वार्षिक प्रतिवेदन
Annual Report
1999-2000

राष्ट्रीय भौतिक प्रयोगशाला, नई दिल्ली

National Physical Laboratory, New Delhi

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FOREWORD

It is a pleasure and privilege to present the Annual Report of the Laboratory for the year 1999-2000. Dr. A.K. Raychaudhuri was the Director, NPL during this year. He was repatriated to his parent institute, Indian Institute of Science, Bangalore in May 2000.

NPL has the l responsibility of maintaining national standards of measurements and providing calibration facilities at the apex level in the country. It pursues R&D work in selected areas of: precision physical measurements; engineering, electronic, soft & polymer materials: materials characteristics and their co-relation with properties: radio and atmospheric sciences: and cryogenics and superconductivity. Sponsered projects and consultancy assignments have been undertaken in all areas of expertise, in addition to the in-house projects. During the year, significant research contributions were related to: development of a new method for measurement of high voltage based on "Stark effect"; quantum confinement of charge carriers in cadmium telluride and silicon nano-crystalline quantum dots; growth of bismuth germanate single crystals and characterization of defects, like *very* low angle boundaries and the effect of annealing on the same; study of abnormally high ultraviolet radiation at high altitudes (Leh and Hanle) in comparison to those at Antarctica, where ozone depletion is known; and effect of columnar defects on flux pinning in Josephson junction arrays. The major applied contributions were related to: design of a noise corridor for Delhi Metro Rail in high density residential locations; development of oval-shape tubes of aluminium alloy for skid landing gear for the Advanced Light Helicopter of HAL; development of special high thermal conductivity graphite for Tokamak; multipurpose alkaline earth aluminate phophors for long decay and plasma decay applications; development of carbon fibre composite based Ilizarov fixtures for polio patients; organic light emitting diodes; biosensors for urea and cholesterol; structural evaluation of highly mismatched GaSb/GaAs layer structures grown by molecular beam epitaxy; automation of an indigenously developed powder X-ray diffractometer; and development of seven Tesla superconducting magnets.

As a part of the Mutual Recognition Arrangement(MRA) among the National Metrology Institutes of the countries, which are signatory to the Meter Convention, NPL participated in CIPM sponsored key comparisons as well as intercomparison under the Asia Pacific Metrology Programme (APMP). Key comparisons of ultrasonic total power measurements in mW range were carried out under CIPM programme. Inter-comparisons were initiated or carried out under APMP on the following: (i) luminous responsivity scale; (ii) two 1 kg mass standards; and (iii) electrical power and energy. A bilateral inter-comparison was carried out with PTB Germany on AC measurements of soft magnetic materials. NPL also conducted proficiency testing in connection with determination of arsenic content in ground water in West Bengal.

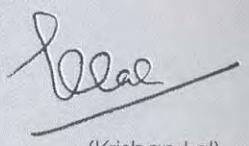
Seven new facilities were created during the year. These include: a portable iodine stabilized He-Ne laser with out put at 633 nm; a low cost Raman spectrometer for high pressure applications; calibration

facilities for H-sensors and magnets; a spray atomization deposition unit; and a computerized multi-channel particle size analyzer.

Three training programmes/NPL industry meet and seven training courses were organized. One of the training courses was on vacuum technology. Seven conferences/symposia including an international conference were held during the year. In one of these meetings, Hindi was the language of all presentations. Four lecturers by eminent scientists: Prof. C.N.R. Rao, Prof. M.M. Sharma, Prof. J.V. Narlikar and Prof. M.S. Valiathan were organized as a part of the Prof. K.S. Krishnan Birth Centenary celeberations.

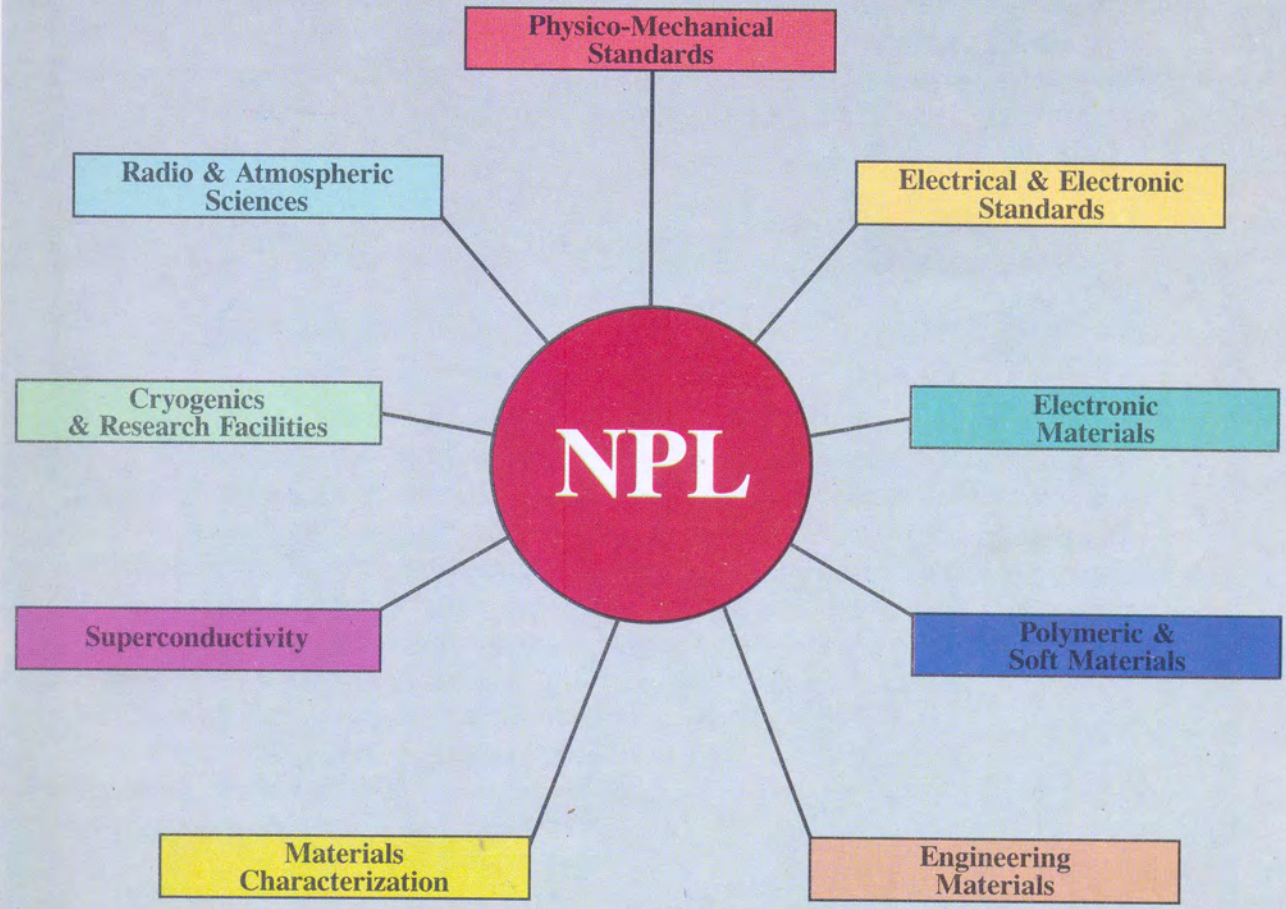
NPL scientists published 110 research papers in refereed journals and 169 papers were presented at conferences/seminars. Eight patents were filed and four students received Ph.Ds during the year. The revenue received from sponsored projects was close to Rs 2.3 crores and that accrued out of consultancy projects was Rs 40 lakhs. Calibration, testing and job works generated more than Rs 2.10 crores. NPL scientists were invited to serve on governing bodies of national institutes. A national delegation constituted by Indian National Science Academy (INSA) was headed by a NPL Scientist and prestigious conferences invited NPL scientists to serve on their committees.

It is a pleasure to acknowledge the R&D contributions of all the scientists and engineers of NPL This report will also help them to achieve higher goals in future. Thanks are due to NPL annual report team for its efforts. I am particularly happy about the efforts made by Dr. V.N. Ojha, Dr. (Mrs) Rina Sharma, Dr. M.K. Goel and Dr. T.D. Senguttuvan, who have spared no efforts to bring out this report.



(Krishan Lal)
Director

R&D Divisions of NPL



भौतिक-यांत्रिक मानक
PHYSICO-MECHANICAL STANDARDS

भौतिक-यांत्रिक मानक प्रभाग की मुख्य गतिविधियॉ ध्वानिक, पराश्रव्यिकी, लम्बाई एवं विमीय मापिकी, दाब एवं निर्वात, बल एवं कठोरता, ताप, अनआयनकारी विकिरण [पराबैंगनी (अल्ट्रावॉयलेट), प्रकाशीय (ऑप्टिकल) तथा अवरक्त (इन्फ्रारेड)], द्रव्यमान, घनत्व तथा श्यानता एवं तरल बहाव के प्राथमिक/राष्ट्रीय मानकों को स्थापित करना व उनका अनुरक्षण करना, अन्तर्तुलन द्वारा इन्हें अन्तर्राष्ट्रीय मानकों के समकक्ष बनाना और उपयोगक्ता स्तर के उद्योगों के उपकरणों का अंशाकंन के द्वारा इनका प्रसार करना तथा पृष्ठीय (Surface) भौतिकी का अध्ययन करना हैं। इसके अतिरिक्त उद्योगों के लिए विश्वस्तर पर आने वाली चुनौतियों का सामना करने हेतु गुणवत्ता में आवश्यक सुधार के लिए तकनीकी परामर्श प्रदान करना और विद्यमान मानकों में संशोधन तथा नए मानकों को स्थापित करने के लिए अनुसंधान एवं विकास परियोजनाओं का उत्तरदायित्व लेना इस प्रभाग के कार्यकलापों में सम्मिलित हैं। इन सभी गतिविधियों ने भारतीय उद्योगों को अंतरराष्ट्रीय स्तर पर स्वीकार्य यथार्थ मापन करने हेतु सक्षम बनाया है। इससे अन्तर्राष्ट्रीय बाजार में भारतीय उद्योगों की प्रतिस्पर्धा को बढ़ावा मिलता है।

The Physico-Mechanical Standards encompasses acoustics; ultrasonics; length and dimensional metrology; pressure and vacuum; force and hardness; temperature; non-ionising radiation (ultraviolet, optical, infrared); mass, density and viscosity; surface physics and fluid flow. The major activities are: i) to establish and maintain primary/national standards, making these traceable to the international standards by intercomparison methods, and disseminate the same to the user level industries by way of calibrating their instruments, ii) to provide technical consultancy to industries for enhancing their quality to meet the challenges in the global scenario, and iii) to undertake research and developmental projects, in particular establishing new standards and improving upon the existing standards. The significance of all these activities pave way for the industries to make precision measurements that are traceable to international standards. This in turn lead to enhancement of competitiveness of Indian industries in the international market.

Acoustics Standards

A noise barrier was designed for the elevated corridor of Delhi Metro Rail Corporation (DMRC), for control of environmental noise pollution, due to transit trains in the corridor. It consisted of an-half T (Y) involving systems with cavities incorporating absorbing materials (Fig.1.1). The whole assembly will be fixed in GI framework in the place of the proposed railings. The expected barrier attenuation of this combination will be about 10-12 dB in the existing situation. As the elevated corridor passes through some high-density traffic zones, a typical residential location was selected and the prevailing noise levels were monitored over the entire day.

Ultrasonics Standards

Work on CIPM key comparison of ultrasonic total power measurement in mW range and also in excess of 1W was started this year using beam calibrator, fixed path vertical float and inverted cone radiation balance. For the online ultrasonic system for testing of rails by their sole manufacturer in India, Bhilai Steel Plant, reference ultrasonic response has been provided from hundreds of simulated defects covering every possible flaw. All the parameters required to be declared for international marketing of ultrasonic medical diagnostic equipment were measured. This would help in the import substitution of such equipment.

A systematic study on modified lead metaniobate resulted in development of a piezoelectric material designated as NPLMN-2 equivalent to EDO-83 and Kezite K-85. The material was found suitable for the applications requiring higher operating temperatures.

Under a sponsored project from NSTL, the last eight units of 38kHz underwater pinger units have been fabricated and supplied to NSTL.

