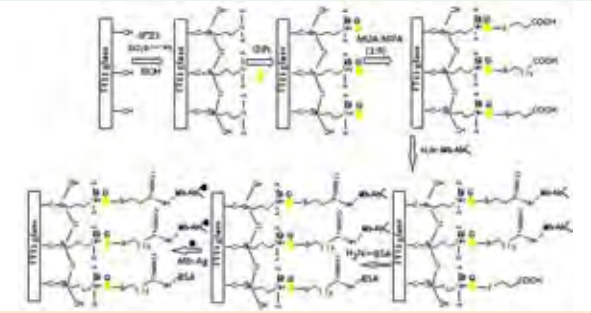


Fig. 2.3

Its exhibits an electrochemical impedance response to protein myoglobin-antigen, Mb-Ag, concentration (Fig. 2.5) in a linear range from 0.01 µg to 1.65 µg mL^{-1} with a lowest detection limit of 1.4 ng mL^{-1}.

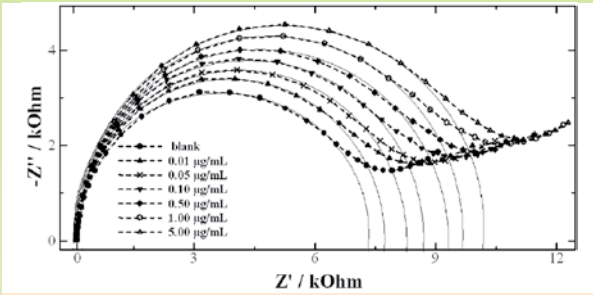


Fig. 2.4

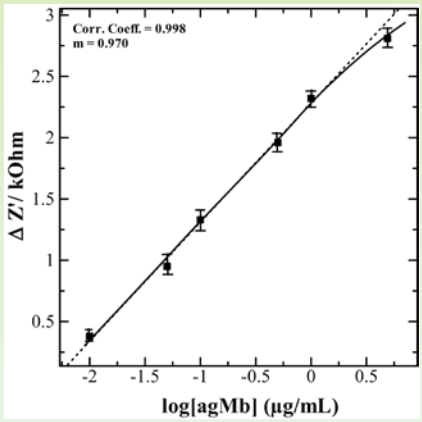


Fig. 2.5

Study of Doped Titanium oxide films and Nanoparticles Synthesized by Sol-gel Route

Fe doped nanocrystalline samples of titanium oxide have been synthesized by sol-gel route and conventional sintering at 450°C under atmospheric conditions. These samples are characterized by XRD, XPS, TEM and dielectric property measurement. Samples with Fe content more that 4 mole % are found to crystallize as rutile phase of TiO_2 and those with less than 4 mole % crystallizes in anatase phase. Nanocrystallite size is strong function of the dopant concentration (Fe) [Figure 2.6 (a & b)]. Crystallite size decreases initially with Fe-concentration when the material is in anatase phase. Sudden increase in the crystallite is observed when phase in the samples takes place. The numerical values of crystallite size, determined from TEM & XRD peak broadening differ by about 25%. Highest value of crystallite size is 86 nm in 10 mole % Fe doped samples and lowest as 20 nm in 4 mole % Fe doped sample

as shown in Figure 2.7 (a & b). Large dispersions and anomalous values of the dielectric constant εr were observed at low frequency in anatase samples. Rutile phase samples exhibit little dispersion over the measurement frequency range of 20 Hz to 10 MHz. the dielectric constant value of all the samples stabilizes to a constant value at higher frequencies. This value is dependent on the final crystalline phase but independent of the crystallite size. The anomalous dielectric behaviour of anatase samples at low frequencies is assigned to the adsorbed –OH ions on the sample surface.

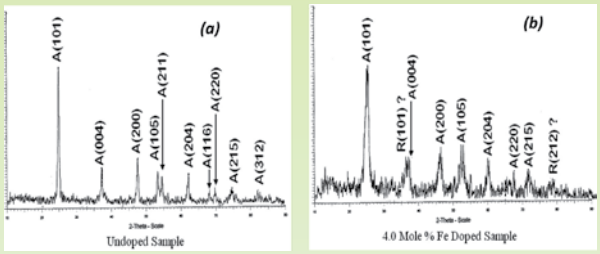


Fig. 2.6: X-ray diffraction pattern of (a) undoped TiO_2 and (b) 4 mole% Fe doped samples

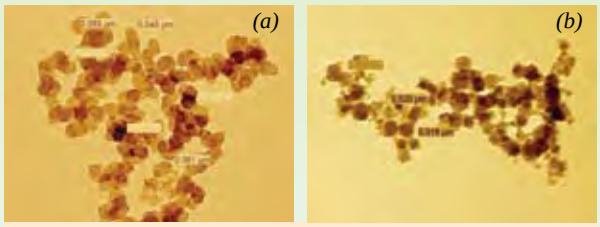


Fig. 2.7: (a) 10 mole% Fe doped Sample (b) 4 mole% Fe doped Sample

Synthesis of vanadium oxide (VO_2) films and study of the electronic properties of chalcogenide nano-particles

Nanoparticles of chalcogenide exhibit excellent charge confinement properties due to which they are now being explored for possible application as photo-sensitizer in DSSC. We have synthesized and stabilized nano-particles of BiS and CdS in solution with cetylpyredinium chloride (CPC) as cationic surfactant, which were subsequently settled on TiO_2 electrode. Photoelectron generation and their subsequent transfer to the FTO electrode via TiO_2 film was studied by cyclic voltameteric experiments carried on Eco Chemie (Netherlands) 302N electrochemical workstation.

Synthesis of vanadium oxide (VO_2) by Sol-gel dip coating offers a route to deposit high quality films on large area substrates in an economic way and hence promise commercial exploitation of the technology. The heart of this technology is the coating sol. We have optimized the sol for coating VO_2 films on glass substrates by Sol-gel dip coating technique. CV of TiO_2 Electrode decorated with CdBiS and CdS nanoparticles under no light (dark) and visible light (light) exposure conditions are shown in Figure 2.8 (a & b). Trial samples are prepared and further studies are in progress to modify the film properties for desired applications.

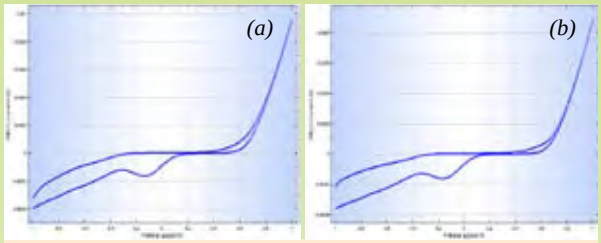


Fig. 2.8 (a) CdS on TiO_2 dark (b) CdS on TiO_2 light

Polyaniline-flyash composite material for shielding against electromagnetic radiation

The formation of tubular structure containing FA particles embedded in between the polymer chains by microemulsion polymerizations enhances the effective anisotropy energy of composite. This contributes to more scattering and leads to the high shielding effectiveness of SET~32dB as compared to conventional materials which depends on dielectric loss and volume fraction of FA in polyaniline matrix.

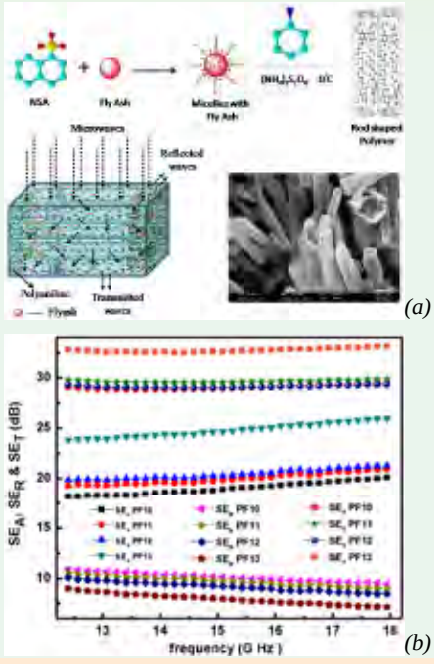


Fig. 2.9: Shielding effectiveness of conducting polyaniline-flyash composites in 12.4 GHz to 18.0 GHz range.

The complex parameters i.e. permittivity (ε* = ε′- iε″) and permeability (μ* = μ ′- iμ″) of PANI-FA composites, have been calculated from experimental scattering parameters (S11 & S21) using theoretical calculations given in Nicholson−Ross and Weir algorithms. The real part or dielectric constant (ε′) is mainly associated with the amount of polarization occurring in the material and the imaginary part (ε″) is a measure of dissipated energy. The dielectric performance of the material depends on ionic, electronic, orientational and space charge polarization. The contribution to the space charge polarization appears due to the heterogeneity of the material. The presence of insulating FA in the conducting matrix results in the formation of more interfaces and a heterogeneous system due to some space charge accumulating at the interface that contributes toward the higher microwave absorption in the composites. The contribution to the orientational polarization is due to the presence of bound charge (dipoles). The shielding effectiveness of PANI-flyash composites with different loadings of flyash in the polymer matrix is given in Figure 2.9.

Promising electromagnetic shielding properties of graphene paper encapsulated with nanoparticles of γ-Fe_2O_3 in X-band

Graphene paper incorporated with nanoparticles of γ-Fe_2O_3 has been prepared which shows electromagnetic shielding effectiveness of the order of 45.26 dB in the microwave range (X−Band) which strongly depends on dielectric loss and volume fraction of γ-Fe_2O_3 in graphene matrix. The pictorial representation of the designing of graphene paper is shown in Fig. 2.10 SEM images demonstrate that nano particles of γ-Fe_2O_3 are sandwiched between graphene layers.

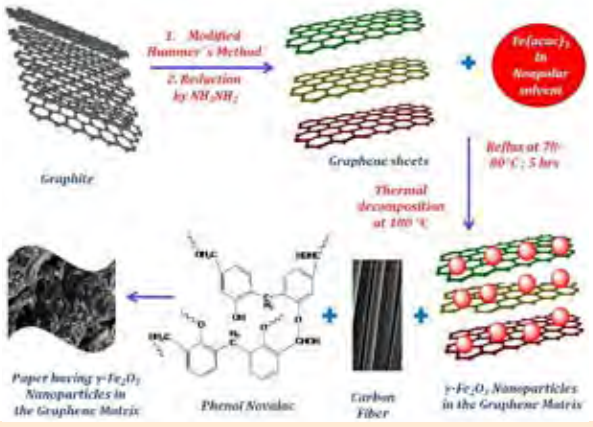


Fig. 2.10: Schematic Representation of incorporation of ferrite particles in graphene matrix and designing of graphene paper

Developement of Highly Adhesive Antifouling and Anticorrosive Nanofiber Network of Conducting Copolymer –Fe_2O_3 Composite for Protection of Iron

Organic coating strategies for corrosion protection with inherently conducting polymers have become important because of restriction on the use of heavy metals and chromates in coatings due to their environmental problems. Present work is directed towards the electro-deposition of highly adherent coating of copolymers based on aniline and 1-amino-2-naphthol-4-sulfonic acid with the incorporation of γ- Fe_2O_3 in the presence of perflouro-octanoic acid as an electrolyte on the iron surface. Corrosion protection efficiency of iron coated copolymer in 3.5 % NaCl has been evaluated using electrochemical impedance spectroscopy, Tafel Extrapolation method and chronoamperometry techniques. SEM micrograph (Fig. 2.11) of the copolymer in PFOA medium shows the formation of needles of the co-polymer.

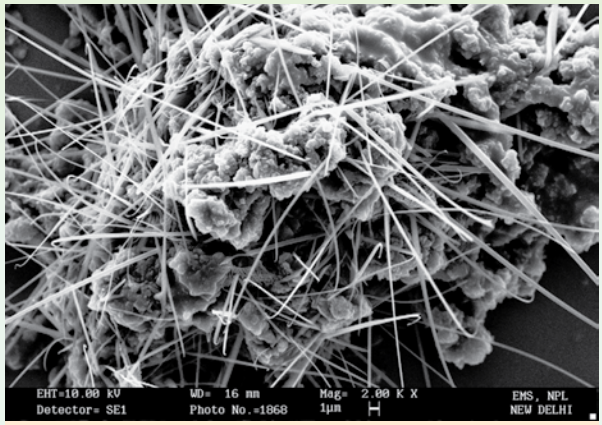


Fig. 2.11: SEM micrograph of copolymer of aniline and ANSA in perfluoro-octanoic acid medium.

In-Situ Growth of Cadmium Telluride Nanocrystals in Poly (3-hexylthiophene) Matrix for photovoltaic application

Nanocrystals of cadmium telluride (CdTe) have been directly synthesized in poly(3-hexylthiophene) (P3HT) matrix without use of any surfactant. In-situ synthesis of nanoparticles in polymer matrix improves the polymer-nanoparticles interface, which facilitates efficient electronic interaction between them. Spectral results suggest that CdTe nanocrystals are bound with P3HT

via dipole-dipole interaction and form a charge transfer complex. Structural and morphological studies reveal that CdTe works as transport media along/between the polymer chains, which facilitate percolation pathways for charge transport. Therefore, enhancement in current density has been observed for the bulk heterojunction (BHJ) device of P3HT-CdTe nanocomposites blended with PCBM. An open circuit voltage (VOC) of 0.80 V was obtained from the BHJ device due to the increase in the energy level offset between the donor and acceptor. This new photovoltaic element could provide a new nanoscale criterion for the investigation of photoinduced energy/charge transport in organic-inorganic interfaces. Proposed mechanism for in situ growth of the CdTe nanoparticles in the P3HT matrix [Fig. 2.12]. (a) P3HT was synthesized by chemical oxidative polymerization route. (b) Schematic of Cd^{2+} ions were assumed to be coupled with the unpaired S along the P3HT planar chain network. (c) Schematic diagram of P3HT capped CdTe nanoparticles after reaction of TOPTe with Cd^{2+} ions coupled P3HT.

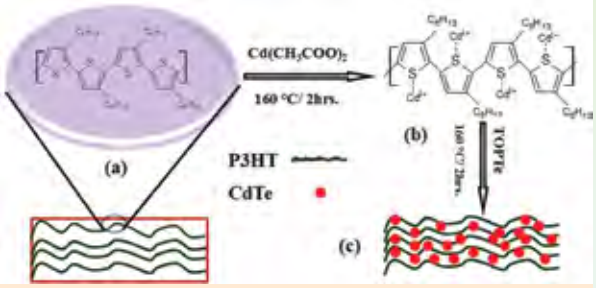


Fig. 2.12: Proposed mechanism for in situ growth of the CdTe nanoparticles in the P3HT matrix

Extraordinary work

- ❖ Static optical memory effect has been predicted and observed experimentally in deformed helix ferroelectric liquid crystals.
- ❖ Detection of cardiac bio marker myoglobin (Mb) in aqueous solution has been done by electro-chemical impedance method.
- ❖ Polyaniline flyash composite material for shielding against electromagnetic radiation has been developed.
- ❖ Development of graphene paper for effective EMI shielding by incorporating some nanoparticles has been invented.

II. Physics and Engineering of Carbon

A leading centre in India dedicated to research in both pure and applied science of carbon with three principal motives i) to develop the process technology of newer carbon products which hold strategic importance and are not available to the country at any cost, ii) to develop products which can be made cost-effective by innovative process suitable to available infrastructure, expertise and resources in India, iii) to promote overall growth of carbon science and technology in the country through sustained R&D, research publications, patents, technology transfer, consultancy to industry, national & international conferences and refresher courses etc.

Development of high density graphite for multistage depressed collection of electron tubes

Development of high density graphite is the XI Plan CSIR sponsored network project on “Design and fabrication/capabilities for very high power microwave tubes” with CEERI, Pilani as the nodal agency.

High density graphite samples were development from coal tar pitch (CTP) derived green coke material mixed with natural graphite (NG), synthetic graphite (SG), carbon black (CB) powders and molded into plates or blocks using hydraulic press or isostatic press. The graphite samples prepared from GC/modified GC at HTT of 2500ºC possessed bulk density of 1.88-1.95gcm^{-3}, bending strength of 71-80MPa, improved compressive strength of 138-140MPa and electrical resistivity of 1.6-1.7mΩcm. These values are close to the targeted values required under the project. The samples were supplied to CEERI, Pilani for testing.

To obtain copper reinforced carbon/graphite (C-Cu composite), the ball milled green coke powder was mixed with pitch coated copper and some additives such as NG, SG in different Cu/C ratios of 0.67-1.5 and then molded into a rectangular plates and carbonized to 1000/1200ºC.

These composites exhibited much better properties as compared to those prepared from uncoated copper and green coke. A patent has been applied for this work.

The C-Cu composites prepared from CTP coated Cu and high amount of coated NG (47%) heat treated at 1100ºC

possessed bulk density of 3.19gcm^{-3}, bending strength of 42MPa, shore hardness of 51, electrical resistivity of 0.40mΩcm and high thermal conductivity of 198W/mK (parallel to the plane). The C-Cu composites (Cu/C=1.0) made at HTT of upto 1100ºC from Cu powder, CTP, SG along with wetting agents significantly improved the properties of the composites. The bulk density of 3.05-3.12 gcm^{-3}, bending strength of 102MPa, shore hardness of 74-80, electrical resistivity of 1.12-1.24 mΩcm and thermal conductivity of 54W/mK were obtained.

The NG and GC powder were also coated with nano particles of Cu of size 20-100 nm using electroless coating technique at NPL and used to prepare copper-graphite composites with different Cu to C ratios. SEM/TEM images confirmed that the Cu particles were of spherical shape with particle size in the range of 20 to 100 nm. The C-Cu nano composites prepared with NG exhibited low bending strength (25MPa) with high thermal conductivity of 30W/mK (perpendicular to the plane) while those prepared with GC possessed high bending strength (109-156MPa) with low thermal conductivity of 8 W/mK (perpendicular to the plane). Further work is in progress.

Development of carbo-graphite material for aeronautical application

This project was for the development of carbo-graphite material to be used as a seal for Kaveri Engine of LCA aircraft sponsored by Defence Materials and Store Research & Development Establishment (DMSRDE), Kanpur. The material for seal in Kaveri Engine should have high density ~1.90 gcm^{-3}, high shore hardness ~85, high compressive strength ~1500 kg/cm^2 and should be stable in air at 650ºC. The samples were made from coal tar pitch derived green coke carbonaceous material as such or modified and heat treated at 1000ºC or higher upto 2500ºC and then impregnated with different boron, phosphorus and other suitable salts in a high pressure-high temperature impregnation assembly and baked at 650ºC. The samples tested for thermal stability at 650ºC in air for different durations (upto 10 hr) have shown excellent results. The project has been successfully completed in September 2010 and the completion report was submitted to the sponsored agency (DMSRDE) in December 2010.

Synthesis of Single or Double graphene by re-exfoliation of Expanded Graphite

Graphene is a transparent single atom-thick planar sheet of sp^2 bonded carbon atoms that are densely packed in a honeycomb crystal lattice. It is regarded as the "thinnest material in the universe" with tremendous strength similar or slightly greater than CNT, but much higher than steel. Gr, as defined, is a two-dimensional (2D) crystal, composed of monolayers of carbon atoms arranged in a honeycombed network with six-membered rings, which is the interest of both theoretical and experimental researchers worldwide. The name comes from graphite and alkene; graphite itself consists of many Gr-sheet stacked together by weak van der Waals forces. This attributed to the monolayer of carbon atoms densely packed into honeycomb structure.

In NPL, we have started the synthesis of graphene by a new approach to produce single and double layer clean large area Gr from re-exfoliation of expanded graphite. Initially expanded graphite prepared from the natural graphite. Fig. 2.13(a) shows the overall schematic of the synthesis of graphene by re-exfoliation of expanded graphite followed by sonication and centrifugation.

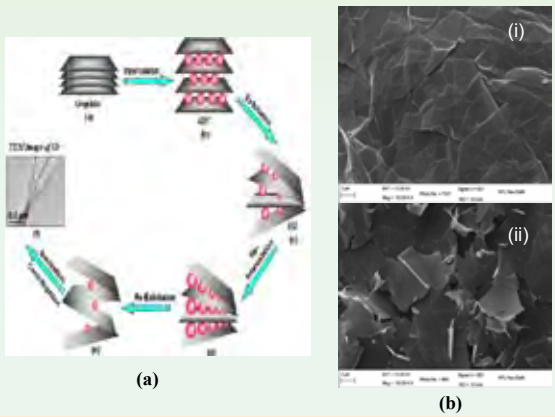


Fig. 2.13: (a) schematic of the synthesis of graphene by re-exfoliation of expanded graphite, (b) SEM of graphene derived from re-exfoliated of expanded graphite

Fig. 2.13(b), shows the SEM micrograph of graphene synthesised from the re-exfoliation of expanded graphite at lower and higher magnification. At lower magnification large number of sheets is visible and some of the sheets are folded (Figure 2.13(a). On the other hand at higher magnification, individual Gr-sheets are separated with clean surface and area of sheets is ~ (12 X 10) µm.

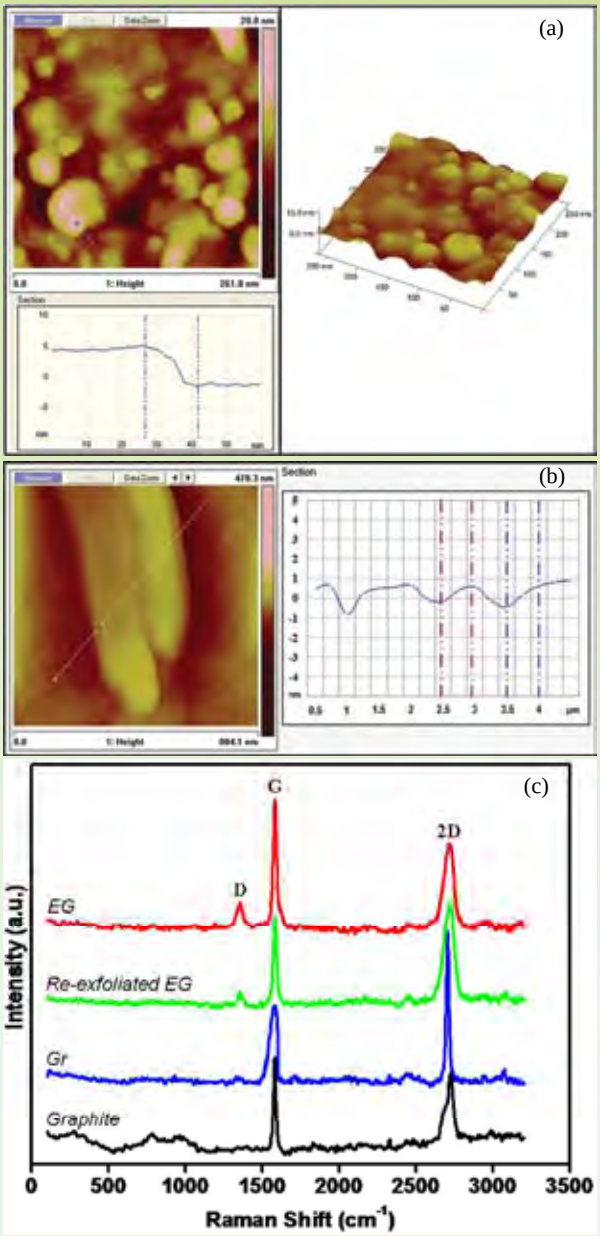


Fig. 2.14: (a) AFM image of graphene derived expanded graphite (b) graphene derived from re-exfoliated expanded graphite (c) Raman spectra

Fig. 2.14 shows the AFM images of Gr-sheet obtained after from expanded graphite. The large amount of isolated Gr-sheets with different dimensions is observed and some of them overlap on edges as shown in Fig. 2.14a. From the AFM image and the corresponding height profile of Gr-sheet, it is observed that the thickness of Gr-sheet is in between 6-7 nm. 3D topographical AFM image of Gr-sheet shows some corrugations appear that possibly arise by partial roll up edges of few layer Gr-sheet. Figure 2.14b, AFM image of graphene sheets obtained after re-exfoliation of expanded graphite in which the thickness of Gr sheet 0.75-1.075 nm which confirms the presence of single and double layer Gr.

Figure 2.14c, shows the Raman spectra of Gr, EG, re-exfoliated EG and graphite. In case EG, the D peak (~1350 cm^{-1}, indicates defects and disorders) is observed with broad 2D peak and high intensity G peak. On re-exfoliation of EG, low intensity D peak and a sharp G peak of higher intensity is observed, if it compared with EG which indicates the presence of few defects. Also, the I(2D)/I(G) ratio of Gr is found to be ~ 1.7 which suggests the presence of single or double layer Gr.

While in case of Gr, D peak is almost disappear. This proves the absence of a significant number of defects. A significant change in shape and intensity of the 2D peak of Gr as compare to graphite is observed. The 2D peak in graphite consists of two components $2D_1$ and $2D_2$, roughly 1/4 and 1/2 the height of the G peak, respectively. In Raman spectrum of Gr, a single, sharp 2D peak is more intense than the G peak. However, the G peak intensity of single layer is comparable with the peak of graphite.

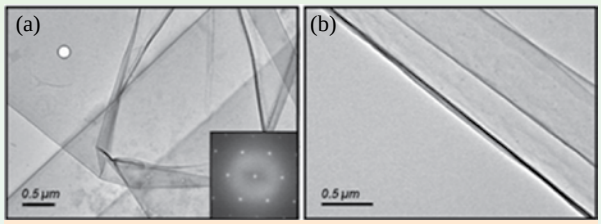


Fig. 2.15: TEM micrograph (a) large area graphene sheet and (b) Graphene ribbon

Fig. 2.15 shows the TEM micrograph of Gr-sheet obtained from re-exfoliated EG. It is clearly seen that the Gr-sheet is almost completely transparent (Fig. 2.15a) and edges of sheets are partially folded due to large area occupied. Moreover, it appears to have rough surface which might be due to the oxidation of sheets. The Fig. 2.15(b) shows the clean surface of Gr-sheet in the form of wide long ribbon this might occur after re-exfoliation of EG. Cutting of the larger Gr-sheet take place in straight line by oxidation with HNO_3. The darker region and wrinkles appeared is might be due to the partially rolled up/folded edge of Gr-sheet.

A more definitive identification of Gr can be made by the analysis of electron diffraction patterns. Normal-incidence selected-area electron diffraction (SAED) is performed on a smooth region (marked with a white dot in Fig. 2.15(a)) to determine its crystalline nature. Fig. 2.15(a), inset shows the well-defined hexagonal diffraction pattern which is similar to that of single-layer Gr prepared by manual peeling off from graphite and also through a confined self-assembly approach which confirm the crystalline structure of the obtained Gr-sheet. The inner layer with stronger spots of {1-100} than those of the outer layer {11-20} planes confirms that the region marked with white dot in Fig. 2.15(a) is monolayer.

We expect that this method will be useful, not only as a low-cost and straightforward way to make Gr but as an enabling technology for applications like Gr-based composites, solar cell and transparent gadgetry, such as crystal-clear, flexible displays.

Development of continuous carbon nanofibers by electro-spinning

The objective of the project is to develop continuous carbon nanofibers by electrospinning of polyacrilonitrile solution. The processing parameters are optimized to draw continuous electrospun nanofibers from different wt % of PAN solution. Figure 2.16 shows the SEM micrograph of electrospun nanofibers drawn from 7.5, 8.5, 9, 10 and 11 wt. % solution of PAN. It is found that, with increasing the PAN content, polymer nanofibers diameter increases, the minimum diameter 200-300 nm is of fiber drawn from 7.5 wt % of PAN -DMF solution. However, with increasing the PAN content from 7.5 to 11 wt % fiber diameter increases from 500-1000 nanometer.

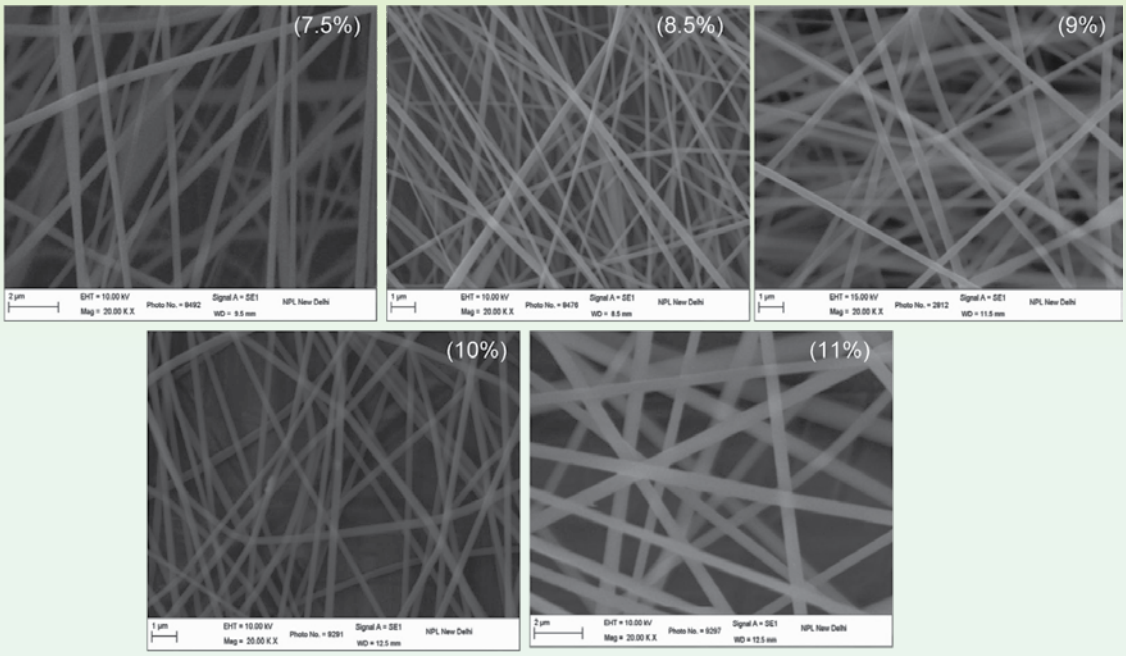
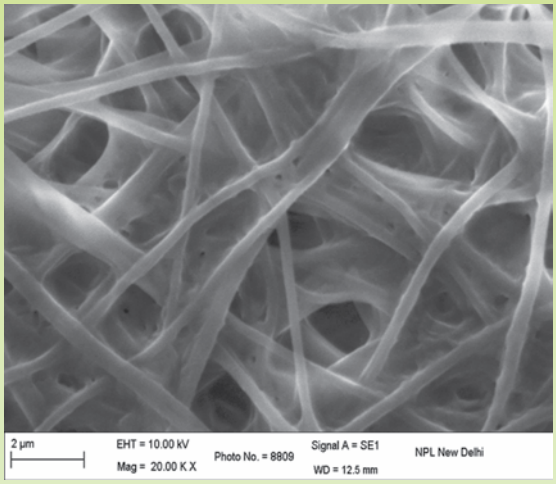


Fig. 2.16: Shows the Scanning electron micrographs of Electrospun nanofibers drawn from different wt % PAN (7.5, 8.5, 9, 10 and 11%.)

The electrospun PAN nanofibers are used for the different enzyme immobilization. It is founds that, electrospun nanofibers acts as excellent support for enzyme immobilization and improved the reusability of the enzymes. Figure 2.17(a) shows the SEM micrograph of nanofibers membrane after chitosanase enzyme immobilization. It shows that the enzyme molecules are attached on the surface of nanofibers by covalent bonding and as a results change in the fiber surface morphology. Also enzyme molecule adsorb in the porous nanofiber membrane. Figure 2.17(b) shows the reusability study of enzyme immobilized nanofiber membrane. It is found that even after ten cycles of reusability of immobilized enzyme membrane the residual activity is still more than 60 % however, residual activity of native enzyme suddenly decreases after one cycle of reusability.



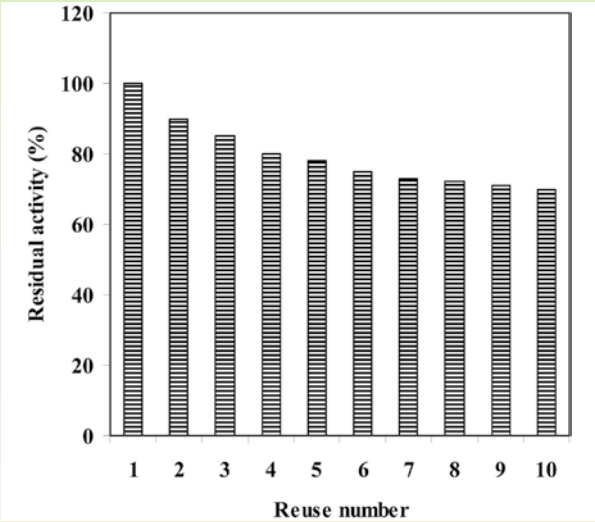


Fig. 2.17: (a) SEM micrograph of immobilized nanofibers membrane, (b) Reusability study of enzyme immobilized nanofiber membrane.

Development and demonstration of polymer electrolyte membrane Fuel Cell (PEMFC) stacks for stationary applications

Development of Bipolar plate

It is in the continuous effort of team CSIR, to develop and demonstrate PEM fuel cell stack made by indigenous components (NPL-bipolar plate and porous conducting carbon paper), Eighty five number of bipolar plates of size 200 mm x 150 mm x 4 mm of requisite properties sent to CECRI madras centre for to make fuel cell stack assembly each of 500 W for durability test.

The bipolar plate of a PEMFC must be able to operate in an acidic environment of pH 3-5 in the presence of SO_4, NO_3, Cl, F ions arising from the Nafion membrane which in direct contact with oxidizing gases such as pure O_2 or air on cathode side and H_2 on the anode side. To check the corrosion resistant in 1 M H_2SO_4 and 2 ppm fluoride solution environment of composite bipolar plates containing different content of phenolic resin (30 to 50 %), natural graphite and lamp black are developed. Figure 2.18 shows the corrosion resistant of bipolar plates and it varies between 1µ A/cm^2 to 5 µA/cm^2. The corrosion rate in the range of 10-30 µm/year of the composite bipolar plate.

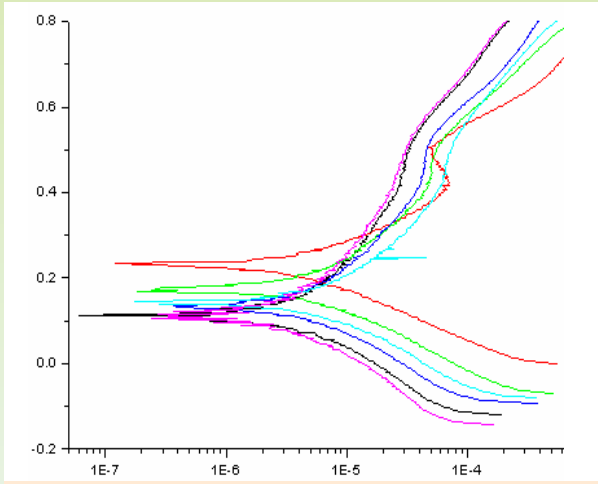


Fig. 2.18: Potentiodynamic curve of composite bipolar plates

Development of carbon paper

Nearly 150 number of Porous conducting carbon papers of size 20 cm X 20 cm, and 85 bipolar plates of size 20 cm X 15 cm were produced and characterized for their thickness, density, electrical resistivity and porosity for the preparation of MEA and to be integrated in India's indigenous fuel cell stack(s).

Improvement in the I-V performance of the fuel cell using modified carbon papers

For controlling the porous network in the carbon paper, experiments were carried out using

(i) Chopped fiber of different lengths during paper making process.

Carbon paper samples were prepared using fiber with different chopped lengths (0.3, 0.6, 1.0, 1.2 and 1.5 cm). With increase in the chopped fiber length from 0.3 to 1.0 cm, reduction in the in-plane electrical resistivity of ~ 30% has been achieved.

For the first time the detailed porous network has been studied and the effect of pore connectivity of the carbon paper on the fuel cell performance has been established. With the help of mercury intrusion porosimetry it has been found that with 0.3 cm chopped fiber length, nearly 95% of the total porosity is connected. This connectivity of the pores decreases with increasing fiber length and reduces to nearly 88% for 1.0 cm fiber length. This is probably because longer fiber have greater tendency for pore blockage. Short fiber length on the other hand leads to the reduction in the pore tortuosity and increase in the exposed surface area, thus providing effective diffusivity to the reactant and product gases

The maximum power density (766 mW/cm^2) has been achieved for carbon paper with 0.6 cm fiber length (S2) in spite of slightly higher value of electrical resistivity and almost similar pore size distribution. as compared to sample S3 with 1.0 cm chopped fiber length (Fig.2.19). Thus the increase in performance can be attributed to the decreased pore tortuosity of sample S2 as well as to the better pore connectivity of S2 where ~ 93% of the total porosity is connected as compared to S3 with ~ 88% of the pores connected.

(ii) Introducing Pore Former during the resin impregnation step

Studies were carried out using various pore formers like ethyl cellulose, ammonium carbonate, naphthalene, sodium carbonate sodium bi-carbonate etc. the introduction of pore former although leads to a slight decrease in the values of electrical conductivity and strength (which still remains in the required range), it helps in providing connected porosity as well as flexibility in the carbon paper samples.

The maximum power density for carbon paper with ethyl cellulose as a pore former is 700 mW/cm^2, as compared to 684 mW/cm^2 for as such carbon paper (Fig. 2.20). With nearly 75% of pores lying in the range of 20 – 50 µm and more than 95% of the pores connected, high performance is achieved especially in the mass transport region. Such samples can prove very useful, especially when the fuel cell is to be operated for extended periods.

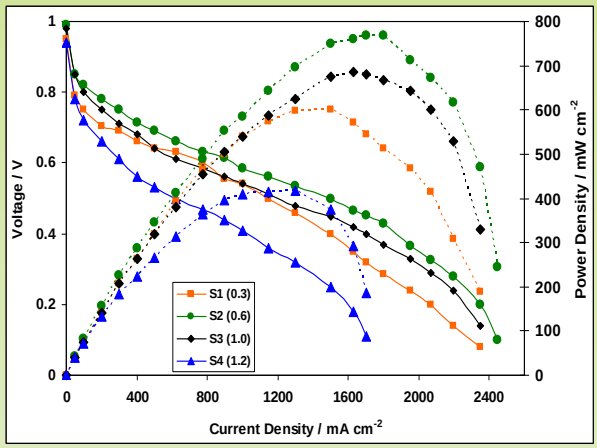


Fig. 2.19: I-V performance of the unit fuel cell with different chopped fibre length

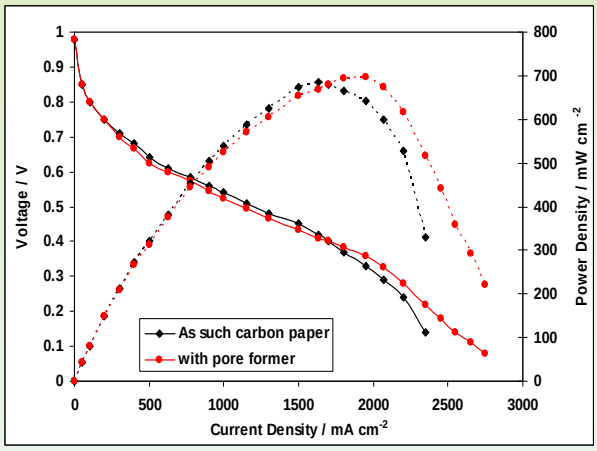


Fig. 2.20: I-V performance of carbon paper prepared with pore former

Dispersion and alignment of CNTs and development of CNT reinforced composites:

(Sponsored by Advanced Systems Laboratory (DRDO), Hyderabad):

The maximum value of flexural strength which could be achieved for CNT/epoxy composites with existing dispersion technique was ~ 115 MPa and flexural modulus ~2-3 GPa with 0.5-1% CNT loading. Amine functionalized tubes shows improved better properties than the acid functionalized tubes based composites. The improvement in the mechanical properties of the resin by 60% following reinforcement of CNTs provides a useful insight to use such modified resin for carbon fibre/CNT-Epoxy mulltiscale composites. The values fall in the range of the global trend.

MWCNTs reinforced Polyurethane Composites for Electrical and EMI Shielding applications:

High aspect ratio MWCNT reinforced polyurethane (PU) 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) and reaches 40 dB for 10wt% loading 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 18 orders of magnitude and the dispersion process.

Development of metal-matrix composites reinforced with carbon nanotubes as well as boron nitride nanotubes

Al-CNT and Al-BN nanotube composites were fabricated by the cold compaction of a homogeneously mixture of Al powder containing different weight percentage of MWCNTs or BN nanotubes at a pressure of 500-550 MPa followed by sintering at 550-600 ºC under a vacuum of about 10^{-2} torr for 3 hours. In the fabrication of these composites both pure as well as amino functionalized nanotubes were used. Amino functionalization of MWCNTs as well as BN nanotubes was carried out by ball milling in the presence of ammonium bicarbonate using ZrO_2 balls. The functionalized nanotubes as well as the composites were thoroughly characterized using XRD, SEM, FTIR, HRTEM and Raman spectroscopy. The composites were made as per ASTM standards and different mechanical properties including microhardness, tensile, compressive and flexure strength of Al-CNT and Al-BN nanotube composites were studied using a Universal testing machine. A typical HRTEM micrograph of Al-composite reinforced with BN nanotubes is shown in Fig. 2.21.

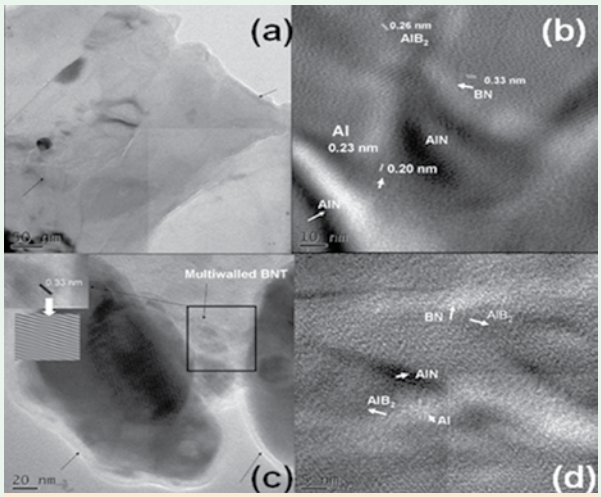


Fig. 2.21 HRTEM micrographs of Al-BN nanotubes composite showing different phases formed during the sintering conditions

Synthesis of Boron Nitride nanosheets

Since the discovery of graphene in 2004 efforts are being made to synthesize a structural analog of carbon. Graphene sheets are characterized as the thinnest material known to mankind possess one-atom-thick 2D layers of sp^2-bonded carbon atoms. Further, these sheets are found to have some outstanding physical, chemical and mechanical properties, thus opening up a new research area for materials science aiming for a wide-ranging and diversified technological application. In a similar manner, it is of considerable interest to synthesize and characterize graphene analogous of boron nitrides (BN), which are likely to have interesting properties and potential applications. It is believed that a 2D ordered BN crystal structure with an exposed (002) crystal surface would be valuable to exploit many unique properties of a graphite-like (002) plane, such as superb thermal conductivity, mechanical strength and others. In addition, boron nitride nanosheets (BNNS) are a unique insulating 2D system to explore. In the year 2010, we have started synthesizing this important material from the chemical exfoliation of hexagonal boron nitride (hBN) powder. Fig. 2.22 shows SEM and HRTEM images of BNNS produced in the present work. This work was carried out in collaboration with Electron and Ion Microscopy Group of NPL.

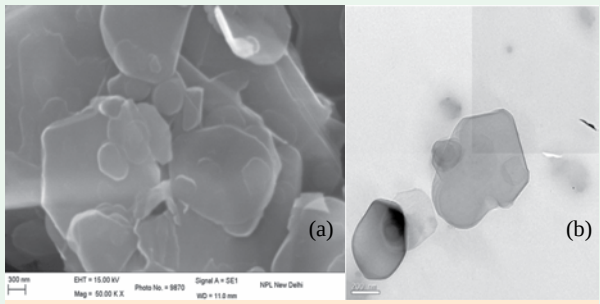


Fig. 2.22 (a) SEM and (b) HRTEM images of BN nanosheets

Establishing the in-house facility for the graphitization of carbon paper samples

An induction heating furnace (Fig. 2.23) capable of graphitizing large bunch of carbon paper samples was procured and commissioned at NPL. A batch of 80 nos. of carbon paper samples was heat treated to 2200°C during the first two runs and found to be meeting the required characteristics. These have been sent to CECRI and NCL for fuel cell stack. The facility will help in speeding up the production rate of carbon paper samples.

Fig. 2.23 A view of the Induction heating furnace commissioned at NPL

III. Luminescent Materials and Devices

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.

Nanophosphors for solar spectrum modification

A spectrum modifying glassy luminescent layer with antireflection properties has been prepared with Eu^{3+} ions embedded in Silica (SiO_2) gel for solar cell applications. Luminescent Eu^{3+} species in amorphous silica matrix show intense red emission at 614 nm by absorbing UV/blue light. Amorphous environment with reduced symmetry for Eu^{3+} ions results in an unprecedented short decay time of 145 µs for $^5D_0$-$^7F_2$ electric dipole transitionas shown in Fig.2.24.

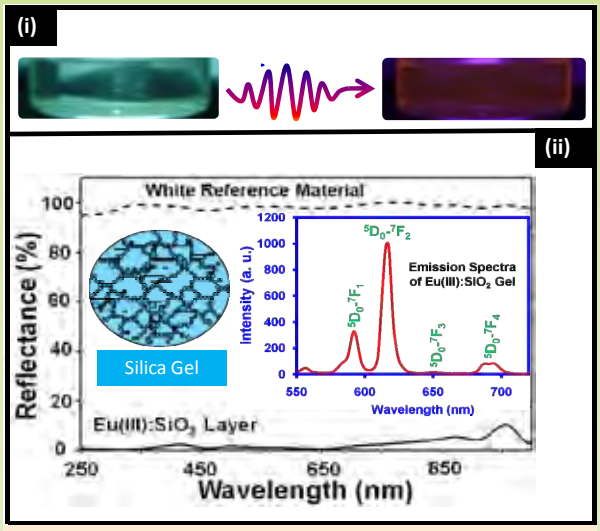


Fig. 2.24: (i) Eu^{3+} embedded silica gel under room light and under UV illumination (ii) Reflectance (%) spectra of prepared Eu(III):SiO_2 glassy luminescent layer (solid line) and Reference white tile (dotted line). The Photoluminescence emission spectra is shown in the inset. The Silica gel in which the volume of the sediment will be nearly equal to the volume of the complete solution is also shown.

In another study, it is shown that confinement of europium (Eu^{3+}) ions in silica (SiO_2) nanospheres yields efficient red-emitting nanophosphors when excited via charge transfer states (CTS) absorption in UV (393 nm) radiation. This is explained on the basis of modulation of f–f transition due to quantum confinement of rare-earth ion in a nanosize host. It is also evidenced that the short range crystallanity and confinement effects provided by the nanospheres increases the Eu^{3+} emission intensity by almost ten times at the expense of CTS.

Upconversion nanophosphor in powder and colloidal forms has been synthesized that produces bright green upconversion luminescence when excited by 980 nm laser. Utility of such nanophosphor for spectrum modification of IR solar radiation to visible for enhancement of solar cell efficiency has been seen.

Quantum dots for enhanced blue luminescence

A simple process with step by step improvement of blue photoluminescence (PL) from ZnS:Ag,Al quantum dots has been achieved. A systematic study of ultra-violet (UV) photolysis together with polysulfide hydrothermal treatment enhanced the PL intensity to 250% as shown in Fig. 2.25. The results obtained are different from those reported earlier for nano-ZnS:Ag,Al and the origin of bright-blue PL is thoroughly investigated. The strong blue PL has wide range applications including

displays, chemical sensing, wave guides, bioanalytical assays, blood-flow monitoring etc.