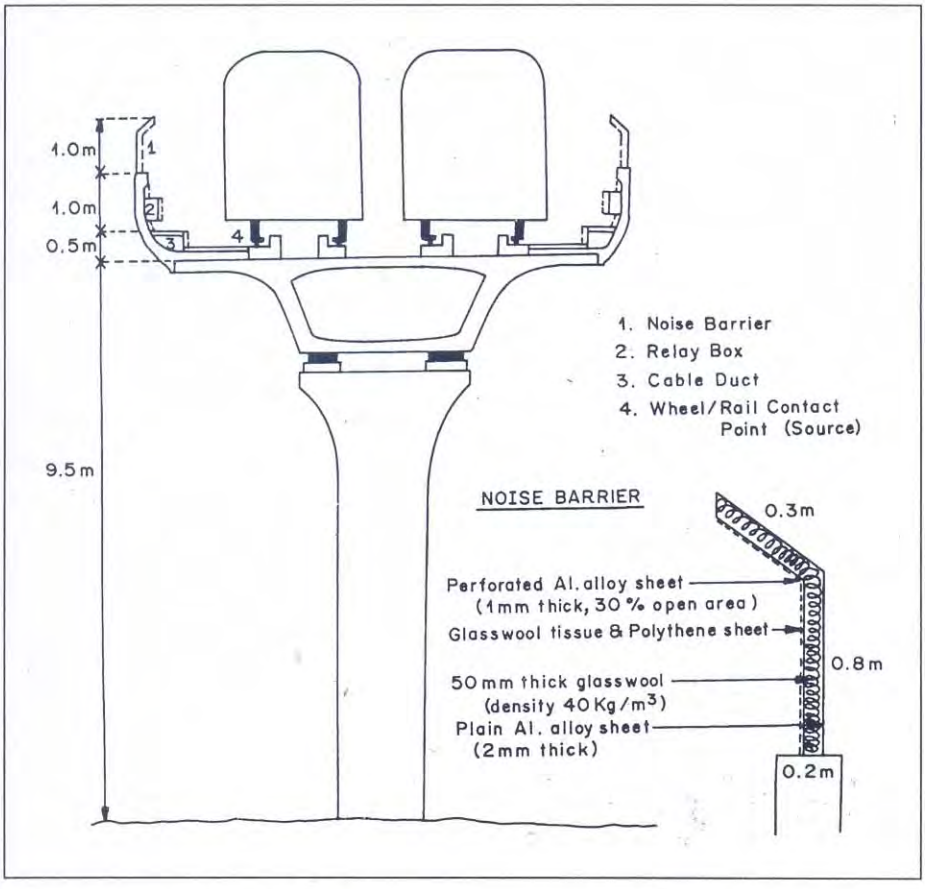


Fig. 1.1: Noise barrier designed by NPL for the elevated corridor of the Delhi Metro Rail Corporation (DMRC)

The consultancy project on studies of encapsulated hydrophones and hydrophone arrays has been successfully completed. A resonant type hydrophone for reception of parametric acoustic signals was developed. A minimum sensitivity of 78mV/Pa at 16.7 kHz with 3 dB receiving bandwidth of 2 kHz was observed showing a very high receiving response as compared to conventional non resonant type hydrophone.

Length Standards

A portable iodine frequency stabilized He-Ne laser at 633 nm wavelength, primary standard of length, was designed and fabricated indigenously (Fig. 1.2). A facility has been set up for corrective measures i.e. adjustment of material temperature sensor and air temperature sensor used for automatic compensation in HP laser interferometer systems. Extended Cavity Diode Laser (ECDL) at 852nm (Fig. 1.3) has been developed and Cs saturated absorption spectrometer has been set up. ECDL has been tuned to observe Cs saturated absorption feature. Precision components were fabricated and supplied to government and private organisations.

Dimensional Metrology

Under a consultancy project, a technique was developed for evaluating the geometrical accuracy of blind holes in 13 m long steel rails having 43 blind holes of 1.5/2 mm diameter with flat bottoms at different orientations. The accuracy of diameter, flatness at the bottom and squareness of axis were measured for all the holes. These rails are to be used by Bhilai Steel Plant as reference standard to calibrate their ultrasonic test system at site.

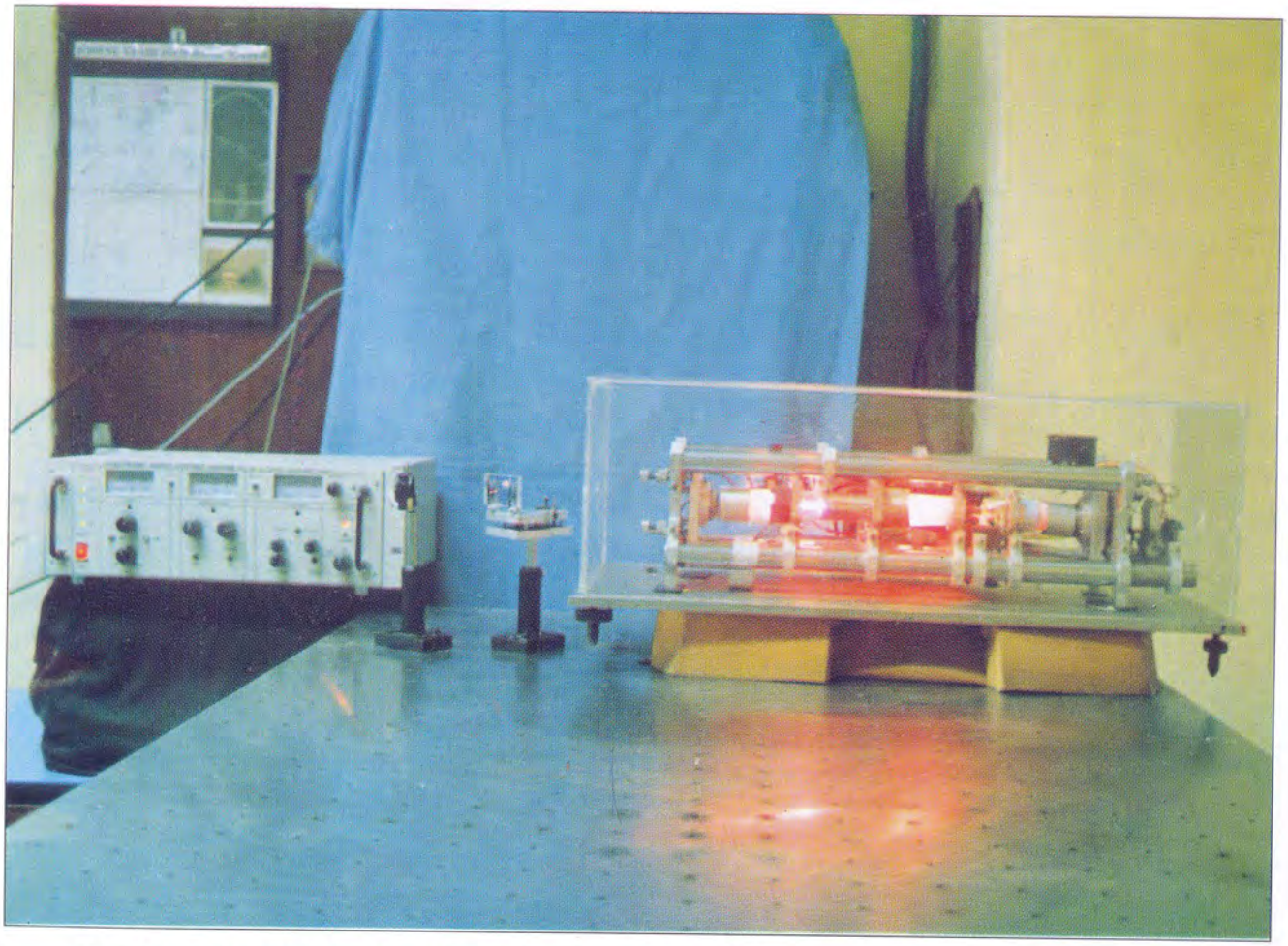


Fig. 1.2: Indigenously developed iodine frequency stabilised 633 nm He-Ne laser based length standard

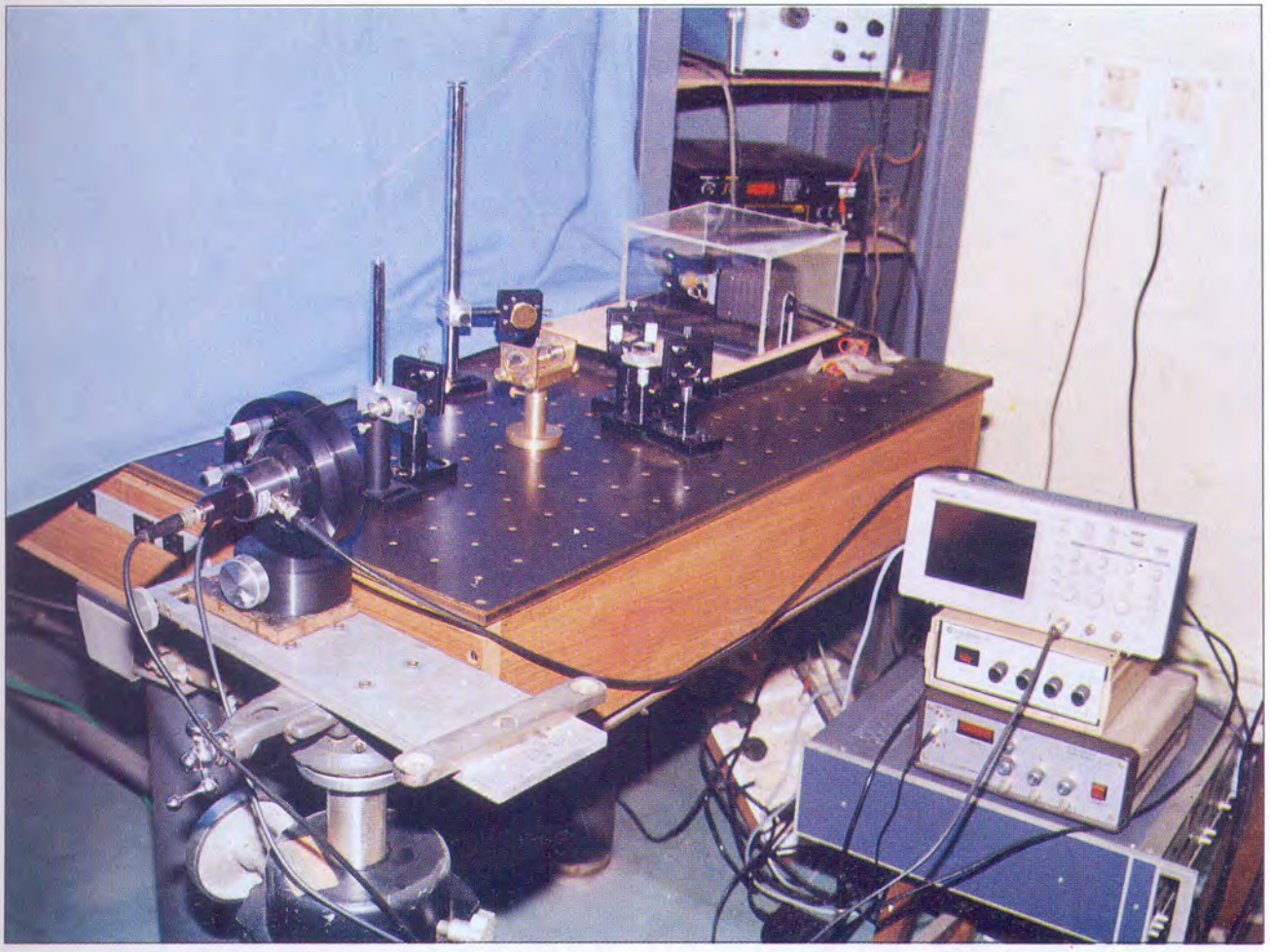


Fig. 1.3: Extended cavity diode laser with cesium saturated absorption spectrometer

A technique was developed to calibrate theodolite with two angular scales placed in x and y axis respectively. No routine facility existed in the laboratory for calibration of theodolite. A new set up was conceived and implemented and the calibration carried out. The work was undertaken for Opto Electronics Factory, Ministry of Defence, Dehradun. Participated as a key laboratory in national intercomparison programme for calibration of slip gauges and in regional key comparison for calibration of surface roughness.

Vacuum and Pressure Standards

The Ultrasonic Interferometer Manometer (UIM), the national primary pressure standard, has been improved by using new data acquisition system. The measurement compatibility is re-established through characterization of transfer primary pressure standard.

The range of leak standards facility has been extended to 10^{-14} mol/s by reducing the blank outgassing rate of the flowmeter manifold from existing 10^{-8} - 10^{-12} mol/s.

The national practical pressure scale for pressures up to 500 MPa has been established. The metrological data, as obtained, have been found to be within the limits of uncertainty budget in the course of international key comparisons and bilateral comparison measurements. Eleven laboratories have undergone the intercomparison exercise in the pneumatic pressure standard in the range (a) 10 - 140 kPa and (b) 0.4 to 4.0 MPa under the Asia Pacific Metrology Program (APMP). NPL, as a pilot laboratory, first metrologically characterized the travelling standard and intercompared with reference to the Secondary standards NPL-4 and NPL-8 in September 1998. The artefact once again arrived at NPL in January 2000 and the

same experiments were repeated. The efficient coordination rendered by this group with other participating laboratories has been appreciated by the APMP Secretariat.

A low cost Raman spectrometer for high pressure applications has been established to study a micron level sample. Raman spectra of a large number of samples were studied.

A quartz digital pressure transducer which can be used as easily transportable transfer pressure standards has been established to measure high hydrostatic pressure up to 275 MPa. Metrological characteristics studied include repeatability, linearity, sensitivity, hysteresis and measurement uncertainty.

The inhouse laboratory intercomparison exercise of *national hydraulic pressure standards was carried out* using an internationally accepted method of cross floating of pressure balances. The compatibility, uniformity and reaffirmation of results is re-established by comparing the values of zero pressure effective area (A_0) and distortion coefficient (b) with the values obtained during bilateral and international key comparisons.

Force and Hardness Standards

An agreement was entered with Real Scientific Engineering Corporation, New Delhi to establish a calibration laboratory for force transducers up to 1MN capacity at their site. The design of this facility has been completed and creation of this calibration facility is in progress.

A consultancy project from Adtranz, Australia was completed for deflection and strain measurements on Locomotive bogies in running conditions with the aim *to evaluate performance of some of the bonded* spheribloc bush and fatigue stresses on the pivot transom. The data collection was successfully done. (Fig. 1.4 a and b)

Fig. 1.4 (a): Locomotive used for deflection and strain measurements

Fig. 1.4 (b): Gear box torque reaction link fixed in the bogie after strain gauging and calibration at NPL

A project sponsored by DST and Transducers India Limited, New Delhi was undertaken for developing strain gauge force transducers to measure applied forces up to 1 MN with an accuracy better than ± 0.03%. A Memorandum of Understanding (MoU) was entered with Canan Testing Services to provide them with facility for verification of the calibration data of their force proving instrument at regular intervals. A consultancy project has also been completed for them for providing guidelines to prepare their quality manual as per the NABL criteria. A consultancy project was undertaken for designing and fabricating 32 numbers of 200 kN and 4 numbers of 500 kN precision load cells to be employed for measurement of load during the testing of a structure under 600 ton load by CBRI Roorkee. The prototypes of these load cells have been approved.

A 5 kN dead weight force standard machine indigenously designed and developed by this division has been upgraded by introducing a special mechanism to calibrate force proving instruments of 2.5kN capacity and it has a best measurement capability (BMC) ± 0.01%.

Temperature Standards

The apparatus for boiling point of nitrogen, an alternate point to triple point of Ar (84K), was fabricated for the calibration of SPRTs according to the procedure followed by other calibration laboratories in the world. Graphite annealing block was fabricated for HTPRT work. The fixed point of silver (961.78°C) was established for thermocouple standards with the reproducibility of 2-3 μV (0.2°-0.3°C). It was compared using type S&R thermocouples calibrated at NPL, UK in 1997. Two standard thermocouples of type R&S have been calibrated at fixed points of Sn, Zn, Al and Ag by cell method and at Au melting point (1064.18°C) by wire-bridge method as per ITS-90 procedure for use as

reference standard thermocouples for calibration of test thermocouples received from user laboratories and industries. This established the calibration facility to industry for thermocouples of type S&R and other base metal thermocouples type-K, J & T in the entire temperature range from 0°C to 1000°C.

Two SPRTs with calibration report were supplied to humidity standards. One set comprising of SPRT/TPW cell/heat pipe was supplied to BARC and two S type thermocouple standards have been fabricated for them as reference standards to realise fixed points of Sn, Zn, Al, Ag and Au as per ITS-90.

Ultraviolet Radiation Standards

Transmission measurement of computer monitor screen in UV-A, UV-B and UV-C spectral regions were carried out for an industry. UV intensity meter calibration facility was upgraded and extended to user industries. A typical measurement of UV-C source for hospital at different distance on the target area of 12 x 12 cm was measured. This was to study the effect of UV-C radiation (254 nm) on animal behaviour. Literature survey has been done on high temperature black body and on synchrotron source to be used as primary radiometric source in UV, VIS and IR spectral regions.

Optical Radiation Standards

R & D efforts were made for establishing facilities for the calibration of Light Emitting Diodes (LEDs) of very high luminance and intensity and of emitting various spectral profiles. This has helped Indian railways by testing and calibrating a large number of traffic signal lighting made of these diodes replacing the existing GLS lamps. Inter-comparison of luminous responsivity scale was undertaken under APMP. The measurements were carried out under specified conditions.

A colour eye system, procured under NPL-PTB phase II programme, has been integrated with the spectrophotometric system and is being used for characterizing various products for their colour

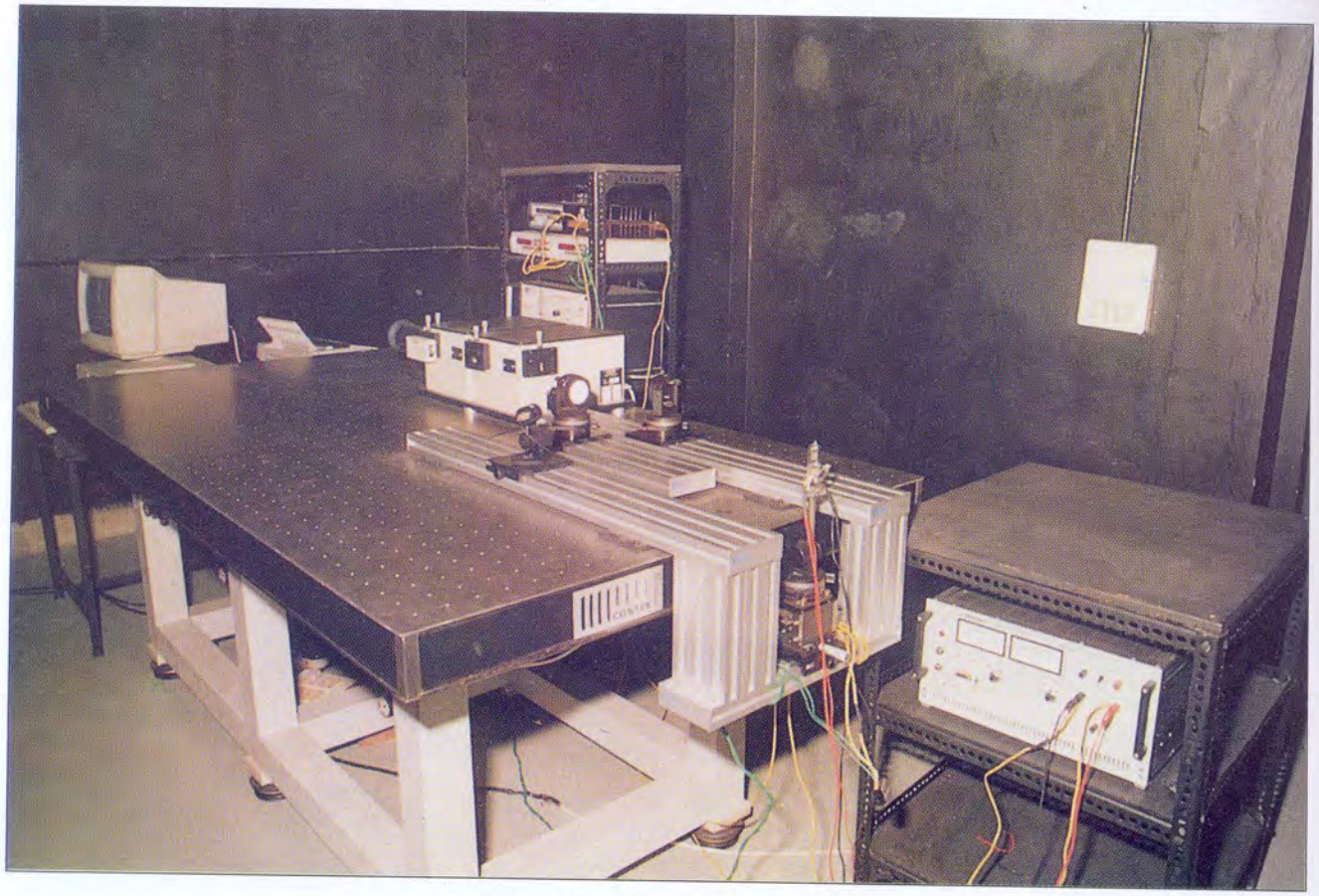


Fig. 1.5: Spectral irradiance comparator

Fig. 1.6: FTIR spectrophotometer set up mounted with integrating sphere for diffuse/total-reflectance/ transmittance studies in the spectral range 2.5 μm to 25 μm

characteristics to help paper, paint and textile industries. A facility for calibration of light sources and detectors for photometric and radiometric parameters was set up. (Fig. 1.5)

Experimental study was undertaken to determine the amplitude and the phase of the spectral degree of coherence by spectroscopic methods.

The phenomenon that correlation between two beams modifies the spectral characteristics of the light field, in a two beam interferometer, is used to estimate the average of the roughness of the surfaces in the sub-scales of optical wavelengths.

Infrared Radiation Standards

The integrating spheres for diffuse/total-reflectance/ transmittance studies were installed in the Fourier Transform Infrared (FTIR) spectrophotometer (Fig. 1.6) and nearly 500 samples were tested besides the regular calibration of IR thermometers and thermovision systems.

In the area of infrared applications a project entitled: "On line determination of systematic recording of sugar contents in sugar cane juices and sugar cane solids" was continued with indigenous near infrared spectrophotometer and error analysis was performed on results obtained on a variety of samples

Mass Standards

The national standards of mass through recalibration of four 1kg transfer standards of mass against the new value of the national prototype kilogram and multiples and submultiples of 1 kg (from 10 kg to 1 mg) was re-

established against the new values of the transfer standards.

Participated in the APMP intercomparison of two 1 kg mass standard programme, coordinated by Thailand, in which national laboratories from 12 countries of Asia-Pacific region, are participating.

Performance studies on the newly established automated solid density standard facility were carried out. The measurement uncertainty of the order of 1ppm and the temperature stability of 0.002 °C have been achieved. New facility for calibration of reference grade hydrometers traceable to the solid density standard, using hydrostatic weighing, was established.

Fluid Flow Standards

Various fittings for the mounting of the flowmeters in the test section, the jigs and fixtures for making the various rotameters compatible for fitting in the test rig were designed and fabricated. The various end connections, pipe fittings and flexible joints were also designed and fabricated. Necessary minor modifications in the piping of the test section were also made to suit the meters to be calibrated. The modifications were done in such a way so as to leave the test section unaltered

Research Activities in the Division

A new theory to estimate concrete strength by ultrasonic non-destructive technique was developed which showed that the addition of one more parameter (surface velocity) increases the reliability in estimation of strength.

Impedance spectroscopic studies has been carried out on Nb_2O_5 doped lead zirconate titanate ceramics, added with $MnCO_3$, which may find application in high power transducer devices.

InGaAs/InP quantum wells (prepared at the Material Science Centre, I.I.T., Kharagpur) were characterized by SIMS depth profile. Quantitative comparison was made assuming the presence of InAsP and InGaAsP interface layers on either side of the well and the relative sputtering rates determined.

Bismuth Germanate (BGO) single crystals grown at NPL crystal growth group showed low angle boundaries. X-ray diffraction studies suggested concentration of impurities around the boundaries. This was further probed using SIMS survey & 2-D imaging mode. Overall survey spectra showed that there was variation in impurity concentration throughout the specimen surface around the boundary. Chemical imaging in 2-D mode was carried out to see the Si concentration distribution around the area of interest.

For development of ultrasonic liquid level indicator, different sets of observations have been recorded for various levels of liquid with conditions of with and without water inside the tube. A method has been developed to optimise the conditions such that maximum ultrasonic energy is transmitted into the pipe from a flat piston type radiator.

For development of a directional SODAR antenna, parametric sounder consisting of two high power ultrasonic air-borne transducers (21.7 kHz and 19.2 kHz) has been attempted for the first time. A directive sound signal of frequency 2.5 kHz has been produced.

Raman studies were done on InGaAs and InP quantum wells. Raman spectra were recorded in the region 1300 – 1600 cm^{-1} to study the uniformity and homogeneity of the diamond films received from General Physics Institute, Russian Academy of Sciences.

Band structure calculations were carried out to study the pressure–induced structural transitions and structural stability of the magnetic compound EuS.

The influence of in situ annealing of Mn-promoted oxidation of Si(111) surfaces which were exposed to 20 L oxygen at 10^{-8} torr pressure at room temperature were studied.

A new approach based on a well known effect called the 'Stark effect' is being used for measuring high voltage with a high level of accuracy. It can serve as a reference standard for the measurement of high voltage giving accuracy near to that realised in frequency determination.

A large number of cancerous tissues have been studied by near infrared Fourier transform spectrophotometer.

विद्युत तथा इलेक्ट्रॉनिक मानक
ELECTRICAL & ELECTRONIC STANDARDS

विद्युत एवं इलैक्ट्रॉनिक मानक प्रभाग विभिन्न विद्युत एवं इलैक्ट्रॉनिक प्राचलों के प्राथमिक/राष्ट्रीय मानकों यथा डी सी वोल्टेज, धारा एवं प्रतिरोध, ए सी वोल्टेज, धारा एवं प्रतिबाधिता (ए सी प्रतिरोध, धारिता, एवं प्रेरकत्व); ए सी पावर एवं ऊर्जा; ए सी उच्च धारा एवं उच्च वोल्टेज, एल एफ एवं एच एफ वोल्टेज, धारा, पावर, प्रतिबाधिता (स्थानीकृत पैरामीटर्स), एच एफ संकीर्णन, माइक्रो वेव पावर, संकीर्णन, प्रतिबाधिता व शोर, समय और आवृत्ति और चुम्बकत्व मानकों के अनुरक्षण व विकास में संलग्न है। प्रभाग अपने मानकों की विभिन्न द्विपक्षी, क्षेत्रीय एवं अन्तर्राष्ट्रीय अन्तर्तुलना में भागीदारी करता है, ताकि इन मानकों को अन्तर्राष्ट्रीय स्तर पर अनुमार्गणीय (Traceable) बनाया जा सके। यह विभिन्न अंशांकन प्रयोगशालाओं और उद्योगों को अंशांकन एवं परामर्श सेवाएं भी उपलब्ध कराता है। सीज़ियम परमाणु घड़ी के सामूहिक प्रभाव का उपयोग करते हुए भारतीय मानक समय (IST) का अनुरक्षण (Maintain) किया जाता है और इन्सेट उपग्रह का प्रयोग करते हुए एस टी एफ एस (STFS) के माध्यम से इसका प्रसार किया जाता है। इस वर्ष के दौरान इस प्रभाग की विभिन्न प्रयोगशालाओं का 'आई एस ओ/ आई इ सी गाइड 25' के अनुसार बेहतर पर्यावरण स्थितियां उपलब्ध कराने के लिए नवीनीकरण किया गया है। प्रभाग में गुणवत्ता प्रणाली को लागू करने की शुरूआत कर दी गयी है और गुणवत्ता नियमावली और अन्य दस्तावेज तैयार कर लिए गए हैं। प्रभाग में भौतिक तथा चिकित्सा सम्बन्धी यंत्रीकरण के अनुसंधान और विकास का भी कार्य किया जाता है।

The Electrical and Electronic Standards Division is engaged in development and maintenance of primary/national standards of electrical and electronic parameters such as DC voltage, current and resistance; AC voltage, current and impedance (AC resistance, capacitance and inductance); AC power and energy; AC high current and high voltage; LF and HF voltage, current, power, impedance (lumped parameters); HF attenuation; microwave power, attenuation, impedance and noise; time and frequency and magnetic standards. The Division participates in bilateral, regional and international intercomparisons of its standards to establish international traceability. It also provides calibration and consultancy services to various calibration laboratories and industries. The Indian Standard Time (IST) is being maintained using an ensemble of cesium atomic clock and is disseminated through STFS using INSAT satellite. During this year, most of the laboratories of the Division were renovated to provide better environmental conditions as per ISO/IEC Guide 25. The implementation of quality system in the division has been initiated and the quality manual and other related documents have been prepared. The Division also does R&D in standards and medical instrumentation.