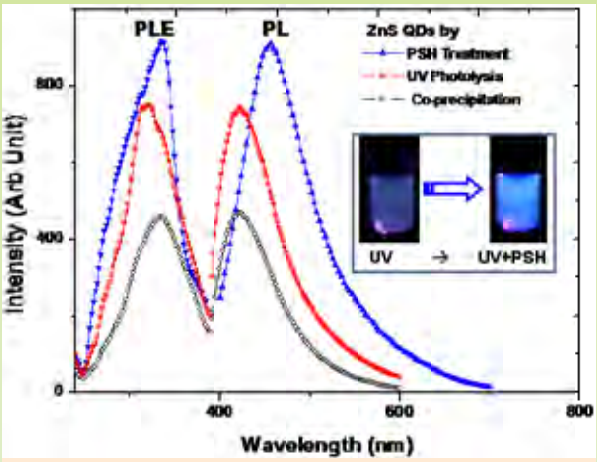


Fig. 2.25: The step by step improvement of blue PL from ZnS:Ag, Al quantum dots under various processing treatments.

Luminescent, magnetic hollow core ZnO nanoparticles

Stand alone hollow core nanoparticles of undoped and Cr^{3+} doped ZnO have been successfully prepared by co-precipitation method. The morphology varied from hollow hexagonal nanotubes for undoped ZnO to hollow core nanosphere for ZnO:Cr (2%) and hollow nano parallelepipeds for 10% Cr doped ZnO as shown in Fig. 2.26. Room temperature ferromagnetism and blue luminescence emission from ZnO: Cr^{3+} hollow core nanoparticles formed by a simple aqueous growth technique make it an attractive material for wide variety of applications mainly spin Light Emitting Devices (LEDs) and nanocapsules for biological applications.

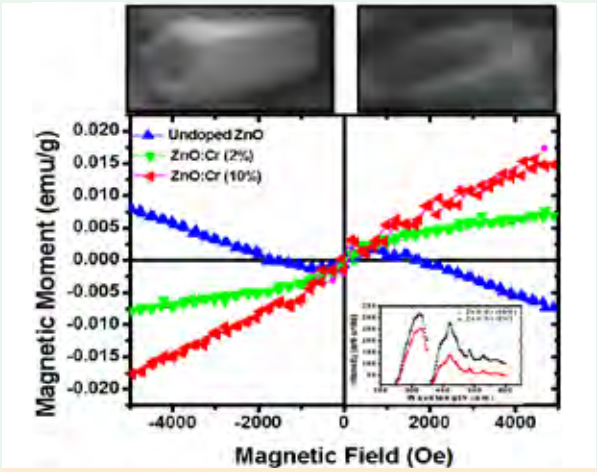


Fig. 2.26 Luminescence and magnetic behaviour of hollow core ZnO:Cr nanoparticles

Significant Publications (related to text provided above):

1. A.F. Khan et al, Materials Research Bulletin, 45, 1562–1566, (2010) Cited in Nature India doi:10.1038/nindia.2010.161; Published online 17 November 2010 http://www.nature.com/nindia/2010/101117/full/nindia.2010.161.html
2. Sahai S. et al. J. Colloid and Interface Sci. 357 (Mar-2011): 379-383.
3. Haranath D. et al. Chem. Phys. Lett. 496 (Aug-2010):100-103.
4. K. Jayanthi et al. J. Phys. Chem. C, 114, 18429-18434, (2010)

- **Extraordinary Research Highlights:**

  Europium doped glassy luminescent layer of silica gel with antireflection properties has been successfully prepared which is highly useful for enhancing the solar cell efficiency. This work has been cited by Nature India [Published online 17 November 2010]

  http://www.nature.com/nindia/2010/101117/full/nindia.2010.161.html]

VI. Biomedical Instrumentation

Mandate/mission

One of the principle objectives of the Division is to develop molecular electronics devices for a health care, biosciences, and environmental sciences. Besides this, the division coordinates the various research activities of the groups located both in the country and overseas who have interest in the development of conducting polymer based sensors, molecular electronics and controlled target drug-delivery systems.

i) Developing, identifying and building new information and knowledge based strategies for generating new materials for molecular electronic applications such as conducting polymers, self-assembled monolayers, nanophosphors, sol-gel films, Langmuir Blodgett monolayer films etc.

ii) Fabricate on-line, in-situ and non-invasive tools of diagnostic devices.

iii) Highly specific, sensitive and selective polymeric multivariate biosensor, whole cell biosensor for pesticides/heavy metal detection etc.

iv) Nucleic acid hybridization biosensors for microbial detection.

v) Technological development of novel devices, processes and methodologies, and transfer of technical expertise for pilot production of biomedical sensors.

vi) To generate and supplement technical manpower in the area of biosensors and bio-molecular and molecular electronics.

vii) Generate high quality research papers and patents.

viii) Transfer of technical know-how on molecular electronics devices to pertinent industries

Electrochemical Genosensor Based on Modified Octadecanethiol Self-Assembled Monolayer for *Escherichia coli* Detection

An electrochemical genosensor based on 1-fluoro-2-nitro-4-azidobenzene (FNAB) modified octadecanethiol (ODT) self-assembled monolayer (SAM) has been fabricated for *Escherichia coli* detection, shown in Fig. (2.27). The results of electrochemical response measurements investigated using methylene blue (MB) as a redox indicator reveal that this nucleic acid sensor has high sensitivity (0.5 x 10^{-18} M) and linearity as 0.5×10^{-18} M - 1×10^{-6} M within 60s of response time. The sensor has been found to be stable for about four months and can be used about ten times. It is shown that water borne pathogens like *Klebsiella pneumonia*, *Salmonella typhimurium* and other gram negative bacterial samples has no significant effects in the response of this sensor.

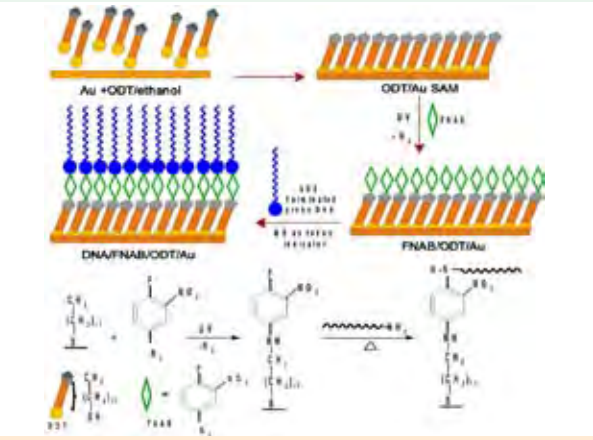


Fig. 2.27. shows the fabrication of DNA/FNAB/ODT/Au bioelectrode

Polyaniline/carbon nanotubes platform for sexually transmitted disease detection.

Polyaniline/carbon nanotubes composite (PANI-CNT) electrochemically deposited onto indium-tin-oxide (ITO) coated glass plate has been utilized for *Neisseria gonorrhoeae* detection by immobilizing 5′-amino-labeled *Neisseria gonorrhoeae* probe (aDNA) using glutaraldehyde as a cross-linker (Fig.2.28). PANI-CNT/ITO and aDNA-Glu-PANI-CNT/ITO electrodes have been characterized using scanning electron microscopy (SEM), Fourier Transform Infrared (FT-IR) spectroscopy, cyclic voltammetry (CV) and differential pulse voltammetry (DPV). This bioelectrode can be used to detect N. gonorrhoeae using methylene blue as redox indicator with response time of 60 s and stability of about 75 days when stored under refrigerated conditions. DPV studies reveal that this bioelectrode can detect complementary DNA concentration from 1 x 10^{-6} M to 1 x 10^{-17} M with detection limit of 1.2 x 10^{-17} M. Further, this bioelectrode (aDNA-Glu-PANI-CNT/ITO) exhibits specificity towards N. *gonorrhoeae* species and shows negative response with non-*Neisseria gonorrhoeae Neisseria* species (NgNS) and other gram negative bacteria (GNB).

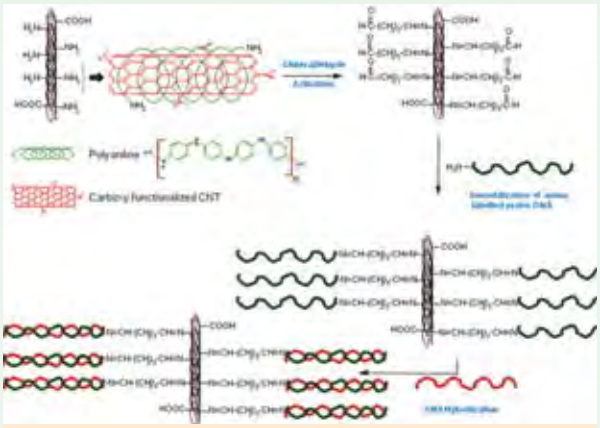


Fig. 2.28. Fabrication of PANI/CNT composite based DNA sensor: A DNA immobilization onto PANI/CNT/ITO using glutaraldehyde as a cross linker for DNA Hybridization detection.

Fabrication of sexually transmitted disease biosensor based on Chitosan-MWCNT Platform.

We report results of studies relating to preparation and characterization of DNA electrodes based on the

chitosan–MWCNT/ITO nanobiocomposite platform for electrochemical detection of gonorrhoea, the most common bacterial sexually transmitted disease. The fabricated biosensing electrode (Fig. 2.29) has been

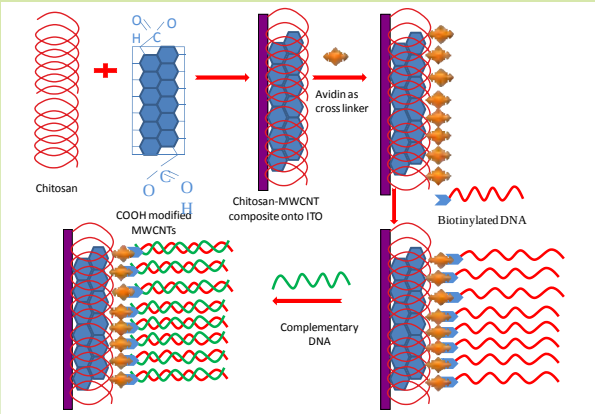


Fig. 2.29. Schematic preparation of BDNA-Avi-Chit-MWCNT/ ITO electrode and DNA hybridization

characterized using FT-IR, SEM, cyclic voltammetry, differential pulse voltammetry, etc. The sensing characteristics have been investigated in phosphate buffer saline using methylene blue as the hybridization indicator. This DNA biosensor has a response time of 60 s and is found to be stable for about 4 months when stored at 4 °C. DPV studies reveal that this bioelectrode can detect complementary DNA concentration in a wide range of 1×10^{-6} M to 1×10^{-17} M with a detection limit of 1×10^{-16} M.

Self Assembled Monolayer Based DNA Sensor for detection of Sexually Transmitted Disease

A sequence-specific electrochemical sexually transmitted disease (STD) sensor based on self-assembled monolayer of thiolated DNA probe specific to target opa gene for detection of Gonorrhoea (a sexually transmitted disease) has been fabricated (Fig. 2.30). 6-Mercapto-1-hexanol (MCH) has been used as a blocking agent to facilitate oligos "stand" up at the surface, a configuration favoring subsequent DNA hybridization and to repel non-specific adsorption of undesired DNA. The results of differential pulse voltammetric studies of this STD sensor reveal low detection limit (1.0×10^{-18} M) and a wide dynamic range (from 1.0×10^{-6} M to 0.5×10^{-18} M) arising due to the stable hybridization using methylene blue as electro-active DNA hybridization indicator. The experimental results with genomic DNA, clinical patient sample of Neisseria gonorrhoeae, culture of non-Neisseria gonorrhoeae Neisseria species (NgNS) and gram negative bacteria indicate that the fabricated sensor is specific to this STD.

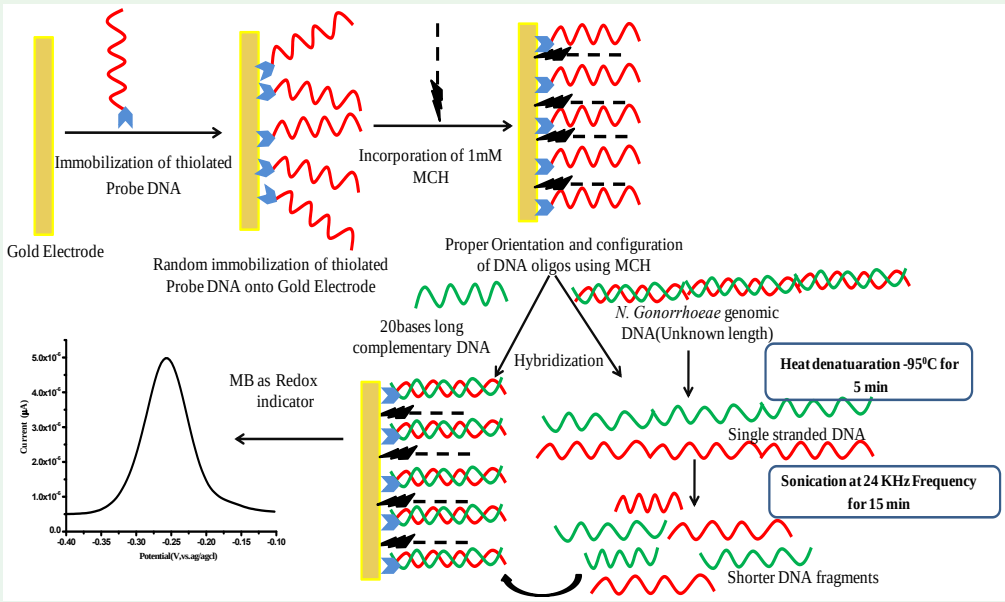


Fig. 2.30. Schematic representation of procedure used to modify the electrode with thiolated DNA oligomers and MCH blocking agent. MCH prevents nucleotide adsorption, resulting in a more radial configuration of the DNA and subsequent DPV experiments with MB as redox indicator

Antibody immobilized cysteamine functionalized-gold nanoparticles for aflatoxin detection.

Aflatoxin B1 antibody (aAFB1) covalently attached to cysteamine functionalized-gold nanoparticles (C-AuNP) has been immobilized onto 4-mercaptobenzoic acid (MBA) based self assembled monolayer (SAM) on gold electrode (MBA/Au), for the fabrication of BSA/aAFB1-C-AuNP/MBA/Au immunoelectrode as depicted in Fig.2.31. This immunoelectrode has been characterized by Fourier Transform Infrared Spectroscopy (FT-IR), Scanning Electron Microscopy (SEM) and electrochemical characterization techniques. The electrochemical response studies reveal that the BSA/aAFB1-C-AuNP/MBA/Au immunoelectrode can be used to detect AFB1 in the range of 10–100 ng dL^{-1} and has sensitivity as 0.45 µA ng^{-1} dL, limit of detection as 17.90 ng dL^{-1} and a response time of 60s.

Application of nanostructured ZnO films for electrochemical DNA biosensor

Nanostructured zinc oxide (nsZnO) films have been fabricated onto conducting indium–tin–oxide (ITO) coated glass plate, by cathodic electro-deposition to immobilize probe DNA specific to M. tuberculosis via physisorption based on strong electrostatic interactions between positively charged ZnO (isoelectric point = 9.5) and negatively charged DNA to detect its complementary target. Electrochemical studies reveal that the presence of nano-structured ZnO results in increased electro-active surface area for loading of DNA molecules. The DNA–ns ZnO/ITO bioelectrode exhibits interesting characteristics such as detection range of 1×10^{-6} – 1×10^{-12} M, detection limit of 1×10^{-12} M (complementary target) and 1×10^{-13} M (genomic DNA), reusability of about 10 times, response time of 60s and stability of up to 4 months when kept at 4°C. Fig. 2.32 (A-D) show the SEM studies.

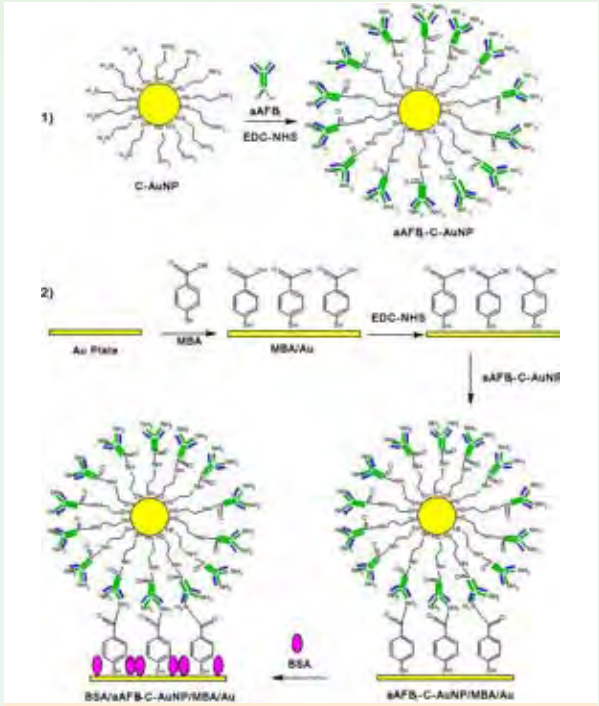


Fig. 2.31.It shows fabrication of BSA/aAFB1-C-AuNP/MBA/Au immunoelectrode

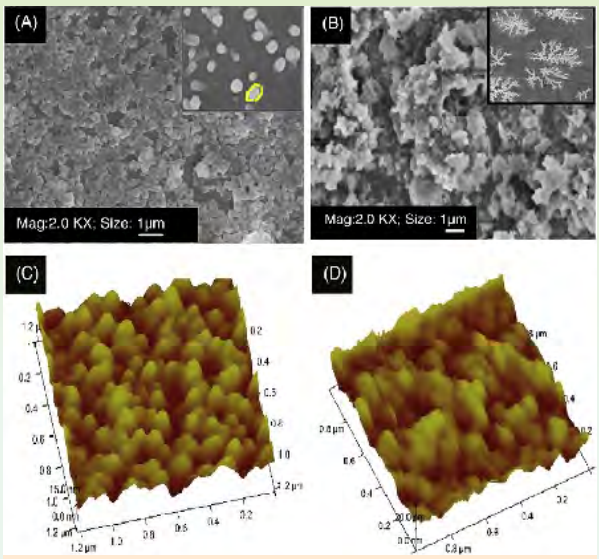


Fig. 2.32. SEM (Fig.A) studies of nsZnO/ITO film reveal that the size of the grain is regular with hexagonal morphology having particle size ranging from 50-100 nm without any cracks and voids. The formation of rough and porous microstructure (Fig. B) is attributed to the electrochemical deposition of ZnO film. The roughness parameters for nsZnO/ITO surface (Fig. C) and for DNA–nsZnO/ITO (Fig. D) surface have been experimentally determined as 3.51 and 2.74 nm, respectively. It may be noted that the decreasing roughness in DNA–nsZnO/ITO surface arises due to the immobilization of DNA onto the porous ZnO film. The particle size of nsZnO film obtained from AFM study ranges from 30 to 100 nm.

Nanostructured zinc oxide platform for food toxin detection.

Nanostructured zinc oxide (Nano-ZnO) film has been deposited onto indium–tin–oxide (ITO) glass

plate for co-immobilization of rabbit-immunoglubin antibodies (r-IgGs) and bovine serum albumin (BSA) for ochratoxin-A (OTA) detection. The results of X-ray diffraction (XRD) studies reveal the formation of Nano-ZnO with average particle size as ~5.0 nm. Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), electrochemical impedance spectroscopy (EIS) techniques have been used to characterize Nano-ZnO/ITO electrode and BSA/r-IgGs/Nano-ZnO/ITO immunoelectrode. Electrochemical impedimetric response of BSA/r-IgGs/Nano-ZnO/ITO immunoelectrode obtained as a function of OTA concentration exhibits linearity as 0.006–0.01 nM/dm^3 (Fig.2.33), detection limit of 0.006 nM/dm^3, response time as 25 s and sensitivity of 189 Ω/nM/dm^{3}cm^{-2} with a regression coefficient of 0.997.

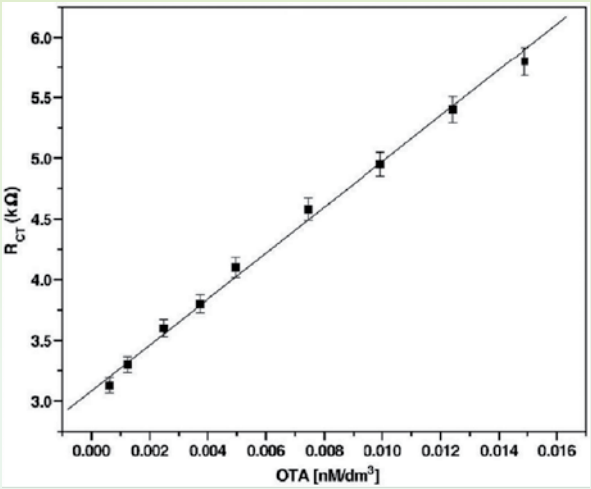


Fig. 2.33. Linear response curve of BSA/r-IgGs/Nano-ZnO/ITO immunosensor obtained between OTA concentration and RCT value.

Self-assembled monolayer based impedimetric platform for food borne mycotoxin detection

A self-assembled monolayer (SAM) of 11-amino-1-undecanethiol (AUT) has been fabricated onto a gold (Au) substrate to co-immobilize anti-ochratoxin-A antibodies (AO-IgGs) and bovine serum albumin (BSA) to detect food borne mycotoxin [i.e., ochratoxin-A (OTA)]. AUT/Au electrode, AO-IgGs/AUT/Au immunoelectrode and BSA/IgGs/AUT/Au immunoelectrode have been characterized using scanning electron microscopy (SEM) and electrochemical studies such as cyclic voltammetry (CV), differential pulse voltammetry (DPV) and electrochemical impedance spectroscopy (EIS). Electrochemical studies reveal that the AUT-SAM with NH_2 groups provide favorable conditions to immobilize AO-IgGs with better orientation, resulting in enhanced electron transport to obtain improved sensing characteristics. The EIS response studies of the BSA/AO-IgGs/AUT/Au immunoelectrode obtained as a function of OTA concentration reveal that the value of the charge transfer resistance (RCT) increases with increased OTA concentration. The BSA/AO-IgGs/AUT/Au immunoelectrode exhibits linearity over 0.5–6.0 ng/dl, detection limit of 0.08 ng/dl using 3sb/m criteria, response time of 30s and sensitivity of 37.86 U/ng dl1 cm2 with a regression coefficient of 0.999, shown in Fig. 2.34. Attempts have been made to monitor the change in RCT of BSA/AO-IgGs/AUT/Au immunoelectrode on addition of coffee samples.

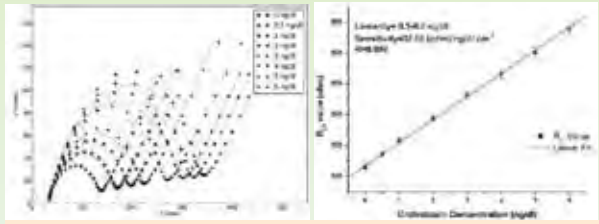


Fig. 2.34. EIS response studies of BSA/AO-IgGs/AUT/Au immunoelectrode exhibits linearity over 0.5–6.0 ng/dl and sensitivity of 37.86 U/ng dl1 cm^2 with a regression coefficient of 0.999.

Carbon nanotubes – chitosan nanobiocomposite for immunosensor.

Carboxylic group functionalized single walled (SW) and multi walled (MW) carbon nanotubes (CNT) have been incorporated into biopolymer matrix of chitosan (CH) to fabricate nanobiocomposite film onto indium–tin–oxide (ITO) coated glass plate for co-immobilization of rabbit-immunoglobulin (r-IgGs) and bovine serum albumin (BSA) to detect ochratoxin-A (OTA). The results of electrochemical studies reveal that presence of both CNT results in increased electro-active surface area of CH leading to enhanced electron transport in these nanobiocomposites. Moreover, in CH–SWCNT and CH–MWCNT nanobiocomposites theavailability of NH_2/OH group in CH and surface charged CNT also increases loading of the r-IgGs resulting in enhanced electron transport responsible for improved sensing characteristics. Compared to BSA/r-IgGs/CH–MWCNT/

ITO immunoelectrode, electrochemical response studies of BSA/r-IgGs/CH–SWCNT/ITO immunoelectrode carried out as a function of OTA concentration exhibits improved linearity as 0.25–6 ng/dL, detection limit as 0.25 ng/dL, response time as 25 s, and sensitivity as 21 µA ng dL−1cm−2 with the regression coefficient as 0.998.

Nanostructured nickel oxide-chitosan film for application to cholesterol sensor.

Cholesterol oxidase (ChOx) has been physisorbed onto NiO nanoparticles (22nm) chitosan film prepared using co-precipitation method shown in Fig.2.35. X-ray diffraction (XRD), Fourier transform infrared (FTIR), scanning electron microscopy (SEM), cyclic voltammetry (CV), and electrochemical impedance spectroscopy (EIS) studies have been used to characterize nano-NiO-CHIT/ITO electrode and ChOx/nano-NiO-CHIT/ITO bioelectrode. The results of electrochemical response studies conducted on ChOx/nano-NiO-CHIT/ITO bioelectrode exhibit linearity of 10–400 mg/dl, detection limit 43.4mg/dL, sensitivity as 0.808 µA/(mgdLcm^2), fast response time of 15s and shelf-life of about 10 weeks. The low value of Michaelis–Menten constant (Km) obtained as 0.67 mM indicates high affinity of ChOx towards the substrate.

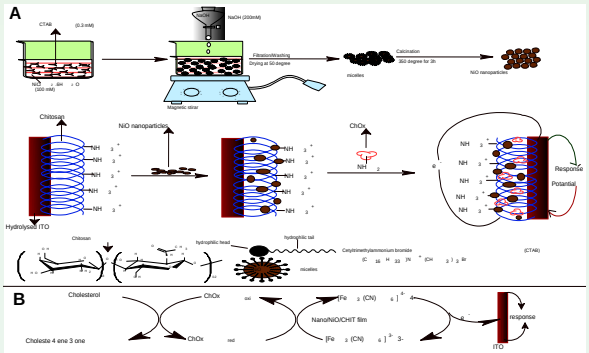


Fig. 2.35. (A) Proposed schematic for the fabrication of ChOx/nano-NiO-CHIT/ITO based cholesterol biosensor (B) Schematic illustration of biochemical reaction at ChOx/nano-NiO-CHIT/ITO bioelectrode

Polyaniline – Carboxymethyl Cellulose Nanocomposite for Cholesterol Detection

Cholesterol oxidase (ChOx) has been covalently immobilized onto polyaniline–carboxymethyl cellulose (PANI–CMC) nanocomposite film deposited onto indium-tin-oxide (ITO) coated glass plate using glutaraldehyde as a cross-linker. Fourier transform infrared (FTIR) spectroscopic and electrochemical studies have been used to characterize the PANI–CMC/ITO nanocomposite electrode and ChOx/PANI–CMC/ITO bioelectrode. Scanning electron microscopy (SEM) studies reveal the formation of PANI–CMC nanocomposite fibers of size ~150 nm in diameter. The ChOx/PANI–CMC/ITO bioelectrode exhibits linearity as 0.5–22 mM, detection limit as 1.31 mM, sensitivity as 0.14 mA/mM cm^2, response time as 10 s and shelf-life of about 10 weeks when bioelectrode is stored at 4ºC. The low value of Michaelis-Menten constant (Km obtained as 2.71 mM reveals high affinity of immobilized ChOx for PANI–CMC/ITO nanocomposite electrode.

Electrophoretically deposited polyaniline nanotubes based film for cholesterol detection

Polyaniline nanotube (PANI-NT) based films have been fabricated onto indium-tin-oxide(ITO) coated glass plates via electrophoretic technique. These PANI-NT/ITO electrodes have been utilized for covalent immobilization of cholesterol oxidase (ChOx) using glutaraldehyde (Glu) as cross-linker. Structural, morphological and electrochemical characterization of PANI-NT/ITO electrode and ChOx/Glu/PANI-NT/ITO bioelectrode have been done using FT-IR spectroscopy, SEM, electrochemical impedance spectroscopy and cyclic voltammetry techniques. Response studies of the ChOx/Glu/PANI-NT/ITO bioelectrode have been carried out using both linear sweep voltammetry (Fig.2.36) and UV-Visible spectrophotometry. The results of the biosensing studies reveal that this bioelectrode can be used to detect cholesterol in wide detection range of

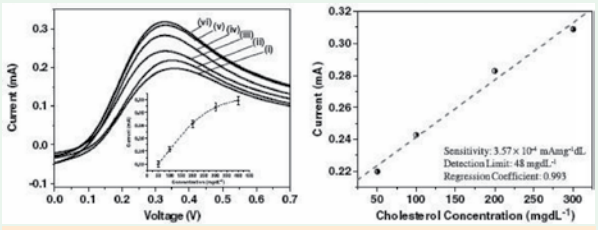


Fig. 2.36. Linear sweep voltammograms recorded for ChOx/Glu/PANINT/ITO as a function of cholesterol concentration; 0 mg/dL (i), 50 mg/dL (ii),100 mg/dL (iii), 200 mg/dL (iv), 300 mg/dL (v), and 400 mg/dL (vi) in PBS (50mM, pH 7.0, 0.9% NaCl) solution with inset showing the calibration plots derived from LSV at 0.34 V as a function of cholesterol concentration; Linear regression curve plotted to estimate the values of sensitivity, detection limit and regression coefficient.

25–500mg/dL with high sensitivity of 3.36 mAmg1 dL and fast response time of 30 s at pH 7.4. This bioelectrode exhibits very low value of Michaelis–Menten constant of 1.18mM indicating enhanced interactions between cholesterol and ChOx immobilized onto this nanostructured PANI matrix.

Polyaniline/Single-Walled Carbon Nanotubes Composite Based very-low-density lipoprotein Biosensor

Nanocomposite film comprising of polyaniline (PANI) and single walled carbon nanotubes (SWCNT) has been fabricated onto indium-tin-oxide (ITO) coated glass plate using electrophoretic technique. Co-immobilization of glycerol dehydrogenase (GDH) and lipase (LIP) has been done via N-ethyl-N'-(3-dimethylaminopropyl) carbodiimide and N-hydroxysuccinimide chemistry to explore its application for triglyceride (tributyrin) sensing. Response studies (Fig.2.37) have been done using linear sweep voltammetry revealing that LIP-GDH/PANI-SWCNT-TB/ITO bioelectrode can detect tributyrin in the range of 50 to 400 mgdL^{-1} with low Michaelis–Menten constant of 1.138 mM, improved response time of 12 s, high sensitivity as 4.28–10.4 mAmg^{-1}dL and storage stability of about 13 weeks.

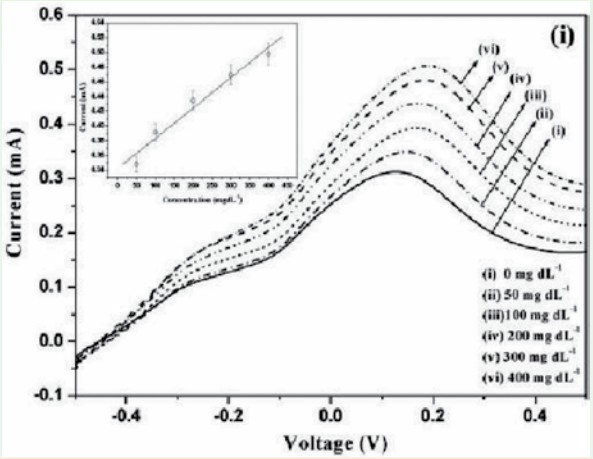


Fig. 2.37. Linear sweep voltammograms recorded for LIP-GDH/PANI-SWCNT-TB/ITO bioelectrode as a function of different concentrations of tributyrin. Inset shows the calibration plots derived from the LSV measurements as a function of tributyrin concentration.

Extraordinary Research Highlights

Two Papers published in **"Nanoscale"** having **Impact factor of 7.0** are highlights of our recent work.

- Solanki P, Kaushik A., Manaka T., Iwamoto M., Agrawal V. V., and Malhotra B.D., "Self-Assembled Monolayer Based Impedimetric Platform for Food Borne Mycotoxin Detection" Nanoscale, Vol. 2 No.12, pp 2811 - 2817 , 2010.
- Dhand C, Das M., Sumana G, Kim C.G. Datta M., Malhotra B.D., "Polyaniline Nanospheres: Preparation, Characterization and Application", Nanoscale , Vol. 2, pp 747–754,2010.

Major Facilities

The indents for the procurement of other equipments like AFM, Pharmacy refrigerator, Particle size analyzer, Inverted microscope, HPLC, Spin coater, Dehumidifier are at the various stages.

V. Optical Thin Films

Synthesis of ZnO nanostructures by thermal CVD technique

We have observed the formation of various nanostructures of ZnO with different morphologies by thermal CVD at different temperature and oxygen flows. Characterization of these nanostructures have been carryout by XRD, PL, SEM/EDX, optical absorption, and AFM and TEM, and RAMAN techniques. Four research papers have been sent for publication in the above subject.

Synthesis of Titania Nanostructures by plasma assisted MOCVD technique

We have observed the formation of various nanostructures of anatase titania with different morphologies (nanorods, nanoparticles, and comb like structures by thermal plasma assisted MOCVD technique simply by varying the deposition pressure, keeping rest of the parameters constant. Characterization of these nanostructures have been carryout by XRD, SEM, and EDX and FTIR techniques. One research paper has been sent for publication in the above subject.

Development of ZnO template for GaN film depositions

Process has been developed to deposit ZnO templates on sapphire substrates by sputtering technique, for the growth of GaN films. Characterization of these films have been carryout by XRD, SEM/EDX, PL, 2θ FWHM

value of 800 arc sec of XRD peak, and the PL band edge at 370 nm has been achieved. Further work to improve the high crystallinity is in progress.

Misc. research activities

A simple but effective technique for increasing the transmittance of indium tin oxide (ITO) coated glass plates over the visible region was developed. ITO coated glass plates find extensive use as transparent conducting coatings for solar cells, liquid crystal displays and many other optoelectronic applications. Their transmittance over the visible region is typically 82 – 89%, and it can be enhanced by as much as 10% by depositing a thin film (thickness 70 - 90 nm, not too critical) of a material like silicon dioxide on top of the ITO coating. Theoretical calculations and modeling were carried out and their predictions were verified by repeatable experimental deposition runs.

Using the **multi-target sputter deposition facility**, thin films of indium tin oxide (ITO), ZnO, Ti, Ni, W, etc. were successfully deposited on glass and silicon substrates by reactive magnetron sputtering (argon and oxygen gases), using substrate heating up to 250ºC as well as substrate rotation. Later, the sputtering system was used extensively for the deposition of thin films of MgO and Ni to fabricate magnetic tunnel junction devices. For this purpose, special jigs and fixtures were designed, fabricated and fitted into the system to increase the sputtering rate several-fold and deposit very thin films of high purity.

Characterization facility to various groups at NPL

The **Stylus-based Surface Profiler** and **UV-visible-near IR Spectroscopic Ellipsometer**, unique facilities in NPL, were extensively used to characterize a wide variety of thin films for their thicknesses and optical constants, for users both in NPL as well as outside agencies.

High Temperature Superconducting Materials & Devices

In the continuation of the development of joining tubes of (Bi, Pb)$_2$ $Sr_2Ca_2Cu_3O_{10+x}$ HTS and in order to improve the superconducting properties with minimum losses at the superconducting joints, an improved process for joining has been developed. After optimization, nearly one meter long joint tube assembly having outer diameter of 12.4mm with a wall thickness of 2mm which can carry almost the same transport current as that through the component tube (330A at 77K in self field). Some of the data is tabulated in Table 2.1. Fracture strength of the improved joint (204MPa at RT) has been found to be nearly 1.5 times more than that of our own process (122MPa at RT).Such a joint HTS tube assembly which can be very useful as it reduces the total loss to 1/10th when used as a current lead in LTS/HTS magnets, SC magnet systems: High energy particle accelerators (LHC), MRI, SMES etc. and also as SC transmission cables.

Table-2.1

Sample No.	Dimensions of tubes to be joined OD x ID x L (mm)	No. of tubes/ joints	Joined tube length (mm)	Critical Current (Ic) 77K,0T (A)		% Retention of Ic
				Component Tube	Joined Tube	
1	12.4X10.1X122	Two/ One	244	330	324	98
2	12.4X10.1X122	Two /One	244	330	330	100
3	12.4X10.1X320	Two/One	640	330	330	100
4	12.4X10.1X320	Three/Two	960			
		Joint A		330	330	100
		Joint B		330	330	100

Apart from the above applied studies, to understand the nature of pairing and pinning in search of effective centers, samples of (Bi, Pb)$Sr_2Ca_2Cu_3O_{10+x}$ doped with Tb (0-0.1M %) bar shaped were prepared by solid state method. Superconducting properties of these samples were investigated using X-ray powder diffraction (XRD), scanning electron microscope (SEM), electron dispersive X-ray (EDX) and electrical resistivity,

measurements. The XRD showed the enhancement of (Bi, Pb)-2223 phase formation until Tb = 0.02M%, beyond which a strong phase transition from (Bi, Pb)-2223 phase to (Bi, Pb)-2212 and Ca_2PbO_4 phases was observed as shown in Fig.2.38. SEM studies showed that Tb degrades the phase formation and the intergrain connectivity. In addition, the superconducting transition temperature (Tc) and the hole-carrier concentrations (p), determined from electrical resistivity measurements, were found to decrease as the Tb-contents increased as shown in Fig.2.39. On the other hand, the critical current density (Jc) increased until x = 0.02, and then decreased with further increase of Tb contents as shown in Fig.2.40. This indicated that the low-contents of Tb, can generate locally weak superconducting region that enhance flux pinning strength and hence improve the physical properties of (Bi, Pb)-2223 superconducting phase.

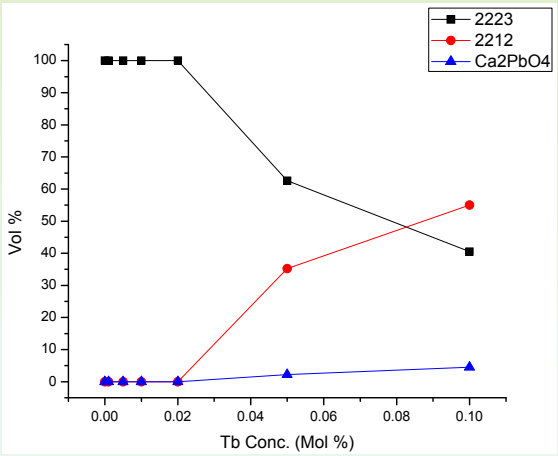


Fig. 2.38: Variation of Vol % of (Bi, Pb)-2223, (Bi, Pb)-2212 and Ca_2PbO_4 with Tb concentration

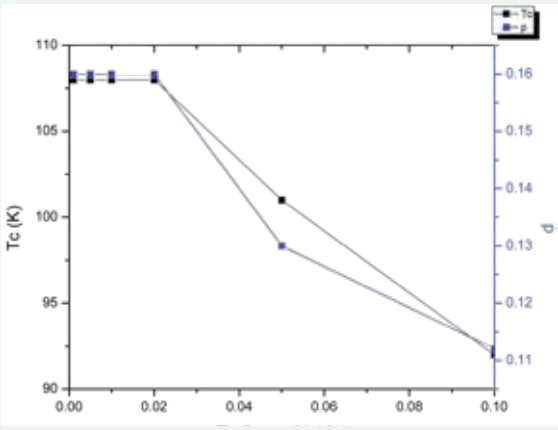


Fig. 2.39: Variation of Tc and p with Tb concentration

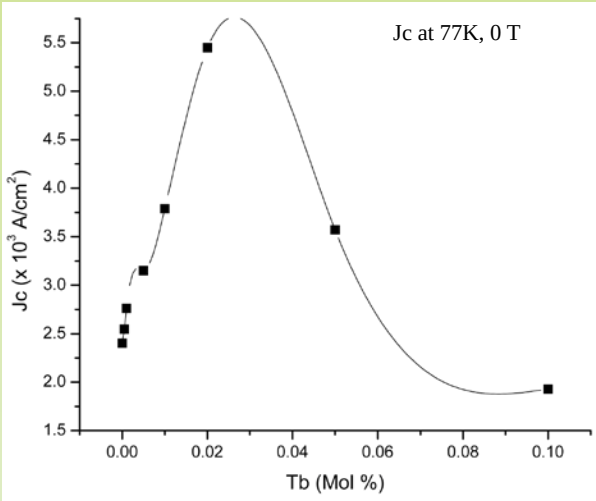


Fig. 2.40: Variation of Jc with Tb concentration

Further investigations like magnetoresitance and CESR measurements of these samples are being carried out.

- Updating of exiting sputtering, plasma assisted PECVD systems to carryout depositions at high temperatures,
- Fabrication of thermal CVD system for synthesis of nanostructures.

VI. Metals and 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 ware started in the group during the year on the development of nanocomposite thermoelectric materials & devices and development of nanocomposite permanent magnet material.

Development of bulk nanocomposites of nanocrystalline aluminium alloys reinforced with ceramic particulates employing cryomilling and spark plasma sintering – Network Project

The work under this on-going project was further continued this year. Al 5083 alloy (Mg-4.5%, Mn-0.9%, Fe-0.4%, Si-0.4%, Cu-0.2%, Ti-0.15%, Zn-0.25% and rest aluminium) powder (~ 15 µm) was ball milled with 10 wt.% SiCp (~20 nm) nanoparticulates under argon atmosphere for 15 h. The average crystallite size and

lattice strain measured employing XRD were to found be ~25 nm and 0.43, respectively, after 15 h of high energy ball milling. The powders at the starting stage of milling were spherical shape with an average size of 15 µm having broad particle size distribution and the ball milled powders exhibited flattened morphology and the particle size was observed to be ~ 40-50 µm using scanning electron microscopy. However, the average crystallite size estimated from TEM analysis was 28 nm.

The ball milled nanocomposite powders were subsequently consolidated and sintered using spark plasma sintering technique (Fig.2.46). Back scattered SEM images of spark plasma sintered Al5083/SiCp confirmed that nano-sized SiC particulates are embedded and distributed along the Al 5083 matrix. The sintered nanocomposite exhibit a hardness of about 250 Hv in comparison to 130 Hv obtained for Al 5083 alloy. High-resolution TEM was employed for detailed microstructural investigations of the spark plasma sintered Al 5083/10 wt.% SiCp nanocomposite. From Fig. 2.41(a), it is observed that, ultra-fine scale distributions of grains were noticed clearly in the Al 5083 matrix. Apart from the reinforcement embedment, neither voids nor cracks were detected and nanoparticles of SiC surrounding the nanostructured Al 5083 grains were clearly elucidated. Lattice scale imaging (Fig. 2.41 (b)) revealed the planes of SiCp (d-spacing: 0.25 nm) and Al 5083 (d-spacing: 0.23 nm) with an interface with a thickness of 1.5 to 2 nm. From Fig. 2.41(b) it was noticed that, the interface does not indicate any porosity even at sub nanoscale between Al 5083 and SiCp and there is no evidence of the formation of intermediate phases after SPS. One of the grains of Al 5083 matrix phase resolved at lattice scale shows the arrangement of (111) planes throughout the microstructure as shown in Fig. 2.41(c).

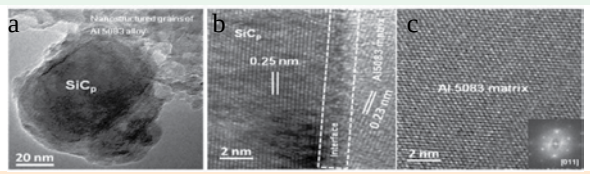


Fig. 2.41 HRTEM images of spark plasma sintered Al 5083/10 wt.% SiCp nanocomposite (a) large number of retained nanocrystalline grains of matrix of Al 5083 alloy (b) Interface between Al 5083 and SiCp (c) Al 5083 alloy matrix lattice imaging

Nanoindentation tests showed hardness and elastic modulus of Al 5083/SiCp nanocomposite near the interface was about 280 Hv and 126 GPa.

Development of light-weight Al and Mg wrought products Extrusion Technique – Network project

Wrought magnesium alloys have been finding increasing interest in the automobile industry for lightweight structural applications. Under this project, two magnesium cast alloys, AZ31 (Mg-3Al-1Zn) and AZ91 (Mg-9Al-1Zn), have been chosen for hot extrusion. The aim is to develop Mg alloy products in different forms having high strength and high ductility. The billets of AZ31 and AZ91 alloys were homogenized and hot extruded at the extrusion ratio of 9:1, 16:1 and 25:1 to develop circular rods. Circular tubes of AZ31 alloy were also developed at the extrusion ratio of 16:1. Fig. 2.42(b) shows photograph of the extruded products of AZ31 alloy. The microstructure of extruded products of AZ31 alloy comprised of single α-Mg phase, whereas, in the case of AZ91 alloy products, precipitates of β-$Mg_{17}Al_{12}$ were distributed in the α-Mg matrix (Fig. 2.42(a)).

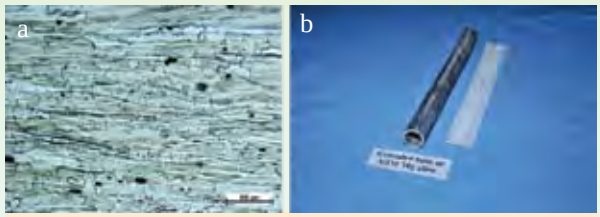


Fig. 2.42 (a) Micrograph of extruded tube of AZ31 Mg (b) Extruded tube of AZ31 Mg

The cast alloys showed poor mechanical properties (UTS~150-175 MPa, %elongation<10%) both for AZ31 and AZ91 alloys. The mechanical properties were found improve on extrusion as solid rods. UTS of AZ91 alloy was enhanced to ~300 MPa compared to ~260 MPa for the AZ31 alloy at similar extrusion ratio of 9:1. Ductility was also found to improve to >15% for both the alloys, on extrusion.

General Motors Sponsored Project entitled "Investigation of the mechanism of dynamic recrystallization and grain refinement of Magnesium alloys in understanding the effect of intermetallics and texture behaviour of extruded Mg-Ce, Mg-Zn alloy system subjected to Hot Extrusion and Severe Plastic Deformation (SPD)".

This project was successfully completed this year achieving the envisaged deliverables and targets. Intermetallics in the binary and ternary Mg alloys and their deformation characteristics during extrusion were analyzed. Effect of deformation characteristics on the mechanical properties of Mg alloys were determined, Electron back Scattered diffraction(EBSD) was carried out (at General Motors lab) on extruded and SPD samples of Mg- Ce and Mg-Zn alloys to understand the texture modification.

The results revealed that minor addition of cerium(0.2%Ce) to magnesium resulted in texture softening and grain refinement under specific extrusion conditions. Increasing Cerium content from 0.2% to 0.5% did not improve ductility further. SEM and EDAX studies revealed the presence of uniform distribution of fine inter-metallic particles and an addition of 3% and 5% Al to Mg (AM30 and AM50) resulted in strength improvement. Addition of Aluminum in combination with cerium enhanced both strength as well as ductility. Extruded $Mg_{-5}Al_{-0.2}Ce$ exhibited the best combination of strength and ductility.

Development of thermoelectric Si-Ge nanocomposites

This work on the development of thermoelectric materials and devices was initiated this year. Enhancement in dimensionless thermoelectric figure of merit (ZT) of thermoelectric Si-Ge bulk nanocomposite is a challenge for the development of high temperature thermoelectric devices for suitable waste heat recovery. The main aim of this work was to enhance the thermoelectric figure-of-merit, employing Si-Ge in the nanocomposite form. In the present study, p-type boron doped Si-Ge bulk nanocomposites were synthesized employing high energy ball milling followed by sintering employing spark plasma sintering. XRD pattern shows the complete dissolution of Ge in host Si matrix as shown in Fig. 2.43. Crystallite size of Si-Ge (B-doped) nanocomposite powder was found to be 15 nm. Optimizing the ball milling and spark plasma sintering parameters, Si-Ge nanocomposites were synthesized with near theoretical density, retaining the nanoscale features.