Josephson Voltage Standard and Superconducting Devices

RF-SQUID effect in magnetic borocarbide superconductor :

RF-SQUID effect due to natural grain boundary weaklinks has been observed in $ErNi_2B_2C$ (T_C=11.5K, T_N=6.5K) and $DyNi_2B_2C$ (T_C=6.5K, T_N=11K) magnetic superconductors. Oscillations in voltage-flux characteristics due to SQUID effect have been observed upto 10K and 5.7K in $ErNi_2B_2C$ and $DyNi_2B_2C$ respectively. The amplitude of SQUID oscillations in $ErNi_2B_2C$ shows a sharp change around 6K($\approx T_N$), which has been attributed to the occurrence of magnetic ordering in $ErNi_2B_2C$. Such a change is not observed in $DyNi_2B_2C$ rf-SQUID since, in this case, $T_C < T_N$. A rapid increase in flux noise has been observed in both the cases as temperature approaches T_C. This has been attributed to flux hopping.

Harmonic generation in YNi_2B_2C superconductor:

Generation of higher harmonics was observed when superconducting intermetallic YNi_2B_2C is exposed to an ac and dc magnetic fields. Application of an ac magnetic field ($H_{ac} > H_{c1}$) leads to generation of higher odd harmonics as expected in conventional intermetallic superconductors. Interestingly, application of H_{dc}, in addition to H_{ac}, causes generation of even harmonics also. Observation of even harmonics is of great significance as they have been observed for the first time in an intermetallic superconductor. This phenomenon is similar to that observed in high-T_C superconductors where grain boundaries behave as Josephson weaklinks. Temperature variation of amplitude of third harmonic shows two peaks. The observed two peaks have been attributed to grain boundary and grains of the superconductors. These observed features have been explained in the frame work of critical state model and grain boundary weak links.

Dielectric resonator for microwave characterisation of HTS thin films:

A shielded Sapphire Dielectric Resonator (SDR) operating at 18 GHz frequency has been designed and fabricated for the microwave characterisation of HTS thin film deposited on 10 mm x 10 mm substrates in the temperature range 20K to room temperature. The Q-value of 90000 was achieved using Ag-doped YBCO thin films placed at both ends of the dielectric puck. The surface resistance of 5% Ag-doped YBCO thin films and YBCO bulk samples was measured as a function of temperature and input microwave power. The Ag-doped YBCO thin films showed very good power handling capability, as non-linearity in surface resistance did not appear for input rf power up to 100 mW.

Accurate expressions have been obtained for the geometrical factors of the sample and metal part of the SDR taking into account the effect of the shield diameter by theoretical modeling of the electromagnetic field inside the SDR. The analysis reveal that the Q-value as high as $5x10^6$ can be achieved by taking shield diameter at least three times the diameter of the sapphire puck. This work will be useful in the development of frequency stable HTS shielded high-Q SDR operating at 9.192 GHz as a flywheel for frequency standard.

Jahn-Teller problem of C_{60} :

The Jahn-Teller problem of C_{60} in icosahedral symmetry is studied. The Jahn-Teller interaction in both the low lying levels T_{1u} and T_{1g} are taken into account and also the vibronic mixing betwen the two under an odd vibrational mode t_{1u} is considered. With respect to the involvement of t_{1u} mode operators the vibronic Hamiltonian is an antisymmetric matrix operator. It is shown that despite this antisymmetry an exact analytical solution of the Hamiltonian in an infinite coupling model can be evolved by using a canonical transformation of t_{1u} mode operators. The ground level is a vibronic doublet. The eigenfunctions are functions of polar angles a and b while the ground energy is independent of these angles. This reflects a symmetry higher than the icosahedral symmetry I_h. It is concluded, therefore that the anharmonic and quadratic coupling terms are essential to wrap this minimum energy surface to local minima, pertaining to I_h symmetry.

DC Standards

This activity maintains national standards of DC voltage, current and resistance and provides apex level calibration for these parameters to calibration laboratories and industries.

The group participated (as national metrology laboratory to give the reference values) in the interlaboratory comparison of resistance. BHEL, Bhopal was the pilot laboratory and nine other laboratories namely four other laboratories of BHEL; ERTL(N), New Delhi; ETDC, Bangalore; ETDC, Hyderabad; ECIL, Hyderabad, and CPRI, Bhopal also participated.

AC Power & Energy Standard

The AC power & energy standard activity is maintaining national standard of AC power and is providing traceability to other laboratories, power sector industries and utilities. Studies carried out during the period are listed below.

Influence of DC/AC magnetic fields on the performance of energy meters was posed to NPL by Central Board of Irrigation and Power (CBIP). This work was taken up as consultancy project in collaboration with magnetic standards activity. The activity had two major components.

a) A detailed study of influence of DC magnets on energy meters for the magnets available in the open market was carried out. Based on this study the following test has been included in the CBIP specification: "The influence of continuous magnetic induction of 0.2 Tesla ± 5% at a distance of 0.5 cm from the surface of the pole of an electromagnet carrying 10000 Ampere turns". The maximum effect is found by placing the electromagnet on all accessible surfaces of the energy meter.

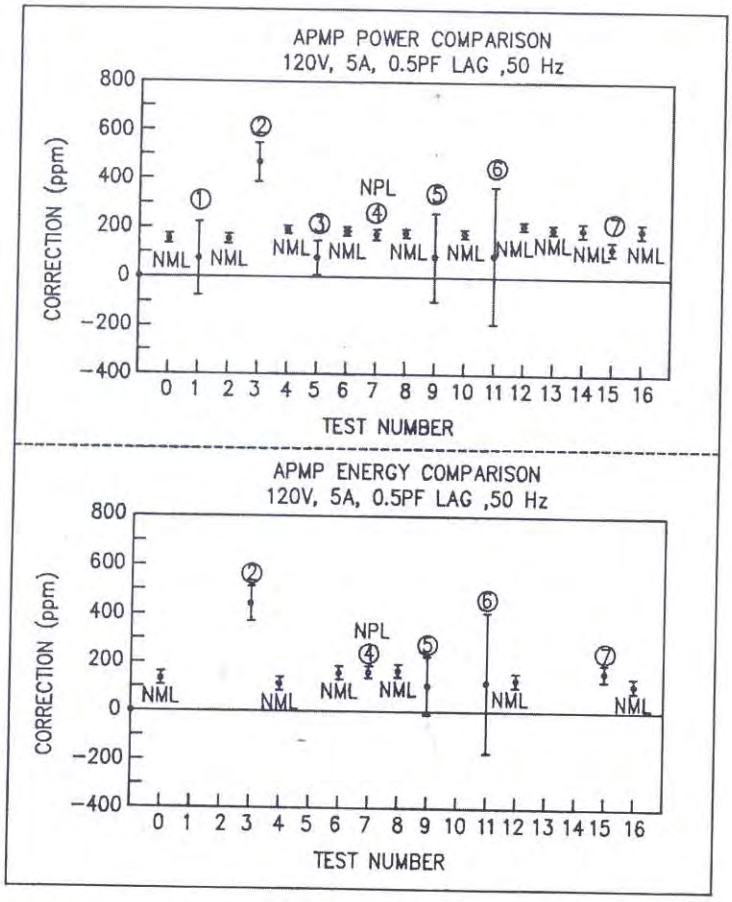


Fig. 2.1: Measured value of correction, in ppm, to AC power measurement instrument under test

b) Several coils were developed for producing AC magnetic fields and the influence of AC magnetic induction was also studied and the following test has been included for AC probe type of field in the CBIP specification : "The influence of AC probe coil having 0.2 Tesla ± 5% in the central region of either surface of the coil". The maximum effect is found by placing the electromagnet on all accessible surfaces of the energy meter.

The international intercomparison of electrical power and energy was carried out under Asia Pacific Metrology Programme (APMP). The artefact was C 1-2 HEG Germany make watt converter giving 10V-dc output for power and 10kHz output for energy for input power of 240V x 5A, UPF at 50 Hz. The National Measurement Laboratory (NML), Australia acted as coordinating laboratory for the programme and carried out checks on the artefact between the participants. The participant laboratories were: (1) SCL, Hong Kong, (2) CMS/ITRI, Chinese Taipei, (3) KRISS, Korea, (4) NPL, India, (5) NMC/SIRIM, Malaysia, (6) NMC/PSB, Singapore. The comparison was carried out for both power and energy at 120V/240V, 1A/5A. The calibration figures were stated as a correction to the instrument under test in parts per million (ppm) of indicated power.

Correction = {(true power - indicated power)/true power} X 10^6

Our results are in very good agreement to the values indicated by NML, Australia and also the uncertainties quoted are approximately same as quoted by NML. The result of power and energy measurement at 120V, 5A at 0.5 lag power factor are shown in Fig. 2.1. Results were published in APMP Report No. APMP-IC-10-95 (Nov. 99).

AC High Current & High Voltage Standards

Calibration work was carried out for current transformers, CTTS, clamp meters, AC current shunts, weld testers, CTTS jigs, CT burdens and for potential transformers, PTTS,

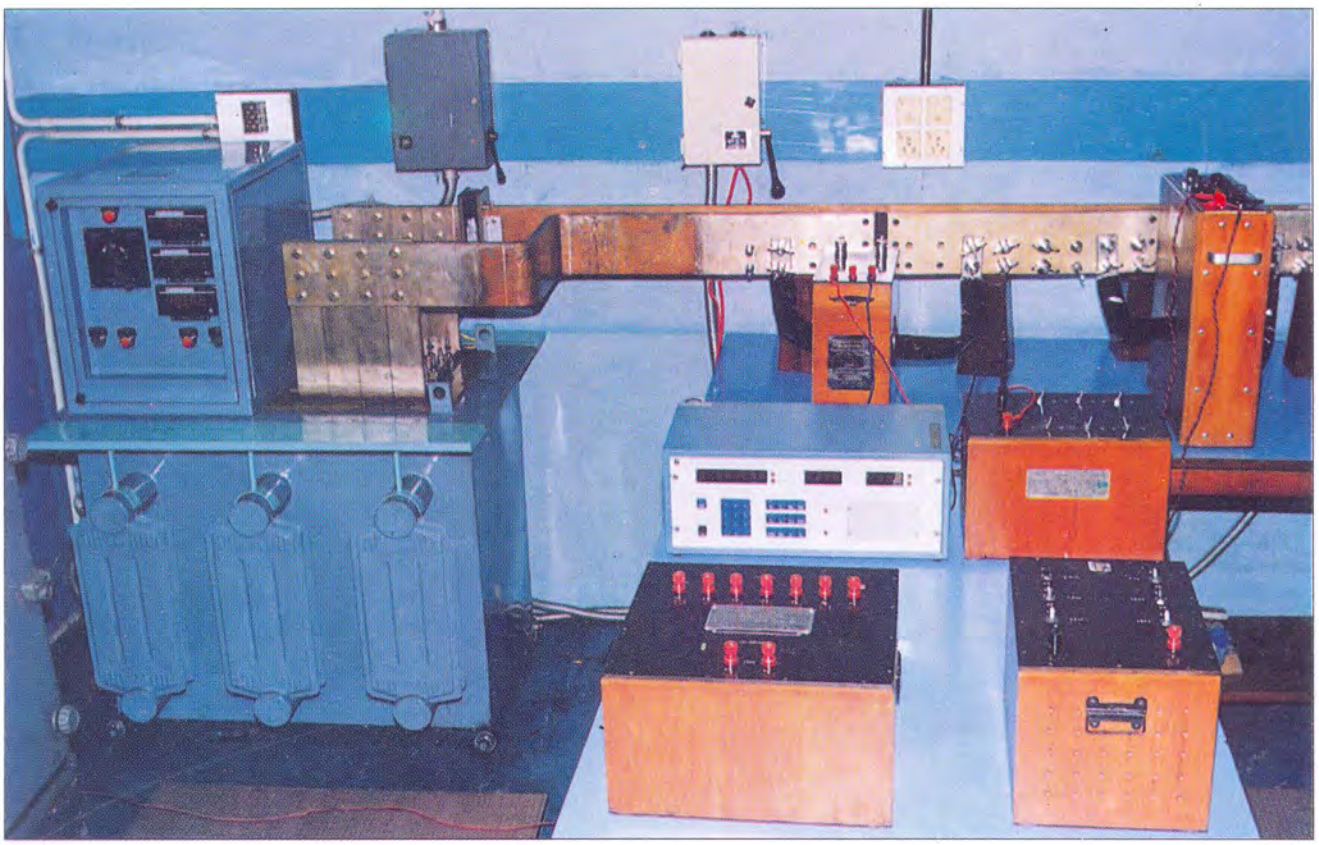


Fig. 2.2: Experimental set up for calibration of current transformers up to 5000 A/5 A, 1 A current ratios

HV probe, electro-static volt meters, HV breakdown test sets and PT burdens etc.

Calibration range for current transformers and other allied instruments was extended from 2000A to 5000A (Fig. 2.2) at power frequency. The uncertainty in calibration of CT burdens and PT burdens has been improved from 1% to 0.5% at 50 Hz.

LF & HF Impedance Standards

This activity is working to establish, maintain and update primary and transfer standards of Capacitance,(Fig. 2.3) Inductance, A.C. Resistance and Q at low and high frequencies. As such this activity provides apex level calibrations for the above parameters to various user organisations all over India.

Work has been initiated to develop 10 pF capacitors using Ultra Low Expansion (ULE) Quartz for use by accredited calibration laboratories, in collaboration with National metrology laboratory, South Africa. This work has been financially supported by Department of Science & Technology, Govt. of India.

Work has been initiated on an in-house project entitled "Development and fabrication of direct reading resistance bridge based on inductive voltage dividers". This bridge would be used for calibration of AC resistances upto a frequency of 10kHz and with an uncertainty of ± 5 ppm for 1k ohm resistance at 1kHz.

LF, HF & MW Voltage, Current and Power Standards

This activity is maintaining national standards of AC & LF voltage and current (10Hz to 100kH), HF voltage (1MHz to 1000 MHz), HF & MW power & noise (10MHz to 18 GHz). During the year following devices have been developed to facilitate some specialised calibration work.

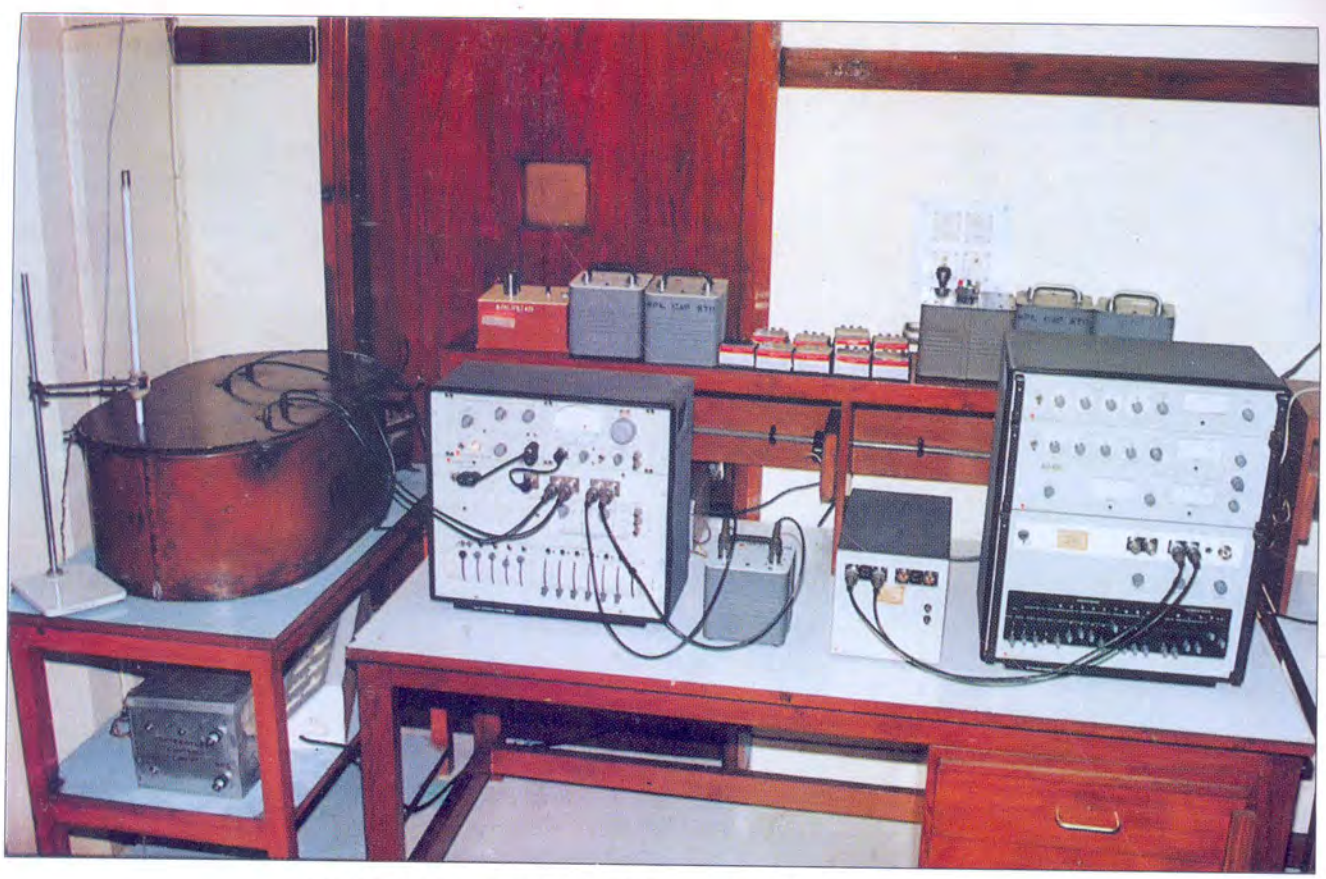


Fig. 2.3: Experimental set up for calibration of standard capacitor

Fig. 2.4 (a): Photograph of 25 cm pole diameter electromagnet

A Tee adapter used for the calibration of current measuring instruments has been designed, fabricated and evaluated. Such adapters are not commercially available.

Tee adapters in N type male, female and GR874 have been designed and fabricated for calibration of high frequency measuring instruments such as thermal voltage converters. This will avoid errors due to connector length of commercially available Tee adapters.

A training consultancy in the area of frequency counter and oscilloscope calibration and evaluation of associated uncertainty in their calibration was provided to the scientists/engineers of Opto Electronic factory, Dehradun at their site.

HF & Microwave Attenuation & Impedance Standards

The attenuation and impedance standards and associated equipments for various organisations were calibrated and calibration reports were issued. The quality manual documents were prepared to establish the quality system in the standards laboratory.

Magnetic Standards

Generation of standard magnetic fields using NMR Gaussmeter:

Facilities have been established for the calibration of H-sensors and magnets using known values of magnetic fields traceable to National Standards. Standard fields have been generated, in the range of 500-10,000 Gauss, using 25 cm pole diameter electromagnet with homogeneous field and precision power supply with NMR measuring set up. Fig. 2.4 (a) and (b) show the facilities established.

Bilateral international intercomparison:

To establish international traceability bilateral international intercomparison with PTB, Germany was

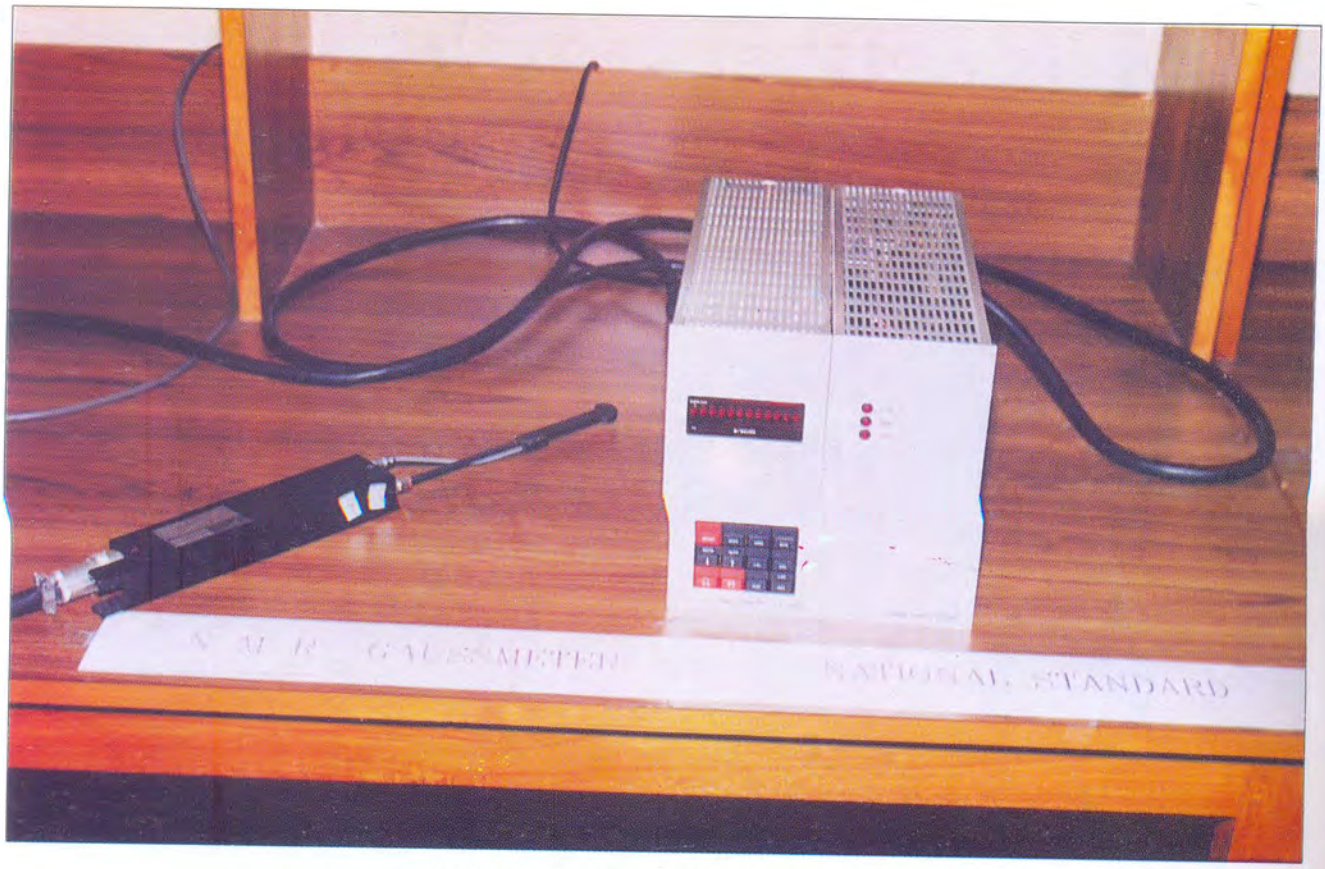


Fig. 2.4 (b): Photograph of NMR Gaussmeter

carried out for AC measurements on soft magnetic materials using standard 25 cm Epstein frame. Measurements were conducted on two electrical steel samples No. 400-50A (non-oriented) and No. 8/84 (grain oriented) in the month of May 1999. The results of power loss (Ps) measurements at different values of magnetic polarisation (J) conducted on these two samples both at NPL and PTB are given in Table 2.1. The overall uncertainty in the measurement of power loss is ± 0.1%. There is a good agreement between the measurement results of NPL and PTB.

Time and Frequency

The 'Teleclock' service, know how of which was transferred some times back, has started functioning

Table 2.1 : Power loss measurements

Sample No. 400-50A			Sample No. 8/84		
J	NPL (India) Ps	PTB Ps	J	NPL (India) Ps	PTB Ps
(T)	(W/kg)	(W/kg)	(T)	(W/kg)	(W/kg)
1.0	1.511	1.514	1.0	0.474	0.473
1.1	1.792	1.797	1.1	0.567	0.566
1.2	2.107	2.114	1.2	0.671	0.670
1.3	2.475	2.482	1.3	0.791	0.790
1.4	2.918	2.926	1.4	0.932	0.931
1.5	3.443	3.437	1.5	1.113	1.111
			1.6	1.361	1.355
			1.7	1.674	1.673

with the formal launching as an operational service on 15th Feb.,2000 by DG, CSIR . This will be useful for many users whose time accuracy requirement is within 1 sec. of IST. This teleclock service can also be used to set Real Time Clock (RTC) of a computer through a telephone line via a standard modem. NPL has already developed a software to set RTC of a computer.

Under the Indo-US project involving development of a novel Cs hyperfine frequency synthesizer, a fractional frequency step of $2x10^{-17}$ has been achieved. Preliminary tests on the new synthesizer design indicates an internal fractional frequency stability of $1x10^{-15}$ at 10sec. and $1x10^{-18}$ at 1 day dominated by the daily room temperature variations. This will be useful for the new generation of frequency standards based on Cs fountain and ion storage devices, as well as for frequency multiplier chains from microwave to optical frequencies.

Work is also going on to improve the frequency stability of atomic time and frequency standards by suppressing quantum noise through squeezed states in collaboration with NIST, USA. Experiment has already been done on the application of the squeezed light for obtaining the higher optical pumping rate and also narrow resonance fluorescence. The optical pumping is used for particle preparation, which plays an important role in determining the S/N and the frequency stability of the standard. Theoretically it has been found that squeezing the detection light can reduce the resonance fluorescence signal line width to 1/5th. This may improve the frequency stability of the optically pumped Cs clock almost by an order of magnitude. Work is also being done on differential global positioning system (DGPS) which is a typical use of GPS. The error due to the selective availability (SA), which otherwise cannot be removed, gets cancelled with the use of DGPS.