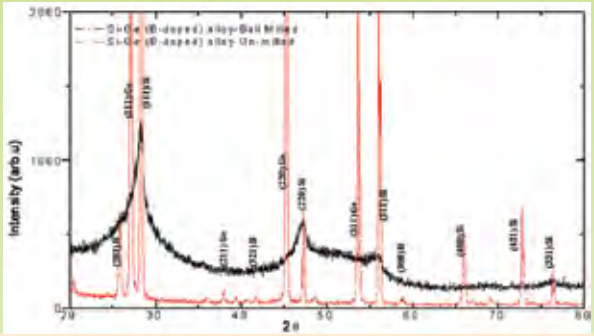


Fig. 2.43: XRD peak profile of Si-Ge (B-doped) nanocomposite powders

Development of thermoelectric Magnesium Silicide and its related alloys

The aim of this work is to synthesize cheap, Pb/Te free thermoelectric materials with high figure of merit. It is proposed to synthesize Mg-Si-Sn based solid solutions to increase the thermoelectric figure-of-merit. Mg and Si elemental powders were ball milled under controlled Argon gas atmosphere in high energy ball mill. The ball to powder weight ratio, milling speed and milling time were optimized. The milled powders were sintered by using spark plasma sintering to obtain Mg_2Si. The powder X-ray diffraction analysis shows that the complete formation of Mg_2Si was obtained after spark plasma sintering at 600ºC (Fig. 2.44). It is rather difficult to synthesizing stoichiometric Mg_2Si primarily due to the reactivity and vaporization of Mg. Different techniques were used to synthesize Mg_2Si, however, ball milling followed by SPS technique was found to be the optimized way to produce stoichiometric Mg_2Si.

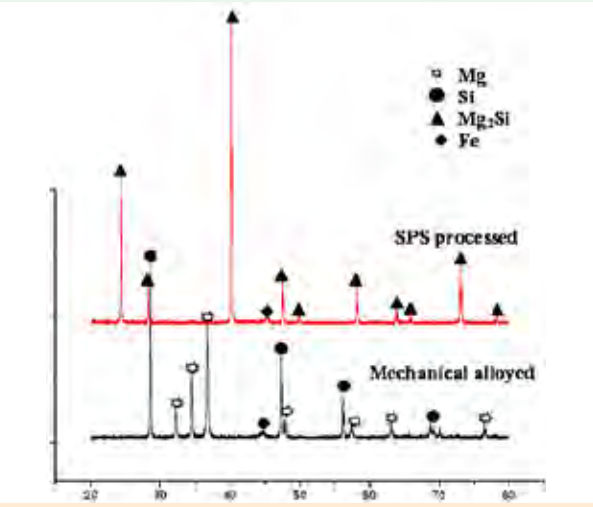


Fig. 2.44: XRD of mechanical alloyed powder and MA with SPS

Synthesis of Rare-Earth free Permanent Magnetic Materials

The main objective of this activity is to synthesize Rare-Earth Free Permanent Magnetic Material Mn-Al Employing Powder Metallurgy and Spark Plasma Sintering techniques. For this purpose elemental Mn and Al powders were weighed in stoichiometric ratio and ball milled for few hours under argon atmosphere in a Fritsch 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 high energy ball milled powder was spark plasma sintered. The sintered samples were characterized by XRD and SEM. Fig.2.45 shows SEM and EDX analysis of sintered material. The magnetic τ phase which is a metastable phase will be obtained by high temperature (1050°C-1150°C) solutionizing in ε-phase (hcp structure) followed by water quenching. Subsequent to that the Mn-Al alloy will be annealed at around 500°C-700°C for the synthesis of τ phase. The samples will be characterized by XRD and SEM and the magnetic properties will be measured using a vibrating sample magnetometer. This work is presently in progress.

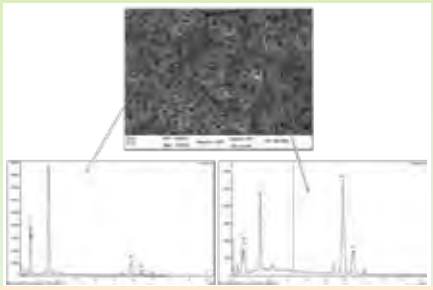


Fig. 2.45 SEM and EDX of high energy ball milled and spark plasma

Major Facilities Created: Spark Plasma Sintering Unit

Under the Network Project, a state-of-the-art experimental facility of Spark Plasma Sintering System (SPS) was installed and commissioned during the year. SPS is a modified hot pressing technique in which pulsed DC current and uni-axial pressure (max 250 KN) are applied simultaneously. The pulsed current passes through the electrically conductive graphite die and sample resulting in rapid heating rate up to 500ºC/min which makes SPS a fast consolidation method, especially for nanocomposites.

Fig. 2.46 Spark Plasma Sintering Unit (SPS) and (a) inset showing the die in hot condition during SPS

वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद्
CSIR · INDIA ·

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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 हट्र्ज 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 need of the nation in the area of radio physics and applications, space weather and ionosphere, chemistry and physics of the earth atmosphere, atmospheric pollutionand climate change etc. Different R&D works being done in this division have been categorized into four broad activities : (i) Radio Science, (ii) Atmospheric chemistry, (iii) Spectroscopy of Atmosphere, and (iv) Simulation and Modeling for Atmospheric Physics.

Radio Science : Here we are mainly involved in 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, monitoringand 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 wellf 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 is 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 activity 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 cfharacterisation 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.

I. Radio Science

Mobile communication measurements and model evaluations over eastern rural and western India

We have characterized the mobile radio wave propagation in the Jharkhand & Orissa rural regions by conducting field strength measurements using nine base stations situated along the railway track and comparing the observed results with various prediction methods in the UHF band. These base stations are 1. Chakradharpur (CKP) 2. Goilkera (GLK) 3. Mahadevsal (MDS) 4. Mahadevsal tunnel top (MDST) 5. Posoita (PST) 6. Manoharpur(MHR) 7. Jaraikala(JKL) 8. Bondamunda(BMD) and 9. Rourkela (RKL), situated along the track and continuously transmitting the carrier at 320MHz.

Comparison of observed path losses with the two ray theory, Hata open and suburban regions and ITM method (Fig 3.1), all predict lowest standard deviation for JKL base station (the lowest is that of ITM method). For a given base station the standard deviations of all the methods vary by 2 to 3 dB. In the region filled with vegetation all the methods show deviations of the order of 9-11 dB. Path loss exponents have been deduced from observed path losses and are found to vary between 2 to 3 and in tunnel environments the values shoot up to more than 6. Due to the tough environment and its varying nature more and more experimental campaigns should be conducted to develop suitable models for this region.

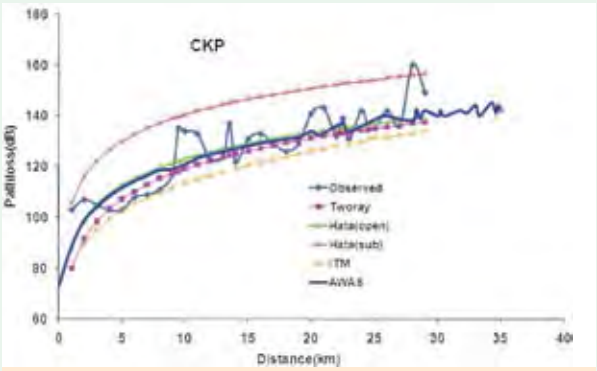

Fig. 3.1: Comparison of various prediction methods with the observed losses for CKP base station

Recent developments in the telecom sector of the country spurred lot of activity in the WiMAX systems based on IEEE 802.16 standard. As a part of this activity experiments at 2.3 GHz using wimax transmissions were conducted in urban western India at stations located in the dense urban region of Mumbai. All sites transmitted 43 dBm power. Coverage predictions using various models and their comparison with observed data have been carried out. Path loss exponents, mean errors and standard deviations of all the prediction methods have been deduced and suitable models have been identified.

Space – Weather impact and TEC and Scintillation variations on Polar region

NPL initiated a program to establish a Space Physics Laboratory at South Pole, Antarctica (at Maitri; 70.65° N, 11.45° E) in collaboration with National Centre for Antarctic and Ocean Research, Goa to observe the real time measurement of ionosphere over polar region. The study performed during the adverse space weather conditions on 11 October 2008 (Ap = 95) using Ionospheric total electron content (ITEC) data obtained with the help of GPS at Maitri shows that the plasma density increases for a short duration as soon as the Ap-index as well as AE-index reached to its maximum level. To investigate the generation of polar plasma patches and ionospheric scintillations, two global ionospheric scintillation and total electron content monitoring (GISTM) systems are installed at both the polar regions (Maitri, Antarctica and Himadri, Arctic (78.55°N, 11.56°E)). It is observed that scintillations of similar magnitude (0.3-0.4) were obtained at both the stations. The difference of approximately 20TECU has been seen for the day side and night side polar region ionosphere. The irregularities caused strong TEC fluctuations and the occurrence percentage of L-band scintillation is higher over the dayside (Arctic) polar region than that of night-side (Antarctic) polar region.

Development and Validation of Regional Ionospheric Empirical Model (RIEM) :

A new technique using the Gaussian fitting over the latitudinal distribution of foF2 has been developed to study the Equatorial Ionization Anomaly (EIA) by using the limited number of ground based monitoring stations. Results suggest that the EIA crest exhibits the features of latitudinal shifting and expansion with increasing solar activity. We have deduced for the first time over the Indian sector the relationship between the EIA

parameters and solar activity by using the regression analysis. The results is used for development of Regional Ionospheric Empirical Model (RIEM) to predict the various parameters of the Equatorial Ionization Anomaly (EIA). The result has been validated for 19th solar cycle and is better than the IRI predictions in locating the EIA crest and its foF2.

Airglow Modeling

Modeling of 557.7 Å day-glow Emission shows the morphological features of greenline dayglow emission under equinox conditions (Fig 3.2). The morphology is obtained from the emission profiles of greenline dayglow emission using the updated glow model by incorporating newly discovered temperature dependent rate coefficient of the reaction N2(A3 ∑u+) +O. The recently proposed correction for the atomic oxygen density in MSIS-90 neutral atmosphere model is also included at mesospheric altitudes to achieve the consistency with the WINDII measurements. The ratio of modeled morphology of greenline dayglow emission is presented between 50˚S and 50˚N latitudes for the months of March and April using Solar 2000 V2.25 model. It has been found that this emission shows asymmetry between the northern and the southern hemispheres.

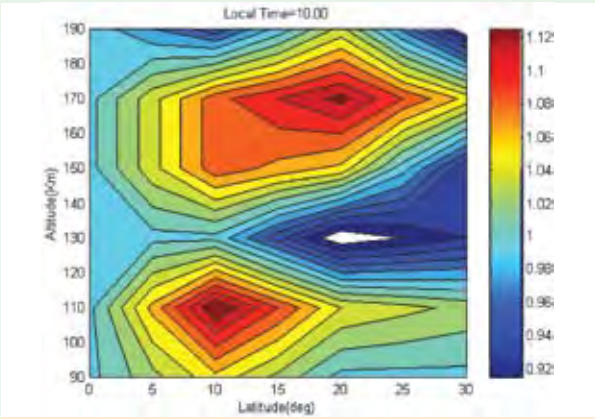

Fig. 3.2: The ratio of Volume emission Rate (Ph cm -3 s-1) of Northern Hemisphere to the Southern Hemisphere.

Space – Weather Impact on Earth Atmosphere:

Most studies dealing with solar flare effects in the upper ionosphere, where ionization is caused by EUV photons, have been based upon X-ray fluxes measured by SOLRAD and GOES series of satellites. To check the validity of such studies, we compare simultaneous observations of GOES X-ray fluxes and SOHO EUV fluxes for ten X-class solar flares which occurred during maximum phase of sunspot cycle 23. We find that the peak intensities of the X-ray and EUV fluxes, for these flares, are poorly correlated. However, this correlation improves vastly when the central meridian distance (CMD) of the flare location is taken into account. The correlation, though poor with the X-ray flux, improves greatly when CMD of flare location is considered.

Comparisons of IRI predictions with TEC during high solar activity period

TEC observations over New Delhi, obtained from Symphonie-II satellite during high solar activity (1979) are used to validate the latest available International Reference Ionosphere (IRI-2007) model. Fig. 3.3 shows the observed TEC values along with the median and IRI predicted values using three options: i) IRI-2001. ii) IRI-2001 (Correction) and iii) NeQuick, for the months of January and April. All the options provided in IRI generate more or less similar diurnal variations, the agreement between the model and the observed median TEC values is better for both the months in the time period from around midnight to pre-noon hours, the discrepancies being the least during January, while for April, the IRI model values slightly overestimate the observations.

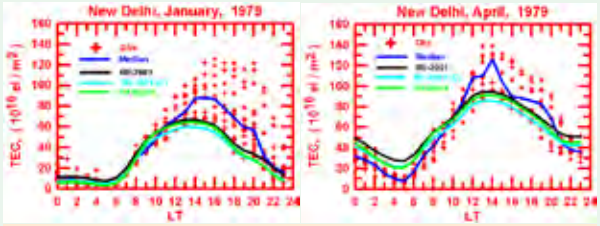

Fig. 3.3: Diurnal variation of observed (Total Electron Content) TEC values along with the median values and (International Reference Ionosphere) IRI-2007 model predicted values using three options for the period of high solar activity.

II. Atmospheric Chemistry

National Energy Sector GHG Emission Inventory

A national GHG emission inventory has been developed for greenhouse gases (GHGs) like CO_2, CH_4 and N_2O which are emitted from fossil fuel combustion in electricity generation from coal based thermal power plants in India. Based on the IPCC methodology,

emissions estimates from this sector have been made for the period 1999 to 2008 for the country. These estimates reveal that while the Coal consumption has gone up from 225.7 million tons in 1999 to 356.2 million tons in 2008, the CO_2 emissions have increased from 425.8 Tg to 659.8 Tg, CH_4 emissions have increased from 4.43 Gg to 6.87 Gg and N_2O emissions have gone up from 6.65 Gg to 10.30 Gg during this period. The scenario of state level GHG emissions reveals significant increases during this period in states like UP, Maharashtra and Andhra Pradesh (Fig 3.4).

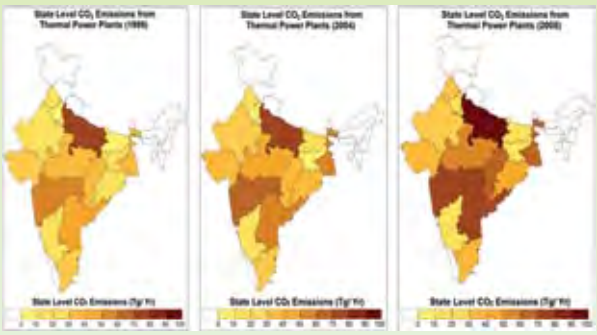

Fig. 3.4: State level CO_2 emissions from Coal Fired Thermal Power Plants

Methane emission from landfills in Delhi

Municipal solid waste (MSW) is the major source of GHG emissions. The most common disposal method (70-90%) in India for MSW is open dumpsites and about 90% of the MSW is disposed in landfills while the remainder is composted. The degradable organic waste by anaerobic decomposition in landfills generates landfill gas (LFG) methane (~60%) and carbon dioxide (~40%) together with small quantities of nitrous oxide (N_2O), non-methane volatile compounds and other trace gases. Delhi has three landfills, Ghazipur, Bhalswa and Okhla from where methane emission measurement have been conducted to develop site specific methane emission factors for generation of methane emission inventory with reduced uncertainties. The study showed that Ghazipur, Bhalswa and Okhla landfills emit methane of the order of 4.6, 4.2 and 1.4 Gg/year respectively

Chemistry and Sources of PM10 aerosols in the Indo-Gangetic Plain region

Among the analyzed ions, on an average NH_4^+, NO_3^- and SO_4^{2-} together contributed 87% of total mass of water soluble fraction in PM_{10} aerosols during Land campaign II at Allahabad (Fig 3.5). Potential source contribution function analysis identified Uttar Pradesh, Punjab, Haryana, and northern Pakistan as source regions for NO_3^-. The thermal power plants in UP and Haryana, agricultural farms along Punjab, Haryana, and UP belt were sources of nitrates and/or its pre-cursors while emissions from cattle excreta and application of nitrogenous and ammoniacal fertilizers are likely to have contributed to ammonia emissions.

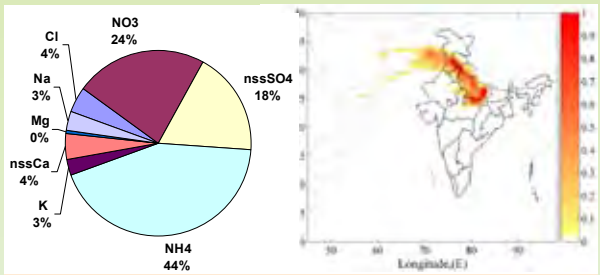

Fig. 3.5: Percent contribution of major water soluble ions (left) and potential source contribution region for NO_3^- at Allahabad in IGP

The chemical characterization of heavy metals in PM_{10} aerosols over Delhi showed the maximum contribution of Zn as 62% followed by Pb, Cr, Cu, Co and Ni. The main source of Zn in the atmosphere is transportation activities, Pb is mainly contributed by lead smelters and battery recycling processes, Cr is released through metallurgical industrial activities, Co and Ni through small scale industries. Figure 3.6 shows the percent contribution of heavy metals over Delhi

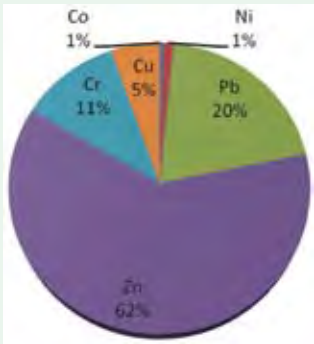

Fig. 3.6: Percent contribution of heavy metals in PM_{10} aerosols over Delhi

Stable isotopic characterization of atmospheric aerosols over India and surrounding ocean

We report elemental concentrations of C and N, their isotopes ($\delta^{13}C$, $\delta^{15}N$) and TC/TN ratios of bulk

carbonaceous aerosol particles over Bay of Bengal (BOB) and Arabian Sea (AS) collected during March-May, 2006 ICARB campaign (Fig 3.7). Bulk aerosols over AS have significantly higher TC/TN ratios (~50±10) compared to aerosol over Indian cities (5.6±2.6) as well as over BOB (6.8±12.5), most likely due to having significant inorganic carbon contributed by mineral dust. $\delta^{13}C$ of aerosols over AS and BOB do not show significant variation (25.6‰±0.6, 26.5‰±0.8; n=24 and 21 respectively), however $\delta^{15}N$ values showed a conspicuous difference between BOB and AS (10.6‰±2.7 over BOB and 1.4‰±3.3 over the AS). Depleted $\delta^{15}N$ of aerosols over AS can be interpreted in terms of significant mixing of isotopically depleted nitrogenous compounds (NH_3 and NO_{xs}) emitted from the underlying (denitrifying) waters.

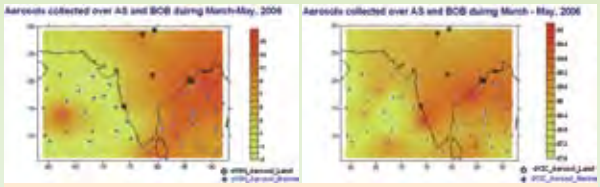

Fig. 3.7: $\delta^{13}C$, $\delta^{15}N$ values for aerosols collected over ocean and land

Ammonia emission from soil under wheat and rice crops

Ammonia (NH_3) concentration at the crop canopy of wheat and rice of the subtropical agricultural area was measured during different growth stages to study the diversity in NH_3 emission. The NH_3 concentrations at the wheat crop canopy were recorded as 48.6 to 83.2; 21.4 to 40.8; 10.2 to 27.9; 11.7 to 34.0 and 13.9 to 28.0 µg m^{-3} during sowing, crown root initiation, panicle initiation, grain filling and maturity stages respectively. The NH_3 concentration at the canopy level followed a diurnal pattern with significant correlation with ambient temperature at different crop growth stages. Cumulative seasonal NH_3 flux was accounted for ~11% loss of applied fertilizer N during the wheat crops' growing period.

Mixing ratios of ambient NH_3, NO and NO_2 were also measured at Delhi, Dibrugarh and Thiruvananthapuram during 2009-10 to study their variations and source apportionment. The average mixing ratio of NH_3 at Delhi, Dibrugarh and Thiruvananthapuram were recorded as 13.24 ± 0.39, 13.46 ± 2.52 and 12.65 ± 1.51 ppb respectively. The average mixing ratio of NO_2 was recorded as 12.69 ± 0.39 ppb with maxima of 20.22 ppb and minima of 0.75 ppb at Delhi whereas, the mixing ratio of ambient NO_2 ranges from 0.65 to 3.65 ppb and 0.83 to 3.02 ppb at Dibrugarh and Thiruvananthapuram respectively.

Emission estimates of particulate matter (PM) and trace gases (SO_2, NO and NO_2) from biomass fuels consumed in rural sector of Indo-Gangetic Plain, India

The emission estimates of PM, SO_2, NO and NO_2 emitted from biomass fuels used as energy in rural area of Indo-Gangetic Plain (IGP), India has been done using experimentally determined emission factors. The average emission factor of PM from dung cake, fuel wood and crop residue over Delhi, Uttar Pradesh, Punjab, Haryana, Uttarakhand and Bihar are estimated as 16.26 ± 2.29 g/kg, 4.34 ± 1.06 g/kg and 7.54 ± 4.17 g/kg respectively. Similarly, the average emission factor of SO_2, NO and NO_2 from dung cake, fuel wood and crop residue over this region are also determined (SO_2: 0.28 ± 0.09 g/kg, 0.26 ± 0.10 g/kg and 0.27 ± 0.11 g/kg, NO: 0.27 ±0.21 g/kg, 0.41 ± 0.25 g/kg and 0.54±0.50 g/kg and NO_2: 0.31±0.23 g/kg, 0.35±0.28 g/kg and 0.54±0.47 g/kg respectively).

Long term changes in stratospheric water vapour over Pune

The temporal variations of stratospheric ozone and water vapour over Pune (18N, 73E) are studied in order to find the correlation between observed ozone and observed water vapour. The analysis of ozone data from satellite based SBUV observations for the period 1978-03 give indications to the existence of three turning points (TPs) namely June 91, January 94 and January 99 in the ozone trend line. The seasonal and annual trends in ozone from SBUV data have significant negative values during 1994-99 and positive values during the period 1999-03 at Umkehr layers 6-8. Ozone data from ground based Umkehr observations, support the existence of three TPs. Because of the change in ozone trend at the TP of January 1999, a TP of January 1999 is also assumed in the analysis of water vapour data from HALOE for the period 1994-05. From the statistical analysis, an increase

in water vapour from 1994-99 and decrease from 1999-05 at pressure level 3-10 hPa corresponding to Umkehr layers 6 and 7 is seen as shown in Figure 3.8 suggesting an anti-correlation between water vapour and ozone.

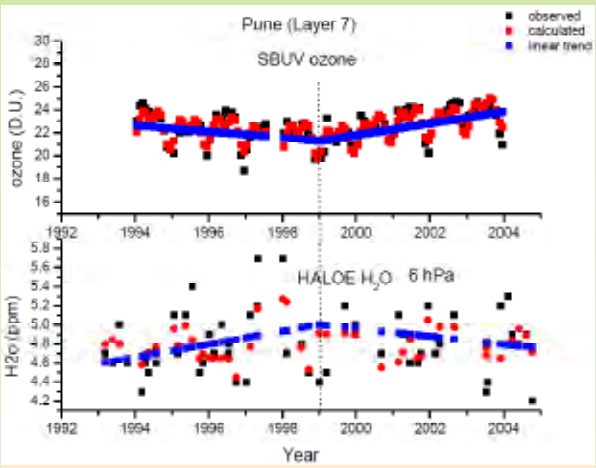

Fig. 3.8: Observed (black) and model calculated (red) ozone from SBUV data and water vapour from HALOE data after eliminating seasonal, QBO and solar components from the data series over Pune at 6 hPa. A piecewise linear trend is shown in blue color. The TP of January 1999 is depicted by vertical dashed line.

III. Spectroscopy of Atmosphere

Lidar detection of atmospheric gravity waves during the solar eclipse

To find out observational evidence of gravity waves generated in the lower troposphere during solar eclipse, a vertically staring back scattering LIDAR was operated during the solar eclipse of July 22, 2009 at NPL, New Delhi. The LIDAR uses 355 nm light pulses of 10 ns pulse width with a pulse repetition rate of 20 Hz. The telescope diameter is 15 cm with a field of view < 1 m radian. The signal is detected by photo-multiplier tubes and the profile is recorded by an analog to digital converter or by photon counting device and subsequently stored on a computer.

The Eclipse started in India at 5:31 AM and ended at 7:24 AM with its greatest phase at Delhi at 06:26 AM, had a maximum obscuration of 82.7%. Patchy clouds but calm wind conditions existed during eclipse period but after the eclipse, from about 08:20 AM onwards dark dense clouds emerged in the sky. Figure 3.9 illustrates the time-height Lidar scan of back scatter intensity observed during the early hours of July 22, 2009 at NPL showing the signature of gravity waves of about 24 to 35 minutes of period. Waves like structure were observed in the lower troposphere from 200 meter to 2 km height. The gravity waves signature were also reflected in time height scans of extinction, back scattering.

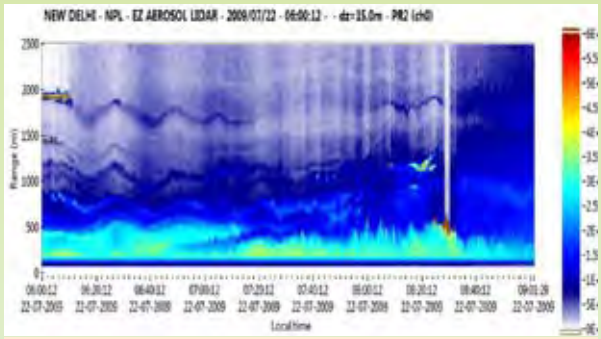

Fig. 3.9: A time height Lidar plot showing the gravity waves during eclipse

Estimation of aerosol SSA and AAE by measuring scattering and absorption coefficients

Simultaneous measurements of aerosol absorption and scattering coefficients for the PM2.5 aerosols particles were done at NPL, Delhi during April 2008-March 2009 to estimate the aerosol single scattering albedo (SSA) and the Angstrom absorption exponents (AAE) at the surface. The annual average SSA at 0.55 mm was 0.70±0.07 with only slight variations during the four seasons. However, average absorption and scattering coefficients showed large variation. The average absorption coefficients during summer, monsoon, winter and spring were found to be 62.47±21.27, 50.95±43.61, 189.65±85.94 and 90.65±33.06 Mm-1 respectively. The corresponding scattering coefficients were 110.46±36.15, 95.34±49.46, 565.59±274.59 and 236.56±96.25 Mm-1. The Angstrom absorption exponent (Fig 3.10) remained close to unity throughout the year strongly indicating that the absorption at Delhi aerosol is mainly due to the abundance of black carbon of fossil fuel origin.

Total Solar Irradiance and anomalous Indian Summer Monsoon

Identifying the pattern of natural climate variability is of immense importance to delineate the effects of anthropogenic climate changes. Global and regional climates are suspected to vary, in unison or with delays, with the Total Solar Irradiance (TSI) at decadal to

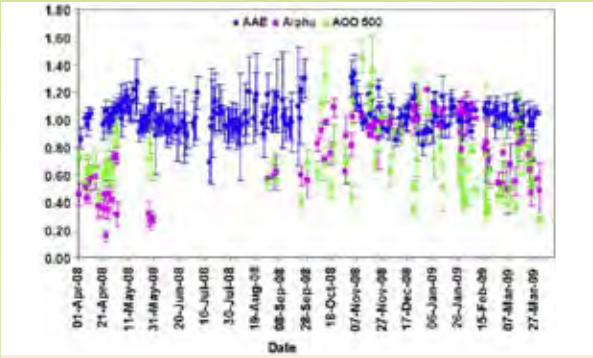

Fig. 3.10. Angstrom absorption exponents (AAE), AOD and Angstrom exponent over Delhi

centennial timescales. Here we show that the Indian summer monsoon rainfall correlates well with the temporal derivative of TSI on multi-decadal timescales. This linkage between the temporal derivative of TSI and the Indian summer monsoon is tested and corroborated both for the instrumental period (1871-2006) and for the last ~300 years using a speleothem $\delta^{18}O$ record representing rainfall in southwestern India. Our analyses (Fig 3.11) indicate anomalous dry periods of the Indian monsoon are mostly coincident with negative TSI derivative. This study thus demonstrates the potential of 'TSI derivative' as an important indicator of natural monsoon variability on an inter-decadal timescale. It shows that most severe droughts recorded in India were during the episodes of large negative TSI derivatives.

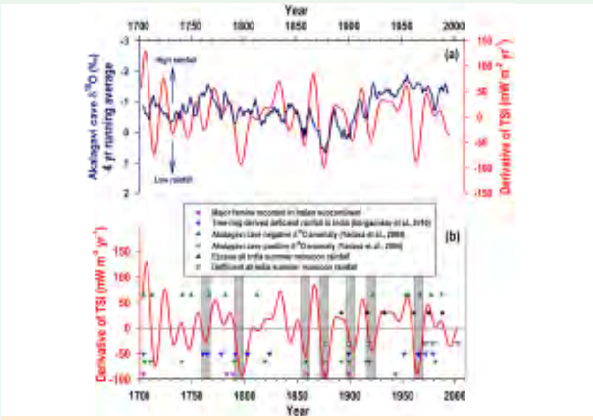

Fig. 3.11: Graphs of equivalence at ozone mole fractions 80 nmol/mol for all participants in BIPM. QM-K1 in the present cycle

Primary Ozone Standard at NPL and key comparison with BIPM

The NIST Standard Reference Photometer, SRP 43 has been setup at NPL, New Delhi on February 13, 2009, for quality assurance of surface ozone measurements, in particularly, traceability of ozone measurements in the country. The instrument operates by measuring the absorption of UV radiation at 253.7 nm by an ozone/air mixture flowing through its gas cell. The concentration of ozone is calculated from attenuation of the light intensity in air containing ozone compared with the same air without ozone. In the frame work of the CCQM comparison programme, the BIPM has coordinated the comparison (CCQM-P28) of ozone reference standard of 23 national metrology laboratories of different countries. The reference standard for these comparisons was a NIST-SRP (SRP27) maintained by the BIPM.

As a part of this key comparison the ozone national standard at National Physical Laboratory of India (NPLI) was compared with the common reference standard maintained by the Bureau International des Poids et Mesures (BIPM), via a transfer standard maintained by the National Institute of Standards and Technology (NIST). The instruments have been compared over a nominal ozone mole fraction range of 0 nmol/mol to 500 nmol/mol. The degrees of equivalence between the NPLI standard and the common reference standard BIPM SRP27 indicate good agreement between both the standards. Graphs of equivalence of all participants with results are displayed in figure 3.12.

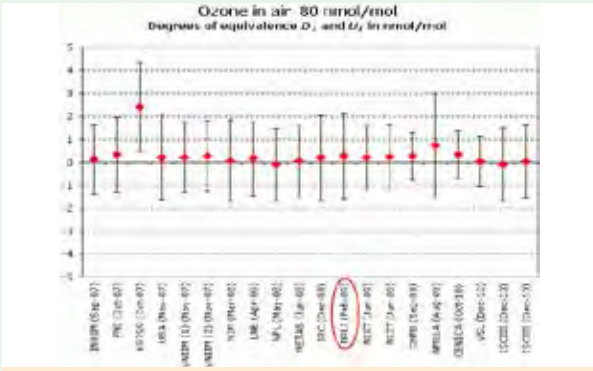

Fig. 3.12: Equivalence at 80 nmol/mol ozone mole fractions for all participants in BIPM.QM-K1 in the present cycle.

IV. Simulation and Modeling for Atmospheric Physics

Modeling optical properties of mineral dust

The optical properties (like Single Scattering Albedo, SSA; Asymmetry parameter, g and Extinction

efficiency, Qext) of different model shapes (based on the morphological information) for the polluted mineral dust, are computed using Discrete Dipole Approximation, DDA code. The SSA was found to vary depending on hematite content (0-8%) and model shape composition. In figure 3.04.1, we can see that for the two-sphere BC-mineral dust system, hematite was found to be dominating absorber compared to that of black carbon as the Rbc/Rdust decreases (i.e. with increase of dust sphere size compared to black carbon sphere in the composite two-sphere system). SSA was found to be very sensitive to the hematite content when both of the spheres (i.e. mineral dust and BC) are nearly of same size. SSA of the polluted dust system is overestimated if the polluted dust is considered as pure dust sphere (with 4% hematite, D-4) while underestimation is observed for Qext. The deviation in size averaged SSA and Qext relative to D-8 (dust sphere with 8% hematite) sphere is found to be ~ 32.1% for OCDF-8 (organic carbon, dust and fly-ash system with 8% hematite). Among all the polluted dust systems, BrCDD (one BrC sphere attached to two dust spheres) showed the maximum deviation in size averaged SSA i.e. 11% by increasing hematite from 0 to 8%. The modeled polluted dust optics will provide a better basis for radiative forcing estimation and many sensitivity studies.

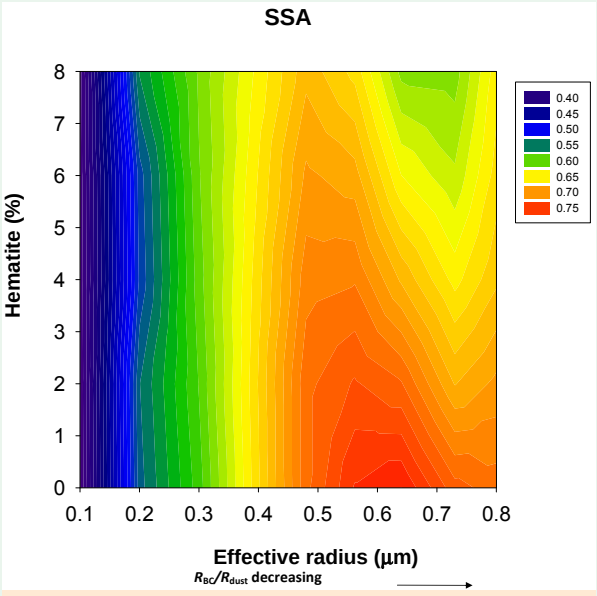

Fig. 3.13: SSA of two sphere BC-mineral dust cluster with varying hematite percentage

Effect of BC on optical properties of aerosols and the DARF

The effect of Black Carbon (BC) concentration on AOD, SSA and asymmetry parameter g and the resulting direct aerosol radiation forcing (DARF) was done using the 'urban' aerosol type of the OPAC and the SBDART radiative transfer model (Fig 3.14). We have found that an increase in BC concentration from 2 to 20 μgm^{-3} leads to a decrease in SSA from 0.90 to 0.60. The change in asymmetry parameter is from 0.68 to 0.63 and an increase in AOD at 500 nm is from 0.57 to 0.91. These optical properties were used in the SBDART model to estimate the DARF at TOA, at the surface and in the atmosphere for every 2 $\mu g/m^3$ change in BC concentration keeping all other parameters constant. The DARF at the surface increases from –31W/m^2 (least negative value) at the BC concentration of 2 $\mu g/m^3$ to –74 W/m^2 as BC concentration increases to 20 $\mu g/m^3$. On the other hand the DARF at the TOA remained negative till the BC concentration was up to 4 $\mu g/m^3$ and then it became positive when the BC concentration increased further. The DARF in the atmosphere, which is the difference between the DARF at TOA and surface, shows a positive forcing which increases from 25 W/m^2 to 95 W/m^2 as BC concentration increases from 2 $\mu g/m^3$ to 20 $\mu g/m^3$.

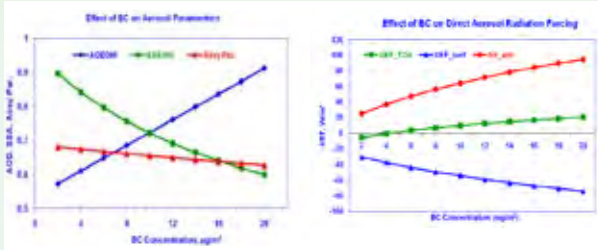

Fig. 3.14: Simulation of effect of increase in BC concentration on aerosol parameters and direct aerosol radiation forcing

Mega-city atmospheric pollution precursor process modelling

For undertaking the mega-city wide near real time modeling and prediction of accumulation of toxic gases in ambient air in different urban and peri-urban regions of the city of Delhi, inventory of the emissions of trace atmospheric species from all the sources for Delhi region has been completed. For example, the developed emission inventory from coal consumed in power plants in Delhi show an increase of CO_2 emissions from 6.7 Tg

in 2001 to 6.5 Tg in 2009. The reduction in emissions during recent years is due to the switching of fuel from coal to more greener fuels like compressed natural gas in thermal power stations in Delhi. Similarly, emissions of NO and SO_2 have also shown an increase during the period 2001 to 2008 but thereafter declined in 2009 (Fig 3.15). These emissions values will be used in the air quality forecasting model for simulation of air quality status in Delhi.

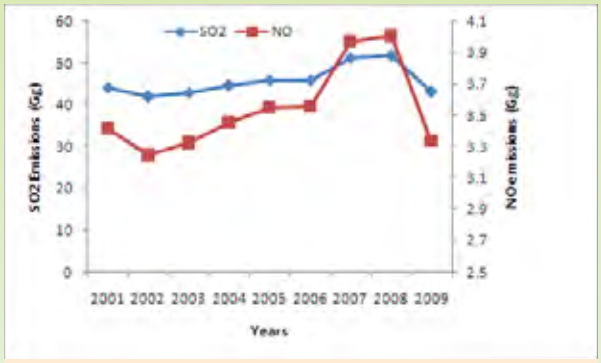

Fig. 3.15: SO_2 and NO emissions from coal fired thermal power plants in Delhi

BC emission estimates using BC concentration measurements

In addition the BC concentration along with the mixing layer height (MLH) and wind speed was applied in a simple box model to estimate the average BC emission. On an average, it varied in the range 11,000 to 17,000 kg of BC per day. The maximum emission during the day averaged every hour for different months lied in the range 1000 to 2100 kg hr-1. The mean monthly emission varied in the range 0.35 Gg to 0.52 Gg per month giving rise to an annual estimated emission of 4.86 Gg in the year 2006 over Delhi (Fig 3.16).

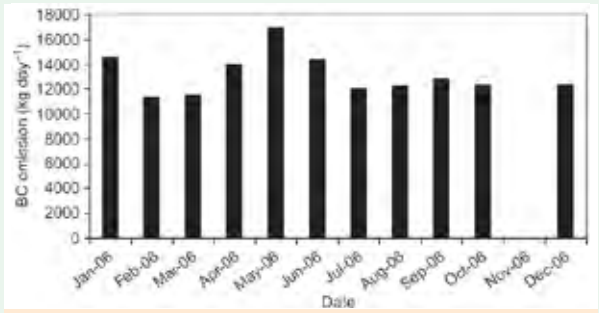

Fig. 3.16: Monthly averaged BC emission estimates over Delhi during 2006

V. Major Facilities installed in Division

Commissioning of Permanent Global Ionospheric Scintillation and Total Electron Content Monitoring Station at NPL

A Novatel make dual frequency, 12 channels Global Ionospheric Scintillation and Total Electron Content Monitoring (GISTM) system is installed at Radio and Atmospheric Sciences Division, National Physical Laboratory, New Delhi, during September 2010. The instrument is capable for real time round the clock monitoring of various ionospheric parameters e.g. integrated electron density (Ionospheric Total Electron Content) along the satellite to ground ray path, L-band Amplitude and Phase Scintillation. The system is quite advanced and it directly provids the ionospheric total electron content of the ray-path through which the signal is crossing the ionosphere. The system is capable of finding out accurate position of the location with a maximum error of 1 meter. For minimizing the multipath reflection a chock ring antenna system is used (Fig. 3.17). The data collected through the GISTM system is now in use to study the day-to-day and seasonal variation of Ionospheric Total Electron Content (ITEC) and occurrences characteristics of ionospheric scintillation over Delhi and its dependence on space weather events.

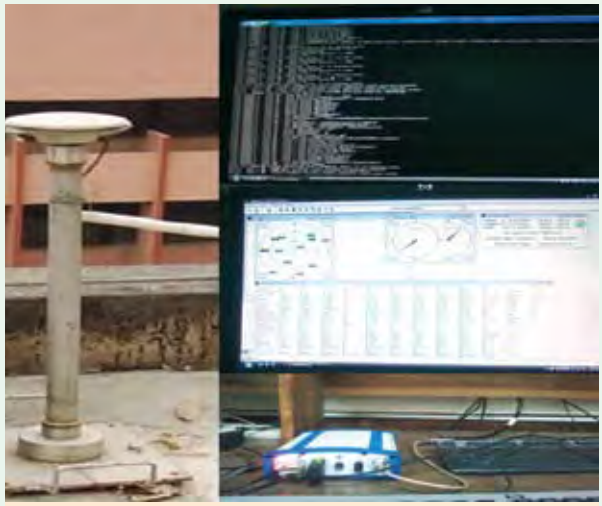

Fig. 3.17 : Newly installed Global Ionospheric Scintillation and Total Electron Content Monitoring (GISTM) System at Radio and Atmospheric Sciences Division, National Physical Laboratory, New Delhi.

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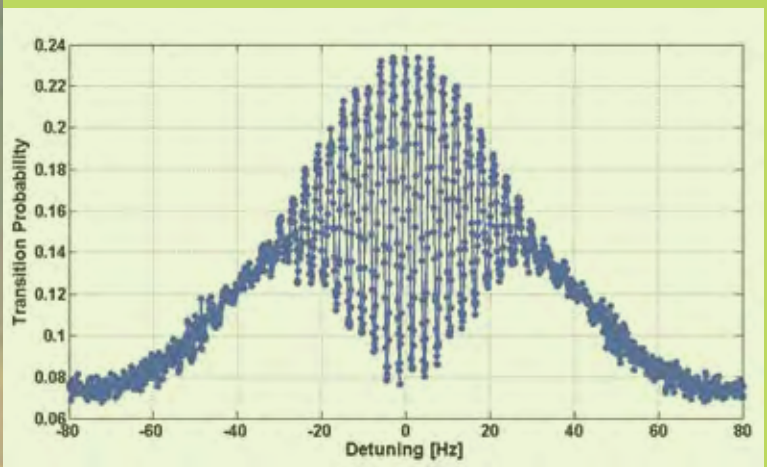
समय, फ्रीक्वेंसी और वैद्युत मानक



Ramsey Fringes

Time, Frequency and Electrical Standards

समय, फ्रीक्वेंसी और वैद्युत मानक

इस समूह द्वारा निम्नलिखित मानक क्रियाकलापों का निष्पादन किया जाता है :

- अति स्थायी परमाण्विक फ्रीक्वेंसी स्रोत
- अतत परमाणुओं की भौतिकी
- परिशुद्ध समय मापन प्रणाली
- वैद्युत मापविज्ञान
- निम्न फ्रीक्वेंसी और उच्च फ्रीक्वेंसी प्रतिबाधा और डीसी मानक
- निम्न फ्रीक्वेंसी और उच्च फ्रीक्वेंसी वोल्टता, धारा और सूक्ष्म तरंग मानक
- एसी उच्च वोल्टता एसी उच्च धारा मानक
- एसी शक्ति एवं ऊर्जा मानक

इस प्रभाग द्वारा वैद्युत एवं इलेक्ट्रॉनिक पैरामीटरों से संबंधित विभिन्न प्राथमिक/राष्ट्रीय मानकों से संबंधित क्रियाकलाप किए जाते हैं। इस प्रभाग द्वारा उद्योग एवं अन्य प्रयोगशालाओं को अंशाकन के माध्यम से इन मानकों से संबंधित तथ्यों से अवगत कराया जाता है। इस प्रभाग द्वारा किए जा रहे अन्य क्रियाकलापों में अंतर्राष्ट्रीय बाट तथा माप ब्यूरो (बीआईपीएम), एशिया–पेसिफिक मेट्रोलॉजी प्रोग्राम (एपीएमपी) आदि जैसे अंतर्राष्ट्रीय निकायों द्वारा आयोजित अंतर्राष्ट्रीय इंटर–कंपैरिजन से संबंधित क्रियाकलाप शामिल हैं। इसके अतिरिक्त, कुछ द्विपक्षीय कंपैरिजन क्रियाकलाप भी आयोजित किए जाते हैं। इस प्रभाग द्वारा विकसित अधिकांश पैरामीटरों की अंशाकन और मापन क्षमताएं अंतर्राष्ट्रीय स्तर पर स्वीकृत हैं और इनका बीआईपीएम की वेबसाइट पर उल्लेख है।

Time, Frequency and Electrical Standards

This group covers the following Standards activities :

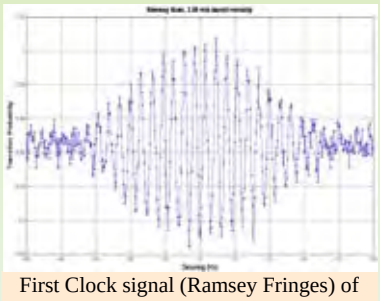
- Ultra stable Atomic Frequency Sources
- Physics of Cold Atoms
- Precise Timing Systems
- Electrical Metrology
- LF & HF Impedance & DC Standards
- LF & HF Voltage, Current & Microwave Standards
- AC High Voltage & AC High Currents Standards
- AC Power & Energy Standards

Various Primary/National Standards of Electrical and Electronic parameters are maintained by this Division. Traceability of these standards is provided to industry and other laboratories through calibration. 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. The Calibration and Measurement Capabilities of most of the parameters in the Division are internationally accepted and appear on the BIPM website.

I. Time and Frequency Standards

Time and Frequency Division has been developing one of the most accurate clocks on the earth. The development of an elaborate optical set-up and the physics package of the fountain clock have been completed. It has been demonstrated that such a system can trap about 10 million atoms, cool them to about 6 µK (lowest temperature realized in our lab so far) and launch them up to a meter high and detect the return signal by measuring the fluorescence. The atoms are made to interact with microwaves during the flight and the very first clock signal was observed. The first and only fountain clock in India is successfully developed and is undergoing optimization at NPL.

Fig. 4.1: Cesium Fountain Clock



First Clock signal (Ramsey Fringes) of Cs Fountain Clock

The Physics Package of Space Qualified Rubidium Atomic Clock was developed at NPL. Two of the Design Verification Models were handed over to Space Applications Center (SAC), ISRO. The work on NPL-SAC joint development of Engineering Thermal Model of Rubidium atomic clock for the Indian Regional Navigation Satellite System (IRNSS) is under progress.

Time and Frequency division is also working on dissemination of time to various users in the country and abroad. It was demonstrated that a computer clock could be synchronized to the Indian Standard Time using the tele-clock service provided by NPL via any landline or mobile telephone network.

A new advanced GPS receiver is in process of integration in order to improve the time scale.

LF and HF Impedance Standards

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 transformers 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.

Bilateral Comparison with BIPM

This group had a bilateral comparison with BIPM, France for standard silica capacitors. Standard Silica Capacitors of 10 pF (Sr. No. 1228 & 1229) and one 100 pF (Sr. No. 1312) were received from BIPM for the bilateral comparison. Measurements were carried out on precision capacitance bridge at frequency of 1kHz and 1.592 kHz. The measurement results have been sent to BIPM and the comparison is in progress.

APMP Inter-comparison of 6½ Digit Precision Multimeter

This group is coordinating inter-comparison (P1-APMP.EM-S8) of 6½ Digit Multimeter (DMM) under Asia Pacific Metrology Programme (APMP). 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, Mongolia, Philippines, Malaysia, Indonesia, Syria and India. Technical Protocol has been prepared and finalized for this comparison. The comparison will take about two years time. The DC measurements are being carried out by this group and ac measurement by LF & HF Voltage, Current and Microwave Standards. .

Evaluation of day to day variation in value of standard mica capacitors

It has been observed that most of the calibration laboratories complete the calibration of standard mica capacitors in one or two days. To verify reliability of such calibration, standard Mica capacitors of two different values: 1µF and 0.01 µF were taken for study. These

capacitors were kept at some particular temperature (25 ±1°C) and humidity (50±10)% for few days.