Instrumentation

A new programme on the 'development and establishment of standards and calibration facilities for electro-medical equipment' has been initiated, for better healthcare in the country. The biomedical systems like ECG, EEG and ENG etc. have been chosen, to start with, for establishing their calibration facilities, with the main emphasis on the calibration of implantable cardiac pacemakers. As is known, these days, the human body is being exposed to different types of radiations and there are effects on the soft tissues. Ultrasound machines are in common use for both diagnosis and treatment. Biological tissues have thus been characterised for thermal, ultrasonic and electrical properties, to enable develop 'safety standards' for avoiding side effects on the surrounding delicate nerves and fibres. Ultrasonic properties of both soft and hard tissues have been studied and correlated with the anatomy and chemical consitutents of the organs or tissues. The effect of ultrasound intensity on the tissue structure, particularly thermal behaviour, has been studied in detail. The hard biological tissues studied in the present work are human teeth, bone and skull, and the soft tissues are 'leiomyoma uteri' (uterus tumour) and 'breast tumour', procured from AIIMS, New Delhi, and other local hospitals. The safety limitations of dosage level are established on the basis of the basic findings

Investigations have shown for the first time that acoustic stimulation catalyses stone disintegration in lithotripters, used for the removal of kidney stones without surgery. A special 'Variable-Frequency Variable-power ultrasonic Transducer (VFVAT) has been developed and used in the present work to carry out the research in detail. VFVAT was used to investigate the optimum frequency and optimum power (amplitude) to enhance the bubble implosion and, in turn, the stone fragmentation. The system was used with the lithostar transducer to apply ultrasonic stimulation in phase with the main shock wave pulse. Due to the limitation of the power handling capacity of the single PZT disc element, ultrasound energy was concentrated at the focal lobe, by using specially developed acoustic lenses. A novel smart silicon sensor was developed to measure the acoustic power output of the ESWL. The sensor consists of a four-arm Wheatstone strain gauge and the associated electronic circuitry on the same chip. The sensor is very useful in the study of the pressure amplitudes of the shock wave lithotripter.

Metals and Alloys

The Metals & Alloys Group has been engaged in the primary, secondary processing and characterization of monolithic and composite materials and is currently undertaking collaborative projects with national and international agencies. The main objectives to undertake these projects are the following:

- Interact and collaborate with Indian industries on programmes and projects related to indigenisation of strategic components.
- Process ferrous , non ferrous metals, alloys, composites, and Hi-Tech materials, such as Mg, Al-Li, Al based MMCs employing hot extrusion and forging.
- Development of closed die cold/warm forging technology for near-net-shaped components.
- Design and fabrication of laboratory/pilot plant equipments used in metal forming and processing industries.

Development of forging technology to manufacture near net shaped parts (an international project):

Mechanical Engineering Laboratory, Japan and National Physical Laboratory, New Delhi are having a long term collaborative programme till 2001. Trial runs, for the development of hexagonal headed and allen headed titanium fasteners, were carried out using cold/warm forging techniques and a detailed characterization of these fasteners are currently being undertaken.

Development of oval shaped tubes for advanced light helicopter (HAL sponsord project):

In this HAL sponsored project, oval shaped tubes of Aluminium alloy 2024 are being developed as a part of weight reduction programme of the Advanced Light Helicopter (ALH). This developmental project involving conversion of circular tubes to oval shaped tubes, to be used as skid landing gear. Process of oval shaped tubes was demonstrated to the representatives of HAL. The process and the equipment was approved by the officials of Centre for Military Airworthiness & Certification, (CEMILAC), Bangalore. These oval shaped tubes with specification - 150 x 100 (oval cross-section) mm and with 3 mm wall thickness and approx. 4.5 m length developed at NPL met the desired dimensional tolerances, as laid down by HAL.

The second phase of this project involves the following three main developmental jobs:

- Heat treatment of the oval shaped tube in T3 condition
- Cold drawing to achieve a 2% reduction in cross section
- Bending the tube to 800 mm radius

To carry out the heat treatment of the oval tube, certain modifications were carried out in our existing furnace by replacing the already installed circular tube with the 200 mm dia. stainless steel tube. This was done to accommodate the actual tube alongwith the fixtures. To carry out heat-treatment; a special fixture was designed & fabricated at NPL to avoid distortion of this long tube. Modifications to minimize the heat losses and to maintain uniformity of temperature, throughout the length of the tube, has also been achieved in the existing furnace. After heat treating, the tubes will be cold drawn, to achieve desired reduction.

Spray atomization & deposition and property evaluation of aluminium alloys – (an AR&DB sponsored project):

Under this project, a detailed design and fabrication of the spray atomization and deposition unit was made which consists of the following sub-assemblies :

- vacuum chamber
- induction furnace
- substrate movement assembly (hydraulically operated)
- inert gas purging and inert gas atomizing unit
- cyclone separator and exhaust system

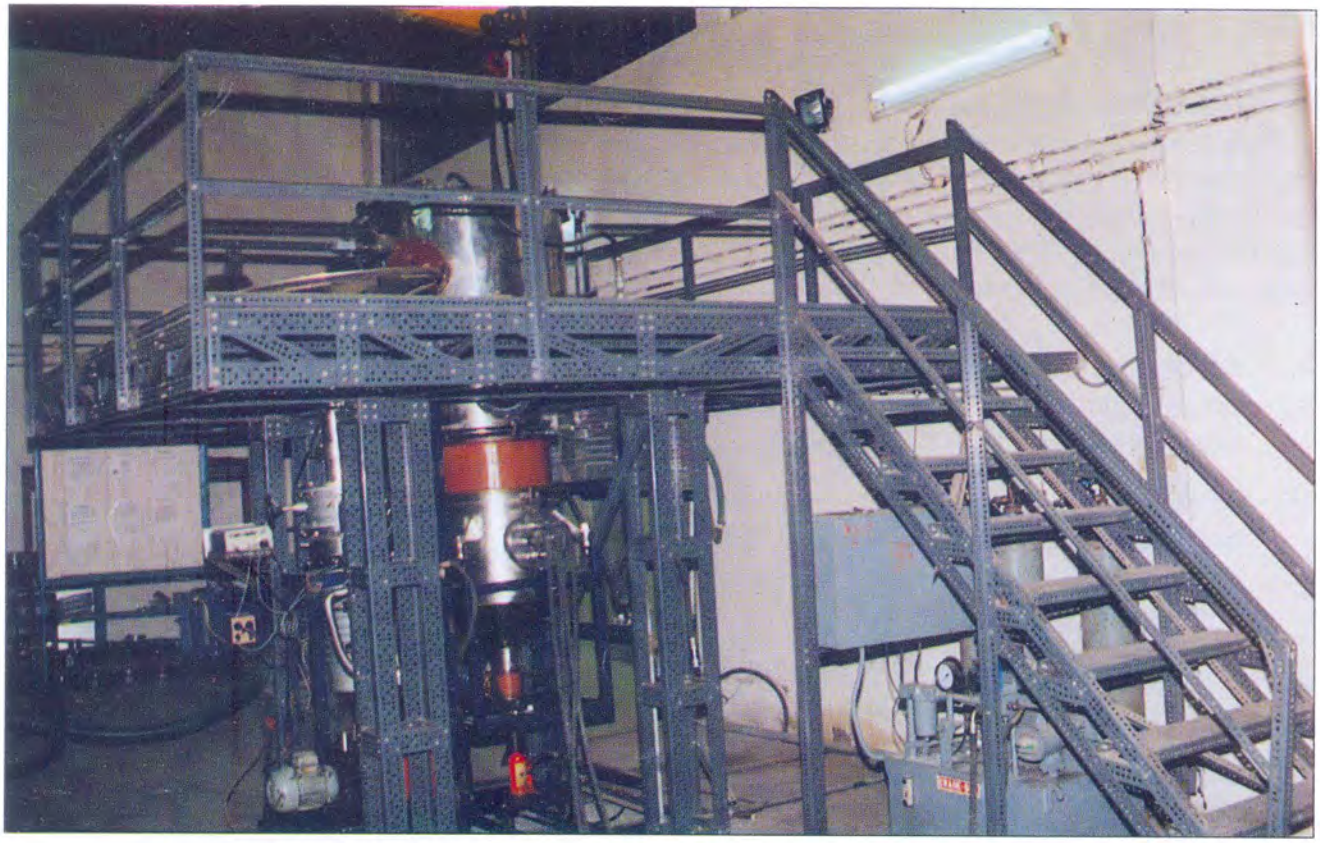


Fig. 3.1: Spray atomization and deposition unit designed and integrated at NPL

All the sub-assemblies of this system have been integrated and is being used to synthesize aluminium alloys using rapid solidification.

Spray atomization and deposition process essentially employs rapid solidification technique. Spray atomization involves energetic disintegration of molten metal into micron-sized droplets using high velocity inert gas jets followed by deposition onto a water cooled substrate where the droplets impact and accumulate into a preform. A pictorial view of the spray deposition unit is shown in Fig. 3.1.

Detailed experimental studies involving aluminium alloy was taken up and flat disc shaped and conical shape deposits were made. Various process parameters, such as, atomization gas pressure, super heat temperature, metal/gas flow ratio, nozzle-substrate flight distance and substrate temperature are being optimized to get deposits of uniform microstructure with minimum porosity. A detailed mechanical as well as physical characterization of various samples was being carried out.

Development of titanium fasteners for aerospace applications (HAL sponsored project):

A few exploratory experiments were conducted to form warm forged titanium fasteners. Mechanical and metallurgical characterization of these fasteners was carried out.

Setting up of powder metallurgy facility:

After procuring different equipments, such as, planetary ball mill, mixer and a vacuum degassing unit, the installation and commissioning of these equipment were carried out to set up a facility for developing powder metallurgical products. Initial trial runs of powder degassing were carried out using copper powder up to a vacuum of 10^{-4} Torr.

Advanced Carbon Products

The advanced carbon products group of NPL has been awarded the "1999 CSIR Technology Shield for Process Technology" for their sustained development of valuable knowledge based expertise and several advanced carbon products of industrial, societal and strategic importance that have enabled India to move forward on the path of technological self reliance.

This group is engaged in both basic and applied research, covering various aspects of carbon. In addition, projects of national importance on pitch-based carbon monofilament (ARDB), fibers (IOC), high thermal conductivity graphite for SST–1, Tokamak (IPR) are being carried out and three new projects on the development of (1) high thermal conductivity C-C composites (Indo-UK project) (2) porous conducting paper (Naval Materials Lab.) and (3) dense isotropic non-graphite pyro-carbon (BARC) have been initiated in the current year.

Development of high density isotropic graphite:

Having completed the project entitled, "Development of green coke based high density isotropic graphite", sponsored by M/s. Graphite India Ltd., Calcutta/ Bangalore, a two-week demonstration cum training was provided to a senior engineer of this company. The graphite produced during this demonstration/ training was found to possess a bulk density of 1.9–2.0 g cm^{-3}, bending strength of 60–90 MPa, Young's modulus of 9–13 GPa, Shore hardness of 60–80 and an electrical resistivity of 1.0–2.0 m Ω cm. Some of the green coke based high density isotropic graphite products made at NPL are shown in Fig. 3.2.

Development of high thermal conductivity graphite:

Under the project entitled "Development of high thermal conductivity special graphite for first wall component

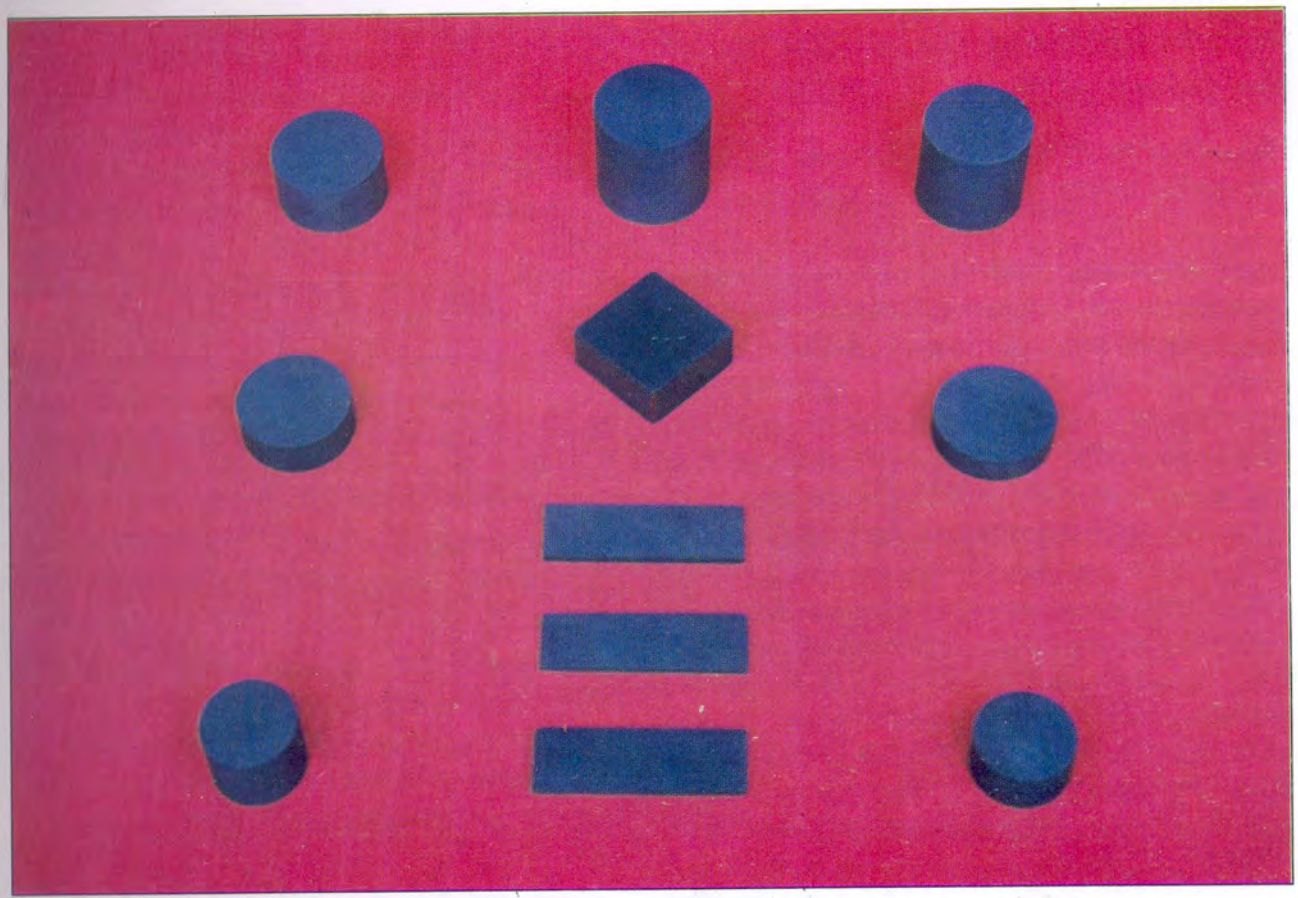


Fig. 3.2: Green coke based high density isotropic graphite artefacts made at NPL

of SST–1 tokamak", sponsored by Institute for Plasma Research (IPR), Gandhinagar, the 'green coke' method of producing the high density graphite was made the basis for such a graphite. A QI-free pitch was used to produce the green coke by suitable heat-treatment. This green coke was subjected to solvent extraction or oxidation treatment and then used to produce the special graphite (HTT = 2600 °C). It was found that the solvent extracted green coke leads to a special graphite having a thermal conductivity of 80 W/mK compared to a value of 70 W/mK obtained for the graphite involving oxidised green coke. The value of 80 W/mK is quite close to 90 W/mK, the minimum target value that was to be achieved. Besides this, a series of experiments were conducted to develop the special graphite which involved incorporation of either needle coke or synthetic graphite or natural graphite in the green coke with a view to enhance the electrical and thermal conductivity of the special graphite. Needle coke and synthetic graphite appear to cause no improvement in the thermal conductivity of the resulting graphite (as estimated by the electrical resistivity measurements), whereas the natural graphite has shown considerable decrease in electrical resistivity.

Development of pitch-based carbon monofilament:

Extensive work was carried out under the project entitled "Development of carbon monofilament suitable for CVD-based SiC fibers", sponsored by ARDB. The carbon monofilament, envisaged to be developed is to have a diameter (of 33 ± 5μm), tensile strength of 700 MPa, tensile modulus of 35 GPa and a strain-to-failure of about 2 %. Several series of experiments were carried out with coal tar pitches and petroleum pitches, as well as, their mixtures under nitrogen atmosphere and also under reduced atmospheric pressure, which was followed by solvent extraction. It was found that neither coal tar pitch nor petroleum pitch, alone, can lead to the desired pitch of zero quinoline insolubles (QI) and softening point (SP) of 175– 250°C, since coal tar pitch forms more QI initially while the petroleum pitch is more reactive and solidifies fast as SP increases above 170°C. However, a blend of coal tar pitch and petroleum pitch (50: 50 by weight) heated at 405–435°C under reduced atmospheric pressure of 4 cm of Hg produces a pitch of almost zero QI and SP in the range of 165–240°C. These pitches, when subjected to melt-spinning on newly developed pitch spinning assembly, showed excellent spinability. The fibers on preliminary oxidation and carbonisation are found to possess a tensile strength of 600 MPa, Young's modulus of 30 GPa and a strain-to-failure ratio of 2%. Besides the above, a pitch distillation assembly was designed and developed. Vigorous R & D efforts are continuing to improve the strength of the green pitch fibers.

Feasibility studies of petroleum streams as precursor for high performance carbon fibers:

Under the IOC-sponsored project entitled "Feasibility studies on various petroleum refinery streams as precursor for high performance carbon fibers", five petroleum streams, namely, Short Residue (SR), Clarified Oil (CLO), Residual Fuel Oil (RFO), Blue Oil Extract (BOE) and Coker Fuel Oil (CFO), received from R & D Centre,IOC Faridabad, were heat-treated at 400–430°C for 4–5 h under nitrogen atmosphere and subsequently at 310–410°C under a reduced atmospheric pressure of 4 cm of Hg to obtain various pitches from them. The SR was found to give the highest pitch yield of 35.5% but its coking value and specific gravity were the lowest (33.1% and 1.06, respectively). The CLO and CFO, on the other hand, gave low pitch yields (5.8 and 3.5%, respectively) of pitches, but their coking values were found to be higher (55.9 and 53.5 %, respectively).

Development of carbon-carbon composites by sol-gel method:

Carbon-carbon (C-C) composites were developed using carbon fibers coated with titania (TiO_2) sol after complexing the titanium atom in titanium isopropoxide with acetyl acetone. It was found that TiO_2 coated fibers helped in enhancing the mechanical properties of the composites.

Synthesis of SiC and TiC whiskers from rayon fibers through sol-gel technique:

The work on the synthesis of SiC_w from rayon fibers was continued employing substituted silicon alkoxides like MTEOS, DMDEOS and PTEOS. These alkoxides contain carbon attached to silicon atom and thus can help in the formation of SiC without external carbon. It was observed that carbon present in the subsituent helps in the formation of CO that is very important for the synthesis of SiC. It was also noticed that aspect ratio of SiC_w prepared with the above compounds is > 100 as revealed by SEM studies.

It was observed that TiC_w can be synthesised by sol-gel technique only in the presence of NaCl. Samples prepared without NaCl as a constituent areTiO_2 particles. The preparative details indicated that argon atmosphere is essential for the synthesis since the product obtained by employing nitrogen atmosphere did not show any TiC_w.

Development of flame proof cloth:

Viscose rayon is used as one of the precursors for making carbon fibers. However, the yield of carbon from this precursor is very low (15-30%) only and therefore it was used for making activated carbon fibers. Another application for this precursor has been identified as a flame proof material.

A process was developed to convert viscose rayon based cloth in to flame proof cloth. This cloth find applications in fire fighting suits, curtains & aircraft interiors etc. The cloth was first given a chemical treatment before processing it into flame proof material. The cloth was found to have Limited Oxygen Index (LOI) of about 40 and good flexibility.

Creation of infrastructure for the synthesis of carbon nanotubes:

An experimental set-up for producing single and multiwall carbon nanotubes by creating DC arc between two graphite electrodes was established. The system is designed in such a way that a constant arc gap and therefore arc current is sustained even when one of the electrodes is getting consumed.

Carbon fibre composite based Ilizarov fixator for orthopaedic applications:

Around 30 Carbon composite rings of 160mm diameter were supplied for field trials on polio patients at Agrawal Orthopaedic Hospital, Gorakhpur for clinical trials. The feed back received was excellent.

Asbestos free brake pad materials for automobiles:

Samples of size 130mm x 30 mm x 3 mm were fabricated using different reinforcements like chopped glass fibers, carbon fibres and kevlar fibre pulp and phenolic resin as binder matrix. These composites were characterized for their physical, mechanical and thermal properties. Samples were also sent to IIT, Delhi for the evaluation of their tribological behaviour.

High Pressure Physics & Technology

The high pressure group is involved in the study of material under high pressure and temperatures. The work involves the use of a 200 ton cubic press where pressure upto 50 kb and temperature upto 1300°C can be achieved. NPL has another high pressure equipment i.e. 1000 ton belt type press which can go upto higher pressure (60 Kb) and temperature (1600°C) conditions for a much longer duration. Presently it is out of order, so an in-house project for the repair of this press was taken up in this financial year.

Repair of 1000-ton press:

Pressure generation in different steps up to 40 kb was achieved using a dummy block of steel. A variac was also procured for heating the sample as the heating control unit of press was out of order and the press was made operative.

Diamond synthesis under high pressure and temperature in the presence of non-conventional catalyst solvent:

Efforts were made to study the graphite-diamond conversion in the presence of non-conventional catalyst, such as, zinc and brass. It was found that the pressure and temperature required for any diamond formation to take place using zinc and brass were much higher (P > 70 kb, T > 1700°C) than those required using copper as a non-conventional catalyst. The yield of diamonds formed was also very low using these catalysts. It was concluded that although they are new catalysts they are not as effective as the conventional Iron group catalysts. Part of this study was carried out at Anna University, Chennai.

इलैक्ट्रॉनिक पदार्थ
ELECTRONIC MATERIALS

एन पी एल का इलैक्ट्रॉनिक पदार्थ प्रभाग, इलैक्ट्रॉनिक पदार्थ, साधनों व सम्बन्धित प्रौद्योगिकी विकास की तैयारी व अभिलक्षणन में कार्यरत है। इसकी गतिविधियां सिलिकॉन व सिलिकॉन डिवाइसेज़, संदीप्तिशील पदार्थ और साधन, तनुपरत प्रौद्योगिकी, विशिष्ट मृत्तिका और सूक्ष्म संरचना साधनों के क्षेत्र में है।

ये गतिविधियां भिन्न अनुप्रयोगों की विविधता हेतु बड़ी संख्या में अर्धचालक और विद्युत रोधी तत्वीय व संघटित दोनों में और इसके अतिरिक्त मोटी और तनु पर केन्द्रित हैं। मुख्य गतिविधियां पदार्थ एवं उन पर आधारित साधनों जैसे सिलिकॉन, प्रकाश वोल्टीय सेल, फास्फर्स (संदीपक) व प्रदर्श साधन, उच्च ताप अतिचालकता घटक, सरंध्र मृत्तिका फिल्टर्स, बीटा अल्युमिना और तनु परत प्रकाशीय व विशिष्ट लेपों के लिए प्रौद्योगिकी विकास से सम्बन्धित हैं।

Electronic Materials Division of NPL is engaged in the preparation and the characterization of electronic materials and related technology developments. It consists of the silicon and silicon devices group, thin film technology group, special ceramic group , luminescent materials and devices group and microstructure device group.

These groups are working on a large number of semiconductors and insulators, both elemental and compound, in bulk and thin film forms, for a variety of diverse applications. Some of the important activities relate to the development of technology for production of materials and devices, such as silicon photovoltaic cells, phosphors and display devices, high temperature superconducting components, porous ceramic filters and thin film optical and special coatings.

The Silicon Devices Group conducted some theoretical and experimental studies relating to PIN silicon photodiode and its response to high-energy particles. The Luminecent Materials & Devices Group initiated work on alkaline earth aluminates towards obtaining even longer decay phosphers than the conventional zinc sulphide based ones. Thin Film Technology Group continued its studies on antiglare coating for ophthalmic lenses, amorphous silicon coating on glass substrates for use in optically addressed spatial light modulator (OASLM) and diamond like carbon (DLC) films. Special Ceramic Group continued its work on current carrying high temperature superconducting BPSCCO tapes and tubes and Beta alumina tubes of different dimensions for Na metal productions by IGCAR, Kalpakkam. Microstructure Materials & Devices Group continued its investigations in the fabrication of Cd Te and CIS solar cells and ferroelectric and pyro-electric oxide thin–film for non-volatile memory devices.