A calibrated 1000 pF air capacitor (GR1404-C) kept in oil bath at constant temperature was used as an external standard. The oil bath is kept at constant temperature using a temperature controller unit, Techne make TU-20D. The capacitors were measured against this standard using GR1620 Capacitor assembly at 1 kHz.

The calibration of mica capacitor of 1 µF and 0.01µF has been done by taking a set of five reading in a day at an interval of 5 minutes against the external standard of 1000 pF. Similarly, a single reading was also taken for the same two mica capacitor of 1 µF and 0.01µF against the same external standard air capacitor of 1000 pF using 1620 capacitance measuring assembly for ten days.

Table 4.1. Calibration data and type A uncertainty of 0.01 µF capacitor

Day	1	2	3	4	5	6	7	8	9	10	
Value in pF	9992.00	9992.71	9992.67	9992.93	9993.02	9992.75	9992.82	9992.99	9992.17	9992.25	
	9992.04	9992.73	9992.67	9993.02	9993.02	9992.75	9992.89	9993.03	9992.16	9992.27	
	9992.12	9992.75	9992.77	9993.02	9993.10	9992.85	9992.89	9993.04	9992.16	9992.27	
	9992.18	9992.78	9992.77	9993.02	9993.10	9992.85	9992.90	9993.06	9992.16	9992.27	
	9992.22	9992.81	9992.86	9993.04	9993.10	9992.85	9992.99	9993.09	9992.06	9992.27	
Average	**9992.11**	**9992.76**	**9992.75**	**9993.01**	**9993.07**	**9992.81**	**9992.90**	**9993.04**	**9992.14**	**9992.27**	**9992.75**
Std. Deviation	0.09	0.04	0.08	0.04	0.04	0.05	0.06	0.09	0.05	0.01	0.37
Type A	0.04	0.02	0.04	0.02	0.02	0.02	0.03	0.04	0.02	0.00	0.12

Table 4.2. Calibration data and type A uncertainty of 1 µF capacitor

Day	1	2	3	4	5	6	7	
Value in pF	1000062	1000075	1000086	1000097	1000085	1000074	1000046	
	1000072	1000073	1000096	1000095	1000086	1000074	1000037	
	1000072	1000079	1000104	1000086	1000085	1000075	1000038	
	1000087	1000090	1000097	1000094	1000086	1000084	1000035	
	1000087	1000086	1000097	1000090	1000086	1000078	1000043	
Average	**1000076**	**1000081**	**1000096**	**1000092**	**1000086**	**1000077**	**1000040**	**1000078**
Std. Deviation	10.84	7.23	6.44	4.39	0.55	4.24	4.55	18.53
Type A	4.85	3.23	2.88	1.96	0.24	1.90	2.03	7.00

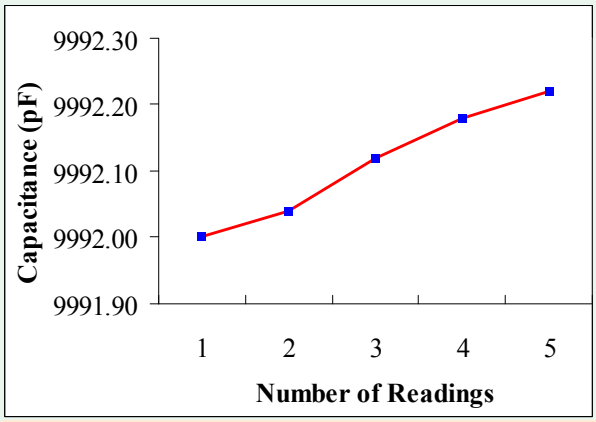


Fig. 4.2: Variation in Capacitance of 0.01 µF in Day 1

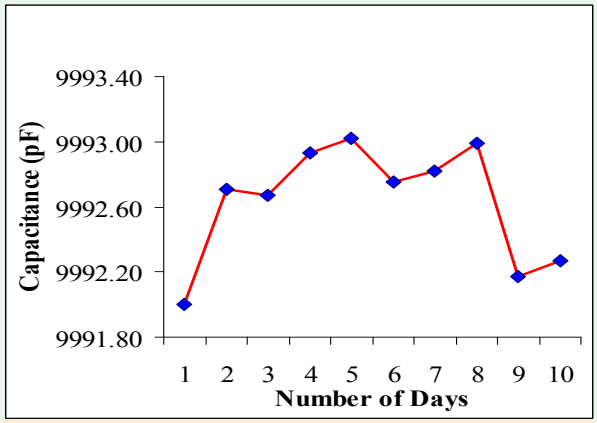


Fig. 4.3: Variation in Capacitance of 0.01 µF in 10 days

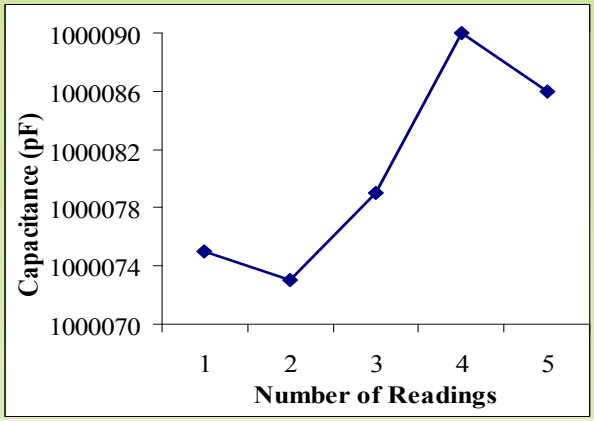


Fig. 4.4: Variation in Capacitance of 1 µF in single day (day 2)

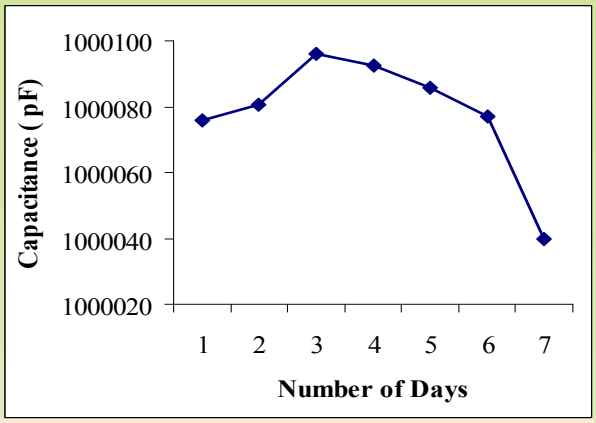


Fig. 4.5: Variation in Capacitance of 1 µF in 10 days

From the above study, it is found that the value of 0.01 µF mica capacitor calibrated in a single day ranges from 9992.11 to 9993.07 pF compared to 9992.75 pF for calibrated in 10 days. Similarly, for 1 µF, the value ranges from 1000040 pF to 1000096 pF for calibration in single day whereas it is 1000078 pF for calibrated in 10 days. It is also found that the uncertainty of 0.01 µF mica capacitor which was calibrated for ten days is 12 ppm while it is maximum 4 ppm for capacitor calibrated in a single day. Similarly for 1 µF capacitor it is 7 ppm for calibration in 10 days, compared to 0.24 to 4.85 ppm for capacitors calibrated in single day. It shows that mica capacitor which was calibrated for ten days covers a wide range of uncertainty variation as compared to mica capacitor which was calibrated in a single day.

Therefore, it can be said that value and uncertainty assigned to the mica capacitor over 7 to 10 days calibration is much more reliable than the value and uncertainty obtained by the calibration of mica capacitor in a single day. Therefore it can be concluded that the value and uncertainty assigned in 7 to 10 days measurements will be more reliable.

II. LF & HF Voltage, Current and Microwave Standards:

This group of Electrical Standards is providing apex level calibration services to nation by disseminating the standards for maintaining the traceability of measurements in Low frequency Voltage, Current, RF Power and RF Attenuation and Impedance as per ISO: 17025 to STQC Labs, DRDO, ISRO, BEL etc. This group has indigenously design & developed a Current Tee for the establishment of High Current measurement facility from 30 Ampere to 100 Ampere as shown in Fig.4.6. It will be used for assigning AC DC Current transfer difference in the low frequency range from 10 Hz to 10 KHz.

Fig. 4.6: High Current Tee

Fig. 4.7: Results of VNA

This group has established a Vector network analyzer based Broadband S-parameter 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. The established facility has enabled the measurement of VSWR/ reflection

coefficient, required for the uncertainty budgets in RF power measurements as shown in Fig.4.7 and 4.8.

Fig. 4.8: Vector Network Analyzer

The RF DC transfer difference has been assigned to establish thermal power sensor (NRV Z51) as a reference standard of RF Voltage in the frequency range of 1 MHz to 1000 MHz and its traceability is obtained through the determination of its effective efficiency, RF impedance and DC resistance against each of the parameter's reference standard as a function of frequency. The results are given in Table 4.3.

Table 4.3 RFDC Trf Diff Results

Freq (MHz)	RF DC Trf Diff (exp -4)	Expanded Unc. (exp -4)
10	5.6	7
100	28.7	14
300	58.1	22
500	81.0	28
700	-28.8	39
1000	-49.7	53

We have applied for the Software Copyrights for our indigenously developed automation softwares in IPMD CSIR HQ, New Delhi.

Fig. 4.9: View of automation setup

Traceability of the transfer standard VM7 attenuator and & signal calibrator at 30 MHz, 60 dB dynamic range has been re-established against the Primary standard 30 MHz WBCO attenuator (Range 60 dB, uncertainty ±0.004 dB/10dB) to calibrate the transfer standards of the user organizations. The final report on the APMP Attenuation Key comparison (APMP.EM.RF-K19.CL), piloted by NIM China shows that the results of NPLI are close to the KCRV taken for Intercomparison as shown in Fig. 4.10.

Primary standards of Impedances, a precision coaxial airline and a set of indigenously developed Precision waveguides in Xn-, X- & Ku-bands (5.8 – 18 GHz), traceable to dimensional metrology are used to calibrate the Transfer standards coaxial mismatches & waveguide standard mismatches(indigenously developed) using coupled sliding load technique & tuned reflectometer technique. The stabilized RF Ratiometer has been calibrated at 1 kHz, 30 dB dynamic range against the Inductive voltage divider to re-establish the traceability.

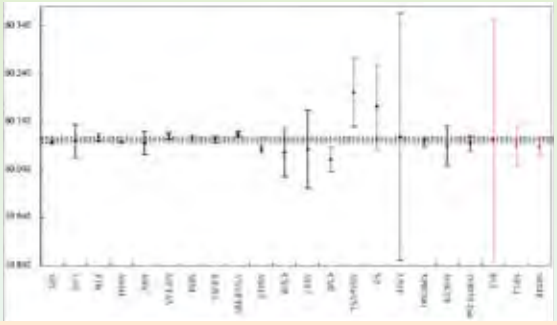


Fig. 4.10 Intercomparison results (60 dB,5 GHz)

III. AC High Voltage & High Current Standards

This section is maintaining National Standards of AC High Current and High Voltage Ratios at power frequencies (50Hz) by using Reference Standard Current Transformers and Reference Standard High Voltage Ratio Measuring System. Calibration services were provided for the calibration of Current Transformers, Current Transformer Testing Sets, Clamp Meters, CT Burdens and for Voltage Transformers, Voltage Transformer Testing Sets, HV Probes, Electrostatic Voltmeters (ESVMs), HV Break Down Test Sets and Voltage Transformer Burdens etc. As many as 55 Calibration Certificates were issued to the electrical manufacturers and utilities.

The National Standard of AC High Current Ratio Measuring System upto 5000A/1A, 5A is shown in Fig. 4.11.

Fig. 4.11

The National Standard of AC High Voltage Ratio up to 100kV/100V comprising of the Compressed Gas Capacitor, Air Capacitor & the Electronic Voltage Divider (EVD) is shown in Fig. 4.12.

Fig. 4.12

- Major Facilities developed/ created/ established during the academic year 2010-11

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

AC High Current & High Voltage Standards have established the National Standards for the calibration and measurement of AC High Voltage Capacitance and Tan δ upto 200kV at 50Hz. 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 very high accuracy.

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

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

National Standard for AC High Voltage Capacitance and Tan δ

Fig. 4.13

- Extraordinary Research Highlights

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

IV AC Power & Energy Standard

AC Power and Energy Standard maintains the National Standard of AC Power & Energy and actively involved in upgradation of the national standard of measurement compatible to international standards through research and development. We provide traceabilty to all power sector organizations, other laboratories and electricity suppliers.

MAJOR FACILITIES CREATED

Shock system machine has been setup for performing shock test on energy meters as per IS/IEC specifications. Impulse voltage test has also been included (1.2µ second/50µsecond) up to 12 killo volts.

PPCS (primary power calibration system) has been integrated with its main building units calibrated form PTB at present and its testing is in process. Now onwards our uncertainties will be established to within 30ppm. This system will be traceable to NPL standards only with DC voltage, resistance and time.

The system has been established and our national standard COM3000 has been calibrated using the new system, which was previously calibrated by PTB Germany in June 2008.

Also a single phase Watt Converter MSB 100 has also been calibrated which was calibrated by NIST USA in March 2009. In future we will take part in Bilateral Comparisons.

The draft A report for CCEM comparison supplementing Eoromet comparison, EURAMET.EM-K5.1 Comparison of 50/60 Hz Power (EURAMET Project 687) has been received. The results are very close to the reference values.

Fig. 4.14 Front side showing integrated primary standard

Fig. 4.15 Back side of the primary standard showing different components

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NPL - INDIA

शीर्ष स्तरीय मानक एवं औद्योगिक मापिकी

Apex Level Standards and Industrial Metrology

शीर्ष स्तरीय मानक एवं औद्योगिक मापिकी

शीर्ष स्तरीय मानक एवं औद्योगिक मापिकी प्रभाग (एएलएसआईएम) राष्ट्रीय मानकों को स्थापित करने, उनका अनुरक्षण और उनके उन्नयन तथा अन्य प्रत्यायित प्रयोगशालाओं को मार्गदर्शन प्रदान करने से संबंधित कार्य करता है। इस प्रभाग के अंतर्गत कुल आठ उप–प्रभाग शामिल हैं, जो अनुसंधान, नई सुविधाओं के संस्थापन, अंतर्राष्ट्रीय या द्विपक्षीय इंटर–कम्पैरिजन संबंधी क्रियाकलापों तथा भौतिकी, यांत्रिकी, प्रकाशीय और तापीय पैरामीटरों के अंशाकन और मापन से संबंधित क्रियाकलापों का निष्पादन करते हैं। ये उप–प्रभाग हैं :

- द्रव्यमान मानक
- विमा मानक
- ताप एवं आर्द्रता मानक
- प्रकाशीय विकिरण मानक
- बल एवं कठोरता मानक
- निर्वात एवं दाब मानक
- ध्वानिक और पराध्वानिक मानक
- द्रव प्रवाह मापन मानक

इन सभी उप–प्रभागों की अंशाकन तथा मापन क्षमताओं (सीएमसी) की नियमित अंतरालों पर अंतर्राष्ट्रीय स्तर के विशेषज्ञों द्वारा समीक्षा की जाती है। अंतर्राष्ट्रीय स्तर पर मापन और अंशाकन में तुल्यता बनाए रखने के लिए विभिन्न द्विपक्षीय और अंतर्राष्ट्रीय इंटर–कम्पैरिजन में प्रतिभागिता सुनिश्चित की जाती है।

इन उप–प्रभागों के क्रियाकलापों से संबंधित मुख्य–मुख्य बातें निम्नानुसार हैं :

द्रव्यमान मानक

- इस अवधि के दौरान आधारभूत अनुसंधान एवं विकासात्मक क्रियाकलाप किए गए, राष्ट्रीय प्रोटोटाइप किलोग्राम संख्या 57 के जरिए चार द्रव्यमान मानकों और अन्य मानकों की उपादेयता पुनः स्थापित की गई। विशिष्ट तोल तकनीकों के जरिए द्रव्यमान के टीएस के नए मान निर्धारित किए जाते हैं।
- अंशांकन तथा मापन क्षमताओं (सीएमसी) के पुष्टिकरण हेतु चार द्रव्यमान मानकों अर्थात् 500 ग्राम, 20 ग्राम, 2 ग्राम और 100 मिलिग्राम हेतु (KRISS), कोरिया के साथ एपीएमपीएमएम–के2.1, द्विपक्षीय इंटर–कम्पैरिजन के सीडीवी का निष्पादन किया गया।
- गुणवत्ता अवसंरचना के क्षेत्र में सार्क और पीटीबी के बीच सहयोग स्थापित करने के लिए नई दिल्ली में 5–24 नवंबर, 2010 के दौरान आयोजित ''मापविज्ञान विषय पर क्षेत्रीय सहयोग'' नामक कार्यशाला में भाग लिया। इस कार्यशाला में भारत की राष्ट्रीय भौतिक प्रयोगशाला (एनपीएल) के अतिरिक्त विभिन्न देशों से आए 15 प्रतिभागियों ने भाग लिया।

विमा मानक

- मापन (भारतीय मापविज्ञान सोसाइटी द्वारा प्रकाशित जरनल) एक विशेष अंक प्रकाशित किया गया है, जिसमें लंबाई और विमा मापिकी पर विशेष लेख संकलित किए गए हैं।
- पृष्ठीय रुक्षता के छः प्रतिदर्शों पर पृष्ठीय रुक्षता (एपीएमपी एल–के 8) : आठ पैरामीटरों का मापन किया गया है। संबंधित परिणाम प्रारूप ख रिपोर्ट में प्रकाशित किए गए हैं।
- स्टेप गेज (एपीएमपी एल–के 5) : 620 मिलिमीटर लंबाई के स्टेप गेज पर 31 स्टेपों का मापन किया गया है। संबंधित परिणाम प्रारूप ख रिपोर्ट में प्रकाशित किए गए हैं।
- लाइन स्केल (एपीएमपी एल–के 7) : 620 मिलिमीटर लंबाई के स्टेप गेज पर 31 स्टेपों का मापन किया गया है। संबंधित परिणाम प्रारूप ख रिपोर्ट में प्रकाशित किए गए हैं।
- एंगल गेज (यूरो मैट एल–के 3) : एक आठ फलकों वाले बहुभुज मानक तथा चार एंगल गेज ब्लॉकों का मापन किया गया। संबंधित परिणाम प्रारूप ख रिपोर्ट में प्रकाशित किए गए हैं।

ताप एवं आर्द्रता मानक

- प्लैटिनम प्रतिरोध तापमापी मानक की सहायता से आर्गन त्रिक बिंदु (–189.3442 डिग्री सेल्सियस) प्राप्त किया गया, जिसमें अनिश्चितता की मात्रा $\pm$ 1 m ^{0}C थी।
- बीआईपीएम के की–कम्पैरिजन डेटाबेस (केसीडीबी) के परिशिष्ट ग में ताप पैरामीटर संबंधित चार सीएमसी प्रकाशित किए गए।
- एपीएमपी के की–कम्पैरिजन में भाग लेने के लिए 1324 ^{0}C पर स्थित Pt/Pd तापयुग्म की तुलना में हेतु कोबाल्ट–कार्बन यूटैक्टिक फिक्स्ड पॉइंट सेल का अभिकल्पन और विकास किया गया।
- एक ''संहत मिश्रित प्रवाह आपेक्षिक आर्द्रता जनित्र'' का अभिकल्पन और विकास किया गया, जिसमें 5% से 95% RH की रेंज में परिशुद्धता 0.1% के भीतर आर्द्रता सृजित करने की क्षमता है।

प्रकाशीय विकिरण मानक

- ज्योति फ्लक्स इंटर–कम्पैरिजन एपीएमपी के–4 परिणाम प्रकाशित किए गए और एनपीएल–2 के भारत परिणाम एपीएमपी क्षेत्र की अन्य प्रयोगशालाओं के अनुरूप हैं।
- प्रावस्था विचित्र प्रक्षेत्र में बहुवर्णी प्रकाश के असंगत स्पेक्ट्रम आचरण से संबंधित प्रायोगिक अन्वेषण तथा इनडोर और आउटडोर प्रकाशीय संचार हेतु अदीप्त रिक्त गाउसीय प्रकाश पुंज (डीएचजीबी) आधारित फ्री स्पेस ऑप्टिकल (एफएसओ) लिंकों की संभाव्यता और महत्त्व के संबंध में जानकारी प्राप्त करने के लिए बहुवर्णी केंद्रित डीएचजीबी पर संसक्ति और ध्रुवीकरण परिवर्तन के प्रभाव का अध्ययन करना।

बल कठोरता मानक

- कुल भार पर 20 पीपीएम के भीतर तथा उत्तोलक पक्ष पर 90 पीपीएम से कम आरोपित बल की कथित अनिश्चितता के साथ एक नया एक–MN बल मानक सुविधा स्थापित करना।

- नए एक–MN बल मानक मशीन की पीटीबी, जर्मनी के साथ 0.5 से कम प्रसामान्यीकृत त्रुटि सहित अंतरा–प्रयोगशाला कम्पैरिजन।
- ग्राहकों को ब्रिनेल स्केल में अंशाकन सेवा उपलब्ध कराने के लिए ब्रिनेल कठोरता प्राथमिक मानक सुविधा संस्थापित करना।
- आरआरएसएल को स्वतंत्र रूप से बल एवं बल–आघूर्ण अंशांकन से संबंधित कार्य को करने में सक्षम बनाने के लिए विभिन्न आरआरएसएल में तकनीकी मैनुअलों, प्रशिक्षण तथा आईएसओ 17025 को कार्यान्वित करने के लिए मार्गदर्शन से युक्त बल एवं बल आघूर्ण मानक मशीनें स्थापित करने की परियोजना को पूरा करना।
- रॉकवैल कठोरता स्केलों, एचआरए और एचआरबी तथा 50 के एन और 100 के एन बलों का एपीएमपी की–कम्पैरिजन।

निर्वात एवं दाब मानक

- 50 MPa से 500 MPa की दाब रेंज में सीसीएम प्रायोजित अंतर्राष्ट्रीय की कंपैरिजन के ड्राफ्ट–ए में इस प्रभाग के लेख का प्रकाशन, जिसके लिए संपूर्ण एपीएमपी क्षेत्र के केवल कुछ देशों को ही भाग लेने की अनुमति है, एक उपलब्धि सिद्ध हुआ है तथा हम प्रायोगिक अनिश्चितता की सीमा के भीतर पहुंच चुके हैं।
- Dy_2O_3 और CeO_2 के असंगत आचरण को प्रदर्शित करने वाले उच्च दाब रामन अध्ययनों से Dy_2O_3 की घन संरचना के मोनोक्लिनिक संरचना में परिवर्तित हो जाने की जानकारी मिलती है। तथापि, अति सूक्ष्म संरचना होने के कारण इसकी घन संरचना को षट्कोणीय संरचना में परिवर्तित किया जा सका।

ध्वानिक और पराध्वानिक मानक

- प्राथमिक कंपन अंशाकन मानक की एक नई सुविधा संस्थापित की गई है। यह प्रणाली आईएसओ 16063–11 के अनुसार 0.1 हर्ट्ज से 20 किलो हर्ट्ज तक की फ्रीक्वेंसी रेंज में संदर्भ एक्सीलैरोमीटरों के अंशाकन में सक्षम है। इसके अतिरिक्त, ध्वानिक उत्तेजन के कारण प्ररित कंपन केबीच सह–संबंध स्थापित करने के लिए व्यापक अन्वेषण किए गए हैं तथा अनुभवाश्रित व्यवस्था विकसित की गई है। इस प्रयोगशाला में विकिरण बल तुला का देश में ही विकास किया गया है तथा इसका पराध्वनिक शक्ति के प्राथमिक मानक के रूप में प्रयोग किया जाता है। इस तुला का अंतर्राष्ट्रीय इंटर–कम्पैरिजन सीसीएयू वी.यू.–के3 में प्रयोग किया जा रहा है।
- राष्ट्रीय भौतिक प्रयोगशाला (एनपीएल) में विद्युत चुंबकीय ध्वानिक ट्रांसड्यूसर प्रणाली नामक एक नई सुविधा का पूरी तरह से संस्थापन कर दिया गया है। इस व्यवस्था का प्रयोग करके अब 0.3 ns की विभेदन क्षमता तक पराध्वनिक उड़ान समय का मापन करना संभव हो गया है।

द्रव प्रवाह मापन मानक

- एक जल प्रवाह अंशाकन मानक (अर्थात प्राथमिक प्रवाह मानक) डीएन 100 को अभिकल्पित किया गया है और इसे मैसर्स भारती ऑटोमेशन प्रा. लिमिटेड, नई दिल्ली के तकनीकी सहयोग से विकसित किया जा रहा है। डाइवर्टर त्रुटि, जो अनिश्चितता का एक महत्वपूर्ण स्रोत है, कम करने की दृष्टि से एक नई अभिकल्पन तकनीक का उपयोग किया जाएगा।

Apex Level Standards and Industrial Metrology

The division of Apex Level Standards and Industrial Metrology (ALSIM), responsible for establishing, maintaining and upgrading the national standards and providing traceability to other accredited laboratories, is constituted by the eight sub divisions, which are involved in the research, establishing new facilities, international or bilateral inter comparisons, calibration and measurement of physical, mechanical, optical and thermal parameters. The sub divisions are as follows :

- Mass Standards
- Standards of Dimensions
- Temperature & Humidity Standards
- Optical Radiation Standards
- Force and Hardness Standards
- Vacuum and Pressure Standards
- Acoustics and Ultrasonic Standards
- Fluid Flow Measurement Standards

The Calibration and Measurement Capabilities (CMCs) of all these sub divisions are peer reviewed at regular intervals. To maintain equivalence in measurements and calibrations at the international level, participation in various bilateral and international inter comparisons is ensured.

The highlights of the activities of the sub divisions are as:

Mass Standards

- Basic Research and Development carried out during the period, the traceability of four mass standards and other standards were re-established through National Prototype Kilogram No. 57. The new values of TSs of mass are assigned through specialized weighing techniques.
- Bilateral inter comparison KCDB indexed APMP.M.M- K2.1 with KRISS, Korea for Four mass standards, i.e. 500 g, 20 g, 2 g, and 100 mg was carried out for affirmation of the CMCs.
- To establish Cooperation between SAARC and PTB in the field of quality infrastructure, participated in a 'Planning Workshop called Regional Cooperation in Metrology', which was held at New Delhi, during November 5-24, 2010. Fifteen participants from different countries besides NPL I took part in it.

Standards of Dimensions

- One special issue of MAPAN (Journal of Metrology Society of India) has been published focused on Length and Dimension metrology.

- Surface Roughness (APMP L-K8) eight parameters are measured on six specimens of surface roughness. The results are published as draft B report.
- Step Gauges (APMP L-K5): Thirty one steps are measured on a step gauge of length 620 mm. The results are published as draft B report.
- Line Scale (APMP L-K7): Thirty one steps are measured on a step gauge of length 620 mm. The results are published as draft B report.
- Angle Gauges (Euromat L-K3): one eight face polygon standard and four angle gauge blocks were measured. The results were published as draft B report.

Temperature and Humidity Standards

- Argon triple point (-189.3442 ^{o}C) was realized with standard platinum resistance thermometers with an uncertainty of 1m $\pm^{o}$C.
- Four CMCs in temperature parameter were published in the Appendix-C of key comparison database (KCDB) of BIPM.
- Designed and developed the Co-C eutectic fixed point cell for comparison of Pt/Pd thermocouple at 1324 ^{o}C to participated in the APMP Key Comparison.
- A 'compact mixed flow relative humidity generator' was designed and developed with a capacity to generate humidity precisely within 0.1% in the range from 5% to 95% RH.

Optical Radiation Standards

- Luminous flux intercomparision APMP K4 results published and NPLI results are comparable with other laboratories in the APMP Region.
- Experimental investigations on anomalous spectral behaviour of polychromatic light in phase singularity domain and the impact of coherence and polarization change on polychromatic focused dark hollow Gaussain beam (DHGB) for seeking the possibility and significance of DHGB based free-space optical (FSO) links for indoor and outdoor optical communications.

Force and Hardness Standards

- Establishment of a new one-MN force standard facility with the claimed uncertainty of applied force within 20 ppm on dead weight side and less than 90 ppm on the lever side.
- Inter-laboratory comparison of the new 1-MN force standard machine with PTB, Germany with normalized error less than 0.5.
- Commissioning of the Brinell Hardness primary standard facility to provide the calibration service in Brinell scale to the customers.
- Completion of the project to establish force and torque standard machines at the various RRSLs with technical manuals, training and guidance to implement ISO-17025 in order to make the RRSLs competent in taking up force and torque calibration independently.

- APMP key comparison in Rockwell Hardness scales, HRA and HRB, and in Force at 50kN and 100kN.

Vacuum and Pressure Standards

- The publication of draft A of the CCM sponsored International Key Comparison (KC) (CCM. P.-K13) in the pressure range 50 MPa to 500 MPa where only a few countries from the entire APMP region were permitted to participate and we are well within the experimental uncertainty.
- High pressure Raman studies in Dy_2O_3 and CeO_2 showing an anomalous behaviour the former is expected to transform cubic structure to monoclinic. However, due to its nanostructure, it progressed from cubic structure to hexagonal structure.

Acoustics and Ultrasonic Standards

- A new facility of primary vibration calibration standard has been setup. The system is capable of calibrating the reference accelerometers in frequency range from 0.1Hz to 20 kHz as per ISO 16063-11. Also, extensive investigations have been carried and empirical formulations developed to correlate the vibration induced due to acoustic excitation. Radiation force balance has been indigenously developed in the laboratory and is used as Primary Standard of ultrasonic power. The balance has been used in international inter-comparison CCAUV.U-K3.
- A new facility, Electro-Magnetic Acoustic Transducer System, has been fully installed at NPL. Using this system, it is now possible to measure ultrasonic time of flight to a resolution of 0.3 ns.

Fluid Flow Measurement Standards

- A Water Flow Calibration Standard (i.e. Primary Standard of Flow) of size DN100 has been designed and is being developed in technical collaboration with M/s. Bharti Automation Pvt. Ltd., New Delhi. A novel design technique would be used to reduce the diverter error which is a significant source of uncertainty.

I. Mass Standards

The NPL transfer standards (TSs) are traceable to National Prototype Kilogram No. 57. This year traceability of transfer standards was re-established in March 2011 using a well established special type of weighting design. All the measurements were carried out under controlled environmental conditions using computer controlled 1 kg mass comparator (CC1000S-L) with four alternators during night time to prevent vibration effect and reduce CO_2 content. The new values of TSs of mass are assigned.

This section has provided apex level calibration facilities for the mass, density, volume and viscosity to the Govt. Organizations namely ISRO, DRDO, BHEL, IOC, ERTL, ETDC, MSME, NTH etc. and pharmaceutical industries namely Cipla, Ranbaxy, Zydus, Dabur, Cadila, Pfizer, Hetero Drugs, Ratio Pharma, Piramal, Johnson & Johnson, Ajanta Pharma etc. and other calibration service providers such as Shriram Institute for Industrial Research and NABL accredited laboratories etc.

In addition to the above mentioned measurements, traceability was provided to the Nepal Bureau of Standards and Metrology (NBSM), Nepal and various standards groups of NPL namely Force & Hardness Standards, Pressure & Vacuum Standards, Fluid Flow Measurement Standards, Chemical Metrology, Nano-Magnetic Fluid etc.

Proficiency Testing (PT) in Mass Measurement (No. NPL-NABL/M/1/2010) had been started in December 2010 in two loops consists of 27 laboratories. Already six laboratories in loop one and six laboratories in loop two completed PT and submitted the results.

This section strongly supporting SAARC counties (Pakistan, Nepal, Bangladesh, Sri Lanka, Afghanistan, Bhutan, Maldives) under PTB program for the activities like inter-comparison, traceability of artifacts, on-site trainings. The Phase-I is completed and Phase-II has started.

Research Highlights

We successfully went through the International Peer Review in October, 2008. During the peer review, we reduced our CMCs for 1 kg [28 µg against 40 µg] and (sub)multiple of 1 kg [15 µg against 152 µg for 500 g, 6 µg against 62 µg for 200 g and so on]. Intra-RMO of APMP and Inter-RMO named as COOMET, AFRIMETS & EURAMET accepted our improved CMCs but SIM had objection due to lack of international inter-comparison in this level. Finally, with kind suggestion of the Chairman, CCMWG (CMCs), we went through the bi-lateral inter-comparison namely APMP.M.M-K2.1 with KRISS, Korea for four mass standards i.e. 500 g, 20 g, 2 g & 100 mg. We reported 15.6 µg for 500 g, 4.6 µg for 20 g, 1.4 µg for 2 g & 1.3 µg for 100 mg. However, after linkage with CCM.M-K2 for the degrees of equivalence required by the MRA, our CMCs reached marginally higher i.e. 18 µg for 500 g, 8 µg for 20 g, 2.5 µg for 2 g and 2 µg for 100 mg. Now we are waiting for approval of our CMCs from SIM as well as BIPM. The draft B of APMP.M.M-K2.1 results are shown in Fig. 5.1.

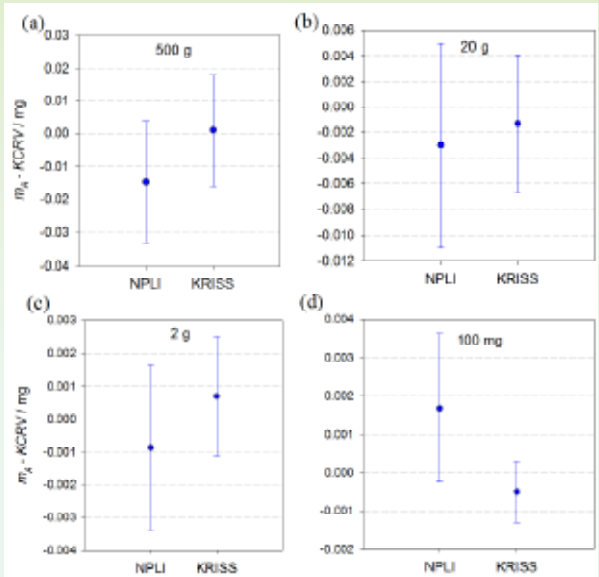


Fig. 5.1 APMP. M.M-K 2.1 results.

II. Standards of Dimensions

R & D Activities

- Peer review of the Standards of Dimensions, Apex Level Standards & Industrial Metrology was carried out by the technical expert from National Metrology Institute of Japan (NMIJ) in October 2009. The CMC's as claimed were approved by the technical expert. All the CMC's after due scrutiny with in the APMP region and intra region have been uploaded on the BIPM web site in May

2011. The CMC's of Standards of Dimensions have not only reaffirmed but some CMC's have been improved from the last peer review.

- International inter-comparisons during this period. Our results are comparable with other NMIs of the Asia pacific region.
- The NPL Standards of Dimensions participated in International Inter-comparison coordinated by Developing Economic community of APMP. The results of this inter-comparison have been accepted and presented as Draft 'B' in the workshop held at KIM LIPI Indonesia during May 2010.
- This year Standards of Dimensions, Apex Level Standards & Industrial Metrology has provided calibration services to the Indian Industries, NABL accredited laboratories, calibration laboratories both from government as well as private sector and to the neighbouring countries.

  365 reports were issued and revenue of Rs 50 lakhs was contributed to Laboratory reserve funds though the calibration fee. This includes ten site calibrations for the various types of length measuring machines. Also thirty in-house calibration reports were generated. This team includes all staff member.

  Work on establishing in-house traceability of step gauges using laser interferometer has been initiated with an uncertainty better than ±0.5µm/m.

- **Coordination of NABL sponsored proficiency testing for dial gauges:**

  NABL-Length-PT010: A three set of dial gauges are selected to conduct proficiency testing among forty labs all over the India. The measurement range covers (0-25) micrometer and (0-10) mm. The least count of these dial gauges is 0.5,10 micrometer respectively.

- **Participated in APMP international Inter-comparison:**

  Surface Roughness (APMP L-K8): eight parameters are measured on six specimens of surface roughness. The results are published as draft B report.

  Step Gauges (APMP L-K5): Thirty one steps are measured on a step gauge of length 620 mm. The results are published as draft B report.

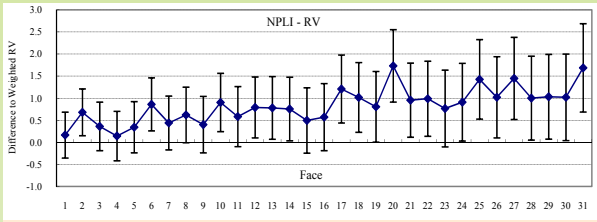


Fig. 5.2 Reference value of NPLI (Line Scale)

Line Scale (APMP L-K7): Thirty one steps are measured on a step gauge of length 620 mm. The results are published as draft B report.

Angle Gauges (Euromat L-K3): one eight face polygon standard and four angle gauge blocks were measured. The results were published as draft B report.

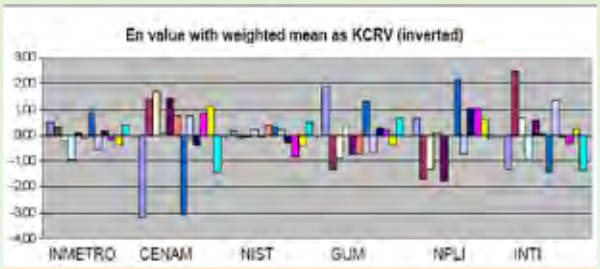


Fig. 5.3 En value with weighted mean (Angle gauge)

Gauge Blocks (APMP-DEC): Ten gauge blocks of steel and tungsten carbide were measured. The results are published.

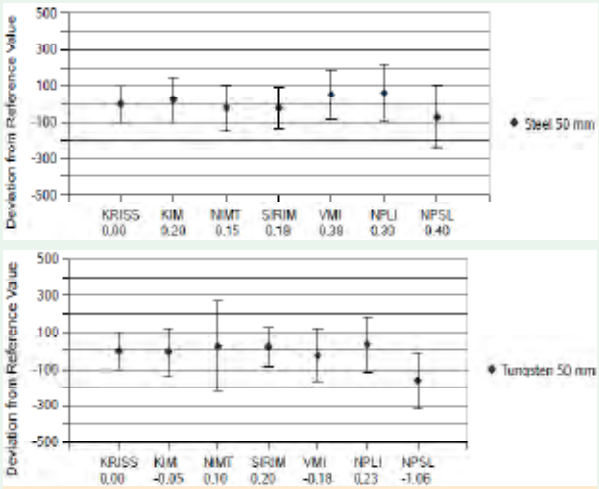


Fig. 5.4 Doviation from Reference value Gauge Blocks

III. Temperature and Humidity Standards

R & D Activities

- Temperature standard is maintained in the form of International Temperature Scale of 1990 (ITS-90). ITS-90 is defined on the basis of fixed points called the equilibrium states of pure substances and the defined standard thermometers. The traceability is maintained through platinum resistance thermometers calibrated on fixed points (Ar, Hg, TPW, Ga, In, Sn, Zn, Al and Ag), extending the range from 84 K to 1234 K and by photo-electric radiation pyrometer calibrated against high stability tungsten strip lamps traceable to PTB, Germany in the range from 1234 K to 2500 K. The total radiation thermometers are also traceable to international standards through comparison of blackbody source and tungsten strip lamps using standard radiation pyrometer. Thermocouples (Type-S or R) are directly traceable to ITS-90 by calibration on the fixed points (In, Sn, Zn, Al, Ag, Cu, Au and Pd). Fig. 5.5 shows the set-up for realization of fixed points by SPRTs.

Fig. 5.5 Set-up for Realization of Fixed Point by SPRTs

- The humidity standard is maintained through an aspirated psychrometer based on well matched dry and wet bulb temperatures of high precision quartz thermometers and pressure in a controlled humidity chamber. The quartz thermometers and pressure indicators are traceable to the international standards through NPL.
- The four CMCs in temperature parameter have been published in the Appendix-C of key comparison database (KCDB) of BIPM and remaining 28 CMCs are under reviewing process at APMP level.
- This Section is providing apex level calibration facilities for the temperature and humidity standards and instruments. A large number of instruments namely SPRTs, RTDs, LIGTs, Liquid baths, Dry-block Calibrators, Sensor based digital Indicators, thermocouples (S&R), optical and IR-pyrometers, Thermal imagers, tungsten strip lamps and blackbody sources were calibrated during this period. A significant ECF is generated through calibration of these instruments.
- In-house calibration-In addition to the above mentioned calibration work for outside customers, a number of Temperature indicators, Humidity & temperature meters, RH Indicators, RTDs, and Furnaces were also calibrated for various groups of NPL.
- For the 12th Five Year plan we have formulated an innovative project entitled "Determination of Boltzmann constant and realization of thermodynamic temperature by acoustic gas thermometry" with a tentative budget of 20 Crores. The project has been presented at various committees including NPL, RC.
- APMP key comparisons-This year our Group has prepared for the experimental facilities to participate in two APMP key comparisons, one in LIGT (-40 ºC to 250 ºC) and the other in Pt/Pd thermocouple on Co-C eutectic fixed point (1324 ºC) scheduled on August-September 2011.
- Participated in the APMP key comparison TK4 for freezing point of aluminum (660.323 °C), piloted by KRISS, Korea. The final draft report of the comparison concludes that NPL, India has qualified to obtain acceptable CMC entry for this fixed point.
- Our Group has participated in the CSIR Techno-Fest 2010 and presented two technologies developed at our laboratory namely, "Improved constant temperature bath" and "Portable Relative Humidity (RH) Generator" and our Theme Pavilion on Ecology & Environment was awarded with Gold Medal by DG-CSIR.

- Designed and developed of a "Compact Mixed Flow Relative Humidity Generator" to be used in the range of 5 % to 90 % RH. Its capacity to generate very low level of relative humidity of high accuracy and stability at low cost along with its easy portability would be enormously useful for the calibration of hygrometers employed for industrial and R&D environments.
- **National Collaboration with NABL**

  Our group is 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. Expertise is provided to NABL for laboratory accreditation in the field of thermal calibration. Expertise is also provided by attending the Accreditation Committee meeting relating to thermal area.
- **International Collaboration 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 kick-off workshop was organized during 24-25 November 2010, held at Hotel Clarion Collection, New Delhi. The workshop was attended by the participants from BSTI Bangladesh, NBSM Nepal, NPSL Pakistan, MUSSD Sri Lanka, ANSA Afghanistan, Bhutan and Maldives. 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). The workshop was financially supported by PTB, Germany.

Major Facilities

Work has been carried out to establish calibration facility for infrared total radiation pyrometers in the range from 600 ºC to 3000 ºC. The high temperature blackbody source, Model M390 of M/s MIKRON Infrared Inc. USA to be used in the calibration set up has been received and satisfactorily been installed in the Temperature & Humidity Standards. The measurements are under process in order to evaluate the calibration set-up for its use in the comparison of high temperature radiation pyrometers against the reference pyrometer and estimating the uncertainty in the measurement. This will be the new measurement facility for high temperature calibration. The results will be explored later. The photograph of the equipment is as shown in Fig. 5.6.

Fig. 5.6 High Temperature Blackbody Source (600-3000ºC)

IV. Optical Radiation Standards

The luminous intensity scale is traceable to international standard. The traceability is maintained through luminous intensity lamps which are calibrated from PTB, Germany. The scales for illuminance and illuminance responsivity are maintained through luminous intensity standard and standard illuminance meters. The illuminance meters are also traceable to international standards. Absolute scales of luminous flux are prepared using a Gonio-photometer. The scale is maintained through direct measurement of illuminance responsivity of the cosine corrected V(λ) matched silicon photodiode . 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.

This section is providing world class calibration facilities for the photometric parameters namely luminous intensity, luminous flux, luminance, illuminance, illuminance responsivity, colour coordinates and colour temperature. Numbers of light sources, illuminance meters, colorimeters and special type of light sources (e.g., signal lighting) were calibrated during this period. A significant ECF is generated through these calibration activities.

In addition to the above mentioned measurements, 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.

Research Highlights

Experimental investigations were carried out on anomalous spectral behaviour of polychromatic light in phase singularity domain. The study explores some very significant and interesting results. The impact of coherence and polarization change on polychromatic focused dark hollow Gaussian beam (DHGB) was investigated thoroughly (Fig. 5.7). On the basis of experimental and numerical analysis, the possibility and significance of DHGB based free-space optical (FSO) links for indoor and outdoor optical communications were explored.

In another study we derived some significant and interesting contrived ideas. We demonstrated a novel type scheme to encode and process information at multiple levels through spectral switching. A new technique was also investigated to establish multiple parallel FSO links using a single critical direction in phase singularity domain of diffracted polychromatic light. On the basis of theoretical and experimental studies on spectral switching, some multi-channel information processing schemes were demonstrated. These are contrived ideas but might have potential applications in optical computing, state-of-art techniques like SIMO (single input multiple output) and indoor FSO. The techniques might be exploited for formation of spectral switching based free-space optical interconnects and designing of (one input and N output ports) and (one input and output ports) channel optical information processors. These results will appear in different journals soon.

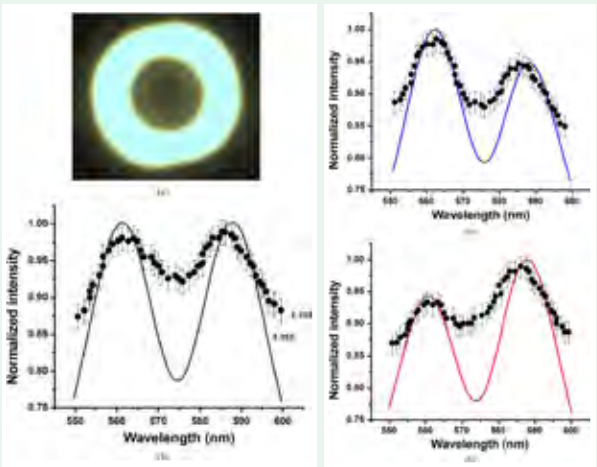


Fig. 5.7 Experimental observations of DHGB

V. Force and Hardness Standards

Emphasis is on enhancing calibration and measurement capabilities and establishing their equivalence with leading NMIs in force, torque and hardness parameters. It is also aimed to develop force and torque transducers of improved accuracy. The group is further engaged in providing technical support to industry and other user organizations in calibration of reference standards, providing training, etc. In recent years, work has been undertaken to develop force and torque standard machines in order to enhance force and torque calibration capability outside NPL.

The Brinell Hardness primary standard machine was commissioned and project completion report was sent to NABL/DST. The CMC realized with the machine was evaluated from the measured uncertainty of the force calibrated against a standard load cell and uncertainty of the measuring microscope using a standard stage micrometer, both traceable to NPL, U.K. The claimed CMC is 1.5% at k=2 for all scales. The facility was introduced in the Quality Management System & the calibration service to the customers was commenced.

The CMC realized by the Brinell hardness primary standard as well as Vickers primary standard were verified by calibrating standard blocks from a UKAS accredited laboratory and MPA, Germany and evaluating the normalized error, which is less than unity as shown in Fig. 5.8.

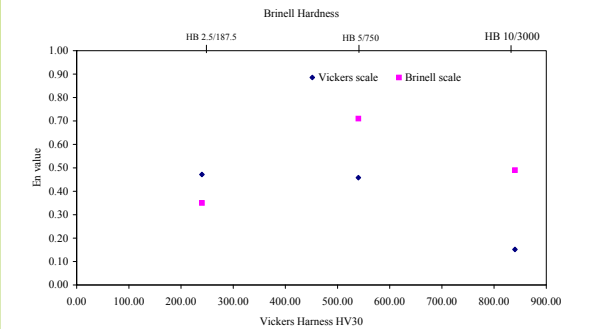


Fig. 5.8 Normalized error of Hardness values realized in Vickers and Brinell standard machines compared with values traceable to NMIs

The project by the Department of Legal Metrology for establishment of force and torque standard machines at the various RRSLs was completed with establishment of torque primary standard machines. As a corollary of this project, a 100 kN comparator force machine was developed procuring some components under the project (accuracy ~0.05%).

The one MN force standard machine (Fig. 5.9) was installed and commissioned by engineers from GTM, Germany. The infrastructure requirements such as strengthening of the floor, installation of the air-conditioning for appropriate temperature and humidity conditions, dust-free enclosure space, facility of the

Fig. 5.9 A view of 1 MN Force Standard Machine

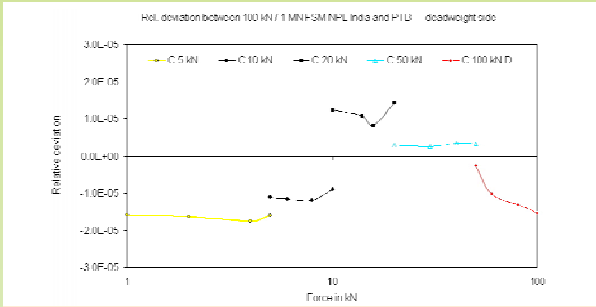


Fig. 5.10 Relative deviation of realized force in the range 1 to 1000 kN between NPL(I) and PTB (G) force standard machines

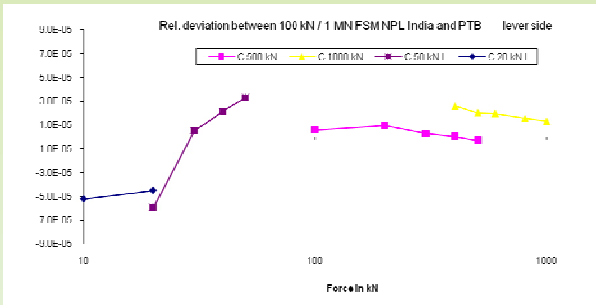


Fig. 5.11 Relative deviation of realized force in the range 1 to 1000 kN between NPL(I) and PTB (G) force standard machines

cranes for shifting and assembly heavy parts, etc. were arranged. The machine was commissioned and tested O.K. with the claimed uncertainty of applied force within 20 ppm on dead weight side and less than 90 ppm on the lever side. Inter-laboratory comparison of the machine was carried out with PTB using 8 transfer standards and was found to be satisfactory. The En ratio of the measured force values of the transfer standards in the NPL and PTB machines is shown in Fig. 5.10 and 5.11. It is seen that the En value is less than 0.5 for almost all steps from 1 to 1000 kN applied force on the dead weight side and the lever side. A certificate for verification of the claimed CMCs of the machine was provided by PTB.

APMP key comparison in Rockwell Hardness scales HRA and HRB was carried out. 16 standard hardness blocks were received from the pilot laboratory, NIMT, Thailand and were calibrated. Draft A of calibration results were communicated to the pilot laboratory. Key comparison results are awaited. APMP key comparison in Force at 50 kN and 100 kN was also carried out. Two force transducers of each of these two capacities were received from the pilot laboratory KRISS, Korea and were calibrated in the new one MN

force standard machine having the lowest uncertainty. The calibration results have been communicated to the pilot laboratory.

The ECF realized by providing national traceability in force, torque and hardness (Rockwell, Vickers and Brinell scales) parameters was approximately Rs 40 lakh. About 450 calibration reports were issued to different users during the year including first-ever site calibration of two torque calibration machines at M/s Kudale Calibration laboratory, Pune.

Major Facilities Established

One MN force standard machine having uncertainty of applied force less than 20 ppm on dead weight side and less than 90 ppm on the lever side was installed, commissioned and CMCs established.

VI (a). Vacuum and Pressure Standards

Research Highlights

- **Characterization Force Balance Piston Gauge**

One Force Balance Piston Gauge (FPG) is procured under Net work Project (NWP 45) and commissioned during July 01, 2010. This FPG can be used both in absolute and gauge mode measurements covering the range 1.0 Pa to 15.0 kPa. It is characterized against UIM, the Primary Pressure Standard and Gas operated Piston Gauge for gauge mode measurements in their overlapping pressure regions during July 2010 to December 2010. After equipping this FPG with 6 KVA on-line UPS (exclusively for Inductive Load: Rotary and Turbo Pumps), it is characterized against UIM for absolute mode measurements from February 2011 to June 2011.

Fig. 5.12 Force Balance Piston Gauge with support equipments

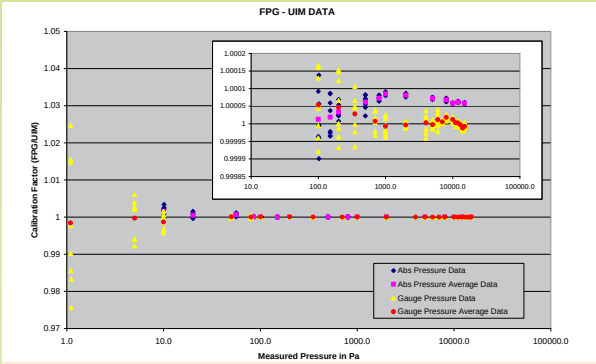


Fig. 5.13 FPG-UIM Data Force Balance Piston Gauge with support equipments

- **Effective Area Estimation of Piston-Cylinder assembly**
  - As given by DHI Calibration Certificate: 980.453 mm^2 (23ºC)
  - Estimated at NPL India : 980.473 mm^2 (23ºC)
- **Estimation of expanded uncertainty**
  - **Gauge Pressure :** Q(0.012 Pa, 0.0025 % of reading) at k=2 (1000 Pa).
  - **Absolute Pressure :** Q(0.012 Pa, 0.0024 % of reading) at k=2 (1000 Pa).
- **Proficiency Testing Program in the Barometric Pressure Region.**

Towards fulfilling its societal responsibility, NPL is organizing Proficiency Testing (PT) programs for the benefit of user industries and institutions, especially in the Barometric Pressure region, under NPL-NABL collaborative project CLP 003732 (NABL) covering three different pressure ranges, (i) 10.0 kPa to 260.0 kPa (abs), (ii) 10 kPa to 100.0 kPa (g) and (iii) -90.0 kPa to -10 kPa (g).

In response to the preliminary enquiry conducted among 243 NABL certified (in Mechanical Discipline) Institutions / Industries / Calibration Laboratories, 24 have consented to be participants in this PT Program.

Towards successful implementation of this program, an artifact that is to be used as Transfer Standard (TS) is indented, purchased, commissioned and characterized covering all the three ranges. A Carry Box with safety accessories is also designed and developed. A Technical Protocol that specifies the procedures to be followed in this Inter-laboratory comparison

has been prepared in accordance with the NABL Guidelines for Proficiency Testing Program for Testing and Calibration Laboratories (NABL Document No.: 162) After getting vetted from the Director, NPL, this Protocol is sent to all 23 participants. The travelling sequence of the Transfer Standard (TS) is planned in two loops: The first loop consists of 12 labs located in eastern and southern parts of India and the second loop consists of 12 labs located in northern and western parts of India. Presently the TS (Fig. 5.14) is traveling in the first loop, precisely at the third Lab of the loop.

Fig. 5.14 Travel Sequence for the TS

VI (b). Vacuum and Pressure Standards

Participation in International Key Comparison (CCM.P-K13)

NPLI has successfully participated in the CCM sponsored International Key Comparison (KC) (CCM. P.-K13) in the pressure range 50 MPa to 500 MPa of hydraulic gauge pressure. This KC was organised by the CCM High Pressure Working Group to obtain and renew the degree of equivalence to provide a link for regional KCs. The KC was piloted by PTB and carried out from November 2008 till March 2010. The group of selected participants originally included 9 laboratories with 2 representatives from EURAMET (PTB, Germany and LNE, France), 2 from COOMET (PTB, Germany and VNIIFTRI, Russia), 2 from SIM (NIST, USA and CENAM, Mexico) and 4 from APMP (NPLI, India, NMIJ, Japan, KRISS, Korea and NIM, China). One of them, VNIIFTRI, Russia, could not perform measurements because of problems with its standard. Also, KRISS, Korea withdrawn its participation after the release of Draft A report because their standard was broken.

The transfer standard was KC was a piston-cylinder of having nominal effective area of 2 mm2. Effective area of the transfer piston-cylinder unit was taken as a comparison parameter. Results of all the participants except NIM agree with the reference values and with each other within their estimated expanded uncertainties. Most of them agree even well within their standard uncertainties (including all results of NPLI, India) In addition, the results were analysed in terms of the zero pressure effective area and the pressure distortion coefficient. The results of the comparison demonstrate equivalence of the laboratory standards and of the Calibrating and Measurement Capabilities currently presented in the Key Comparison Data Base of BIPM. The deviation from the linear fit and KCRV values are shown in Figs. 5.15 (a) and 5.15 (b), respectively. The NPLI and NMIJ values would be used to provide linkage for the on going regional KC i.e. APMP. M. P-K13. The NPLI has already completed its measurements during January 2011.

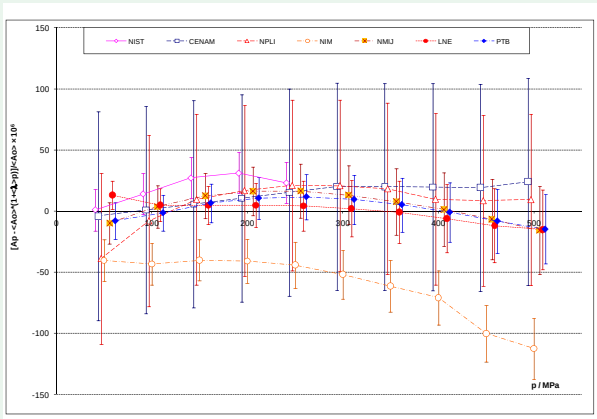


Fig. 5.15 (a) Relative deviations of the participants' results from the linear fit. Vertical bars are the standard uncertainties of the participants.

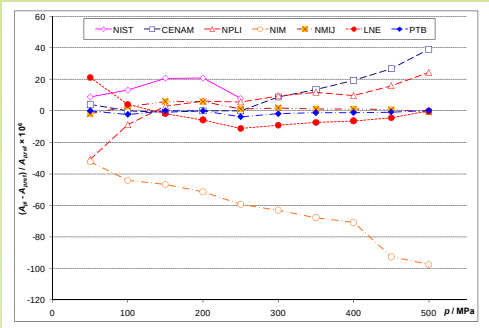


Fig. 5.15 (b) Relative deviations of the participants' results from the reference values

Final Report of the Proficiency Testing Programme

The NPLI organized a proficiency testing programme for 9 laboratories that are accredited by the National Accreditation Board for Testing and Calibration of Laboratories (NABL). The artifact used for the comparison was a pressure balance covering the pressure range (7 to 70) MPa. The comparison began during March 2008 and ended during April 2010. For assigning the reference values, the pilot laboratory (NPLI) carried out 3 calibrations of the transfer standard; the first one at the beginning, the second at the middle and the last one at the end of the programme. The comparison was carried out at 10 pressure points i.e. (7, 10, 15, 20, 25, 30, 40, 50, 60 and 70) MPa throughout the entire pressure range of (7 to 70) MPa. The measurements were carried out by each laboratory with their own resources (personnel, calibration systems, environmental conditions in their installations). The deviations for each laboratory were compared against the reference values and the compatibility of results was calculated using the normalized error value method. Out of the total 87 measurement results reported, 68 (78.2%) results are found in good agreement with the results of the reference laboratory (Fig. 5.16). The normalized error (En) values of 5 laboratories out of the total 9 were found well within +1 over the entire pressure range. However, 2 other laboratories had shown good agreement with reference values except one pressure point each. The En values of one of the participating laboratory were found beyond acceptable limits at all measurements points. Another laboratory had acceptable results only at 3 pressure points. The deviations between laboratory values and of the reference values were found well within the uncertainty band of the reference values for 37 % measurement results. The relative deviations for 82 measurement results were found well within 0.05 %.

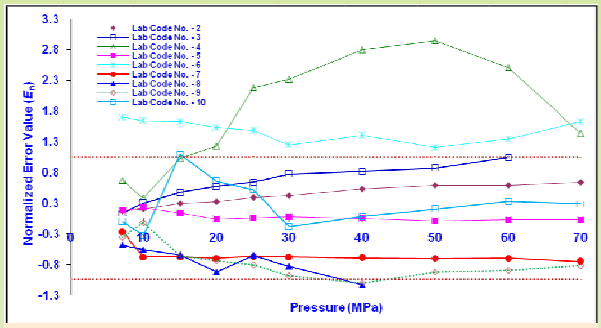


Fig. 5.16 The summary of the normalized error value (E_n) as a function of measured pressure (p') for each laboratory. The gap between two horizontal dotted lines shows the acceptable limit of the normalized error value.

VI (c). Pneumatic Pressure 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 are 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.

Further, another recent activity includes ANSYS simulation of the behaviour of piston-cylinder assemblies of our pneumatic dead weight testers to obtain the deformation profiles, strain, deformation coefficient etc. In this context, simulation has been carried out on 8 and 20 MPa piston-cylinder assemblies and the results published.

A proficiency testing program in pneumatic pressure range upto 50 bar was also started in which seven labs all over India are participating. This program was started in Nov. 2010 and is scheduled to be completed Sept. 2011.

Research Highlights

Anomalous high pressure behaviour under pressure has been reported and published in Dy_2O_3 and CeO_2. The former is expected to transform from cubic structure to monoclinic. However, due to its nanostructure, it progressed from cubic structure to hexagonal structure. The mechanism of such a transformation was discussed. Similarly, CeO_2 which was shown to have varying transformation pressures from cubic to orthorhombic structure when the particles have nano-size was found to undergo the same transition with unaltered pressures despite the sample being of nano-size.

In continuation of this work, Tb_4O_7, HO_2O_3, Yb_2O_3 and PrO_2 were also studied under high pressures. The detailed analysis of results is underway.

Raman Spectra of HO_2O_3 at increasing Pressure

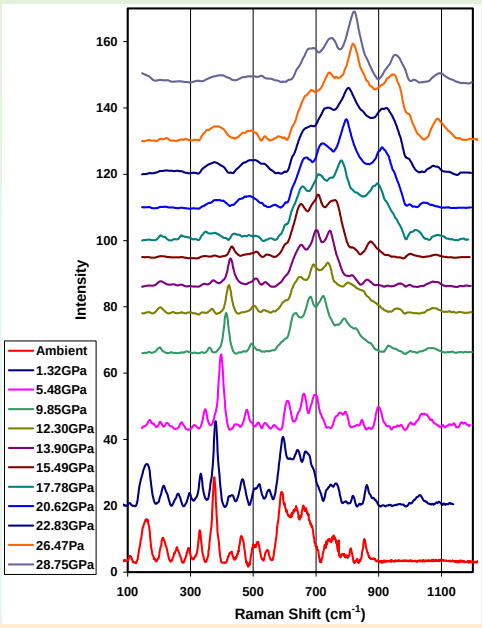


Fig. 5.17 Increase drop presure

In our simulation studies on the piston-cylinder assemblies using ANSYS, excellent agreement between the experimentally obtained and simulated results were obtained wherein the agreement between the simulated and experimental effective area was found to be about 5 ppm at 8 MPa pressure.

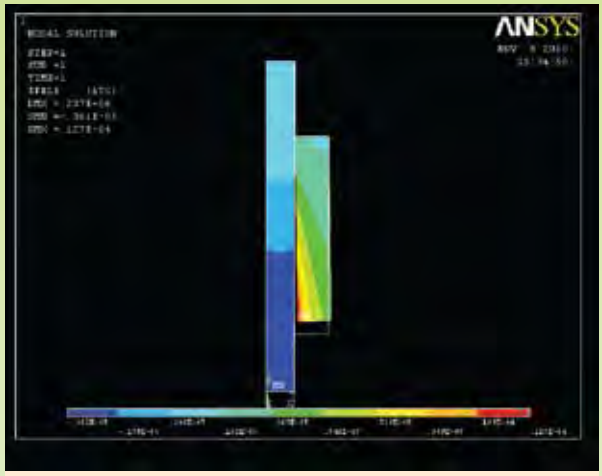


Fig. 5.18 Image of distroted piston cylinder ausembly after ANSYS simulaction in free depormation mode

VII. Acoustics, Ultrasonics, Shock and Vibration Standards

1. Noise Abatement

The section had been engaged in numerous consultancy projects sponsored by Archaeological Survey of India and private organization (M/s Fenesta Building system, Gurgaon) for noise and vibration abatement. The experimental investigations conducted in reverberation chamber in conjunction with theoretical analysis has led to very interesting conclusions. An exhaustive testing of sound transmission loss through window glazing's viz., single, double and triple was done with the collaboration of M/s Fenesta Building systems, Gurgaon. The findings of study have been published.

2. Expansion in frequency range in Vibration metrology

The new facility of primary vibration calibration standard in extended frequency range of 0.1 Hz to 20 kHz has been established in Acoustics standard this year. Although this facility, being a commercial system, there are numerous investigations carried out for preparation of uncertainty budgets, 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 CMCs for vibration have been posted for inter-RMO review. The primary vibration calibration standard of NPL was commissioned this year Fig. 5.19. The system is capable of calibrating the reference accelerometers in frequency range from 0.1 Hz to 20 kHz as per ISO 16063-11. The

system has been procured from TMS, Modal Shop, USA.

Fig. 5.19 Primary Vibration Calibration Standard

3. Correlation of Vibration with acoustic excitation

A comprehensive investigation on vibration induced due to acoustic excitation was conducted to ascertain the criteria for damage in buildings due to high acoustic loads. Extensive investigation was carried out to correlate the vibration induced due to acoustic excitation in diffuse field conditions and the empirical formulations developed have been extrapolated to free-field conditions to ascertain the maximum levels of vibration induced due to high acoustic loads.

4. Intercomparison CCAUV.U –K3

Ultrasonic transducers are best characterized by measurement of their total power output. NPL maintains Primary Standard of ultrasonic power using radiation force balance, developed indigenously in the laboratory (Fig.2). An international inter-comparison (BIPM/ CIPM key Comparison) CCAUV.U –K3 was carried out between 11 laboratories of various countries with PTB Germany as nodal laboratory. For this purpose, NPL's radiation force balance was modified as stated below for making excellent improvements and obtaining better uncertainty.

a. Measurement of temperature of water required a sensor that could be placed in water very near to the target causing no distortion to the ultrasonic beam. A digital Temperature Sensor using silicon chip was designed, fabricated and calibrated at NPL

b. A $LiNbO_3$ transducer was fabricated for checking the performance and working of the ultrasonic power measurement system.

c. An absorbing target of 50x60 mm2 size was designed and fabricated with suspension arrangement and weighing about 10 gm when submerged into water.

d. For shielding against the environmental disturbances, a Perspex Chamber was designed and got fabricated for housing the radiation force balance.

A novel approach in this intercomparison was an average of 600 independent observations taken with variations in ultrasonic power-on-time, separation between transducer and target and by complete dismantling and reassembling.

Fig. 5.20 Radiation Force Balance

5. Ultrasonic Characterisation of Snow

Feasibility study of ultrasonic characterisation of snow was completed with a view to increase the accuracy in prediction of avalanche. The study was done at -20ºC in the Cold Lab of Snow and Avalanche Study Establishment, Manali. Samples of snow with varying porosity and crystalline structure were used in the study.

6. 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. The major parameters of the developed transmitter are as follows.

a. Tone frequency adjustable from 30kHz to 100kHz

b. Pulse Repetition Frequency RR adjustable from 1Hz to 10Hz

c. Pulse duration 10 cycles/ burst

d. Output impedance less than 1Ω.

e. Loaded transducer output voltage 400 Vpp

The transmitter (Fig. 5.21), complete with electronics and tubular piezoelectric transducer (made at NPL), was tested in Chennai NIOT tank. It was derived at 125 Vpp drawing a current of 1.6 amperes (pp) with the help of L2 amplifier and function generator. The receiver circuit (Fig. 5.22) made at NPL was tried using NIOT's Massa transmitter 1025C.

The system worked very well and showed accurate distances of reflectors on a digital display.

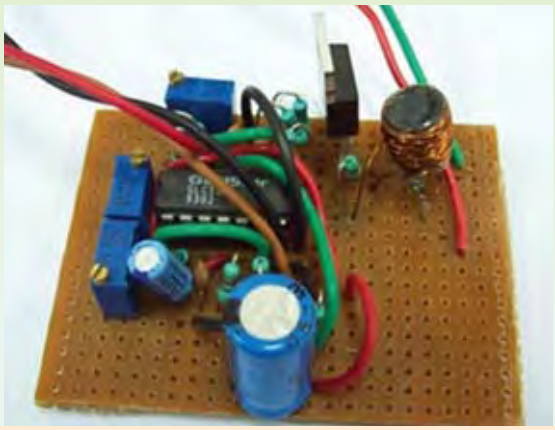


Fig. 5.21 Transmitter of object detector

Fig. 5.22 Receiver of Object Detector

7. Electro-Magnetic Acoustic Transducer System

For the residual stress measurement in metallic blocks, an Electro-Magnetic Acoustic Transducer System (Fig. 5.23) has been fully installed at NPL. Finding out the time of flight to a resolution up to 1ns has been a challenging problem. Using a digitizer with a sampling rate of 2GS/s and interfacing it with receiver circuit using Lab VIEW, it has been possible to measure ultrasonic time of flight to a resolution of 0.3 ns.

Fig. 5.23 EMAT transducer on an aluminium block

VIII. Fluid Flow Measurement Standards

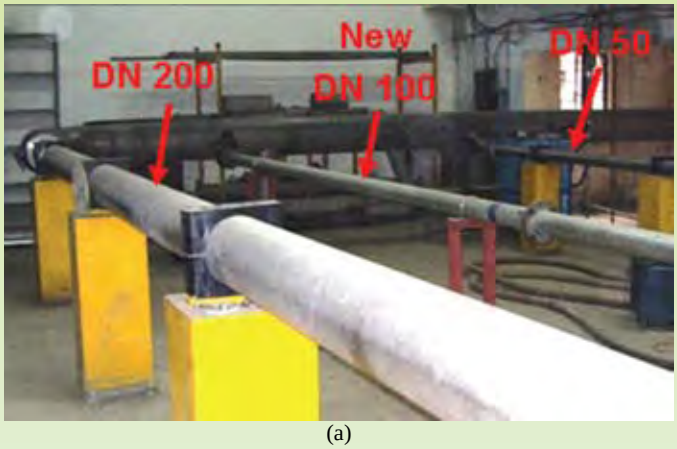
The Fluid Flow Measurement Standards group has the mandate to provide apex level testing and calibration services for the different types of domestic and industrial water flowmeters. The group has a Water Flow Calibration Facility (i.e. Primary Standard of Flow) comprising of two Test Rigs of sizes DN50 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.

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. This facility is traceable to National Standards of Mass, Temperature, Time & Frequency and Pressure Standards of NPLI. During this period, total 12 test reports were issued and an ECF of Rs. 1,95,928/- was generated for NPL.

Major Facilities developed/created/established

Presently, a Water Flow Calibration Standard (i.e. Primary Standard of Flow) of size DN100 has been designed and is being developed in technical collaboration with

M/s. Bharti Automation Pvt. Ltd., New Delhi. A novel design technique would be used to reduce the diverter error which is a significant source of uncertainty. The different parts of this system i.e. Weighing Tanks, Load Cells, Flow Control Valves, Drain Valves, Flowmeters, On/Off valves, Diverter, Fishtail, pneumatic pipes, pressure regulator devices, etc. have been installed and integrated. Now automation work of this prototype system is in progress. Fig. 5.24 shows the photograph of this new system.



(a)

(b)

(c)

Fig. 5.24 Photographs of a New Water Flow Calibration Standard

क्वान्टम परिघटना एवं अनुप्रयोग

Quantum Phenomena and Applications

क्वान्टम परिघटना एवं अनुप्रयोग

पहली बार अत्यधिक अभिविन्यस्त बहु–क्रिस्टलीय $Sm_{0.55}$ $Sr_{0.45}MnO_3$ तनु परतों {(001) पर $LaALO_3$, $SrTiO_3$ और एल एस ए टी उप–संस्तर} तैयार की गई तथा चुंबकीय और परिवहन गुणों पर ऑक्सीजन रिक्तियों द्वारा उत्पन्न शमित अक्रम विकार तथा उप–संस्तरों द्वारा प्रेरित विकृति के प्रभावों का अध्ययन किया गया। यह ज्ञात हुआ कि शमित अक्रम विकार ऑक्सीजन रिक्तियों की क्रम व्यवस्था/अक्रम विकार तथा उप–संस्तरों द्वारा प्रेरित विकृति के स्वरूप से काफी अधिक संबंधित है। ऑक्सीजन रिक्ति द्वारा प्रेरित परतों द्वारा वर्धित T_C/T_{IM} =165 K प्रदर्शित होता है। T_C/T_{IM} में अधिक संवर्द्धन की परिघटना की व्याख्या स्थानिक रूप से असमरूप विकृति तथा क्रमिक ऑक्सीजन रिक्तियों के प्रभाव द्वारा उत्पन्न सह–संबंधित शमित अक्रम विकार के परिणाम के रूप में की जाती रही है। ऑक्सीजन रिक्ति अक्रम विकार और साथ ही तपानुशीतन के फलस्वरूप अनुचुंबकीय तथा रोधी–धातु संक्रमण तापों में काफी अधिक कमी आती है।

पहली बार प्रयोग द्वारा विद्युत क्रॉस–स्पेक्ट्रमीय घनत्व मैट्रिक्स और प्रसामान्यीकृत स्टॉक्स पैरामीटरों को ज्ञात किया गया तथा हमने यंग इंटरफेरोमीटर के आशोधित रूप में विद्युत चुंबकीय व्यतिकरण नियम का सत्यापन किया। हाल में यह ज्ञात हुआ है कि कतिपय दशाओं के अंतर्गत तापीय प्रकाश या पहले से ही सह–संबंद्ध प्रकाश बाधित फोटोन युग्मों के गुणों का अनुकरण करते हैं। हमने पुनर्संरचित प्रतिबिंब की गुणवत्ता और विभेदन से संबंधित विभिन्न पैरामीटरों के प्रभाव का अध्ययन करने के लिए निकट क्षेत्र और दूर क्षेत्र प्रयोग किए हैं। अपने संचरण अक्ष के अनुदिश प्रावस्था विचित्रता का वहन करने वाले प्रकाश पुंजों के सदिश ध्रुवन का अध्ययन करने के लिए भी प्रयोग किए गए हैं। प्रणाली के म्युलर मेट्रिक्स का मूल्यांकन करने के साथ ही ध्रुवण मात्राओं का भी निर्धारण किया गया है और इस व्यवस्था को ध्रुवण व्यवस्था के रूप में कार्य करते हुए देखा गया है। क्लासिकल ऑप्टिकल्स में ध्रुवण द्वारा बाधित फोटोनों को प्राप्त करने के लिए एक नई तकनीक की भी खोज की गई है।

कैंसर–रोधी औषधियों (विनक्रिस्टाइन, विनब्लास्टाइन, कार्बो–प्लेटिन आदि) का डी एन ए के साथ अंतःसंबंध का अध्ययन करने के लिए अवरक्त तथा रामन स्पेक्ट्रम विज्ञान की उपादेयता का उपयोग किया गया। अस्पतालों से कैंसर पीड़ितों की छाती से ताजे, सामान्य और सांघातिक ऊतकों को संगृहीत किया गया तथा फूरिये रूपांतरण अवरत स्पेक्ट्रमिकी का प्रयोग करके उसका विश्लेषण किया गया। हम कुछ महत्त्वपूर्ण आई आर शिखरों को चिह्नित करने में सफल हुए, जो सामान्य या कैंसरयुक्त ऊतक में से किसी एक में ही अवस्थित होते हैं। रोडोप्सिन प्रोटीन अणुओं में लेज़र–प्रेरित असंरेखीय अवशोषण प्रक्रमों का सैद्धांतिक विश्लेषण किया गया है। कुछ हाल में संश्लेषित प्रकाशवर्णी आण्विक तंत्रों के अरैखिक ट्रांसमिशन अभिलक्षणों का भी विश्लेषण किया गया है।

हमने $NdFeAs_{0.50}F_{0.20}$ के अति चालकता नमुने का सॉलिड–स्टेट अभिक्रिया विधि से एकल चरण में एक निर्वातित (10^{-3} Torr) क्वार्टर्ज संपुविकरण (Tube) मे बनाया। इस तंत्र का स्थान समूह P4/nmm) मे चतुष्कोणीय संरचना पाया गया, तथा 50 K ताप पर अतिचालकता प्रदर्शित की गई, जिसमे निम्न क्रांतिक क्षेत्र लगभग 0.1 Tesla पर H_{c1}(5K) तथा अति उच्च ऊपरी क्रांतिक क्षेत्र 4_{c2} 350 Tesla पाया गया। ताप वैधुत क्षमता (TEP) ऋणात्मक पाई गई और वह क्रांतिक ताप T_c तक थी, जिसे यह सिद्ध हुआ कि $NdFeAs_{0.80}F_{20}$ अति चालक मे प्रभावी वाहक n-type (प्रकार) के है। इस यौगिक के भौतिक गुणों के व्यापक अभिलक्षणों का वर्णन यूरो फिजिक्स, जे.बी.79, 139–146 (2011) में किया गया है। बेहतर निष्पादन हेतु संश्लेषण ताप के प्रभाव का अध्ययन nano (n)-SiC मिश्रित स्थूल MgB_2 अति चालक के प्रावस्था निर्माण के संदर्भ में किया गया है। हमने अध्ययन किए गए ऋणात्मक–n-SiC डोपित और 140 KOe क्षेत्र के अंतर्गत 750 डिग्री सेल्सियस पर संश्लेषित MgB_2 के लिए उपर्युक्त 15K के Tc(R=0) का इष्टतमीकरण किया

है, जो विभिन्न प्रकार से प्रक्रमित और अति सूक्ष्म कणों से युक्त MgB_2 को प्राप्त करने के लिए अब तक प्रयुक्त सर्वोच्च मान है। इससे संबंधित परिणामों की रिपोर्टें सप्लीमेंटरी साइंस एंड टेक्नोलॉजी 24,045013 (2011) में प्रकाशित की गई हैं। स्थूल बहु–क्रिस्टलीय Bi_3N_i अति चालक पदार्थों को निर्वात संपुटिकरण विधि द्वारा संश्लेषित किया जाता है और इसके अति चालक गुणों का विस्तार से अध्ययन किया जाता है। प्रायोगिक और सैद्धांतिक अर्थात घनत्व प्रकार्यात्मक गणना द्वारा इलेक्ट्रॉनिक संरचना पर विचार–विमर्श किया जाता है। यह ज्ञात हुआ है कि इस अति चालक में अवस्था घनत्व में प्रधान भूमिका अधिकतर छप द्वारा निभाई जाती है तथा Ni(3d) और Bi (sp) के प्रबल कक्षीय संकरन के कारण यह अचुंबकीय स्वरूप का है। संबंधित परिणाम की रिपोर्टें सप्लीमेंटरी साइंस एंड टेक्नोलॉजी 24,08522 (2011) में प्रकाशित की गई हैं। Sm(4f) और CO(3d) चक्रणों की जटिल अंतर–क्रिया SmCoAsO में प्रदर्शित होती है। यह यौगिक Fe आधारित निकटाइड अति चालक परिवार से संबद्ध है और समसंरचनात्मक SmFeAsO की तुलना में लुप्त अति चालकता को समान रूप से प्रदर्शित करता है। संबंधित परिणाम की रिपोर्टें फिजिक्स रिव्यू बी 81, 212501 (2010) में प्रकाशित की गई हैं।

Quantum Phenomena and Applications

Highly oriented polycrystalline $Sm_{0.55}Sr_{0.45}MnO_3$ thin films (on (001) $LaALO_3$, $SrTiO_3$ and LSAT substrates) were prepared for the first time and the effect of quenched disorder caused by oxygen vacancies and substrate induced strain, on the magnetic and transport properties was investigated. Quenched disorder is found to be related intimately to the ordering/disordering of the oxygen vacancies and the nature of substrate induced strain. on the magnetic and transport properties was investigated. Quenched disorder is found to be related intimately to the ordering/disordering of the oxygen vacancies and the nature of substrate induced strain. Oxygen vacancy ordered films show enhanced T_C/T_{IM}≈165 K. The large enhancement in T_C/T_{IM} has been explained as a consequence of correlated quenched disorder caused by the effect of spatially non-uniform strain and ordered oxygen vacancies. The paramagnetic-ferromagnetic and insulator-metal transition temperatures are reduced appreciably by oxygen vacancy disordering as well as oxygen annealing.

For the first time, the electric cross-spectral density matrix and the generalized Stokes parameters were realized experimentally and the electromagnetic interference law was also verified by us in a modified version of the Young's interferometer. Recently it was found that under certain conditions thermal light or classically correlated light mimics the properties of entangled photon pairs. We have performed experiments at near field and far field to study the influence of various parameters on the quality and the resolution of the reconstructed image. Experiments are also performed with optical beams carrying phase singularity along its axis of propagation to study its vector polarization. Polarization quantities are quantified with the evaluation of Mueller matrices of the system and the setup is observed to perform as a polarization filter. A new technique for obtaining polarization entangled photons in classical optics is also explored.

Potential of Infrared and Raman spectroscopy was explored to study the interaction on anti cancer drugs (Vincristine, Vinblastine, Carboplatin, etc.) with DNA. Fresh, normal and malignant breast tissues were collected from hospital and analyzed using Fourier transform infrared spectroscopy. We were able to mark some important IR peaks which are present only in either normal or cancerous tissue. Theoretical analyses of laser induced nonlinear absorption processes in rhodopsin protein molecules have been performed. Nonlinear transmission characteristics of some newly synthesized photochromic molecular systems are also analyzed.

$NdFeAsO_{0.80}F_{0.20}$ system synthesized by a single step, via solid-state reaction route by encapsulation in an evacuated (10^{-3} Torr) quartz tube, crystallized in teragonal structure with space group P4/nmm. It showed superconductivity at 50 K with lower critical field H_{c1}(5K) around 0.1 T and a very high upper critical field H_{c2}(0) of up to 350 Tesla. Thermo-electric power (TEP) is negative down to T_c, thus indicating doninant carriers to be of n-type in $NdFeAsO_{0.80}F_{0.20}$ superconductor. Effect of synthesis temperature is studied on the phase formation of *nano*(*n*)-SiC added bulk MgB_2 superconductor for its better superconductor for its better performance. We optimized the $T_c(R = 0)$ of above 15K

for the studied n-Sic Doped and 750ºC synthesized MgB_2 under 140 kOe field, which is one of the highest values yet obtained for variously processed and nano-particle added MgB_2 in literature to our knowledge. Bulk polycrystalline Bi_3Ni superconductor is synthesized by vacuum encapsulation method and its superconducting properties are studied in detail. Both experimental and theoretical, i.e. electronic structure from density functional calculations are discussed. It is found that in this superconductor the density of states are mostly dominated by Ni and it is non-magnetic in nature due to strong Ni(3d) and Bi(sp) orbital hybridization. The complex interplay of the Sm(4f) and Co(3d) spins is seen in SmCoAsO. The compound belongs to the Fe based pnictide superconductors family, and brings out the fact of missing superconductivity in the same in comparison to iso-structural SmFeAsO.

I. Quantum Transport in thin film hetreostructures

Magnetic tunnel junctions (MTJ) have attracted increased intense attention in recent time due to potential applications as magnetic random access memory and high-density read/write heads. Spin dependent tunneling leads to a very large magnetoresistance (MR) in the ferromagnet/insulator/ferromagnet multilayer. The electron transport properties are critically dependent on the quality of the tunneling barrier, with MgO being the overwhelming choice. For improving the quality of MTJ, maximizing the MR is still an important goal. The MR value depends on the spin polarization of the top and bottom ferromagnetic layers and the quality of the MgO. Fabrication of high quality junctions requires that the barrier be free of pinholes, smooth and has proper stoichiometry.

Ni thin films were deposited on (100) Si substrates using DC magnetron sputtering with a base pressure $2x10^{-6}$ Torr. The nickel thin films were characterized by X-ray diffraction and AFM. Ni thin films were found to be smooth by AFM with average roughness of 1.35 nm and textured by X-ray diffraction with a texture coefficient of 0.77 for (111) reflection. MgO thin films which act as barrier between two ferromagnetic films were deposited by RF magnetron sputtering. X-ray diffraction scan of MgO thin films shows the (200) peak as the predominant peak. The junctions were grown using shadow masks with the structure Ni (500A)/MgO (20A)/Ni (500A).

Impact of quenched disorder in rare earth doped manganites

Quenched disorder arises due to the cationic size mismatch, oxygen vacancy, valence fluctuations, etc. and plays a crucial role in deterring the magnetoelectronic properties in low bandwidth manganites.

(a) Enhanced ferromagnetic and metal insulator transition in $SmO_{0.55}Sr_{0.45}MnO_3$ thin films

We have synthesized polycrystalline $Sm_{0.55}Sr_{0.45}MnO_3$ (SSMO) thin films and investigated the effect of the substrate induced strain and oxygen vacancy ordering/ disordering on the magnetic and transport properties. This compound shows a T_C~135 in single crystalline form. In contrast we observed a T_C/T_{IM}~165 in films annealed in air (S-A, Fig. 1&2). Oxygen annealing (S-O, Fig. 6.1 & 6.2) and quenching after air annealing (S-Q, Fig. 6.1 & 6.2), both lead to lower T_C ~130 K and ~135 K, respectively. The large enhancement in T_C/T_{IM} observed in films annealed in air has been explained as a consequence of correlated quenched disorder caused by the effect of spatially non-uniform strain and ordered oxygen vacancies. Quenched disorder is related to the ordering of oxygen vacancies and its impact is also reflected in the electrical transport in these films. (Published in Appl. Phys. Lett. 97, 182503 (2010)).

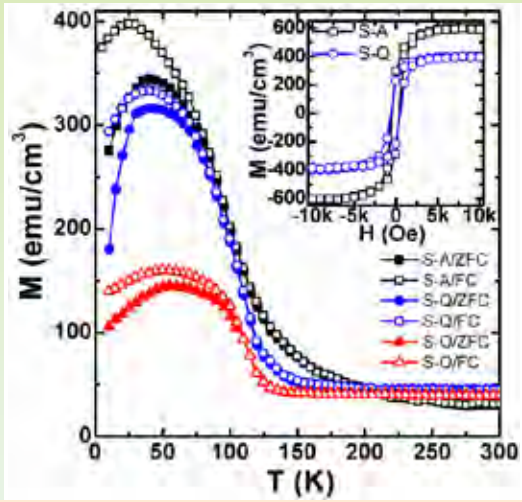


Fig. 6.1 Temperature dependent ZFC (solid symbols)/FC (open symbols) magnetization of the SSMO films. The M-H loop of the S-A and S-Q film is inserted in the inset

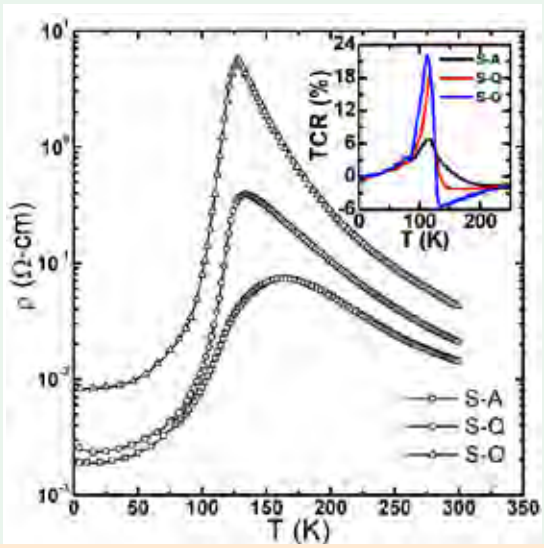


Fig. 6.2 Temperature dependent resistivity of the SSMO films. The inset shows the temperature coefficient of resistivity of the three films.

(b) Impact of size mismatch induced quenched disorder on phase fluctuation and low field magnetotransport in polycrystalline $Nd_{0.58-x}Gd_xSr_{0.42}MnO_3$

We have studied the effect of the quenched disorder arising from the size disorder (measured by the variance σ^2) at the RE site in polycrystalline $Nd_{0.58-x}Gd_xSr_{0.42}MnO_3$. Although both T_C and T_{IM} are observed to decrease with increasing σ^2 the former becomes broad while the latter is sharpened. This feature is attributed to phase fluctuation due to the size disorder caused by Gd doping. The large difference in the T_C and T_{IM} at lower values of σ^2 suggests the dominance of the grain boundary disorder over the quenched disorder/phase fluctuation. Gradual sharpening of the insulator metal transition (IMT) with increasing σ^2 is followed by very sharp metallic transition around σ^2=0.009 857Å^2 (Fig. 6.3). At further higher σ^2 the T_{IM} again becomes smaller than T_C and IMT finally vanishes.

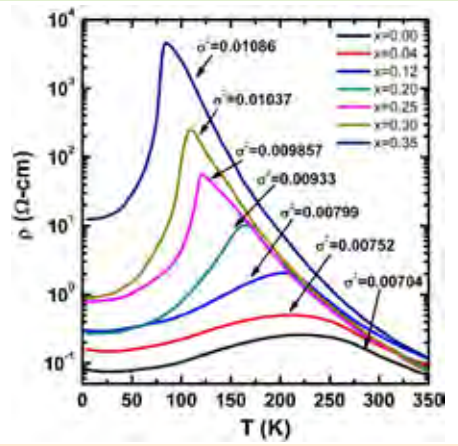


Fig. 6.3 Variation of resistivity as a function of Temperature of $Nd_{0.58-x}Gd_xSr_{0.42}MnO_3$ and variance σ^2.

Large low field MR observed in the vicinity of σ^2=0.009 857Å^2 (Fig. 6.4) demonstrates the importance of quenched disorder/phase fluctuation in manganites. (Published in J. of Applied Physics 107, 09D726 (2010)).

II. Nanoscale Measurements

In this group, R&D relating to realization of unit Metre and traceable nano dimension measurements are carried out. During this year realization of SI unit metre as per the recommendations of BIPM was continued. The metre is realized through an He-Ne Laser whose Frequency is Stabilized w.r.t hyperfine transitions

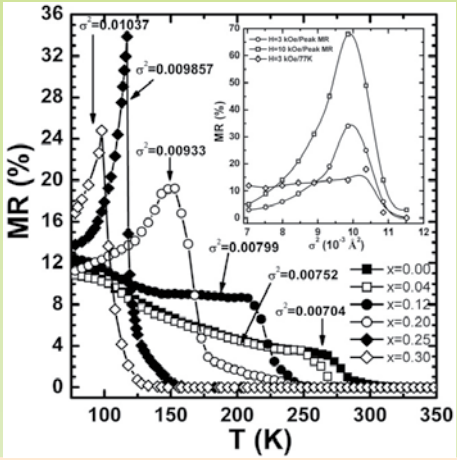


Fig. 6.4 Temperature dependence of MR measured at magnetic field H=3 kOe. The inset shows the variation of peak MR (%) with σ^2.

127I2. The traceability to metre was provided through calibration and testing.

A new facility 'Fizeau interferometer with phase shifting and automatic computation has been installed and was established for measurement of flatness of optical flats. Various optical flats of flatness ranging from λ/60 to λ/10 were measured. Values obtained by three flat test on λ/20 flats compared well with those given by NPL UK , in their calibration certificates.

In nanotechnology, nanodimension measurement plays an important role. Various instruments like SPM 's are used for such Nanomeasurement. Traceability of such measurements is essential for ensuring comparability of nanomeasurement. To fulfill such emerging needs of Nanometrology NPL is carrying out a project" Generic Development of Nanometrology for Nanotechnology at NPL-I" funded by Department of Information Technology, Ministry of Information Technology. The Optical profiler established under this project was applied to measurement of roughness of Mass standards, silicon wafers, MEMS, Roughness standards and step heights etc. An activity was initiated to understand the difference between nano particle sizes determined by various characterization techniques. ZnS and ZnS-Si nanoparticles were developed and characterized using XRD, UV-VIS spectra, Photo Luminescence, SEM and TEM methods. A method for measurement of aperture area using imge processing techniques was developed.

III. 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 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.

Potential of Infrared and Raman spectroscopy was explored to study the interaction on anticancer drugs (Vincristine, Vinblastine, Carboplatin, Amsacrine, Epirubicin, 5-Fluorouracil) with DNA. Different molar ratios of anticancer drugs with constant DNA concentration were prepared in aqueous solution at physiological conditions and subsequently analyzed to find the binding constant, binding mode and the effect of drug-DNA complexation on stability and secondary structure of DNA.

Ninety samples (45 pairs) of fresh, normal and malignant breast tissues were collected from Max Super Specialty hospital, New Delhi and analyzed using Fourier transform infrared spectroscopy. The malignant tissue showed appreciable biochemical deviations from their normal forebears in all the cases. The changes occurring in NADH (Nicotinamide adenine dinucleotide phosphate) and FAD (Flavin adenine dinuleotide), cellular energy molecules, in cancerous tissues with respect to their normal counterpart were examined. We were able to mark some important IR 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 were 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 polarization when a fundamental mode from an intensity stabilized laser is transformed into phase singular beam. Mueller matrix approach is adopted to quantify changes in polarization in diffracted orders of the computer generated hologram containing optical vortices. Decomposition of the Mueller matrices is used to evaluate the polarizing properties, such as diattenuation, retardance and depolarization of the diffractive device. We observe the crossing of two polarization components of vortex photons in which orthogonally polarized states are found to have equal probability for the incident state. This indicates that the setup can lead to the genesis of a new technique for obtaining polarization entangled photons. In addition, the same polarization behaviour for the central order and vortices reveals that the spin angular momentum and orbital angular momentum of photons are not coupled. Polarization discrimination observed for various cases shows that the setup can work as a polarization filter. It is also showed that setup behaves as a weak diattenuator but has significant retardance for each diffracted order.

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.

IV. Superconductivity: Materials and Dissipation Physics

NdFeAsO/F- We report an easy *single step* synthesis route of title compound $NdFeAsO_{0.80}F_{0.20}$ superconductor having bulk superconductivity below 50 K. The title compound is synthesized via solid-state reaction route by encapsulation in an evacuated (10^{-3} Torr) quartz tube. Rietveld analysis of powder X-ray diffraction data shows that compound crystallized in tetragonal structure with space group *P4/nmm*. *R(T)H* measurements showed superconductivity with T_c (R=0) at 48 K and a very high upper critical field (H_{c2}) of up to 345 Tesla (Fig. 6.5). Magnetic measurements exhibited bulk superconductivity in terms of diamagnetic onset below 50 K. The lower critical field (H_{c1}) is around 1000 Oe at 5 K. In normal state i.e., above 60 K, the compound exhibited purely paramagnetic behaviour and thus ruling out the presence of any ordered FeO_x impurity in the matrix. In specific heat measurements a jump is observed in the vicinity of superconducting transition (T_c) along with an upturn at below T=4 K due to the AFM ordering of Nd^{+3} ions in the system. The Thermo-electric power (TEP) is negative down to T_c, thus indicating dominant carriers to be of n-type in $NdFeAsO_{0.80}F_{0.20}$ superconductor. The granularity of the bulk superconducting $NdFeAsO_{0.8}F_{0.2}$ sample is investigated and the intra and inter grain contributions have been individuated by looking at various amplitude and frequencies of the applied AC drive magnetic field.

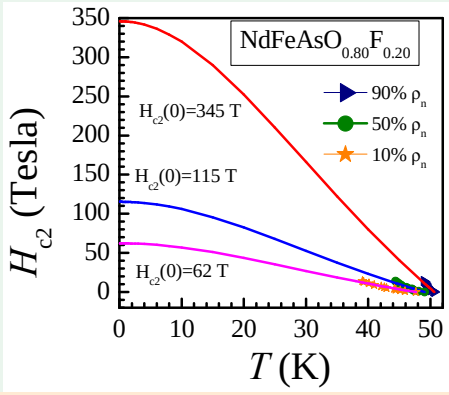


Fig. 6.5 Upper critical field (Hc2) for single step synthesized NdFeAsO/F superconductor.

MgB_2+nSiC- We study the effect of synthesis temperature on the phase formation in *nano(n)*-SiC

added bulk MgB_2 superconductor. In particular we study: lattice parameters, amount of carbon (C) substitution, microstructure, critical temperature (T_c), irreversibility field (H_{irr}), critical current density (J_c), upper critical field (H_{c2}) and flux pinning. Samples of MgB_2+(n-SiC)$_x$ with x=0.0, 0.05 & 0.10 were prepared at four different synthesis temperatures i.e. 850, 800, 750, and 700ºC with the same heating rate as 10ºC/min. We found 750ºC as the optimal synthesis temperature for n-SiC doping in bulk MgB_2 in order to get the best superconducting performance in terms of J_c, H_{c2} and H_{irr}. Carbon (C) substitution enhances the H_{c2} while the low temperature synthesis is responsible for the improvement in J_c due to the smaller grain size, defects and nano-inclusion induced by C incorporation into MgB_2 matrix, which is corroborated by elaborative *HRTEM* (high-resolution transmission electron microscopy) results. We optimized the the T_c(R=0) of above 15K for the studied n-SiC doped and 750ºC synthesized MgB_2 under 140 kOe field (Fig. 6.6), which is one of the highest values yet obtained for variously processed and nano-particle added MgB_2 in literature to our knowledge.

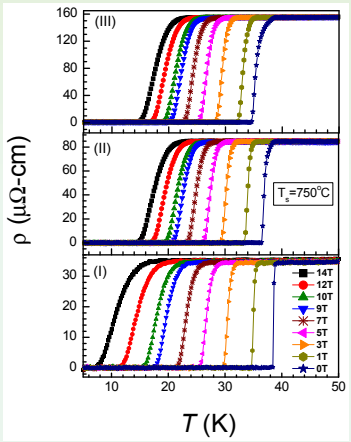


Fig. 6.6 Resistivity versus temperature plots under magnetic field for MgB_2+n-Sic superconductor

SmCoAsO- We present detailed magnetization and magneto-transport studies on the title compound SmCoAsO. SmCoAsO undergoes successive paramagnetic (PM) – ferro-magnetic (FM) – anti-ferro-magnetic (AFM) transitions with decrease in temperature. This is mainly driven via the c-direction interaction of Sm4f (SmO layer) spins with adjacent (CoAs layer) ordered Co^{3d} spins. In this article we present an evidence of kinetic arrest for FM-AFM transition. The isothermal magnetization (MH) loops for SmCoAsO exhibited the meta-magnetic transitions at 6, 8 and 10K at around 80, 60 and 50kOe fields respectively with characteristic hysteresis shoulders along with the non-zero moment at origin, thus suggesting the possibility of kinetic arrest. Suggested kinetic arrest is further evident in zero field-cooled (ZFC) and field-cooled (FC) hysteresis under high fields of up to 140 kOe magnetization (MT) and the magneto-transport measurements R(T)H during FM-AFM transition (Fig. 6.7). The time dependent moment experiments exhibited increase of the same below 20kOe and decrease for 30kOe at 15K.

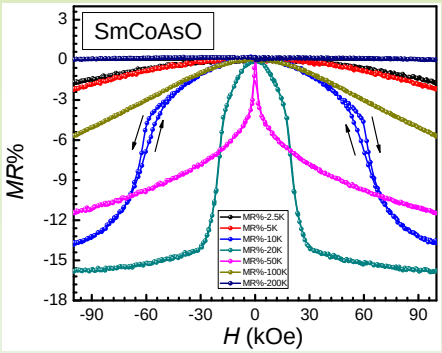


Fig. 6.7 Magneto resistance *R(H)* at 200, 100, 50, 20, 10, 5 and 2.5 K in applied fields of up to 100 kOe during both increasing/ decreasing the field.

Effect of nano-size dopants on transport properties of high Tc superconductors: Nano-size dopants are proving very useful in enhancement of critical current density, J_c, of some superconductors by providing suitable pinning of flux-lines in high magnetic fields. Work has been carried out on Bi-based high T_c superconductor Bi-2223 doped with nano-sized Mo and Ce. Effect of these dopants was studied on various superconducting and magnetic properties of the doped superconductors and it was found that the properties are very sensitive to the way the nano dopants are incorporated in the superconductor. While Ce-addition has not shown any improvement on the critical current property, inclusion of nano-Mo has resulted in significant improvements of J_c of the Bi-2223 superconductor. Correlation of magnetization behaviour and J_c values of Mo-doped samples along with the microstructures observed in the scanning electron microscope bring out the possible role of nano-Mo in improving the J_c values. The studies are being pursued with other nano-dopants.

परिष्कृत और विश्लेषणात्मक उपकरण

Sophisticated and Analytical Instruments

परिष्कृत और विश्लेषणात्मक उपकरण

पदार्थ आधुनिक प्रौद्योगिकियों के संरचनात्मक घटक हैं और आधुनिक जीवन के समस्त पहलुओं में व्याप्त हैं। मौलिक अनुसंधान की दृष्टि से यह समझना अभी भी एक बड़ी चुनौती है कि ये पदार्थ अपने अभिलक्षणात्मक रूप में किस प्रकार आचरण प्रदर्शित करते हैं और हम किस प्रकार से कुछ असामान्य गुणों से युक्त नए पदार्थों का सृजन कर सकते हैं। अनुसंधान और साथ ही अनुप्रयोगों हेतु सामग्रियों को पूर्णतः पूर्व–निर्धारित विनिर्देशनों के अनुरूप होना आवश्यक है। अनुप्रयोग जितना ही अधिक उन्नत होता है, उससे संबंधित विनिर्देशन उतने ही अधिक संख्या में और उतने ही अधिक कड़े होते हैं। पदार्थों के जिन आधारभूत अभिलक्षणों से पदार्थ के गुण–धर्म निर्धारित होते हैं, वे हैं: उसका संघटन, शुद्धता संरचना और क्रिस्टलीय पूर्णता। पदार्थ अभिलक्षणन से संबंधित क्षेत्र पदार्थ के गुणों और उसके अभिलक्षणों के बीच संबंध पर आधारित है। इसके अतिरिक्त, पूर्णतः नियंत्रित गुणों से युक्त पदार्थों के पुनरावृत्त निर्माण और उनकी उपयोगी युक्तियों में परिवर्तन के लिए पदार्थों का अभिलक्षणन एक महत्त्वपूर्ण भूमिका निभाता है। पदार्थों के गुण–धर्म काफी भिन्न होते हैं तथा पदार्थ अत्यधिक शुद्ध तथा पूर्ण एकल क्रिस्टल के रूप में होने से लेकर पूर्णतः अशुद्ध अव्यवस्थित पदार्थ के रूप में भी पाए जाते हैं। पदार्थों के गुण–धर्म इसकी सभी तीनों अवस्थाओं अर्थात ठोस, द्रव और गैस अवस्थाओं से संबंधित होते हैं। इन कार्यों को करने के लिए आवश्यक विशेषज्ञता काफी उन्नत स्वरूप की होती है तथा इसके लिए अत्याधुनिक सुविधाओं का होना अत्यंत आवश्यक है।

राष्ट्रीय भौतिक प्रयोगशाला में पदार्थों के अभिलक्षणन हेतु क्षमता उपलब्ध होने के महत्त्व को इस संस्थान की आयोजना और इसकी नींव रखे जाने के समय भी महसूस की गई थी। अतः रासायनिक विश्लेषण, एक्स–रे क्रिस्टलोग्राफी तथा इलेक्ट्रॉन सूक्ष्मदर्शिकी नामक अनुसंधान समूह संस्थापित करने की योजना बनाई गई। उन्नत विश्लेषण हेतु समय के साथ जिस प्रकार मांग में वृद्धि हुई, उसी के अनुरूप समय–समय पर नई सुविधाएं संस्थापित की गईं।

वर्तमान में सभी पहलुओं अर्थात रासायनिक संघटन, शुद्धता, संरचना (त्रुटियों सहित) और क्रिस्टलीय शुद्यता के संबंध में पदार्थों के अभिलक्षणन हेतु उच्च गुणवत्तायुक्त सुविधाएं उपलब्ध हैं। इसके अतिरिक्त, ठोस पृष्ठीय तनु परतों और अंतर–पृष्ठों के अध्ययन हेतु भी सुविधाएं उपलब्ध हैं। अनेक औद्योगिक इकाइयों और अन्य वैज्ञानिक संगठनों ने भी विभिन्न प्रकार के पदार्थ अभिलक्षणन तथा अपने उत्पादों की गुणवत्ता में सुधार के लिए परीक्षण हेतु इस सुविधा का प्रयोग किया है। इसके फलस्वरूप, प्रयोगशाला को पर्याप्त मात्रा में ई सी एफ का अर्जन हुआ है।

यहां एक उल्लेखनीय तथ्य यह है कि इन सुविधाओं के अनुरक्षण और विकास के कार्य में जुड़े वैज्ञानिक न केवल संगठन के अन्य समूहों तथा बाहरी संगठनों को भी ये अभिलक्षण सुविधाएं उपलब्ध करा रहे हैं बल्कि वे उन्नत क्षेत्रों में अपने स्वयं के अनुसंधान कार्यों में भी काफी सक्रियता से जुटे हैं। इस समूह द्वारा किए जाने वाले कार्यों में यहां उपलब्ध सुविधा का अनुरक्षण, उन्नयन और प्रचालन के साथ–साथ अति सूक्ष्म पदार्थों के क्षेत्र में नए रुझानों के अध्ययन और अन्वेषण`से संबंधित कार्यों को करना भी शामिल है। इससे यह समूह इस क्षेत्र में हुई नवीनतम प्रगतियों से अवगत बना रहता है तथा साथ ही जहां कहीं भी संभव हो, नई जानकारियों को अन्य संबंधितों को उपलब्ध कराने में भी अपना महत्त्वपूर्ण योगदान देता है।

Sophisticated and Analytical Instruments

Materials are building blocks of all modern technologies and pervade all aspect of present day life. From fundamental research point of view it is still a big challenge to understand why these behave in their characteristic manner and how one can generate newer materials with exotic properties. Materials for research as well as for applications have to conform to strict specification. The more advanced the applications the more numerous and strict are specification. The basic material characteristics which control material properties are composition, purity of structure and crystallographic perfection. The area of materials characterization is concerned with ever increasing demands on quanitifying the material characteristics and on throwing light on the relationship between properties of material and characteristics. Also in the repeated preparation of materials with well controlled properties and their conversion into useful devices, characterization of materials play a vital role. The nature of materials is very diverse ranging from very highly pure and perfect single crystal to totally impure disordered materials. 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 importance of the capability for analysis of materials at NPL was realized even at the time of planning and foundation of the institute. Thus research groups for chemical analysis, X-ray crystallography and electron microscopy were planned. With time as the demand for advanced analysis increases, new facilities are introduced from time to time.

At present high quality facilities are available for characterization of materials rgarding all aspects, namely chemical composition, purity, structure (including defects) and crystallographic perfection. Besides, facilities for the study of solid surface thin films and interfaces are also available.

Many industrial units and other scientific organization also make use of this facility for different type of materials characterization and testing for quality improvement of their products, which has results in generation of considerable ECF to the laboratory.

It is worth mentioning that scientists involved in the maintenance and development of such facilities are not only providing these characterization facilities to other groups of NPL and outside organizations but are very actively engaged in their own research programs in advanced areas. Thus responsibilities include maintenance, up-gradation and operation of the facility together with carrying out studies and investigations of new trends in the field of advanced materials including nano-materials. This has enabled the group to remain close to the latest development in the field and to contribute to new knowledge generators wherever possible.

I. X-ray Analysis

Growth and Characterization of strategic and technologically important single crystals

Well characterized single crystals are the building blocks of recent technologies of the modern science. Several important technologies like photonics, microelectronics, communication, computers, lasers, information science, biosensors, and nuclear science etc. require well-characterized single crystals and epitaxial thin films. Due to recent advancements in the industry of photonics, nonlinear optical (NLO) crystals are going to play a major role in laser technology, data storage, signal processing and communication etc. Similarly high energy radiation detector crystals are also very important particularly in the medical diagnostic instruments like CAT scanner and nuclear power plants. In view of these important applications, NPL is fully engaged in growth of technologically important single crystals like LiF, $LiNbO_3$, $Bi_3Ge_4O_{12}$, BSO, Benzophenone etc by Czochralski method and variety of nonlinear optical organic and semiorganic NLO crystals [Benzimidazole, L-alanine, L- alaninium maleate, hippuric acid, 8HQ, methyl p-hydroxybenzoate, acenaphthene, doped ZTS, KDP, ADP & KHP, Phthalic Anhydride, L-Lysine monohydrochloride dihydrate, L-Asparaginium Picrate, L-histidinium perchlorate etc.] by solution growth methods. Semi-organic NLO crystals are specially targeted as these crystals can be engineered for tailor made applications by the incorporation of suitable functional groups/dopants to the host organic material. These organic groups enhance the NLO efficiency and mechanical & chemical stability.

In this financial year along with collaborators, this group has achieved a remarkable and record R&D output, which is published in 45 SCI journals with high impact factors (Four papers have IF > 3 and average IF~2). A few of these investigations are briefly described.

Single crystals of the relatively new nonlinear optical material l-asparagine monohydrate (LAM) have been successfully grown by the slow evaporation solution growth technique at room temperature in aqueous solution. The as-grown single crystals (particularly when their size is large) were found to contain internal structural grain boundaries.

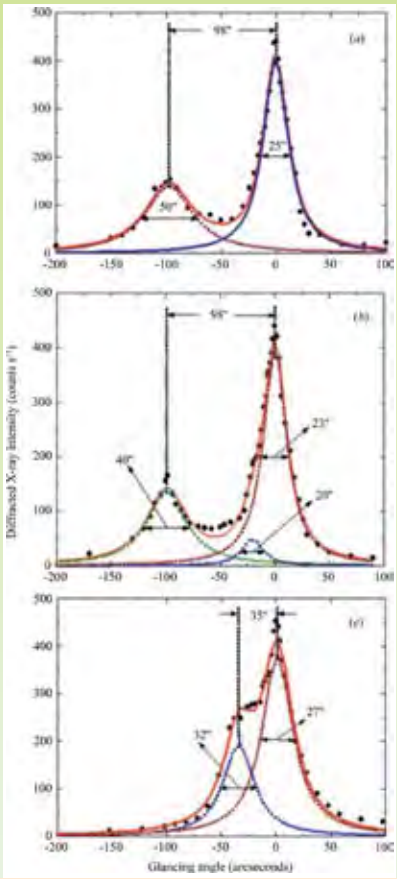


Fig. 7.1 HRXRD curves for a typical LAM single crystal, (a) as grown, and (b) and (c) annealed at 333 and 353 K, respectively, for 6 h.

The crystalline perfection of such defect crystals was found to be improved substantially by annealing at low temperatures. The perfection and the measured physical properties were found to be correlated such that the second harmonic generation (SHG) efficiency, optical transparency, fluorescence and dielectric properties are enhanced as the crystal quality improves. The results are published in J. Appl. Cryst. 43 (2010) 491-497.

In a potassium dihydrogen phosphate single crystal grown by the temperature lowering technique, some interesting growth features revealing the origin of point defects, their agglomeration and dynamics were observed. High-resolution X-ray diffractometry (HRXRD) was employed for in-depth studies of the observed defects. Since the crucial properties of crystal-based devices are very much influenced by such defects, this is an important experimental finding with respect to improving growth techniques or conditions to avoid

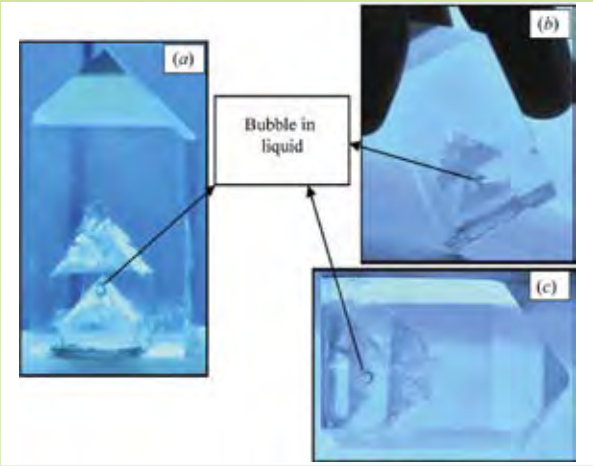


Fig. 7.2 A bubble formed inside a KDP single crystal after a month of its growth in aqueous medium and moving as a result of gravity with changes in the orientation of the crystal and confirming the very important and fundamental aspect of dynamic nature of point defects.

such defects. The results are published in J. Appl. Cryst. (2010). 43, 1372–1376.

A bulk size (~60 mm length and 20 mm diameter) single crystal of l-cysteine hydrochloride monohydrate (LHM) has been successfully grown for the first time by the unidirectional Sankaranarayanan–Ramasamy method and found to be a NLO material by observing the SHG. The grown crystal was found to be highly transparent with good crystalline perfection as revealed by HRXRD. The relative SHG efficiency and laser damage threshold values were found to be respectively 1.2 and 5.5 times than that of the standard KDP crystal. The present investigation reveals that the title compound with its desirable size along a predetermined direction and being a good NLO material with the prerequisite optical and dielectric properties is a good candidate for photonic or opto-electronic applications.

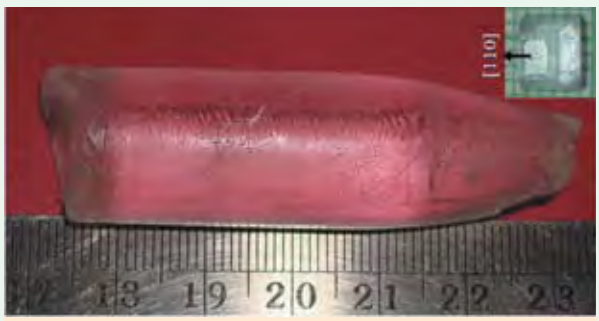


Fig. 7.3 Photograph of the LHM single crystal. The inset showing the SEST-grown crystal used as seed crystal.

The Fe-doped (0.05 mol%) lithium niobate (LiNbO3) bulk single crystal was grown by Czochralski (Cz) method using a co-axial two zone low thermal gradient furnace. The crystalline perfection of the grown crystal was evaluated by HRXRD and found that it does not contain any structural grain boundaries, and the dopants predominantly occupied vacancy sites of Li+ in the lattice. EPR studies revealed the incorporation of Fe3+ ions at Li sites. The Z-cut optically polished 450 µm thick wafer was used for birefringence measurements on prism coupler spectrometer with 632.8 nm wavelength and found that the difference in refractive index (An) for ordinary and extraordinary rays is 0.0833. The optical transmission/absorption spectra were studied by UV-ViS-NIR spectroscopy and found that the grown crystal has a good optical sensitivity for 482 nm wavelength. The present studies reveal that the grown crystal with two zone low thermal gradient furnace has very good device properties needed for holographic data storage applications. The results are in Press of a high ranking SCI Journal 'CrystEngComm' and selected as "Hot article".

Development of Certified Reference Materials for Powder X-ray Diffraction

Under the Network Project (NWP-045) advances in metrology on "Certified Reference Materials", Lanthanum hexaboride (LaB6) is being developed as certified reference material (CRM) for powder X-ray diffraction (XRD) line positions.

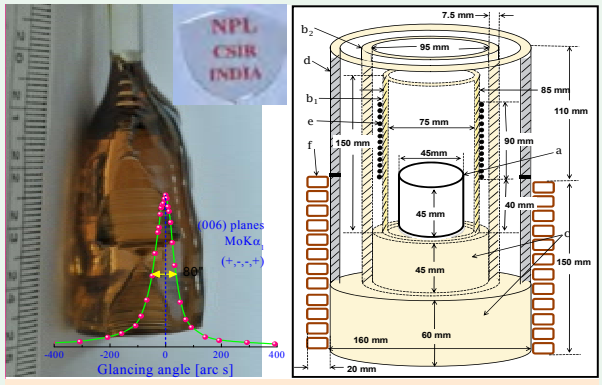


Fig. 7.4 Fe-doped Lithium niobate single crystal grown by CZ-method (left; with a HRXRD rocking curve in the back-ground) using an in-house developed two zone furnace (right).

Synthesis and Characterization of Chalcogenides

Chalcogenides are technologically important materials. For our research work on chalcogenides for phase

change memory applications, preparatory work such as procurement of raw materials, purchase of high temperature furnace etc. was carried out and preparation of bulk samples was initiated.

Infrared and Raman Spectroscopy studies

Infrared angular techniques of specular reflection and regular transmission have been employed to study quantum effects at ambient temperatures which are still far less investigated compared to quantum effects at low temperatures. This study has revealed that quantum effects on solids observed with IR angular techniques at ambient temperatures are complementary to those observed at liquid N_2 and liquid He temperatures. The key result of research work "Evidence of Inelastic infrared scattering in the specular reflection and regular transmission of various materials" predicts the possibility of "Raman Effect" in the almost entire electromagnetic region instead of the well-known but confined infrared region.

Implementation of quality system

Implementation of quality system on the Powder XRD activity is in progress. The second internal audit of the Powder X-ray Diffraction Laboratory was carried out on 22nd July, 2010. Most of the non compliance were closed.

Scientific Support and R&D Collaborations: This group is actively involved in providing scientific support to various groups of NPL CSIR network projects and various outside laboratories through R&D collaborations by characterizing variety of samples by in-house developed multicrystal X-ray diffractometer, Bruker AXS D8 Advance Powder X-ray Diffractometer and the recently established XRF and HRXRD cum XRR systems for purity including phase analysis, structure and perfection. No. of samples characterized to various NPL groups and collaborators: (i) by HRXRD: ~ 180, Powder XRD: ~800, XRF~20 whose notional cost is around Rs. 40 lakhs/-.

Fig. 7.5 X'Pert PRO MRD PANalytical HRXRD cum XRR system

This group was also involved actively in the organization of "Workshop on Materials Characterization Techniques (WMCT-2010)" held during 12th to 16th July 2010 with hand on experiments/practical demonstrations.

The major important technical achievements are:

1. A newly procured PANalytical X'Pert PRO MRD HRXRD cum XRR system has been installed successfully to characterize thin films and nanostructures.
2. A newly procured Rigaku Make ZXS Primus Sequential Wavelength Dispersive Fully Automated X-ray Fluorescence Spectrometer has been commissioned successfully for elemental analysis.
3. A temperature lowering solution technique with bidirectional seed rotation has been developed.
4. A poling unit and P-E loop tracer for ferroelectric crystals have been procured and commissioned.

II. Electron and Ion Microscopy

Electron microscopy facilities are being utilized at NPL as the central facility for the characterization of materials. This group is equipped with state of the art and most modern equipments such as SEM, variable pressure SEM and high resolution TEM with EDS and STEM attachments. Two new facilities were also incorporated in the group, Secondary ion mass spectrometry (SIMS) and Scanning Probe Microscope (SPM). Besides these major facilities, the group also has a Photo luminance measurement unit, vacuum coating unit, a range of furnaces and a chemical synthesis facility for the purpose of research.

Different types of samples in the form of thin films, powders and composites prepared by various techniques, received from different groups of NPL working on the development of new and advanced materials are characterized for particle shape, size, size distribution, surface finish, phase identification, phase transformation, defects and dislocations, voids and twinning, chemical composition and surface studies using the facilities of the group.

Besides being the backbone of the laboratory in the field of microscopy by way of collaboration with groups pursuing research in the field of nano-science, the group members are also carrying out basic research towards shape and size control of nanostructures and synthesis as well as characterization of thermo electric materials as one of the major activity. Synthesis is carried out using chemical as well as physical routes. Support is also provided to user industries and other research institutions.

Scanning Electron Microscope:

The group had two SEM:

- LEO 440 SEM: operating range 300 V- 40 kV and resolution of 3.5 nm in SCI mode and of 5.5 nm in BEI mode. It is equipped with SE, BSD, CLD and SCM detectors.
- EVO MA 10, a variable pressure SEM with resolution of 3.0 nm in SEI mode and 5 nm in BSE mode. It is equipped with SE, BSD, STEM and IR chamber scope. The oxford FDS attachment has a range from Be to U and a resolution of 133 eV.

Fig. 7.6 Vanable pressure SEM-EVONAIO

With the help of the above mentioned SEM facility more than 1600 samples were examined during the year for various NPL research groups and 63 samples were analyzed for industry. Both the SEM and EDS modes were used for- particle shape and size distribution analysis, and compositional and fracture/failure analysis. A total of 35 test /analytical reports were prepared and issued for the industrial work carried out during the year. Sum of approx. Rs. 3 lakh were generated as ECF to the laboratory from this activity.

Some of the materials analyzed were:

- (Al5083+SiC), (AZ91+Mg), (Al+BN) prepared by milling at different conditions.
- MWCNT & SWCNT prepared by arc-discharge, CVD method.
- Amorphous Silicon on Si substrate at different biasing voltages.
- Aerosol samples.
- Gold Nanoparticles, Silver nanocluster.
- Double pervoskite material prepared by solid state reaction in (Ar + 5% H_2) gas atmosphere.

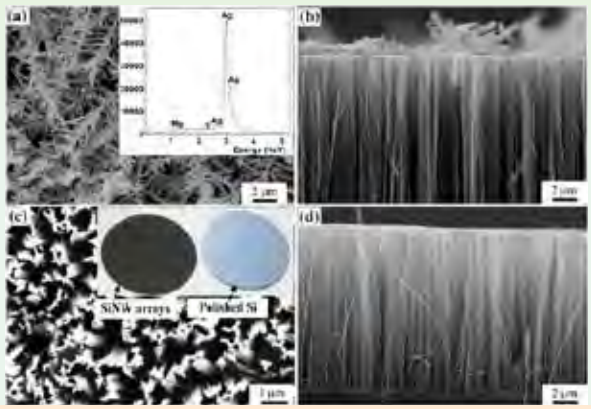


Fig. 7.7 SEM Micrographs of Silicon nano wires grown by electrolysis etching technique.

- Bismuth Telluride, Bismuth Sellenide, Cadmium Telluride for thermoelectric applications.
- Magnetic nanoparticles and oxides
- SAM + cholesterol oxidize enzyme for biosensor applications.
- La-Sr-MnO_3, Pb-Ca-FeO_3 CMR materials, Li-ferrite samples with different concentration on Silicon substrate.

Other S & T Work

Active participation was taken in CSIR's CPYLS Programme NPL Open day celebrations and Users awareness programme of the Material Characterization Division (UAPMAT) held at NPL. Participating members were given demonstration and training on specimen preparation and use of SEM and EDS technique for materials characterization. Also many visitors from different institutes/organization, third world countries under commonwealth programme and summer trainees from colleges, universities and different institutes of engineering were given demonstration on the capability of the TEM, SEM and EDS systems in the field of surface characterization of the materials.

HIGH - RESOLUTION - TRANSMISSION ELECTRON MICROSCOPE:

We at NPL have a state of art FEG high resolution transmission electron microscope, FEI-Tecnai F30 G^2 5-TWIN. 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 and 136 eV respectively. Besides the single tilt and double tilt holder there is a special holder for in situ high temperature measurements studies from 300 to 1000ºC. A total of 250 samples for various research groups of NPL and 4 industrial samples were analyzed using the HRTEM facility.

Designed and development of a thermal conductivity probe for quick determination of K-value of pallet :

The designed probe provides a direct reading within a very short period of contact with the pallet. This result is a function of thermal conductivity of the contacted material. The results of K value measurements obtained on comparision with the results of standards methods, were found to be within 5% of accuracy. Number of thermoelectric materials developed in bulk form have been characterized using this probe to evaluate ZT at ambient temperatures.

Scanning Probe Microscope

Scanning Probe Microscope (SPM) is the central facility of NPL and is extensively used by different R & D groups of laboratory for the surface characterization

Fig.7.8 Photograps of K-Value proves with some samples.

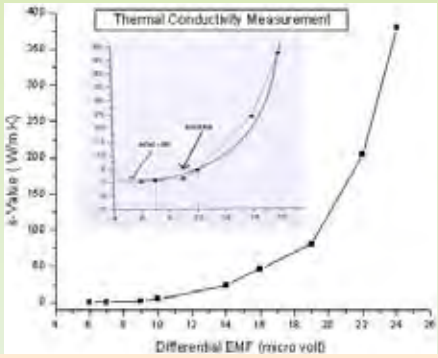


Fig.7.9 Curve between thermal conductivity and the differential EMF

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 several advanced modes like 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 2010-11 161 samples were analysed and it resulted in 6 publications in SCI Journals. Morphological effects like particle size, roughness and other magnetic & electrical properties have been studied for variety of materials like polymers and their composites, CNTs, ZnO, TiO_2 nanoparticles, graphene oxide & graphene sheets, magnetic thin films and biomedical samples like DNA, protein etc.

Advance modes like EFM and Nanolithography were made functional in the past year. EFM. It measures the

electrical properties on the sample surface by measuring the electrostatic force between the surface and biased AFM tip and gives information about surface potential and charge distribution on the sample. Result of standard sample are shown in Fig. 7.10.

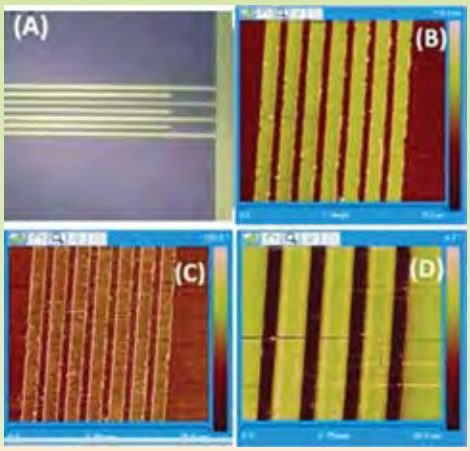


Fig. 7.10 (A) EFM test sample : Interdigitated electrodes. (B) Height Image in Tapping Mode (C) Phase Image (D) Phase image of electrodes in EFM mode with sample bias 2V and Tip Bias 1V

Scanning probe based nanolithography is a technique used to pattern semiconducting and metal surfaces to fabricate and realize nanoscale devices. Nanoscale patterns (~500 nm wide line) made by scratching method using Diamond-tip on CD surface are shown in Figs. 7.11(A). and 7.11(B) shows the Lithography pattern (~ 150 nm wide line) by Local Anodic Oxidation (LAO). LAO is based on direct oxidation of sample by negative voltage applied to the tip with respect to the sample.

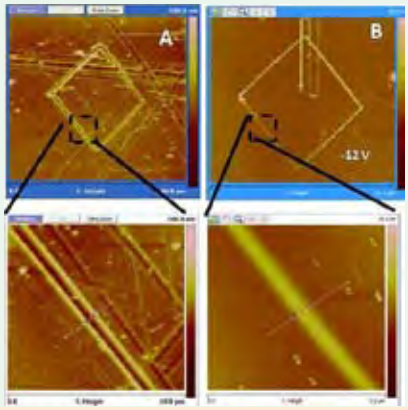


Fig. 7.11 Patterns by (A) nano- scratching on CD (B) LAO on Si

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 is followed by mass spectrometry of the emitted secondary ions.

Fig. 7.12 TOF – SIMS at NPL

In Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS), a pulsed beam of primary ions focus onto a sample surface, producing 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 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.

Three operational modes are available using TOF-SIMS: Surface spectroscopy, Surface imaging and Depth profiling.

More than fifty samples from various groups of NPL were analyzed using TOF-SIMS. Some of the results are mentioned below:

Depth profile of AlN/Si sample is shown in Figure 7.13 where the sharp interface between Al and Si substrate

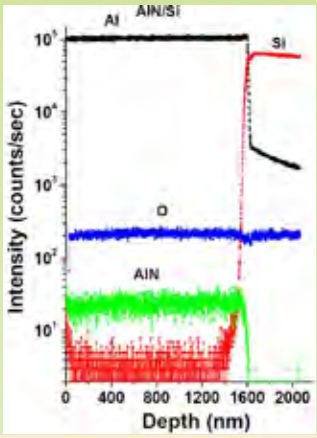


Fig.7.13(a) Depth profile of AlN/Si

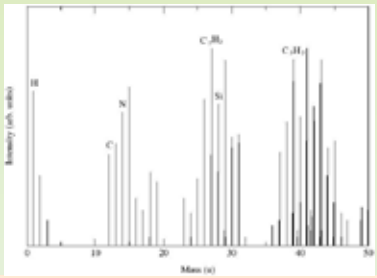


Fig. 7.13(b) Mass spectra of N–DLC

is clearly observed. The film thickness was estimated to be around 1.6 µm. Mass spectra and depth profile of N- DLC sample to analyse the H, N distribution over the sample are shown in Figure 7.13(b).

The VAMAS inter-laboratory round robin test on PTFE sample was conducted using TOF-SIMS at NPL. Sixteen spectrums were taken as per the protocol and the first set of data has already been sent.

III. EPR and IR Spectroscopy

Ferro fluids

Nanotechnology is the engineering of countable number of atoms and molecules which are building block of matter. It involves the manipulation and manufacture of the objects on an atomic scale. Nanotechnology aims at making things smaller, faster and cheaper with atomic and molecular precision.

Ferro fluids are one such technologically advanced nano-magnetic material. The devices based upon them are changing with spectacular pace. Basically ferrofluids are colloidal dispersion of nano-size ferro-ferrimagnetic particles of size 2-10 nm. Since the shape and size distribution of particles plays an important role for the stable and moderate magnetization of ferrofluids, we have optimized synthesis parameter and prepared Fe_3O_4, $CoFe_2O_4$, $Ni_xZn_{1-x}Fe_2O_4$, $MnZnGd_{2-x}$ $Fe_{2x}O_4$ based ferrofluids. These particles were characterized by XRD, FTIR, SEM, HRTEM, AFM, VSM and EPR spectroscopic techniques to reveal their structural, morphological, magnetic and spin behaviour.

EPR spectroscopic studies of kerosene based Fe_3O_4 ferrofluid at low temperatures (10 K to 70 K)

EPR spectra of ferrofluid samples containing nanosize particles at 5K temp gives information about the quantum tunneling of spins which occurs in single domain magnetic particles. The EPR spectrum changes from superparamagnetic (SPR) to blocked SPR and finally evolves quantum superparamagnetic behaviour as the temperature lowers down further. A nanoparticle system of highly anisotropic magnetic material can be qualitatively specified by a simple quantum spin model, or by the Heisenberg model with strong easy-plane anisotropy.

The temperature dependent EPR spectra of magnetic nanoparticles from ambient to 4K temperature studies are used to investigate paramagnetic resonance behavior which acts like a free exchange-coupled giant spin and markedly reduces the line width to ~10 Gauss i.e. comparable to a quantum superparamagnetic state (QSP). At liquid helium temperatures, the quantum paramagnetic state is reached and the quantum tunneling of the surface spin glass reduces the domain size within each nanoparticle. The line width is very sharp in QSP state. The resonance line of high 'g' value of 4.03 indicates the presence of isolated Fe^{3+} in the system. The anisotropic field increases with a decrease in temperature and results in higher tunneling rate. The domain size of the SP particle decreases attributing to prominent transfer of magnetic domains into surface spin glass state.

The SPR line width shows abnormal broadening below the blocking temperature in $MnZnGd_{2-x}Fe_{2x}O_4$ and the line also broadens. The SPR line width depends on the domain size of particles and the anisotropic field. The narrowing of the SPR line width at high temperatures is attributed to the thermal fluctuations of the magnetic nanoparticles while the broadening of the blocked

SPR results from the line up of the magnetizations of all particles that enhances the anisotropic field at low temperatures.

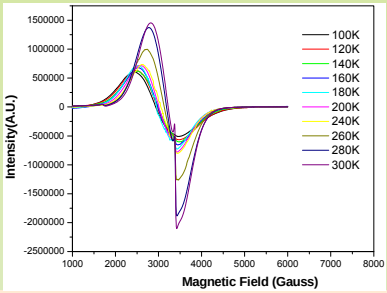


Fig. 7.14(a) The EPR spectra of Fe_3O_4

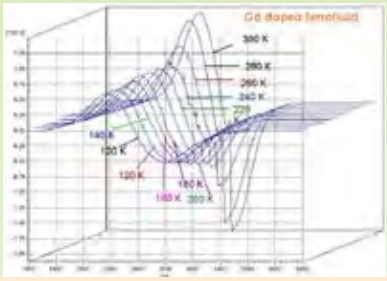


Fig. 7.14(b) Resonance spectra $MnZnGd_{2-x}Fe_2xO_4$

IV. Analytical Chemistry

Chemical analysis, Metrology in Chemistry (MiC) and Certified Reference Material (CRM) are major activities of the Analytical Chemistry sub-division of the Sophisticated Analytical Instruments scientific support division (SASD-7.01) of NPL. This group had rendered support to the chemical characterization needs of NPL in-house research work, government agencies and institutions for characterization of a variety of materials viz. poly aluminum chloride and Alumina Ferric Grade-II used for treatment of water by Delhi Jal Board; indelible ink for election purpose from Election Commission of India; refrigeration gas characterization and gas impurity analysis of helium samples from Common wealth games for VVIP security, metal impurities in graphite, stainless steel etc. Under the CSIR network project 'Advancement in Metrology', focus had been given for SI traceability in chemical measurements with MiC network partners by building capacity, doing R&D in various areas, participating in international pilot & key comparisons and preparation & dissemination of certified reference materials (CRMs). Four CRMs of mono and multi elemental solutions have been released during 2010-11 period for Silver solutions [(BND 501.01; 0.78 ± 0.01 mg/Kg) and (BND 505 .01; 4.78 ± 0.01 mg/Kg)], Potassium solution (BND 2105 .01; 4.75 ± 0.01 mg/Kg) and multi-elements Pb, Cd, Ni solution (BND 2301.01; 0.89 ± 0.01, 0.91 ± 0.01, 0.81 ± 0.01 mg/Kg respectively) in aqueous medium. Two sponsored projects were completed for Ministry of Environment & Forests national communication (NATCOM-SNC) for greenhouse gas (GHG) (QA/QC) measurements and thir quality control activities and traceability. Data analysis under field campaign studies by the group have been done for suspended particulate matter (SPM) and its chemical composition apart from aerosol size and mass distribution by Anderson and quartz crystal microbalance (QCM). Trace gas & aerosol measurements data analysis from residue burning have been carried out for Patiala district of Punjab in collaboration with Thapar University.

Under gas metrology-MiC programme, the infrastructure facilities and establishing of the laboratory for the preparation of Primary Reference Materials (PRMs) for gas mixtures is being developed by gravimetric mixing. Efforts are being made to prepare ambient range green house gas (CH_4, CO_2 and N_2O) mixtures for environmental monitoring. It includes purity assessment of all the starting materials used in the preparation of the gas mixtures and the challenge lies in the identification and quantification of all the impurities present in the starting gases. Quality control samples for methane gas testing using GC-FID system were prepared and are being used for development of quality control chart as quality assurance measures. Advanced new facility creations are being carried out to be comparable internationally in this field. The Group periodically participates in bilateral and multi-laboratory CCQM international comparisons. During this period we participated in international inter-comparison for CCQM-K76 (SO_2 in nitrogen), conducted by NIST USA. The PRMs of SO_2 in nitrogen were prepared gravimetrically. Those prepared mixtures were utilized for the calibration of the SO_2 analyzer and the evaluation of the inter comparison gas mixture.

A facility of NO_x analyzer (Figure-7.15) is being utilized for the determination of impurity concentration of NO, NO_2 and NO_x in the high purity gases.

Fig. 7.15 NO, NO_2 and NO_x analyzer system (Model: CLD 8xx, Make: ECO PHYSICS)

Chemical closure studies on hygroscopic properties were carried out on wheat-straw burning aerosols collected in Patiala, Punjab with the collaboration of Hokkaido University, Japan. Fine mode particles (<0.4 µm) were analyzed for water-soluble composition (major inorganic ions and WSOC) of samples collected using Andersen sampler during agriculture residue burning period in 2007 in Patiala. The extracts were also nebulized to generate aerosol particles, and the growth factor (100 nm) of particles was determined by introducing into "Hygroscopicity Tandem Differential Mobility Analyzer (HTDMA). Chemical data were used (inorganic) as input in AIM model to study the chemical closure. Figure 7.16 shows a typical comparison of hygroscopic property of particles measured by HTDMA (i.e., total water-soluble species) and by AIM model (major inorganic ions only). The results suggest that water-soluble organics in aerosols from agriculture waste burning have considerable water-uptake properties and can significantly influence the cloud condensation nuclei (CCN) activity of aerosols particles when present in dominance during such intense burning period.

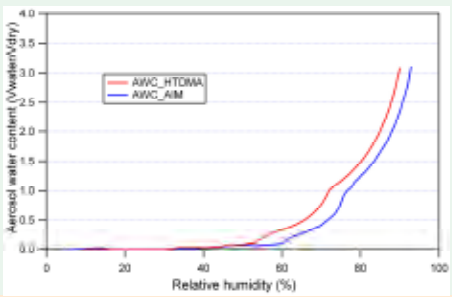


Fig. 7.16 Water uptake properties of aerosols measured using HTDMA and predicted using AIM model

Aerosol chemical composition, i.e., total carbon (TC), organic carbon (OC), elemental carbon (EC), water-soluble organic carbon (WSOC), inorganic ions together with some marker species, e.g., $nssSO_4^{2-}$, $nssCa^{2+}$, $nssK^+$, methanesulfonate (MSA), oxalic acid (C_2), azelaic acid (C_9) and levoglucosan determined in PM10 samples, collected with IIT Mumbai using high volume sampler in Mumbai for summer and winter 2006-2007, revealed that biofuel/ biomass and fossil fuel burning are the major sources of the Mumbai aerosols. Nitrogen-isotopic ($\delta^{15}N$) composition of aerosols total nitrogen range that of 18.1 to 25.4‰ suggested that among them biofuel/biomass burning as the most abundant source in both summer and winter seasons. Plots between $\delta^{13}C$ values and some specific marker ratios, e.g., $nssSO_4^{2-}$/ TC, levoglucosan-C/TC and EC/TC also supported the major sources identified for the Mumbai aerosols. While the plots between WSOC/TC ratios and $\delta^{13}C$ values suggested that the increment in 13_C of aerosol C in wintertime can be regarded as enhanced photochemical processing of organic aerosols in this season (Figure 7.17). Our results suggest that in tropics, the winter aerosols are more aged than the summer aerosols. Model should take life-time effect into consideration.

NABL sponsored proficiency testing (PT) project in chemical discipline (code PT-44) for the determination of trace metal concentration in water for inter-lab comparison among the NABL accredited laboratories has been completed for Phase-II. In this PT, 3 aqueous solutions of single element and 2 aqueous solutions of

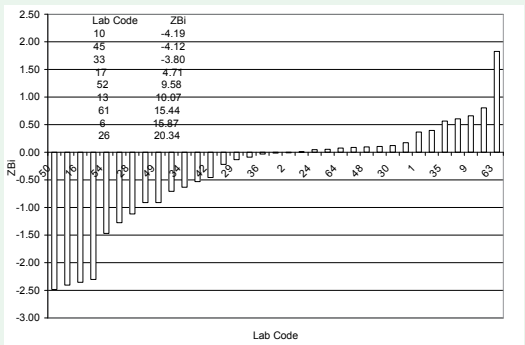


Fig. 7.17 ZBi scores (< ±3) verses lab code for As détermination. Laboratories those having ZBi score > ±3, are listed at the top of the chart

multi-elements with different concentrations were sent to the participating 69 laboratories. Data received from the participating laboratories were statistically analyzed for their quality assurance using Z-score statistics in accordance to the NATA guidelines, which are in compliance with the requirements of OSO/IEC Guide 43.

As a typical example of the results, i.e. in the case of As, Figure 7.18 it was observed that the ZBi (i.e., Z-score between the laboratories) value > ±3 is for the participating laboratories denoted as outlier laboratory with code numbers 6, 10, 13, 17, 26, 33, 45, 52 and 61, however, ZWi (i.e. Z-score within the laboratory) value > ±3 is for laboratories with code number 6, 13 and 26. Laboratories with code numbers 6, 13 and 26 are having the value of Z-score > ±3 in both ZBi and ZWi cases. On the other hand, it was observed that the ZBi value < ±1 are for the participating laboratories denoted as accurate laboratory with code numbers 2, 5, 8, 19, 22, 24, 27, 29, 31, 34, 36, 42, 43, 48, 49, 53, 57, 62 and 64. In this study, it was also found that in several cases, Z scores are much higher than 3, even for the laboratories that were using sophisticated instruments and one of the important factors, which directly affects the analytical results (i.e., in terms of accuracy, precision and reliability) may be the skills of an analyst also, his expertise on the instrument, lab environment, instrument proper maintenance and working, etc.

Fig. 7.18 Trace elemental analycis unity ICP-HRMS systam

During this period, a major instrument installed is Inductively Coupled Plasma (ICP) – High Resolution Mass Spectrometry (HRMS) system, (Model- AttoM, Nu Instr. UK) which can be used for the determination of elements/metals (with atomic mass 6-250) in lower ppb level concentration in water. Primary methods like isotope dilution mass spectrometry (IDMS) technique can also be used for some of the elements. Capillary Electrophoresis (Agilent 7100 CE), which is a separation technique can be coupled with ICP-MS for speciation of several forms of organic and inorganic elements.

NPL exhibit of Certified Reference Materials (CRMs) activity from Analytical Chemistry group was selected as Gold Winner Award under theme pavilion on WATER during CSIR-TECHNOFEST-2010, 'Science & Innovation for transforming India' at International Trade Fair during Nov. 12-27, 2010.

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Scientific and Administrative Support Services

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's 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. 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.

Updates industries, licensees and scientists for any CSIR/DST entrepreneurship/ funding schemes for applying for awards/projects. Also updates scientists about scientific and technical exhibition, events. 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, etc. This group has recently initiated its efforts in setting-up an Incubation Centre and possible knowledge alliance with Sensor Technology Pvt. Ltd., Moser Baer Photovoltaic Limited and Sukrut Systems in the area of sensor electronics, solar energy and biological instrumentations.

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 service. It undertakes several activities in various areas of core competence of the lab and also related to research scholars. The group is involved in various activities, such as, Organisation of Industrial Training in Metrology/Standards, Students' Training/ Project Work for M.Tech./MCA/M.Sc. and other equivalent degree, Institutional Visits, Deputation of NPL staff members to attend conferences, etc,. All these activities eventually lead to the generation of the trained S & T manpower.

International Science and Technology Affairs Group (ISTAG)

International visits play an important part of scientific R & D. Processing of application of the laboratory scientists, CSIR fellows & DST Women Scientists pertaining to international visits viz. International conference, seminars, bilateral exchange programmes, sabbatical leave/study leave etc. for deputations abroad are handled by this group. It also arranges important lectures and invited talks. Arranging training programmes for international candidates is also the job of this group. It also organizes the visit of foreign delegations at NPL. International collaborative projects, Bilateral International cooperation programmes & MoUs of NPL are also the areas of 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, specially in the field of physics and related sciences.

During the current year, KRC subscribed to 85 scholarly journals *(63 foreign journals and 22 Indian journals)* and added 45 S & T books, 92 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 last year 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.

Presently, KRC is in the process of further automating its operations and planning for digitization. To undertake this arduous automation task, a Technical Experts and Evaluation Committee (TEEC) was constituted to get

the best ideas for transformation of NPL-KRC and to select the integrated library management software from among the alternatives (Alice for Windows, Egranthalaya, LibSys, NewGenLib, Virtua etc.).

Towards digitization, we are in the process of compiling information from various libraries where digitization process is completed or is in the process. Further, NPL-KRC is trying to set up an understanding/ MoU between NPL and Indian Institute of Information Technology (IIIT), Allahabad 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.

Central Workshop, Cryogenic Plants & GTU (SASD-5)

During this period, Central Workshop has successfully completed more than 858 jobs related to R&D and maintenance including designing, fabrication and development. Out of the above, most of them are highly sophisticated components related to Cesium Fountain Clock, Rubidium Atomic Clock –a joint project of NPL and Space Application Centre, Ahmedabad. The other important components are belongs to Helmotz Coil, Technology development for Sensors, Fabrication of LED devices & systems for Solid State Lighting applications etc.

In the Cryogenic Plants & Facilities Section, from April 2010 to Dec. 2010, we have produced a total of 600 liters of Liquid Helium (total market value of this production is approximately Rs. 4,30,000/- (Rupees Four lacs and thirty thousand only) and approximately 63,520 liters of Liquid Nitrogen for R&D requirements of NPL (Market value is approximately Rs. 9.50 Lacs only). In addition to this, we have procured a total of 3143 liters of Liquid Helium from outside agencies.

In the Glass Technology Unit we have completed a total of 104 jobs of different sections of NPL and 7 jobs from outside agencies like Indian Oil Corporation, IIT Delhi, IARI etc.

Due to the proper preventive maintenance, most of our Workshop machines including CNC, lathe, cutting, grinding, welding, carpentry, Glass & Quartz blowing machines and Cryogenic Plants (Liquid Helium & Liquid Nitrogen Plants) are working satisfactorily.

More details regarding the job works are given below:

A. Central Workshop

- Total Number of jobs completed at workshop were 858 costing Approx. Rs. 1.06 Crore. (Rs.One Crore and Six Thousand)
- Total Number of jobs completed at drawing & design section –160
- Raw material and spares procured – App. Rs. 2.30 Lacs.
- Procured CATIA CAD/CAM V5R19 Software-Rs. 2.65 Lacs. (Permanent license)

B. Cryogenic Plants & Facilities

- Liquid Helium produced at NPL – 600 liters
- Liquid Helium procured from outside agencies-3143 liters
- Liquid Nitrogen produced at NPL -63520 liters

C. Glass Technology Unit

- Total Internal jobs completed -104
- Total external jobs completed –7
- Value of External Jobs Done-Rs.1.06 (Rs. One Lac and Six Thousand only)

Revolving Advance Expenditure – Rs. 1.89 Lacs.

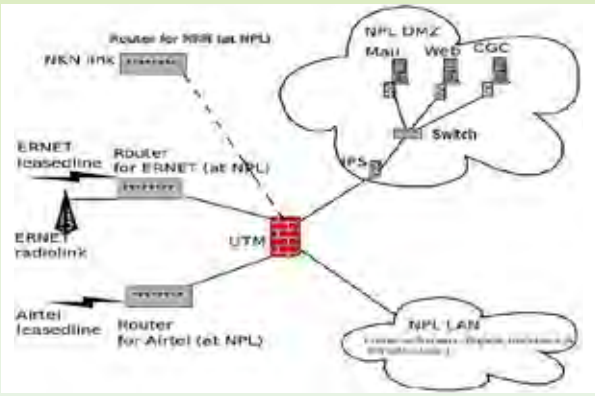
Computation & Network Facility (CNF)

IT Infrastructure

The Computation & Network Facility (CNF) has taken many steps to enhance and modernise the IT infrastructure in the year 2010-11. A state of the art Data Center has been established with several new servers, security devices and solutions like Unified Threat Management system, multi-level firewall, anti-spam, and antivirus solutions. It has elevated the overall network security and improved the quality of service. Currently, servers under 24 X 7 operation include Mail,

Web, DHCP, DNS, Bridge, Intranet, Router, Anti-virus, Computation, Database, Backup and other Divisional servers for providing specific software applications through centralized access.

A Gigabit fiber optics based backbone now connects all buildings on campus providing LAN connectivity to approximately 900 computers including laptops. Internet bandwidth has been raised three times to 12 Mbps. A Video conferencing facility is now available for all at NPL. Apart from this, the CNF also provides IT hardware and software support to the end-users. CNF thus facilitates network connectivity, computing and user-support.



CSIR-NPL is planned to be a part of National Knowledge Network (NKN) in the near future. It will provide an internet bandwidth of 1Gbps. The CNF has started planning, analysis, and design for additional of further important IT facilities like a 128 core computational cluster, Storage Area Network (SAN) and a high end UPS for the Data Centre.

Inhouse Software Development

- An Online Recruitment Application system has been developed and deployed to facilitate recruitment of scientific staff. The system allows web based submission of recruitment applications by candidates and provides various reports to facilitate the processing of the applications at NPL's Recruitment Division.
- A project has been undertaken to automate the library processes.
- The Personnel Inventory System (PIR) developed and deployed earlier, to enable the employees and Central Stores to maintain and the use the records online, has been enhanced to include various report generation facilities to assist Store Administrators in their management tasks. Also enhanced print facility for users in the form of pdf files has been made available.

R & D activities:

- A DST sponsored project entitled "Innovative Product Development Centre" has been started for development of affordable medical instruments. A 12-lead PC plug in ECG device and a battery operated palmtop Pulse Oximeter have been developed.

  These devices were showcased at the CSIR Technofest '10 held during the International Trade Fair. These high quality, low cost solutions to cater to the needs of the Indian healthcare system received an overwhelming response.

  A pilot phase with fifteen ECG units has been planned for feedback from medical professionals before launching the ECG device into the market. A tie up with an industrial partner to manufacture and market the devices is also being pursued.

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 has been revised and new issue has been released. The document manuals are being revised by the various activities. The Quality Policy has been revised and new policy has been displayed in different places of NPL.

Peer review of Acoustic, Vibration & Ultrasonic activity has been initiated. This group helped Ozone Standards activity 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 Thailand. 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 training course on "Quality Management System – Laboratory Management, Need for Calibration / Accreditation as per IS/ISO/IEC-17025 was conducted during 10-12 August, 2010. About 10 participants from different institutes attended the course.

राजभाषा कार्यान्वयन

Rajbhasha Unit

हिन्दी पखवाड़ा

प्रयोगशाला में दिनांक 1.9.2010 से 14.9.2010 तक हिन्दी पखवाड़ा मनाया गया। प्रयोगशाला में स्टॉफ सदस्यों को हिन्दी में अधिक से अधिक कार्य करने के लिए प्रोत्साहित करने के उद्देश्य से वर्ष के दौरान व हिन्दी पखवाड़ा के दौरान विभिन्न प्रतियोगिताओं का आयोजन किया गया।

प्रत्येक वर्ष की भांति इस वर्ष भी जो प्रतियोगिताएं आयोजित की गयी वे इस प्रकार से हैं :– निबन्ध प्रतियोगिता, साइंस क्विज प्रतियोगिता, टंकण प्रतियोगिता, काव्य पाठ प्रतियोगिता, वर्ष के दौरान हिन्दी में किया गया अधिकतम कार्य एवं हिन्दी डिक्टेशन प्रतियोगिता। इस वर्ष से एक नई प्रतियोगिता डेस्क प्रतियोगिता आरम्भ की गयी। इन सभी प्रतियोगिताओं का आयोजन क्रमशः दिनांक 27.4.2010, 12.8.2010, 27.8.2010, 7.9.2010, 6.9.2010 और 3.9.2010 को किया गया। इन सभी प्रतियोगिताओं में प्रयोगशाला के स्टॉफ सदस्यों ने उत्साहपूर्वक भाग लिया व अत्यधिक रूचि प्रदर्शित की।

चित्र न. 1 हिन्दी पखवाडा समापन समारोह का उद्घाटन करते हुए निदेशक प्रो० आर. सी. बुधानी

प्रयोगशाला के आडिटोरियम में दिनांक 14.9.2010 को मुख्य समारोह आयोजित किया गया। इस अवसर पर मुख्य अतिथि के रूप में सुप्रसिद्ध कवयित्री डा. (श्रीमती) कीर्ति काले को आमंत्रित किया गया था। श्री टी वी जोशुवा, प्रशासन नियंत्रक महोदय ने निदेशक महोदय एवं मुख्य अतिथि डा. (श्रीमती) कीर्ति काले व सभागार में उपस्थित प्रयोगशाला के सदस्यों का स्वागत किया और स्टाफ सदस्यों को दैनिक सरकारी कामकाज में हिन्दी का इस्तेमाल करने के लिए प्रेरित एवं प्रोत्साहित करते हुए कहा कि हम सभी को हिन्दी में काम करने में झिझक महसूस नहीं करनी चाहिए और अपना अधिक से अधिक कार्य हिन्दी में करना चाहिए। प्रो. आर सी बुधानी, निदेशक एन पी एल 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। हिन्दी पखवाड़ा मनाए जाने के दौरान आयोजित की गयी प्रतियोगिताओं में से एक काव्य पाठ प्रतियोगिता के प्रथम पुरस्कार विजेता श्री ओम प्रकाश नायक ने अपनी मधुर कविता सभागार में उपस्थित सभी श्रोताओं को पुनः सुनायी। इसके पश्चात् मुख्य अतिथि सुप्रसिद्ध कवयित्री डा. (श्रीमती) कीर्ति काले ने सामाजिक चेतना और रोजमर्रा के जीवन के कुछ प्रसंगों के सौन्दर्य को समेटते हुए कई सुन्दर गीत सुनाकर सभागार में उपस्थित श्रोतागणों को भाव–विभोर कर दिया। तत्पश्चात् निदेशक महोदय ने प्रतियोगिताओं में भाग लेने वाले विजेता प्रतिभागियों को पुरस्कार प्रदान किए।

व्याख्यान

चित्र न. 2 व्याख्यान देते हुए प्रो॰ (डा॰) एस.के. चुग

पिछले कई वर्षों से प्रयोगशाला में विशिष्ट व्याख्यानों की श्रृंखला आरम्भ की गयी है जिसमें समय–समय पर विशिष्ट व्यक्तियों द्वारा उपयोगी विषयों पर व्याख्यानों का आयोजन किया जाता है। इसी क्रम में प्रयोगशाला के सभी सदस्यों के लिए 'स्वास्थ्य' विषय के अन्तर्गत 'हाइपरटेंशन' पर 2 अगस्त, 2010 को एक व्याख्यान

का आयोजन किया गया। 'हाइपरटेंशन' पर 'व्याख्यान' देने के लिए प्रो. (डा.) एस के चुग को विशेष रूप से आमंत्रित किया गया। डा. चुग ने एन पी एल के सभागार में स्टाफ सदस्यों को हाइपरटेंशन के कारणों और उनसे बचने के उपायों के बारे में विस्तार से जानकारी दी। व्याख्यान के पश्चात् श्रोताओं में से कुछ ने प्रश्न भी किए जिनका डा. चुग ने समाधान प्रस्तुत किया।

राष्ट्रीय संगोष्ठी - 2010

मापिकी और समाज के लिए इसकी प्रासंगिकता

हिन्दी आज सम्पर्क भाषा, राष्ट्र भाषा, राजभाषा आदि रूपों में अपनी महत्ता स्थापित कर चुकी हैं। यह सहज सम्प्रेषण की भाषा है जो निश्चय ही व्यक्ति अथवा समूह के स्तर पर चिंतन की भाषा रही हैं, तो सांस्कृतिक संदर्भ की विविध अपेक्षाओं एवं आवश्यकताओं की पूर्ति की भाषा भी है जो भौतिक एवं वैचारिक संस्कृति की व्यावहारिक जीवंत अभिव्यक्ति बन कर आती है। अतः यह कहा जा सकता है कि हिन्दी पूर्णतः लिखित एवं कथित स्तर पर अत्यधिक वैज्ञानिक एवं सामर्थ्य पूर्ण भाषा है।

चित्र न. 3 प्रो॰ आर.सी. बुधानी, निदेशक एनपीएल स्वागत भाषण देते हुए।

मापिकी के क्षेत्र में कार्यरत देश भर के वैज्ञानिकों, इंजीनियरों, उद्योगपतियों एवं विशेषज्ञों को आपसी विचार–विमर्श, अद्यतन विचार धाराओं और अनुभवों के आदान–प्रदान के लिए एक ही मंच पर एकत्र करने की दृष्टि से राष्ट्रीय भौतिक प्रयोगशाला में दिनांक 20–21 मई, 2010 को 'मापिकी और समाज के लिए इसकी प्रासंगिकता' विषय पर हिन्दी माध्यम से एम एस आई के साथ संयुक्त रूप से दो दिवसीय राष्ट्रीय संगोष्ठी का आयोजन किया गया।

मापिकी के विकास में राष्ट्रीय भौतिक प्रयोगशाला और मैट्रोलॉजी सोसायटी ऑफ इंडिया की महत्वपूर्ण भूमिका है। राष्ट्रीय भौतिक प्रयोगशाला मापन के राष्ट्रीय मानकों को सुव्यवस्थित, सुरक्षित और संशोधित करती है व मापिकी सम्बन्धी समस्याओं को हल करने मे उद्योगों और एजेन्सियों की मदद करती है।

संगोष्ठी का शुभारंभ प्रो. आर सी बुधानी, निदेशक एन पी एल के स्वागत भाषण से हुआ। इसके उपरांत प्रयोगशाला के वरिष्ठ वैज्ञानिक डा. पी बनर्जी ने संगोष्ठी विषयक जानकारी प्रदान की और बताया कि प्रयोगशाला पिछले कई वर्षों से हिन्दी में विभिन्न कार्यशालाओं और विज्ञान विषयों पर राष्ट्रीय संगोष्ठियों का आयोजन कर रही है। राष्ट्रीय संगोष्ठी की श्रृंखला में यह दसवीं संगोष्ठी है। तत्पश्चात् प्रयोगशाला में हिन्दी के उत्तरोत्तर प्रचार–प्रसार में राजभाषा यूनिट द्वारा किए जा रहे कार्यों का संक्षिप्त विवरण सुश्री मंजु ने प्रस्तुत किया। इसके उपरांत श्री जी जे ज्ञानी, जनरल सैक्रेटरी, क्वालिटी काउंसिल ऑफ इंडिया द्वारा मुख्य अभिभाषण प्रस्तुत किया गया। मुख्य अतिथि ने अपना अभिभाषण प्रस्तुत करते हुए कहा कि इस प्रकार की संगोष्ठयों के माध्यम से विज्ञान में हो रहे नवीन अनुसंधानों की जानकारी जन साधारण तक उनकी ही भाषा में अर्थात् हिन्दी माध्यम से आसानी से पहुंचायी जा सकती है। उद्घाटन समारोह के अंत में डा. ए के बंद्योपाध्याय ने सबका आभार व्यक्त करते हुए धन्यवाद प्रस्ताव प्रस्तुत किया।

संगोष्ठी में मापन के क्षेत्र में जागरूकता पैदा करने के लिए राजधानी के विभिन्न स्कूलों से लगभग 25 अध्यापकों को आमंत्रित किया गया। सी एस आई आर, आई ए आर आई, डी आर डी ओ और उद्योग जगत आदि से इस संगोष्ठी में शामिल होने के लिए प्रतिभागियों को आमंत्रित किया गया।

इस दो दिवसीय संगोष्ठी को पांच सत्रों में विभक्त किया गया। जिनकी अध्यक्षता क्रमशः प्रो. आर सी बुधानी, डा. पी बनर्जी, डा. बंद्योपाध्याय, डा. कृष्ण लाल एवं श्री बी के अग्रवाल, मारूती उद्योग लि. गुड़गांव ने की। संगोष्ठी में सात आमंत्रित वार्त्ताएं और 41 मौखिक प्रस्तुतीकरण रखे गए। श्रोताओं ने संगोष्ठी में

उत्साहपूर्वक भाग लेकर वक्ताओं को ध्यानपूर्वक सुना व उनसे लाभान्वित हुए। संगोष्ठी में उद्योगों के प्रतिनिधियों और विशेषज्ञों ने निम्न विषयों पर आमंत्रित वार्त्ताएं व शोध पत्र प्रस्तुत किए। संगोष्ठी में जो क्षेत्र सम्मिलित किए गए थे वे हैं : SI मात्रक, प्रमाणित निर्देशक द्रव्य, औद्योगिक मापन व गुणवत्ता आश्वासन, मापन की अनुमार्गणीयता, विधि परक मापिकी, अर्थव्यवस्था और समाज पर MRA का प्रभाव, मापन में अनिश्चितता, मापन में स्वचालन, परिशुद्ध मापन के लिए मापिकी और नैनो मैट्रोलॉजी। इस दो दिवसीय राष्ट्रीय संगोष्ठी को राष्ट्रीय भौतिक प्रयोगशाला तथा मैट्रोलॉजी सोसाइटी ऑफ इंडिया (MSI) द्वारा संयुक्त रूप से आयोजित किया गया। अंत में डा. अशोक कुमार ने माननीय अतिथियों, प्रतिभागियों, राजभाषा कार्यान्वयन समिति के सदस्यों, आयोजकों तथा उपस्थित श्रोताओं को धन्यवाद देकर संगोष्ठी का समापन किया। संगोष्ठी अपने उद्देश्य में पूर्ण रूप से सफल रही। वरिष्ठ वैज्ञानिकों का सहयोग व उनका योगदान विशेष रूप से प्रेरणादायक रहा।

संलग्न

Appendices

APPENDIX-1

PUBLICATIONS
Papers Published by NPL Researchers in SCI Indexed Journals
During April 2010 to March 2011

1. Abdullah, M. M.; Bhagavannarayana, G.; and Wahab, M. A. "Controlled synthesis and structural characterization of polycrystalline GaSe." Journal of Materials Science 45 (Aug 2010): 4088-4092.
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PUBLICATIONS

Papers Published by NPL Researchers in SCI Indexed Proceedings During April 2010 to March 2011

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APPENDIX-2

PATENTS
(01.04.2010 – 31.03.2011)

Patents Filed in India

Sr. No	Title	Application No	Filing Date	Inventors
1.	Nucleic Acid Primers and Sequence for Detection of Neisseria Gonorrhoeae	1391DEL2009	31/05/2010 (complete)	Sood Seema, Rachna, Singh Renu, Gajjala Sumana, Manju Bala, Sumantaray Jyotish Chandra, Pandey Manoj Kumar, Malhotra Bansi Dhar
2.	A Process for the Preparation of Low-Density Multicomponent Graphite Composite Bipolar Plates	0766DEL2010	10.3.2011 (complete)	Mathur Rakesh Behari, Dhakate Sanjay Rangnath, Sharma Shaveta, Dhami Tarsem Lal
3.	Conducting Polymer Paints and Coating Composition for the Corrosion Protection of Iron	0537DEL2010	09/03/2011 (complete)	Dhawan Sundeep Kumar, Sadagopan Sathiyanarayanan, Sulthan Syed Azim, Saini Parveen, S Radhakrishnan
4.	Organic light emitting functional device	0780DEL2010	30/03/2011 (Complete)	M N Kamalasanan, Ritu Srivastava, Amit Kumar, Ishwar Singh, S K Dhawan, S S Bawa
5.	Indelible ink formulations for instantaneous skin marking	0361DEL2011	14/02/2011 (prov.)	R K Sharma, S S Bawa
6.	New Indelible ink formulations for spontaneous marking	0362DEL2011	14/02/2011 (prov.)	S S Bawa, R K Sharma
7.	Development of specific method to identify inorganic phosphate (used as an adulterant) in milk	1582DEL2011	03.06.2011	Ajit Kumar Sarkar, Niranjan Singh and R.C. Sharma

Sr. No	Title	Application No	Filing Date	Inventors
8.	Lithium metal quinolates and process for preparation thereof as good emitting, interface materials as well as N-type dopent for organic electronic devices	1746DEL2011	21.06.2011	Kamalasanan M.N., Srivastava Ritu, Amit Kumar, Ishwar Singh, Dhawan S.K., Bawa S.S.
9.	An improved process for joining of tubes of oxide high temperature superconductors with improved superconducting properties	1748DEL2011	21.06.2011	Gursharan Kaur Padam, Narinder Kumar Arora, Ramesh Kumar Sethi. Shrikant Narayan Ekbote
10.	Light weight high electromagnetic interference (EMI) shilding material based on carbon nanotubes reinforced polymer composites	1793DEL2011	24.06.2011	Singh Bhanu Pratap, Garg Parveen, Pande Shailaja, Mathur Rakesh Behari, Sain Parveen, Dhawan Sundeep Kumar

Patents Granted in India

S. No.	Title	Grant Date	Patent No.	Inventors
1.	An improved cold discharge ion / atom beam source useful for micro - milling and material modification	28/12/2010	244980	Alok Chandra Rastogi, Murari Lal Sharma
2.	Method for detection of earthquake precursors	13/12/2010	244613	B S Gera, H N Duta, Gurubir Singh, V K Ojha
3.	Thin film ethanol sensor and a process for the preparation	07/12/2010	244424	Rastogi A K, Jain K, Gupta H P, Kumar V

Patents Filed Abroad

S. No.	Title	Filing Date	Application No.	Inventors
1.	Process to Make Photo Luminescent Nanostructure Silicon Thin Films	28/06/2010	12/810920	Kumar Sushil, Dixit Prakash Narain, Rauthan Chandra Mohan Singh
2.	Nucleic Acid Primers and Probe for Detection of Neisseria Gonorrhoeae	07/07/2010	PCT/IN2010/000457	Sood Seema, Rachna Verma, Singh Renu, Gajjala Sumana, Manju Bala, Sumantaray Jyotish Chandra, Pandey Manoj Kumar, Malhotra Bansi Dhar
3.	Development of Thick Film Ceramic Gas Sensor:LPG Gas Sensor	07/07/2010	15884	Vipin Kumar, Jain Kiran, Lakshmikumar ST, Raghavendra T
4.	A Process for the Preparation of a Low Contact Resistance Contact on a High Transition Temperature Superconductors	23/07/2010	12/842255	Shrikant Ekbote, Gurusharan Kaur Padam, Narendra Kumar Arora, Mukul Sharma, Ramesh Sethi, Mrinal Kanti Banerjee
5.	Development of Thick Film Ceramic Gas Sensor:LPG Gas Sensor	05/08/2010	AP/P/2010/005255	Vipin Kumar, Jain Kiran, Lakshmikumar ST, Raghavendra T
6.	A Process for the Removal of Arsenic and Chromium From Water	06/02/2011	29/2011	Singh Nahar, Rashmi, Singh Sukhvir, Soni Daya, Pasricha Renu, Gupta Prabhat Kumar
7.	A Process for the Removal of Arsemic and chrocium from water.	11/03/2011	13/046480	Singh Nahar, Rashmi, Singh Sukhvir, Soni Daya, Pasricha Renu, Gupta Prabhat Kumar
8.	A Process for Growing an Electron Injection Layer to Improve the Efficiency of Organic Light Emitting Diodes	31/03/2011	13/077029	Kamalasanan MN, Srivastava Ritu, Grover Rakhi, Dhawan SK, Chand Suresh, Bawa SS

Patents Granted Abroad

S. No.	Title	Grant Date	Patent No.	Inventors
1.	A Process for the Preparation of Novel Sol-Gel Based Enzyme Electrode Useful for Estimation of Cholesterol in Aqueous Medium.	27/04/2010	2512282	Kumar A, Malhotra Bd, and Rajesh
2.	Process for the Preparation of High Temperature Superconducting Bulk Current Leads With Improved Properties and Superconducting Bulk Current Leads Made Thereby	25/05/2010	7722918	Ekbote; Shrikant Narayan , Padam; Gursharan Kaur, Arora; Narinder Kumar, Sharma; Mukul, Sethi; Ramesh Kumar, Banerjee; Mrinal Kanti
3.	A Process for the Preparation of Lactate Bio-Sensing strip Useful for the Determination of Lactate in an Aqueous Solution.	29/06/2010	2512279	Pandey MK, Chaubey A, Pande KK, Sharma RK, Saini KK, Malhotra BD, and Rajesh
4.	A Process for the Preparation of a Low Contact Resistance Contact on a High Transition Temperature Superconductors	7/9/2010	7792560 B2	Shrikant Ekbote, Gurusharan Kaur Padam, Narendra Kumar Arora, Mukul Sharma, Ramesh Sethi, Mrinal Kanti Banerjee
5.	Polymer Coated Long Duration Optical Memory Device and a Method for the Development Thereof	03/09/2010	4580050	Ashok M. Biradar, Sukhwant S. Bawa, Ereuvassi P. Haridas, Subhas Chandra
6.	A Sensitive, Fast Responsive Thin Film Ethanol Sensor and a Process for the Preparation of a Sensitive, Fast Response Thin Film Ethanol Sensor and a Process for the Preparation of a Precursor Solution for Ethanol Sensor	14/09/2010	2466590	Rastogi AK, Jain K, Gupta HP, Kumar V
7.	An Improved Process for the Preparation of Doped Lead Iron Tungstate Relaxor Material for Wide Range Pressure Measurement and a Capacitive Pressure Transducer Made Thereby	01/03/2011	164145	Jain Kamlesh Kumar

APPENDIX-3

TECHNOLOGIES MARKETED
KNOWLEDGE BASE GENERATED AND TRANSFERRED

S. No.	Title of the technology	Date of Transfer	Licensee
1.	Mobile Teleclock Receiver- An improved version of Teleclock Receiver utilizing mobile network	13.04.2010	M/s Sertel Electronics (P) Ltd, Chennai, Tamil Nadu
2.	A new process for the preparation of carbon thrust pads useful for carbon thrust bearings	22.09.2010	M/s Omkar Engineers, Rajkot, Gujarat

APPENDIX-4

R & D COLLABORATIONS

Collaborating Institute	Area
Collaborative Academic Project between C.G.C., NPL and Phys. Dept., Anna University, Chennai	Crystal Growth and Characterization
Collaborative Academic Project between C.G.C., NPL and Crystal Growth Centre, SNN College of Engg., Chennai	Crystal Growth and Characterization
Collaborative Academic Project between C.G.C., NPL and Physics Department, Jamia Millia Islamia	Crystal Growth and Characterization
Thaper University, Patiala	Aerosols & Health
Hokkaido Univ., Sapporo, Japan	Aerosol Chemistry
PTB Braunschweig	Metrology in Chemistry
BAM Berlin, Germany	Metrology in Chemistry
Institute of Experimental Physics, Academy of Science, Kosice, Slovak	Nanomagnetic fluids
NML, Jamshedpur	Ferrofluid
CEERI, Pilani	Ferrofluid
Bhavnagar University, Bhavnagar	Ferrofluid
Delhi Technological University	Raman studies on $Ba_5SmTi_3Nb_7O_{30}$, $CaBa_4LaTi_3Nb_7O_{30}$
IIT Kanpur	Nano-silicon
CEERI Pilani	Diamond thin films on BN rods
IIT Delhi	Graphene, ZnO, BN nanotubes, Si-Ge alloys, Si nanowires etc.
M/s. Bharti Automation Pvt. Ltd., New Delhi	Water flow measurement
MAX Super Specialty Hospital, New Delhi	Tumor Diagnosis

APPENDIX-5

SPONSORED/SUPPORTED R & D PROJECTS

Rs. 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	DOS, Department .of Space 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 Modeling and Computer Simulation ,NAL Belur campus, Bangalore	6.37
4.	Preparation and characterization of silicon for solar energy applications	DST, New Delhi	30.16
5.	Development of gold micro-electrode array with nanometer size opening for use in biosensor at physiological conditions	DBT, Department of Biotechnology	3.75
6.	Advancing the Efficiency and Production Potential of Excitonic Solar Cells (APEX)	DST, New Delhi	185.00
7.	Development of continuous nano fibers by electro-spinning	DST, New Delhi	15.00
8.	Band gap engineering of nano phosphors 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 hybrid electroluminescent materials and low power driven lamps (Women Scientist Scheme)	DST, New Delhi	2.50

Sr. No.	Title of the Project	Agency/Client	Amount Received
14.	A novel way to reduce platinum metal loading in a carbon nano-composite electrode to produce low cost-high efficiency commercially viable Polymer Electrolyte Membrane (PEM) fuel cells Indo	DST, New Delhi	12.00
		Total	**343.06**

CSIR NETWORK PROJECTS

Sr. No.	Name of the Project	Project Code	Nodal Officer	Name of the Laboratory
1	R&D on Photovoltaics and other Solar Energy Applications (Supra-Institutional Project)	SIP 0017	Dr P K Singh	NPL
2	Development of Advance Light Weight Metallic Materials for Engineering Applications	NWP 0028	Dr Anil Kumar Gupta/ Dr R C Anandani	AMPRI. Bhopal
3	Conducting Polymer paints and coatings for corrosion protection and shielding of concrete structures in strategic area	NWP 0012	Dr S K Dhawan	NPL as Nodal Lab (Since Dec' 2008)
4	Technology for Assessment and Refurbishment of Engineering Materials and Components	NWP 0027	Dr Sushil Kumar/ Dr Ashok Kumar	NML, Jamshedpur
5	Fabrication of LED Devices and Systems for Solid State Lighting Applications	NWP 0025	Dr S T Lakshmikumar	NPL
6	Advancement in Metrology	NWP 0045	Dr P Banerjee	NPL
7	Surface analysis of Dispensor Cathodes for High Power MWT	NWP 0024 NPL - II	Dr Mahesh Mumar	NPL as Partner Lab CEERI, Pilani as Nodal Lab
8	Design and Fabrication Capabilities for very High Power Microwave Tubes	NWP 0024 NPL - I	Dr G Bhatia	CEERI, Pilani
9	Mega-city atmospheric pollution precursor process modeling	NWP 0017	Dr M K Tiwari/ Dr C Sharma	IITR, Lucknow

APPENDIX-6

CONSULTANCY PROJECTS

Rs. (In lakhs)

Sr. No.	Client	Title	Contact Value	Amount Received 2010-11
NEW				
1.	SIMCO Calibration Laboratory, Hyderabad	Guidance in implementing of quality system dimensional parameters as per ISO 17025	1.37	0.69
2.	Electronics and Quality Development Centre, Gandhinagar, Gujarat	Metrological characterization of a dual range hydraulic piston gauge	3.39	3.39
3.	Electronics Test and Development Centre, Chennai	Evaluation of metrological characteristics of a pressure balance	3.58	3.51
4.	Rajesh & Rajesh Std Lab, Flat No. G-07, D-Wing, Konark Apartment, Kon Village, Mumbai-Pune Road, Tal Panvel, Dist Raigad	Set-up of laboratory of mass measurement for NABL accreditation	2.49	2.49
NEW & COMPLETED				
1.	Fenesta Building Systems, Plot No. 52, Sector 52, Sector 32,Institutional Area, Gurgaon - 122 003, Haryana	Investigation on sound Insultation properties of Single, Double and triple window glazings	2.76	2.48
OLD & COMPLETED				
1.	Bangalore Metro Rail Corporation Ltd (BMRCL), Bangalore	Noise and vibration study in and around proposed Bangalore metro trains/stations near historic monuments	11.24	0.00
2.	General Motors India Ltd, Bangalore, Karnataka	Recrystallization and grain refinement mechanism during extrusion of magnesium alloys	65.97	13.27
3.	Archaeologigical Survey of India (ASI),Chennai Circle, Chennai, Tamil Nadu	Investigation of induced vibrations due to acoustic excitation from sound show at Brihadisvara Temple, Thanjavur (TN)	4.49	0.00
4.	Archaeologigical Survey of India (ASI),Chennai Circle, Chennai, Tamil Nadu	Investigation on effect of light show at Brihadisvara Temple, Thanjavur (TN)	4.47	0.00

Sr. No.	Client	Title	Contact Value	Amount Received 2010-11
5.	Assam Tourism Development Corporation Ltd (ATDCL), Guwahati, Assam	Investigation of induced vibrations due to acoustic excitation from sound show at Talatal Ghar, at Shiv Sagar, Assam	4.49	0.00
6.	Assam Tourism Development Corporation Ltd (ATDCL), Guwahati, Assam	Investigation on effect of light show at Talatal Ghar, at Shiv Sagar, Assam	4.47	0.00
CONTINUING				
1.	CSIO, Chandigarh	Quality system implementation in geoseimic and medical instrumentation in accordance with ISO/IEC 17025: 2005	0.00	0.00
2.	Regional Reference Standards Laboratory (RRSL), Guwahati, Assam	Setting up of torque standard machine at RRSL, Guwahati	14.29	0.00
3.	Regional Reference Standards Laboratory (RRSL), Faridabad, Haryana	Design, fabrication and installation of primary torque measurement machine at RRSL, Faridabad	31.00	0.00
4.	Aeronautical Development Agency (ADA), Bangalore, Karnataka	Certification of reference blocks of various materials as per 1,2mm FBH standards of ASTME 127-PV3/PV5 (59/704)	9.36	0.00
5.	Regional Reference Standards Laboratory (RRSL),Bangalore, Karnataka	Design, develop and fabricate torque primary standards from 2 Nm-200 Nm within uncertainity of 0.05 %	31.00	0.00
6.	Regional Reference Standards Laboratory (RRSL), Bangalore, Karnataka	Design,erection and commissioning of dead weight force machine at RRSL,Bangalore	101.25	20.15

Sr. No.	Client	Title	Contact Value	Amount Received 2010-11
7.	Regional Reference Standards Laboratory (RRSL), Ahmedabad, Gujarat	Design, primary and secondary torque measuring facility at RRSL, Ahmadabad	14.29	0.00
8.	Regional Reference Standards Laboratory (RRSL), Bhubaneswar, Orissa	Supply of one number of secondary torque measureent facility at RRSL, Bhubaneswar	14.29	2.68
9.	Regional Reference Standards Laboratory (RRSL), Ahmedabad, Gujarat	Design, develop & fabricate secondary force standards upto 50 kN by comparison of 0.05 %	22.29	0.00
10.	Regional Reference Standards Laboratory (RRSL), Bhubaneswar, Orissa	Design, develop & fabricate secondary force standards upto 50 kN by comparison of 0.05 %	22.29	0.00
11.	Regional Reference Standards Laboratory (RRSL), Guwahati, Assam	Design, develop & fabricate secondary force standards upto 50 kN by comparison of 0.05 %	22.29	0.00
12.	Regional Reference Standards Laboratory (RRSL), Faridabad, Haryana	Design, develop & fabricate secondary force standards upto 50 kN by comparison of 0.05 %	22.29	0.00
13.	Raipur Tar Product, Raipur, Chhattisgarh	General consultancy relating to reduction of QI from high QI Coal Tar Pitch	0.98	0.00
		Total	**414.35**	**48.66**

APPENDIX-7

EARNING FROM CALIBRATION & TESTING

Apex Level Standards & Metrology			
Sub-division No.	**Sub-division**	**Charges or Actual Amount Received, Inclusive of all Taxes (In lacs)**	**No. of Reports**
D5.01	Mass Standards	70.46	409
D5.02	Standards of Dimension	48.75	258
D5.03	Temperature & Humidity Standards	32.24	143
D5.04	Optical Radiation Standards	83.51	470
D5.05	Force & Hardness Standards	51.61	390
D5.06	Pressure & Vaccum Standards	28.77	87
D5.07	Acoustics, Ultrasonics, Shock and Vibration Standards	21.49	139
D5.08	Fluid Flow Measurement Standards	1.51	9
Total (A)		**338.34**	**1905**
Time, Frequency and Electrical Standards			
Sub-division No.	**Sub-division**	**Charges or Actual Amount Received, Inclusive of all Taxes (In lacs)**	**No. of Reports**
D4.03	Precise Timing Systems	3.28	15
D4.04.01	LF & HF Impedance & DC Standards	13.03	80
D4.04.02	LF & HF Voltage, Current & Microwave Standards	29.93	78
D4.04.03	AC High Voltage & AC High Current Standards	26.62	50
D4.04.04	AC Power & Energy Standards	19.56	66
Total (B)		**92.42**	**289**

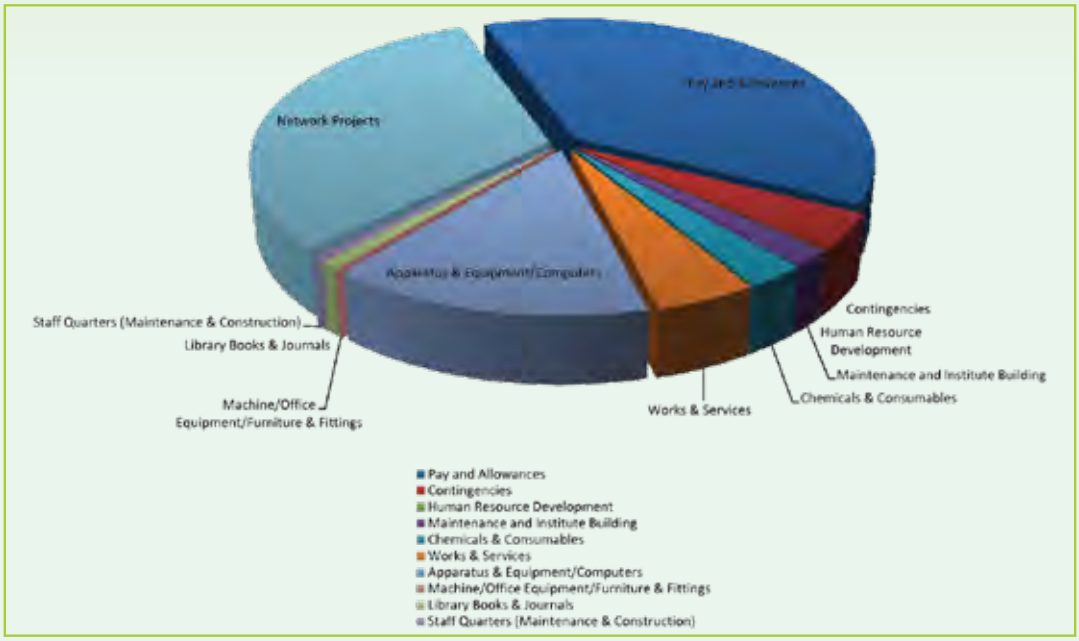
Materials Physics and Engineering.			
Sub-division No.	**Sub-division**	**Charges or Actual Amount Received, Inclusive of all Taxes**	**No. of Reports**
D2.01	Polymer & Soft Material	0.18	2
D2.02	Physics & Engineering of Carbon	2.12	5
D2.04	Multiferroics and Magnetics	3.30	27
D2.06	Optical Thin Films & Ceramics	0.74	11
D2.07	Metals & Alloys	0.49	4
Total (C)		**6.83**	**49**
Physics of Energy Harvesting			
Sub-division No.	**Sub-division**	**Charges or Actual Amount Received, Inclusive of all Taxes**	**No. of Reports**
D1.05	Organic and Inorganic LEDs	0.23	1
Total (D)		**0.23**	**1**
Sophisticated and Analytical Instruments			
Sub-division No.	**Sub-division**	**Charges or Actual Amount Received, Inclusive of all Taxes**	**No. of Reports**
SD7.01.01	X-Ray Analysis	0.05	1
SD7.01.02	Electron & Ion Microscopy	3.78	38
SD7.01.04	Analytical Chemistry	5.35	49
Total (E)		**9.18**	**88**
SUMMARY			
Division	**Division**	**Charges or Actual Amount Received, Inclusive of all Taxes**	**No. of Reports**
D 1	Physics of Energy Harvesting	0.23	1
D 2	Materials Physics & Engineering.	6.83	49
D 4	Time, Frequency and Electrical Standards	92.42	289
D 5	Apex Level Standards & Industrial Metrology	338.34	1905
SD 7	Sophisticated & Analytical Instruments	9.18	88
		447.00	**2332**

APPENDIX-8

ACTUAL EXPENDITURE 2010-11

Rs. (in Lakhs)

Sr. No.	Budget Heads	Expenditure
1.	Pay and Allowances	4533.886
2.	Contingencies	485.904
3.	Human Resource Development	1.038
4.	Maintenance and Institute Building	235.471
5.	Chemicals & Consumables	330.147
6.	Works & Services	567.886
7.	Apparatus & Equipment/Computers	1805.138
8.	Machine/Office Equipment/Furniture & Fittings	11.159
9.	Library Books & Journals	110.000
10.	Staff Quarters (Maintenance & Construction)	81.420
11.	Network Projects	3785.358
	Total	**11947.406**



APPENDIX-9

RECOGNITIONS HONOURS AND AWARDS

Name of the Awardee	Name of the Award/Honour/ Recognition	Honoring Agency/Institute
Dr. O. S. Panwar	MRSI medal	Materials Research Society of India (MRSI)
Dr. Govind	Young Scientist Platinum Jubilee Award-2010 in Physical Sciences	National Academy of Sciences, India (NASI)
Dr. Bipin Kr. Gupta	Indo-US Research Fellowship Award	Indo-US Science and Technology Forum, Fulbright House, New Delhi
Dr. S. R. Dhakate	Advanced Materials letters scientist award 2010	International association of advanced materials and VBRI press
M Arif sanjid, Dr. K P Chaudhary	Technology day Award for copyright of a software	NPL-India
Dr. K P Chaudhary	Chairman, BIS sub-committee PGD25	BIS
Dr. K P Chaudhary	Guest Editor of special issue on length and dimensional metrology	MSI
Dr. K P Chaudhary	Reviewer for BIS standards	BIS
Team award to Dr. Hari Kishan, Bhikham Singh and Shiv Dutt Sharma	Citation plus cash prize of Rs. 5000/- for transfer of technology "portable relative humidity (RH) generator" to M/s Belz Instruments Pvt. Ltd., Faridabad	NPL, New Delhi
Team award to Dr. Hari Kishan, S.K. Aggarwal, R.B. Saxena, Bhikham Singh and Shiv Dutt Sharma	Citation plus Cash prize of Rs. 2500/-for granting patent on "A compact dew point generator",	NPL, New Delhi
Dr. Sanjay Yadav	Member, Editorial Board	Journal of Metrology and Quality Engineering (IJMQE), France
Dr. Mahavir Singh	Visiting Faculty (for the session 2010-11)	Department of Physics, Bundelkhand University, Jhansi
Dr. Naveen Garg	Guest Scientist	Vibration Metrology Division, PTB Germany
Dr. Prabhat K. Gupta	Member, scientific advisory committee of Environ. Monitoring & Research Centre	IMD, MoES

APPENDIX-10

PhDs BASED ON THE RESEARCH WORK DONE AT NPL

Sr. No.	Title	Awardee	University/Institute	Guide(s)
1.	Influence of plasma enhanced chemical vapour deposition process parameters on the growth & properties of hydrogenated micro/ nanocrystalline silicon films	Ayushman Parashar	Delhi University Delhi	Dr. P. N. Dixit, (NPL) Prof. S. A. Hashmi (Delhi University)
2.	Dynamics of memory effect in ferroelectric liquid crystals	Amit Choudhary	Delhi University Delhi	Dr. A. M. Biradar (NPL) Prof. K. Srinivas (Delhi University)
3.	Effect of nanomaterials on the electro-optical properties of deformed helix ferroelectric liquid crystals and their applications	Jai Prakash	Indian Institute of Technology Delhi	Dr. A. M. Biradar (NPL) Dr. D. S. Mehta (IIT Delhi)
4.	Study of Classical and Quantum Correlation Properties of Optical Fields	Nandan Singh Bisht	Delhi University, Delhi	Prof. Enakshi K Sharma (DU) Dr. H.C. Kandpal (NPL)
5.	Experimental Study of Coherence and Polarization Properties of Optical Fields	Bhaskar Kanseri	Delhi University, Delhi	Dr. Shyama Rath (DU) Dr. H.C. Kandpal (NPL)
6.	Study of Partially Coherent Optical Fields and their Applications	Swati Raman	Jamia Milia Islamia, Delhi	Prof. M. Hussain (Jamia) Dr. H.C. Kandpal (NPL)
7.	Theoretical and experimental studies on GaSe, Ga_3Se_4 chalcogenide compounds	M. Abdullah	Jamia Millia Islamia, New Delhi	Dr. M.A. Wahab (Jamia) Dr. G. Bhagavannarayana (NPL)
8.	Synthesis and Characterization of Ferrofluids for Various Device Applications	Vinod Kumar	Kurukshetra University, Kurukshetra, Haryana.	Dr. M.S. Yadav, (Kurukshetra University) Dr. R.P. Pant (NPL, New Delhi)

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 research scholars. All these activities eventually lead to the generation of the trained S&T manpower. 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, where ever 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.

Eight (08) training courses on diverse topics of Mass Metrology, Force, Torque & Hardness Measurements, Calibration of Glass Thermometers , Photometry & Colorimetry, Material Characterization Techniques, etc. were organized by NPL during 2010-11, which were attended by a large number of personal belonging to various national and international organizations, including many from NPL also.

This activity led to an ECF generation of Rs. 5.75 Lacs.

2. 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 over the country, including Students of IITs/IASc-Bangalore, etc., 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 year 2010-11, 102 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. 3.38 lacs.

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 HRD Group. The basic objective is to provide the visitors a glimpse of the NPL activities and achievements, and thus enhance NPL's visibility in the society.

During 2010 -11, Nine institutional visits were organised by NPL, which involved around 250 persons and included prestigious institutions like, IILM Ranchi, Vivekanand Kendriya Vidyala Schools (Assam & Nagaland), INSPIRE Internship Programme (DST) etc.

4. 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 special training programmes conducted by DST, HRDC (Ghaziabad) or other such organisation, or awards instituted by various agencies.

More than 150 different types of HRD-related papers were displayed at 4-5 prominent places of the laboratory each, during the year 2010-2011.

5. Deputation of NPL Staff Members to Attend Conferences / Similar Events

NPL encourages and supports its staff members, including the floating members like 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.

A large number of NPL scientists and other staff members (210 cases) were deputed to participate in various conferences / similar events and different Training Courses held across the country during the year 2010-11.

6. Placement, Ph.D. Registration and other Support to Research Fellows

One of the most prominent activities of the HRD Group 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 in india & abroad 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 2010 -11, 38 research fellows (JRFs/SRFs) were inspired to join NPL, resulting in a total strength of Research Fellows (JRFs+SRFs) in NPL to be 91 as on 31.03.2011.

7. Orientation of Newly-Recruited Scientists

Co-ordination is done for the newly-recruited scientists for undergoing a 2-week Orientation Programme. This consists of meeting with senior scientists, including all Divisional Heads and interacting with them on their research activities. The basic aim of the Orientation Programme is to provide the freshly-inducted scientists an opportunity to have a glimpse of all the research activities being carried out at NPL, right in the very beginning of joining the NPL. This awareness could be very helpful in their proper placement by the authorities as well as in their pursuit of research activities in the future.

8. Formulation of NPL Training Calendar

The formulation of 'NPL Training Calendar' and its communication to the prospective industries / laboratories / scientific institutions is the very first step towards the organization of Training Courses by the NPL. The NPL Training Calendar for the year 2011-2012 was formulated by the HRD Group in consultation with a committee approved by the Director, NPL & Technical Coordinators and sent to all the relevant parties. These training courses, while benefiting the concerned personnel and thus contributing towards the generation of trained S&T manpower in the country, are beneficial to NPL also in terms of its image / visibility enhancement and ECF generation.

OTHER IMPORTANT ACTIVITIES OF THE HRD GROUP

I. Seminar on Advanced Materials & Quantum Metrology for NET-qualified JRFs

A 1-Day Seminar on Advanced Materials & Quantum Metrology was organized on 28th May, 2010. The objective of the Seminar was to give an exposure of the activities being pursued at NPL in the area of Advanced Materials & Quantum Metrology to the NET-qualified JRFs, to attract them to join NPL for their Ph.D. work. The seminar started with welcome by Dr. R.K. Kotnala, Chairman, NPL Academic Committee, followed by the Inaugural address by Prof. R.C. Budhani, Director, NPL. Prof. Budhani delivered a very fascinating lecture emphasizing why the students (JRFs) should join NPL for their Ph.D. work. The various points which he covered, included 'state-of-the-art facilities & infrastructure', 'global visibility of NPL', 'the CSIR connection', 'comfortable hostel accommodation' and 'living in Nation's capital', besides others. After the Inaugural address, there were five lectures by the learned scientists of NPL in the areas of their activities. This was followed by visits to various Laboratories, namely, Quantum Standards, Nano Science & Technology, Surface Physics & Nanostructured Group, Liquid Nitrogen & Liquid Helium Plants, Organic Electronics Laboratory, Time & Frequency Group, and Magnetic Ferro-fluids Laboratory. The ended with lively interaction between the students and the scientist of the NPL. A copy of the technical programme alongwith copies of the Power Point Presentation by the different scientist are attached herewith.

The programme was attended by 32 NET-qualified JRFs. All these students were extremely pleased to see the various activities of NPL and felt interested in joining NPL for their Ph.D. work. These efforts proved fruitful in the joining of 10 students for their Ph.D. work at NPL, in the month of July.

II. CSIR Foundation Day Celebrations

The HRD Group was actively involved in the organisation of this function, in association with all the divisions of NPL. The CSIR Foundation Day – 2010 was celebrated by NPL on 26th Sept., 2010, in a very vibrant and enthusiastic manner. Dr. R.S. Bisht, former Joint Director General, Archeological survey of India, was the Chief Guest, who delivered the CSIR Foundation Day Lecture, entitled "Ideology and Science in the Harappan Town Planning with Special Reference to Dholavira". Various competitions such as drawing & painting competitions, essay competitions, and quiz competitions etc. were organized for the children of NPL staff members and prizes distributed to the winners. The cultural programme, including a skit & songs, was also organised by the NPL Ladies Club, staff & students of NPL, on this occasion. 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. R.S. Bisht 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 and teachers as well as general public. Around 1500 visitors from 24 schools and colleges visited NPL on this occasion. Each of the students was also given a memento (NPL Cap), which was liked by all. The smiles on these young faces won the hearts and minds of the NPL staff members, who were busy attending to Open Day Activities all morning. The happy enthusiasm of the school children made the entire Open Day programme a big success.

III. Organization of CSIR Programme on Youth for Leadership in Science (CPYLS)

The Annual CSIR Program on Youth for Leadership in Science (CPYLS) was organized by NPL at its campus on 25th & 26th November, 2010 and was attended by bright young school children of various schools, specially chosen by the CSIR for this programme. The programme started with an inaugural address by the Director, Prof. R.C. Budhani followed by a very informative and fascinating lecture by Prof. Kehar Singh of IIT, Delhi. The programme included two

other lectures on different topics, namely, "Liquid Crystal Display Devices" and "Nanoscience & Nanomagnetics in Industrial Applications" by the senior scientists of NPL, Dr. A.M. Biradar and Dr. R.K. Kotnala, Chairman- Academic Committee, respectively. The programme also involved visits of the school children to various Research Groups of NPL involving different R&D activities, namely, Pressure and Vacuum Standards, Force & Hardness Standards, Liquid Nitrogen Plant, Time & Frequency Standards, Superconductivity, Mass Standards, Luminescent Materials, Physics & Engineering of Carbon, Organic & Inorganic LEDs, Microcrystalline Silicon Solar Cells, Magnetic Standard, Ozone Calibration System, Nano-Science Lab, to have a glimpse of scientific research being carried out.

The basic objective behind the whole programme was to inspire and motivate the talented school children towards Science and Scientific Research as the Career.

IV. Organisation of National Science Day Function

In honor of Sir C.V. Raman for his legacy and discovery of the Raman Effect on February 28, 1928, the National Science Day 2011 was celebrated at NPL on 28th Feb, 2011, in coordination with the Academic Committee. Prof. Samir K. Brahmachari, DG, CSIR 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. All NPL staff members along with others invited dignitaries visited the posters showing the research work of the students. To recognize and encourage the students for their research work, six best poster awards under two categories, namely Basic Sciences & Technology, were awarded to the students by the Prof. Samir K. Brahmachari, DG, CSIR. The awardees were duly selected by the jury of eminent scientist, specially constituted by DNPL. The main function started in the afternoon with the lighting of lamp by DG, CSIR at NPL auditorium followed by remarks by the Director NPL, Prof. R.C. Budhani. Prof. Brahmachari delivered the inaugural address namely "CSIR Journey to the Future" in which he emphasized the need to change our vision towards the science. He also talked about the CSIR Vision 2022 & roadmap for deployment of CSIR-800 technologies for the society. The DG, CSIR also informed the audience about the newly opened Academy of Scientific & Innovative Research (AcSIR). While telling about history of science in India, he mentioned how the different fields of science had changed from 'personnel excellence' to 'global S & T leadership' during the last few years. Prof. Brahmachari along with DNPL & senior scientists, visited most of the posters. The DG, CSIR had a very lively interaction with the students and suggested them to take advantage of the modern facilities for their research work.

CONFERENCES, SYMPOSIA, WORKSHOPS AND EVENTS ORGANISED BY NPL

20 May, 2010
World Metrology Day Celebration

12-14 July, 2010
Workshop on Material Characterisation Technology

17 July, 2010
CSIR Network Programme

27 July, 2010
Research Council Meeting

28-30 July, 2010
Training Course on Photometry and Colorimetry

10-12 August, 2010
Training Course on Quality System, Laboratory Management, Need for Calibration/Accreditation ISO-17025

11-13 August, 2010
Training Programme on Blood Pressure Measurement and Clinical Thermometry

15 August, 2010
Independence Day Function

16 August, 2010
Steering Committee Meeting

21-23 September, 2010
Training Programme on Mass Metrology

26 September, 2010
CSIR Open day Celebration

7-8 October, 2010
Brain Storming Meeting on Atmospheric Science Network Project

21 October, 2010
A Lecture on Nobel Physics in Science-2010

2 November, 2010
NPL-SSPL Workshop on Advance Hetero-structure and Device

10-12 November, 2010
Training Programme on Force, Torque and Hardness

18-19 November, 2010
Training Programme on Mass Metrology

18-21 November, 2010
IARI Science on Horticulture

22-23 November, 2010
Vigyan Bharati Seminar

25-26 November, 2010
Central Programme on Youth Leadership on Science (CPYLS)

30 Nov-2 Dec, 2010
Seminar on Materials

20-23 December, 2010
I-ConQest-2010

28 December, 2010
12th Fifth Year Plan for Network Project

28 February, 2011
National Science Day Celebration

APPENDIX-13

LECTURES ORGANIZED UNDER NPL COLLOQUIUM SERIES

S. No.	Date	Speaker with Affiliation	Title of the talk
1.	July 16, 2010	Prof G Baskaran IMSc, Chennai	Super Conductivity :100 Years Young!
2.	July 30, 2010	Prof Kalaharan Maiti TIFR, Mumbai	Novel magnetism in non-magnetic materials and its absence in magnetic materials
3.	August 6, 2010	Prof Pratap Raychaudri TIFR, Mumbai	Phase fluctuations in a 3-dimensional conventional superconductor close to the metal-insulator transition
4.	August 13, 2010,	Prof. Animansu Ghatak Indian Institute of Technology, Kanpur	Adaptive Adhesion via Sub-surface Network of Fluid Filled Microchannels
5.	August 20, 2010	Prof Mandar Deshmukh TIFR, Mumbai	Nano electromechanical devices to probe physics at the nanoscale
6.	September 24, 2010	Prof Umesh V Waghmare JNCASR, Bangalore	First-principles Modeling and Simulations of Nano-scale and Bulk Ferroelectrics
7.	October 8, 2010	Dr. Jiji Pulikkotil KAUST, Saudi-Arabia	Magnetism in Iron-pnictides, from first principles
8.	October 29, 2010	Prof Sushil Auluck IIT Kanpur	Computational Material Science
9.	November 8, 2010	Dr S D Bader (Distinguished Scientist Lecture), Argonne National Laboratory, Argonne IL USA	Spintronics
10.	November 12, 2010	Prof C S Unni Krishnan TIFR, Mumbai	Treasures near the Absolute Zero

INVITED TALKS, LECTURES BY NPL SCIENTISTS

Sr. No.	Speaker's Name		Topic	Event and Venue
1.	Dr. P. K. Singh	i	Silicon solar cell R&D at NPL	Indo-Russian workshop, NPL Nov 30-Dec 2, 2010
		ii	Silicon Photovotaics, history, status and outlook	National Conference on Micro and Nanoelectronics System and Devices, university of Rajasthan and Vivekanand Institute of Technology, Jaipur, 18-20 March 2011
		iii	Wafer based Silicon PV technology	National conference on Recent Advances in Physics and technologies, 26-27 March 2011, Agra College Agra
		iv	Solar Photovoltaic technology: An Overview	16th Technology Summit & Technology Plateform: Indo German Partnership, 7-8 Dec 2010, Delhi
2.	Dr. O. S. Panwar	i	Tetrahedral Amorphous Carbon and Amorphous Carbon Films with Embedded Nanoparticles Deposited by Filtered Cathodic Vacuum Arc Technique	MRSI Medal Lecture in the 22nd Annual General Meeting of Materials Research Society of India (MRSI) held at Bhopal (M.P.), Feb.14-16, 2011.
3.	Dr. Sushil Kumar	i	Plasmonic for Silicon thin film solar cell	DST Brainstroming meeting on Plasmonic and Nanostructured Solar Cells on 15-5-2010 at Department of Physics and Astrophysics, Delhi University, Delhi-110007
4.	Dr. Amish G. Joshi	i	X-ray Photoelectron spectroscopy for nanomaterials	Workshop on Material Characterization Techniques (WMCT-2010), July 12-15, 2010,CSIR-NPL, New Delhi
5.	Dr. Govind	i	Surface Characterization by Surface Sensitive Probes	Workshop on Material Characterization Techniques (WMCT-2010), July 12-15, 2010,CSIR-NPL, New Delhi
6.	Dr. S. R. Dhakate	i	Synthesis, characterization of CNTs and Graphene and its applications	One day seminar on materials preparation and characterization on March 29th, 2011, Physics Department, RTM Nagpur University, Nagpur
7.	Dr. Virendra Shanker	i	Advances in luminescent materials for lighting and displays	National Conference on Luminescence and its Applications (NCLA-2011), held at Pt. Ravishankar Shukla University, Raipur, Feb. 7-9, 2011.

Sr. No.	Speaker's Name		Topic	Event and Venue
8.	Dr. Santa Chawla	i	Development of Nanophosphors for solid state lighting, display and solar cell Applications	"Science Quest 2011" National Science day, Mother Teresa Women's, University, Kodaikanal, Tamilnadu, 28th February, 2011.
		ii	Development of core and core shell nanophosphor for lighting and energy harvesting applications	"National Conference on nanomaterials & application: present postion and road ahead NAPRA-2011)", BHU, Varanasi, 16-18 March, 2011.
		iii	Luminescent nanoparticles and their application	"ALIGARGH NANO-I Workshop On Nanoscience and Nanotechnology" AMU, March 26-27, 2011.
		iv	Development of novel Nanophosphors for lighting and Energy Harvesting Applications	"ICMST-2010", International Conference on recent trends in Material Science & Technology, Thiruvananthapuram, 29-31 Oct, 2010.
		v	Luminescent nanoparticles for various applications	"Apex Forum in Nanoelectronics, IETE 2010" CSIO, Chandigarh, 7th May 2010.
9.	Dr. D. Haranath	i	Progress in primary-color emitting phosphors and nanophosphors for dark vision display applications	National Conference on Luminescence and its Applications (NCLA-2011), held at Pt. Ravishankar Shukla University, Raipur, Feb. 7-9, 2011.
10.	Dr. C. Sharma	i	Reactive Nitrogen and Climate Change: An Indian Perspective	South Asia and East Asia Regional INI Partners Joint Consultative Meeting on 'Reactive Nitrogen Flows and Budgets in the South and East Asia Region in Agriculture and Environment' and 'Networking of partners to launch GPNM Asia Platform' held at New Delhi 21-23 July 2010
		ii	GHG emissions from agricultural soils in India	'8th Workshop on GHG Inventories in Asia (WGIA8) – Capacity building for measurability, reportability and verifiability' held at Vientiane, Lao PDR July 13-16, 2010
		iii	Climate Change and Greenhouse Gas Emissions	'Awareness and Capacity Building in Sustainable Energy (ACBSE2010)' held New Delhi, 6 August 2010.

Sr. No.	Speaker's Name		Topic	Event and Venue
		iv	GHG emissions from Indian Paddy Fields	'MARCO/GRA Joint Workshop on Paddy Field Management and Greenhouse Gases' held at Tsukuba, Japan, 1-3, September 2010.
		v	Modeling of Trace Gas Emission Factors of Road Transport Vehicles	Indo-US Workshop on 'Transportation and Greenhouse Gas Emissions' held at CRRI, New Delhi, 10-11 February 2011.
11.	Dr. Sachchidanand Singh	i	Aerosol Studies at NPL	Consultative Meeting on "Aerosol and Greenhouse Gases Monitoring & Research" at India Meteorological Department, New Delhi, Dec 6, 2010.
		ii	Atmospheric Aerosols and its impact on radiation forcing	International Conference on Geophysical Sciences, Energy, Climate Change and Evolution of Human Society (ICON GSECCES – 2010) organized by Deptt. of Geophysics, BHU, Varanasi, Dec 21-23, 2010
12.	Dr. Monika J Kulshrestha	i	Climate change and our understanding on carbonaceous aerosols in Indian region	International Conference on Global Warming, Climate Change, Sustainable Development and Secular Spirituality organized by Santhigiri Research Foundation, Tiruvananthpuram, September, 10-12, 2010.
13.	Mr. Anil Kumar	i	Calibration of UTM	Training Course in Force, Torque and Hardness Measurement, NPL
		ii	Calibration of UTM	AdMet-2011, Bangalore
		iii	Balance and its Calibration Procedure	ITEC/SCAAP, Program at CSIO, New Delhi
14.	Dr K P Chaudhary	i	Application laser in biomedical instrumentation	34th CSIO-DST Training program on biomedical instrumentation for technocrats from Armed forces, CSIO-Delhi, 11 Aug 2010.
		ii	Calibration and measurement: criticality in R&D	Training program on competency development for technical officers, HRDC Ghaziabad, 28 Sept 2010
		iii	Dimensional metrology: principle of metrology and industrial metrology,	43rd international training program on standardization and quality assurance, 26 Nov 2010,

Sr. No.	Speaker's Name		Topic	Event and Venue
		iv	Calibration and measurement: criticality in R&D	Training program on competency development for technical officers, HRDC Ghaziabad, 11 Nov 2010
		v	Calibration and evaluation of uncertainty measurements in analytical related parameters	Management program on operation maintenance and repair of analytical equipments. CSIO-Delhi, 29 March 2011.
		vi	Calibration, error analysis and uncertainty evaluation in analytical instruments using spectrophotometers and monochromators	Management program on operation maintenance and repair of analytical equipments. CSIO-Delhi, 1 April 2010.
15.	Dr. Y. P. Singh	i	Basic Concepts in Temperature Metrology and formulation & Importance of International Temperature Scales (ITS-90)	The two days workshop organized by NRTC, Parwanoo and held at Ambala Cantonment. May 28-29, 2010.
		ii	Temperature Metrology: Its Importance and Applications in Medical Sciences	Three days International Conference, ICNAMS-2010, organized by Kolhapur, University, Kolhapur (MS) during 21-23 October, 2010.
		iii	Recent Trends in Temperature Metrology and Importance of the International Temperature Scales	National conference on Micro and Nano Electronics Systems and Devises-2011, MINO-2010 during March 11-12, 2011, VIT, Jaipur.
16.	Dr. B.K. Yadav	i	Information exchange in free-space using spectral switching of diffracted polychromatic light – possibilities and limitations	EPS Global 1st International Energy Source Forum Kunming, China
17.	Dr. S.K. Jain	i	Recent developments in force measurements	Ist National Symposium on Advances in Metrology, CMTI, Bangalore, 16-18 Feb. 2011
18.	D. Arun Vijayakumar	i	Barometric Pressure Measurements: Devices, Methods, Corrections and Measurement Uncertainty	Training course on Blood Pressure Measurements for Legal Metrology Officers of various states, UT, IILM and RRSL NPL, India
19	Dr. Sanjay Yadav	i	Technical & Metrological Requirements and Test Procedures for Non-invasive Blood Pressure Measuring Instruments Based on OIML Recommendations	NPL, New Delhi
20.	Dr. Ashok Kumar	i	Ultrasonics in Measurement Science,	National Conference on Ultrasonics, Bundelkhand University, Jhansi 25-26, March, 2011

Sr. No.	Speaker's Name		Topic	Event and Venue
21.	Dr. Yudhisther Kumar	i	Ultrasonic Power Measurement and its Biomedical Necessities,	National Conference on Ultrasonics, Bundelkhand University, Jhansi 25-26, March, 2011
		ii	Applications of ultrasonics in measurement	National Conference on Advances in Metrology (AdMet-2011) Feb. 16-18, 2011
22.	Dr. Mahavir Singh	i	Airborne Sound Transmission through Walls and Floors	Visiting Faculty of the Department of Physics, Bundelkhand University, Jhansi
		ii	Sound Transmission through Building Elements	Indo-US Workshop on Nanosonic & Ultrasound (IUWONU2011) and International Conference on Nanotechnology & Ultrasound (ICNU2011), Trichy
		iii	Acoustic Comfort – Noise Control for Buildings	National Conference on Ultrasonics (NCU-2011), Jhansi
23.	Mr. Naveen Garg	i	Aircraft Noise and Community annoyance in India	Intl Conference on Traffic noise at Dresden, Germany
24.	Mr. Shiv Kumar Jaiswal	i	Various metrological activities at National Physical Laboratory, India with particular reference to fluid flow measurement	Fluid Metrology group of NIST, Gaithersburg
25.	Dr. H.C. Kandpal	i	Quantum correlation studies with thermal light sources	International Conference on Contemporary Trends in Optics and Optoelectronics, IIST, Thiruvananthapuram, India, Jan. 17-19, 2011,
		ii	Mercury contents in compact fluorescent lamp-Hazards & Safety	Forum to Facilitate Asian participation & influence in IEC standards Development for lighting held at Beijing, China, June 22-25, 2010
26.	Dr. Ranjana Mehrotra	i	IR Spectroscopy & Measurement Standards	Management Development Programme, CSIO, New Delhi, April 7, 2010
		ii	Application of vibrational spectroscopy in pharmaceutical analysis	International Conference on Recent Frontiers in Applied Spectroscopy (ICORFAS-2010), Annamalai University, Annamalainagar
		iii	Infrared Spectroscopy: Basics	Winter School on recent Trends in Physics of Atoms, Molecules and Lasers, Department of Physics, BHU, Varanasi, January 17, 2011

Sr. No.	Speaker's Name		Topic	Event and Venue
		iv	Application of Infrared Spectroscopy to Medicine	Winter School on recent Trends in Physics of Atoms, Molecules and Lasers, Department of Physics, BHU, Varanasi, January 17, 2011
		v	Application of Infrared Spectroscopy to Industry	Winter School on recent Trends in Physics of Atoms, Molecules and Lasers, Department of Physics, BHU, Varanasi, January 18, 2011
27.	Dr. G. Bhagavan-narayana	i	Crystal Growth and Evaluation of Structure and Perfection by X-ray methods	A special lecture at Phys. Dept. Government College (A), Rajahmundry, Andhra Pradesh April 6, 2011
		ii	Characterization of Single Crystals, Thin Films and Nanostructures by various advanced techniques based on High-resolution X-ray Diffraction, Reflection and Scattering	International Conference held at Nanotechnology Application Centre, University of Allahabad, Allahabad, held September 19-21, 2010
		iii	An introduction to growth of crystals and their characterization for purity, structure and perfection by X-ray methods.	Nesamony Memorial Christian College, Marthandum, Tamilnadu December 20, 2010
		iv	An introduction to growth of crystals and their characterization for purity, structure and perfection by X-ray methods	S.T. Hindu College, Nagercoil, Tamilnadu December 22, 2010
		v	An introduction to Crystal Growth, X-ray Crystallography and Evaluation of Crystal Structure, Purity and Perfection by X-ray methods	Phys. Dept., Madurai Kamaraj University, Madurai, Tamilnadu February 21, 2011 (under their UGC DRS programme).
		vi	Characterization of Single Crystals, Thin Films and Nanostructures by various advanced techniques based on High-resolution X-ray Diffraction, Reflection and Scattering	School of Physics, Bharatidasan Univ., Tiruchirapalli February 22, 2011
		vii	An Introduction to growth of crystals and characterization, thin films and nano structures for purity, structure and perfection by advance X-ray methods	Golden Jubilee Endowment lecture at Phys. Deptt., National College, Tiruchirappali February 22, 2011

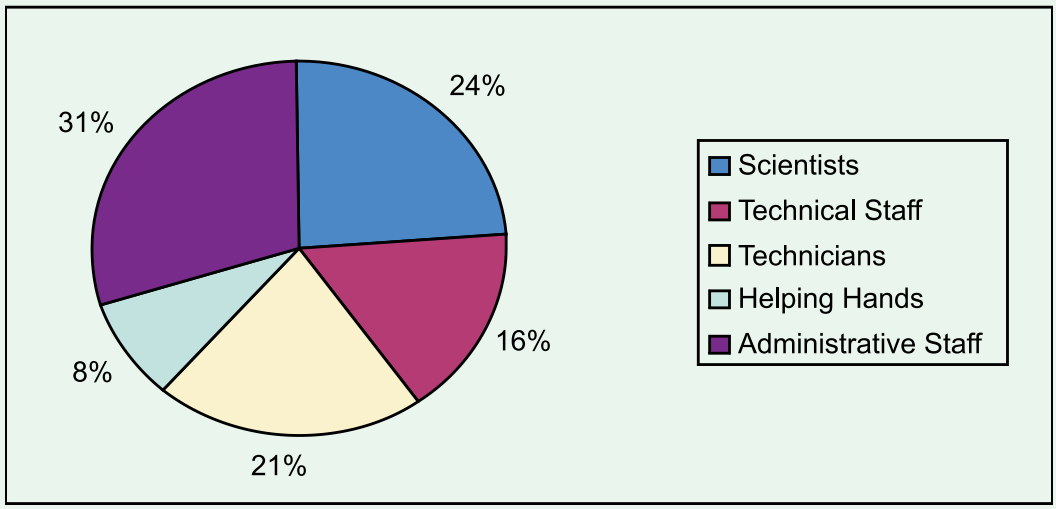
Sr. No.	Speaker's Name		Topic	Event and Venue
		viii	Enhancement of NLO properties in Single Crystals due to Doping/ Annealing and their Correlation with Crystalline Perfection as Investigated by HR-XRD	XXV National Seminar on Crystal Growth, held at Center for Scientific and Applied Research, School of Basic Engineering and Sciences, PSN College of Engineering and Technology, Melathediyoor, Tirunelveli – 627-152, February 23-25, 2011.
		ix	Characterization Single crystals, thin films and nanostructures for purity, structure and perfection by advanced X-ray methods	National Seminar on Recent Trends in nonlinear optical materials and characterization, held at Department of Physics, Sacred Heart College, Chalakudy, 10-11 March, 2011.
28.	Dr. Rashmi	i	Characterization of Materials by X-ray Fluorescence Spectrometry	Workshop on Material Characterization Techniques (WMCT-2010) National Physical Laboratory, New Delhi. 12-16 July, 2010
29.	Dr. N. Vijayan	i	Growth of L-threonine sodium nitrate: A solution grown nonlinear optical crystal	Conference on Crystal Growth held at Department of Physics, Anna University, Chennai during Oct. 18th-19th, 2010 (Conference in Tamil).
		ii	Growth of technologically important single crystals	Physics Association Meeting- Special Invited talk at Dept. of Physics, National College,Trichy, Tamil Nadu 6th January 2011
		iii	Different growth methods of crystal growth Studies	Dept. of Physics, Thanthai Hans Roever Colleg Perambalur, Tamil Nadu, 6 January, 2011
		iv	Single crystals and its applications	Dept. of Physics, SCAD Engineering College, Tirunelveli, 25 February, 2011
30.	Dr. N. Vijayan, Dr. G. Bhagavan-narayana, Dr. K.K. Maurya and Dr. Brijesh Rathi	i	Studies On The Growth, Physical And Other Optical Properties Of Some Amino Acid And Iminodiacetic Acid Complexes	XV National Seminar on Crystal Growth held at PSN College of Engineering and Technology, Tirunelveli, Feb. 23-25, 2011.
31.	Dr. Sukhvir Singh,	i	Basic Fundamentals Involved In Transmission Electron Microscopy	Allahabad university

Sr. No.	Speaker's Name		Topic	Event and Venue
32.	Dr. R.P. Pant	i	An overview of Ferrofluids and its Applications	DBF Dayanand College of Arts and Science, Solapur, 22 Jan. 2011.
33.	Dr. A.K. Srivastava	i	Growth, imaging, spectroscopy and possible applications of nano-structured materials	MRSI Medal lecture, Bhopal, February 14, 2011
		ii	MRSI Medal lecture, Bhopal, February 14, 2011	International Symposium on the Safe Use of Nanomaterials, Lucknow, February 02, 2011
		iii	Synthesis, characterization and possible applications of nanostructured materials, High resolution electron microscopy and associated nano-probe techniques	Allahabad University , January 12, 2011
		iv	Advances in electron microscopy: image interpretations and applications.	International conference on recent trends in materials science and technology, Thiruvananthapuram, October 30, 2010
		v	Nanomaterials: synthesis, characterization and applications	The Indian Institute of Metals, Delhi Chapter, August 24, 2010
		vi	HRTEM, STEM and EELS: Advance Techniques for Nanomaterials Characterization	Burdwan University, April 09, 2010.

APPENDIX-15

HUMAN RESOURCE
As on March, 2011

GROUP IV			**GROUP II**	**Sub-Total :**	166
Director	1				
Scientist H	1		**GROUP I**	**Sub-Total :**	65
Scientist G	31				
Scientist F	42		ADMN-A		6
Scientist EII	22		ADMN-B		77
Scientist EI	29		ADMN-C		42
Scientist C	36		ADMN-C (Cafeteria Staff)		8
Scientist B	24		ADMN-D		96
Sub-Total:	**186**		ADMN-D (Cafeteria Staff)		7
				Sub-Total :	**236**
GROUP III				**GRAND TOTAL :**	**781**
Principal Technical Officer	7				
Supt. Engg. & Asst Engg.	3				
Sr. Technical Officer (3)	23				
Sr. Technical Officer (2)	24				
Sr. Technical Officer (1)	6				
Technical Officer	12				
Tech Asstt Gr III(2)	6				
Tech Asstt Gr III(1)	46				
Junior Engg.	1				
Sub-Total:	**128**				



SCIENTISTS AND OFFICERS AS ON 31.03.2011

Director

Prof R C Budhani

Name	Designation
Physics of Energy Harvesting	
Head : Dr S T Lakshmikumar	
Dr M N Kamalasanan	Scientist G
Dr S T Lakshmikumar	Scientist G
Dr Suresh Chand	Scientist G
Dr Parakram Kumar Singh	Scientist G
Dr Omvir Singh Panwar	Scientist G
Dr S M Shivaprasad	Scientist F
Dr (Ms) Kiran Jain	Scientist F
Dr (Ms) Meenakshi Kar	Scientist F
Dr Abdul Mobin	Scientist F
Sh C M S Rauthan	Scientist F
Sh Sudhanshu Dwivedi	Scientist EII
Dr T D Senguttuvan	Scientist EI
Dr Shailesh Narayan Sharma	Scientist EI
Dr Sushil Kumar	Scientist EI
Dr Amish G Joshi	Scientist EI
Dr Govind	Scientist EI
Dr(Ms) Ritu Srivastava	Scientist EI
Sh Chockalingam Sreekumar	Scientist C
Sh Kamlesh Patel	Scientist C
Dr Muthusamy Senthil Kumar	Scientist C
Dr Vinay Gupta	Scientist C
Ms Vandana	Scientist C
Dr Prabir Pal	Scientist C
Sh Pankaj Kumar	Scientist B
Dr Mahesh Kumar	Scientist B

Name	Designation
Sh Sanjay Kumar Srivastava	Scientist B
Dr Rajiv Kr. Singh	Scientist B
Dr Praveen Kumar Siwach	Scientist B
Sh Ravi Kumar	Principal Technical Officer
Sh Mukul Sharma	Sr. Technical Officer (3)
Sh Gauri Datt Sharma	Sr. Technical Officer (3)
Sh Murari Lal Sharma	Sr. Technical Officer (2)
Sh Jagdish Chand	Sr. Technical Officer (1)

Material Physics and Engineering
Head : Dr Gopal Bhatia

Name	Designation
Dr Gopal Bhatia	Scientist G
Dr Rakesh Behari Mathur	Scientist G
Dr Virendra Shanker	Scientist G
Dr Bansi Dhar Malhotra	Scientist G
Dr Ashok Manikrao Biradar	Scientist G
Dr Tarsem Lal Dhami	Scientist G
Sh Ramesh Chandra Anandani	Scientist F
Dr Sunil Kumar Singhal	Scientist F
Dr R K Kotnala	Scientist F
Dr Tushya Kumar Saxena	Scientist F
Dr Krishan Kumar Saini	Scientist F
Dr S K Dhawan	Scientist F
Dr (Ms) Santa Chawla	Scientist F
Dr Ajay Dhar	Scientist F
Sh Sanjay Rangnate Dhakate	Scientist EII
Dr Narinder Kumar Arora	Scientist EII
Dr K M K Srivatsa	Scientist EII
Dr Rajesh	Scientist EI
Dr Divi Haranath	Scientist EI

Name	Designation
Dr (Ms) Gurusharan Kaur Padam	Scientist EI
Sh Vipin Jain	Scientist EI
Sh. Bhanu Pratap Singh	Scientist C
Dr Preetam Singh	Scientist C
Dr Surendra Pal Singh	Scientist C
Sh.Parveen Saini	Scientist C
Dr Aloysius R P	Scientist C
Dr (Ms) G Sumana Gajala	Scientist C
Dr (Ms) Nidhi Singh	Scientist C
Dr Ved Varun Agrawal	Scientist C
Dr (Ms) Saroj Kumari	Scientist B
Sh Bathula Sivaiah	Scientist B
Sh M Saravanan	Scientist B
Dr Bipin Kumar Gupta	Scientist B
Dr (Ms) Priyanka Heda Maheshwari	Scientist B
Sh Rajiv Sikand	Principal Technical Officer
Sh Tarun Kumar Chakraborty	Sr. Technical Officer (3)
Sh Pinaki Ranjan Sengupta	Sr. Technical Officer (3)
Sh Chander Kant	Sr. Technical Officer (3)
Dr V K Hans	Sr. Technical Officer (3)
Sh Rakesh Khanna	Sr. Technical Officer (2)
Sh Rajesh Kumar Seth	Sr. Technical Officer (2)
Sh Vinod Kumar Tanwar	Technical Officer

Radio and Atmospheric Sciences
Head : Dr B C Arya

Name	Designation
Dr Bhuwan Chandra Arya	Scientist G
Dr M V S N Prasad	Scientist G
Sh Pattamatta Subrahmanyam	Scientist F
Sh Narendra Kumar Sethi	Scientist F

Name	Designation
Sh H K Maini	Scientist F
Sh Thomas John	Scientist F
Dr (Ms) Meena Jain	Scientist F
Sh Deo Raj Nakra	Scientist F
Sh Randhir Singh Tanwar	Scientist EII
Dr Chhemendra Sharma	Scientist EII
Ms Anuradha Sengar	Scientist EI
Dr Tuhin Mandal	Scientist EI
Dr Sachidanand Singh	Scientist EI
Dr(Ms)Monika J. Kulshrestha	Scientist EI
Dr Arun Kumar Upadhayaya	Scientist C
Sh Rupesh M Das	Scientist C
Sh Sumit Kumar Mishra	Scientist C
Dr Rajesh Agnihotri	Scientist C
Dr (Ms) Kirti Soni	Scientist B
Dr Sudhir Kumar Sharma	Scientist B
Sh Shambhu Nath	Sr. Technical Officer (3)
Sh Arun Kumar Ghoghar	Sr. Technical Officer (3)
Ms Shiv Kumari Bhatia	Sr. Technical Officer (3)
Ms Beena Gupta	Sr. Technical Officer (2)
Sh Vinod Kumar Sharma	Sr. Technical Officer (2)
Sh Man Mohan Gupta	Sr. Technical Officer (2)
Sh Alok Mukherjee	Technical Officer

Time, Frequency and Electrical Standards
Head : Dr P Banerjee

Name	Designation
Dr Amitava Sengupta	Scientist H
Dr P Banerjee	Scientist G
Dr Sita Ram Gupta	Scientist G

Name	Designation
Sh Anil Kumar Govil	Scientist G
Sh Mukesh Kumar Mittal	Scientist G
Sh Anil Kishore Saxena	Scientist F
Sh Pramendra Singh Negi	Scientist F
Dr G M Saxena	Scientist F
Sh H R Singh	Scientist F
Sh Joges Chandra Biswas	Scientist EII
Sh Ajeet Singh	Scientist EII
Ms Arundhati Chatterjee	Scientist EII
Sh Kavindra Pant	Scientist EII
Sh M A Ansari	Scientist EI
Sh Rajbeer Singh	Scientist EI
Dr Ashish Agarwal	Scientist EI
Sh Saood Ahmed	Scientist C
Dr (Ms) Poonam Arora	Scientist C
Ms Pranalee Premdas Thorat	Scientist B
Sh Satish	Scientist B
Sh Anil Kumar Suri	Principal Technical Officer
Sh Kul Bhushan Ravat	Sr. Technical Officer (3)
Sh Mohammad Saleem	Sr. Technical Officer (3)
Sh Bijendra Pal	Sr. Technical Officer (2)
Sh Avdhesh Kumar Goel	Sr. Technical Officer (2)
Sh Sridhar Lingam	Technical Officer
Sh Anoop Singh Yadav	Technical Officer

Apex Level Standards and Industrial Metrology

Head : Dr A K Bandhyopadhyay

Name	Designation
Dr Ashis Kumar Bandyopadhyay	Scientist G
Dr Yesh Pal Singh	Scientist G
Dr Ashok Kumar	Scientist G

Name	Designation
Dr Hem Chandra Kandpal	Scientist G
Dr Sushil Kumar Jain	Scientist G
Dr Pardeep Mohan	Scientist G
Dr K P Chaudhary	Scientist G
Sh Subodh Kumar Singhal	Scientist G
Sh Omkar Sharma	Scientist G
Dr Desh Raj Sharma	Scientist F
Sh Anil Kumar	Scientist F
Dr Mahavir Singh	Scientist EII
Sh D Arun Vijayakumar	Scientist EII
Dr Sanjay Yadav	Scientist EII
Dr (Ms) Nita Dilawar	Scientist EII
Dr Sanjeev Sinha	Scientist EII
Sh M P Singh	Scientist EII
Sh Rajesh Kumar	Scientist EI
Dr S Seela Kumar Titus	Scientist EI
Sh Shiv Kumar Jaiswal	Scientist EI
Sh Goutam Mandal	Scientist C
Sh Naveen Garg	Scientist C
Sh Dilip Dhondiram Shivagan	Scientist C
Sh Harish Kumar	Scientist B
Ms Girja Moona	Scientist B
Sh Virendra Babu	Principal Technical Officer
Sh Jagdish Kumar Gupta	Principal Technical Officer
Sh Gurbir Singh	Sr. Technical Officer (3)
Ms Reeta Gupta	Sr. Technical Officer (3)
Dr Yudhisther Kumar Yadav	Sr. Technical Officer (3)
Sh Gurcharanjit Singh	Sr. Technical Officer (3)
Sh K N Basavaraju	Sr. Technical Officer (2)
Sh Ishwar Singh Taak	Sr. Technical Officer (2)
Sh Bhikham Singh	Sr. Technical Officer (2)

Name	Designation
Sh Mukesh Kumar	Sr. Technical Officer (2)
Sh Om Prakash	Sr. Technical Officer (2)
Sh Sudama	Sr. Technical Officer (1)
Sh Mahargha Baran Das	Sr. Technical Officer (1)
Sh Bharat Kumar Yadav	Technical Officer
Sh Harish Kumar	Technical Officer
Sh Rasik Behari Sibal	Technical Officer
Sh Virendra Kumar Gupta	Technical Officer

Quantum Phenomena and Applications
Head : Dr Hari Kishan

Name	Designation
Dr Hari Kishan	Scientist G
Dr Vijay Narain Ojha	Scientist G
Dr Sher Singh Rajput	Scientist F
Dr (Ms) Ranjana Mehrotra	Scientist F
Dr (Ms) P L Upadhyay	Scientist F
Dr. Vijay Kumar (Gumber)	Scientist F
Dr Ratan Lal	Scientist EII
Dr (Ms) Rina Sharma	Scientist EII
Dr Hari Krishna Singh	Scientist EI
Dr Veerpal Singh Awana	Scientist EI
Dr Anurag Gupta	Scientist EI
Ms Manju Singh	Scientist EI
Sh Rajendra Singh Meena	Scientist C
Dr Sudhir Husale	Scientist C
Sh Virendra Kumar Jaiswal	Scientist C
Dr (Ms) Anjana Dogra	Scientist C
(Ms) Priyanka Jain	Scientist C
Dr Ashok Kumar	Scientist B
Ms Santhya Malikar Patel	Scientist B
Dr Parag Sharma	Scientist B
Ms Usha kiran	Sr. Technical Officer (1)
Ms Poonam Sethi Bist	Technical Officer

Administration
Head : Sh T V Joshua

Name	Designation
Sh T V Joshua	COA
Ms Veena Jain	Admn. Ofcr
Sh Vijay Kumar	Sr Security Ofcr
Sh Jagan Nath Prasad	Sr. Technical Officer (2)
Sh Jokhan Ram	Sr. Technical Officer (2)
Sh M C Meena	S O(G)
Sh Rajiv Sharma	S O(G)
Ms Bhawna Guglani	S O(G)
Sh Umesh Gupta	S O(G)
Sh Vikram Singh	S O(G)
Sh Mange Ram	PS
Ms. Paramjit Kaur	PS
Sh Amar Singh	PS
Sh Ram Gopal Meena	PS
Ms Saroj Gandhi	PS

Finance and Accounts
Head : Sh S K Mehta

Name	Designation
Sh S K Mehta	CO (F & A)
Sh Sudipto Chaterjee	F&AO
Sh Ajay Kumar	S O (F&A)
Sh S K Thakur	S O (F&A)

Stores and Purchase
Head : Sh Mukesh Khanna

Name	Designation
Sh Mukesh Khanna	SPO
Sh Bhag Singh	S O (str & pur)

Work and Services
Head : Dr J C Sharma

Name	Designation
Dr Jagdish Chandra Sharma	Scientist F
Sh K P S Yadav	Sr. Supt. Engnr.(Elect)
Sh Deepak Bansal	Sr. Technical Officer (3)
Sh A K Sabarwal	Supt. Engnr.
Sh Mohan Chandra Singh	Sr. Technical Officer (2)
Sh Gurdeep Singh Lamba	Sr. Technical Officer (2)
Sh Rambir Singh	Asstt. Engineer

Workshop
Head : Dr G Bhagavannarayana

Name	Designation
Sh Srinivasan P	Scientist C
Sh Ravi Khanna	Principal Technical Officer
Sh Jai Pal Singh	Sr. Technical Officer (2)
Sh Amar Singh	Sr. Technical Officer (1)

Computation and Network Facility
Head : Dr Ravi Mehrotra

Name	Designation
Dr Ravi Mehrotra	Scientist G
Ms Deepti Chaddha	Scientist C
Sh Ashish Ranjan	Scientist C
Sh Nitin Sharma	Scientist C
Ms Anjali Sharma	Scientist C
Sh Trilok Bhardwaj	Scientist B
Sh Kanwaljit Singh	Sr. Technical Officer (2)
Sh Vijay Sharma	Sr. Technical Officer (2)

Directorate
Head : Prof. R C Budhani

Name	Designation
Prof R C Budhani	Director
Dr Godavarthi Bhagavannarayana	Scientist G
Sh Prabhat Kumar Gupta	Scientist G
Dr Rakesh Kumar Garg	Scientist F
Dr (Ms) Rashmi	Scientist F
Dr Rajendra Prasad Pant	Scientist F
Dr Devinder Gupta	Scientist F
Sh T Raghavendra	Scientist F
Dr Sukhvir Singh	Scientist EII
Dr Avanish K Srivastava	Scientist EII
Dr (Ms) Renu Pasricha	Scientist EII
Ms Santosh Singh Golia	Scientist EI
Dr Nahar Singh	Scientist EI
Dr Kamlesh Kumar Maurya	Scientist EI
Dr (Ms) Prabha Johri	Scientist EI
Dr Shankar Gopal Aggarwal	Scientist EI
Dr Narayanaswamy Vijayan	Scientist C
Dr Nirmalya Karar	Scientist C
Dr Manas kumar Dalai	Scientist B
Dr (Ms) Daya Soni	Scientist B
Dr Sushree Swarupa Tripathy	Scientist B
Sh S B Samanta	Principal Technical Officer
Sh Niranjan Singh	Sr. Technical Officer (3)
Sh V D Arora	Sr. Technical Officer (3)
Dr (Ms) Manju Arora	Sr. Technical Officer (3)
Sh Kedar Nath Sood	Sr. Technical Officer (3)
Sh Ashok Kumar	Sr. Technical Officer (2)
Sh Rajiv Kumar Saxena	Sr. Technical Officer (2)
Ms Abha Bhatnagar	Sr. Technical Officer (2)
Sh Khem Singh	Technical Officer
Ms Anita Sharma	Technical Officer

Intellectual Property and Human Resource
Head : Dr Virendra Shanker

Name	Designation
Sh S Uma Maheshwar Rao	Scientist F
Dr Rajeev Chopra	Scientist F
Dr (Ms) Jyoti Lata Pandey	Scientist F
Dr D P Bhatt	Scientist F
Sh Sushil Kumar Sharma	Scientist F
Sh Ganga Prasad	Scientist F
Ms Indra Tiwari	Scientist F
Sh N K Wadhwa	Scientist EII
Dr R G Mathur	Scientist C
Sh Abhishek Sharma	Scientist B
Sh Jagdish Prasad	Sr. Technical Officer (3)
Sh Ashwani Kumar Suri	Sr. Technical Officer (3)
Sh V K Ojha	Sr. Technical Officer (3)
Ms Shashi Lekha Bhatnagar	Sr. Technical Officer (2)
Sh Rajpal Zamaji Walke	Sr. Technical Officer (1)
Ms Neetu Chandra	Technical Officer

Retired Persons

Sh Narain Singh, Workshop Asstt VII
Dr R K Aggarwal, Scientist G
Dr Mahendra Kumar Goel, Scientist F
Sh Prakash Chand, Sr. Technician (2)
Mrs S K Bajwa, PS
Sh Mahesha Nand, Sr. Technician (2)
Mrs Sushma Malhotra, Asstt (G) Grade -1
Sh Khem Chand I, Jamadar
Dr Chhotey Lal, Scientist F
Dr Bibhash Ranjan Chakraborty, Scientist G
Dr M K Tiwari, Scientist F
Sh Deepak Kumar Tewari, Scientist F
Mrs Manorama Devi, Asst. (G) Grade II
Sh Amarjit Singh, Sr. Technician (2)
Sh D K Khanna, Sr Stenographer (ACP)
Mrs Jaishri Khanna, Sr Stenographer(ACP)
Sh Bateshwar Paswan, Lab Assistant
Dr Sukhwant Singh Bawa Scientist G
Sh Man Mohan Krishna, Scientist C
Mrs Shikha Mandal, Scientist F
Sh Surendra Singh Verma, Scientist G
Sh Ganga Sharan, Sr. Technician (2)
Dr Raj Singh Dabas, Scientist G
Dr Swapan Kumar Sarkar, Scientist G
Sh Prabhu Shankar Tripathi, Sr. Technical Officer (2)
Dr Pradeep Kumar Pasricha, Scientist F
Sh Sadlu Prasad, Sr. Technician (1)

Sh Virender Kumar (Chadha), Sr. Technician (2)
Sh S K Rastogi, Sr. Technical Officer (3)
Sh B V Kumaraswamy, Scientist F
Mrs Kanta Devi, Wash Lady (ACP)/CANTEEN
Mrs Madhu Bahl, Scientist F
Dr Amitabha Basu, Scientist G
Sh Ashok Kumar Sharma Sr. Technician (2)
Sh Deo Raj Nakra, Scientist F
Sh Ganesh Dass, Sr. Technician (2)
Dr G M Saxena, Scientist F
Dr Tarsem Lal Dhami, Scientist G
Sh Ashok Kumar Parnami, Asstt (G) Grade -1

Obituaries

Sh Mewa Lal, Workshop Asstt II
Sh Dinesh Kumar, Sr. Technician (2)
Sh Siya Ram, Karya Sahayak

Scientists Fellow & Emeritus Scientists

Prof Vikram Kumar, Consultant
Dr K K Mahajan, INSA Honorary Sci
Dr Krishan Lal, INSA, President
Dr O P Bahl, Project Adviser / Co-ordinator
Dr.Preeti Bijlani, Part time Medical Officer
Dr S K Joshi, Platinum Jub. Emr. Sci
Dr Vikram Soni, Research Sci C
Dr Vijaykumar Tautam, Scientist Fellow
Dr Jiji Thomas Joseph Pulikkotil, Scientist Fellow
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.
Sh S C Garg, Emeritus Sci.
Dr B R Chakraborty, Emeritus Sci.

Research Fellows / Associates / Interns

Sh Rajeev Kumar, JRF (CSIR)
Ms Amreeta Preetam, JRF (NPL)
Sh Veeresh Kumar, JRF (UGC)
Sh Tilak Joshi, JRF (UGC-NPL)
Ms Aditya Sharma, JRF(CSIR)
Ms Aneeta Kharkwal, JRF(CSIR)
Ms Harjeet Kaur, JRF(CSIR)
Ms Pratibha Goel, JRF(CSIR)
Ms Stuti Joshi, JRF(CSIR)
Sh Ajay Shankar, JRF(CSIR)
Sh Amit Kumar Chauhan, JRF(CSIR)
Sh Ashok Kumar Jangir, JRF(CSIR)
Sh Kajal Kumar Dey, JRF(CSIR)
Sh Manish Verma, JRF(CSIR)
Sh Mohan Lal, JRF(CSIR)
Sh Praba I Pratap Singh Bhadauria, JRF(CSIR)
Sh Sandeep Kumar, JRF(CSIR)
Sh Sandeep Kumar Pundir, JRF(CSIR)
Sh Saurabh Srivastava, JRF(CSIR)
Sh Shijin Babu P., JRF(CSIR)
Sh Suraj Singh Saini, JRF(CSIR)
Sh Surjeet Kumar Mishra, JRF(CSIR)
Ms Nidhi Puri, JRF(CSIR)
Ms Dipti, JRF(CSIR)
Sh Ajay Kumar Kesarwani, JRF(CSIR)
Sh Subhash Chandra, JRF(CSIR)
Ms Meera Singh, JRF(CSIR)
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Sh Pramod Kumar, JRF(CSIR)
Sh Yogendra Kumar Yadav, JRF(NET)-CSIR
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Sh Jitendra Gangwar, JRF(UGC)
Sh Sukhbir Singh, JRF(UGC)

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Ms Savvi Mishra, JRF-DST (Proj. Asst.-II)
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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)
Dr(Mrs) Nupur Bahadur, P.I. Young Scientist
Sh Bhaskar Gahtori, P.I. Young Scientist
Dr Shilaja Pande, P.I.(WOS-A)
Ms Sonal, P.I.(WOS-A)
Dr Jay Singh, RA
Sh Sameer S D Mishra, RA
Ms Indrani Coondoo, RA
Ms Kavita Sharma, RA
Sh Arindam Datta, RA
Dr Arpit Sand, RA, NPL
Ms Anubha Sharma, Res. Intern
Ms Gunjan Mittal, Res. Intern
Ms Namita Gandhi, Res. Intern
Ms Neha Gupta, Res. Intern
Sh Prashant Kumar Gupta, Res. Intern
Sh Himanshu Kumar Sharma, Res. Intern
Sh Raj Kumar, Res. Intern
Ms Poonam Yadav, Res. Intern
Dr (Ms) Punita Singh, Sr. Res. Assoc.
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Dr Ashok Kumar, Sr. Res. Assoc.
Dr Manoj Kumar Srivastava, Sr. Res. Assoc.
Dr Sameer Suwan Dutt Mishra, Sr. Res. Assoc.
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Ms Renu Singh, SRF (CSIR)
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Sh Satya Kumar Kushwaha, SRF (CSIR)
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Sh Deepak Kumar Jangir, SRF (ICMR)
Sh Anil Ohlan, SRF (NET)-CSIR
Sh Vibhav Pandey, SRF (NET)-CSIR
Sh Anoop Kumar S, SRF (UGC)
Sh Ajay Kumar, SRF (UGC-NPL)
Sh Manoj Kumar Srivastava, SRF(CSIR)
Sh Amit Kumar, SRF(CSIR)
Sh Anuj Kumar, SRF(CSIR)
Dr Razi Ahmad, SRF(CSIR)
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Sh Atif Khan, SRF(CSIR)

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Sh Shiva Kumar Singh, SRF(CSIR)	Sh Dharam Pal Singh, SRF-RGN
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APPENDIX-16

RESEARCH COUNCIL, NPL

(01.04.2010 - 31.03.2013)

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12 **Prof R C Budhani** .... Member
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Dr K S Krishnan Marg,
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13 **Sh T Raghavendra** ... .Non-Member
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