Silicon and Silicon Devices

Silicon photodiodes:

Some theoretical and experimental work relating to PIN silicon photodiodes and its response to high-energy particles was carried out. For high frequency application or for a faster response, the capacitance of the photodiode is desired to be small. Fig. 4.1 shows the theoretical calculation of capacitance as a function of substrate resistivity and reverse bias voltage. Capacitance decreases with increase in substrate

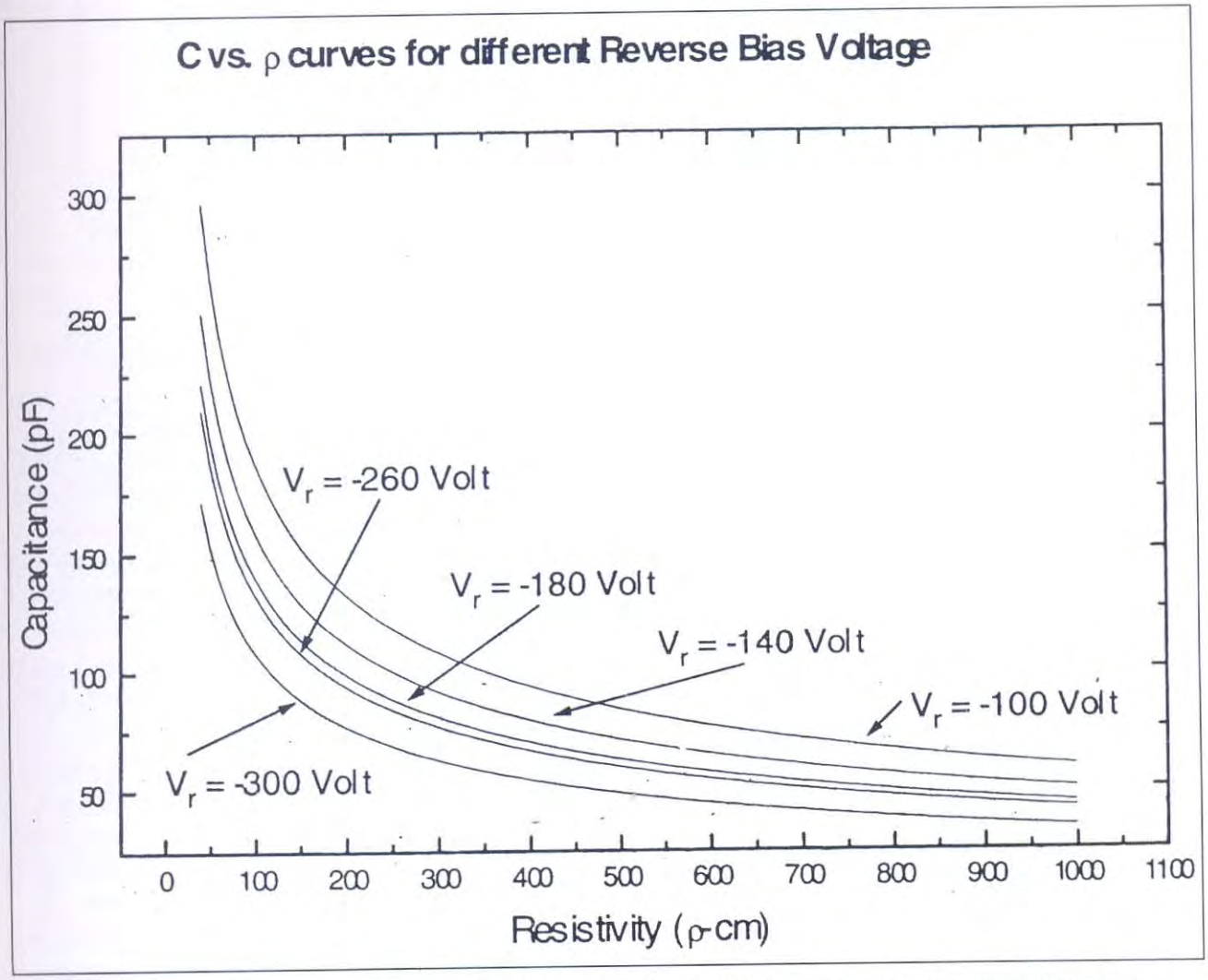


Fig. 4.1: Capacitance vs. base resistivity curves for n^+-p-p^+ structure of silicon for different reverse bias voltages

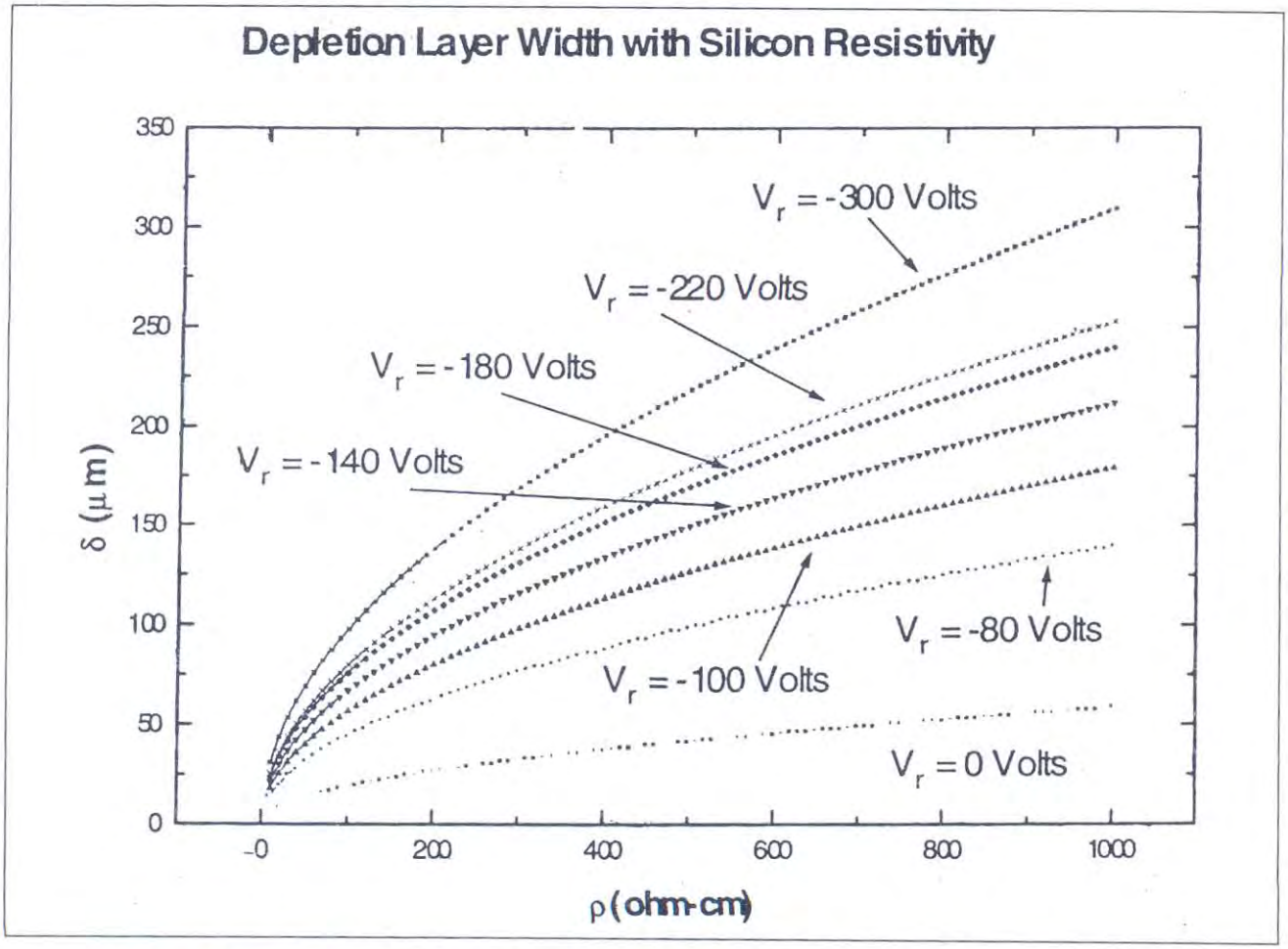


Fig. 4.2: Depletion layer width vs. base resistivity curves for n^+-p-p^+ structure of silicon for different reverse bias voltages

resistivity and reverse bias voltage. For a substrate resistivity of 1000 Ω cm and reverse bias voltage of 300 V, the capacitance is about 15 pF. Another parameter of importance is the depletion width. This parameter depends on the resistivity of the substrate and the reverse bias voltage. Depletion width increases with the resistivity of the substrate and the reverse bias voltage as shown in Fig. 4.2. For a reverse bias voltage of 300 V and substrate resistivity of 1000 Ω cm, the depletion width is as high as about 300 μm, whereas, for no reverse bias voltage and substrate resistivity of 100 Ω cm, depletion width is as low as about 20 μm.

Experiments were conducted to mount n^+p-p^+ silicon structure on a conducting base using a high conductivity silver epoxy and covering the front surface under a glass cover with the help of an optically transparent epoxy. The base of the n^+p-p^+ silicon structure was mounted on a copper clad substrate with the help of Epo-Tek H20E which is a 100% silver based epoxy. The front glass was encapsulated by a transparent epoxy, e.g., Epo-Tek 310. The measurement of illuminated current-voltage (I-V) characteristics of such a structure was carried out under tungsten halogen light source without and with the glass cover on the structure. Because of the glass cover the open circuits voltage (V_{oc}), curve factor (C.F.) and efficiency (η) fell by 30.8 mV, 0.095 and 1.4% respectively. The short circuit current (I_{sc}) did not show any significant reduction. The spectral response (SR) also did not show significant deterioration due to the presence of the glass cover. The front area of the device was 5.3 cm^2 and the device operated at 25 °C. This structure was also used in conjunction with a BGO crystal under X-ray irradiation. Significant photovoltage and photocurrents could be detected in the microvolt and microampere ranges.

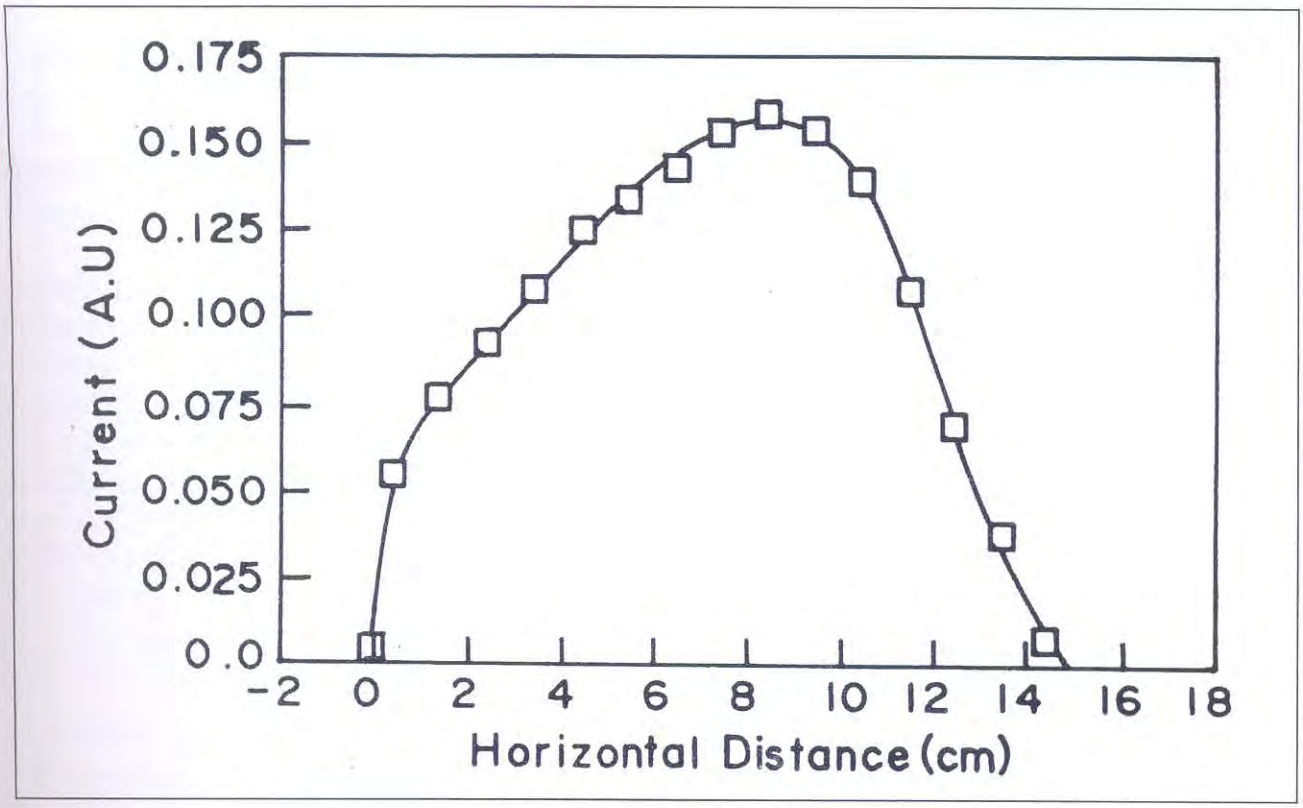


Fig. 4.3: Illumination as a function of distance across a cell diameter

Spectral response of large area solar cells:

Spectral response (SR) measurement of a large area cell is desired to be carried out by illuminating the entire cell rather than a portion of it. The intensity of the incident light on the cell should not vary spatially. In a practical SR measurement set up this is difficult to achieve. As shown in Fig. 4.3 the intensity of illumination is generally highest at the center of the test base and thereby also in the center of a 100 mm diameter cell placed on it and falls off gradually with distance towards the peripheral region of the cell. Short circuit current density (J_{sc}) values calculated for 100 mW/cm^2 intensity of AM 1.5 solar spectrum using the measured spectral response of large area silicon solar cells showed that there is mismatch of the calculated J_{sc} value with the measured J_{sc} value. For a cell of area 78.6 cm^2 the later value was less than the former by a factor 1.2.

Measured SR values of the large area test cell in 400-1100 nm wavelength range were found to depend on the exposed area of the cell; SR had got degraded as the exposed area was increased. Fig. 4.4 shows the measured SR of a cell with exposed area being limited to 4, 9, 16, 25 and 78.6 cm^2. In the last case the entire cell was exposed to light. The area of the reference Si cell was 4 cm^2. The mismatch or the correction factor defined experimentally as above was found to be unity for the case when exposed area of the cell was equal to the area of the reference solar cell. Using the measured radial distribution of intensity shown in Fig. 4.3, the average intensity (I_{ave}) for each exposed area of illumination was calculated. In general, the mismatch factor was determined correctly as the ratio of the average value (I_{ave}) of the incident monochromatic light for the reference cell and I_{ave} for the exposed area of the test cell. It was found to be ~1.2 for the case when entire cell area (78.6 cm^2) was exposed and had matched the experimental value. Determination of I_{ave} value thus provided a novel methodology for finding out the desired correction factor to determine true J_{sc} of a large area cell from the measured SR data of the cell.

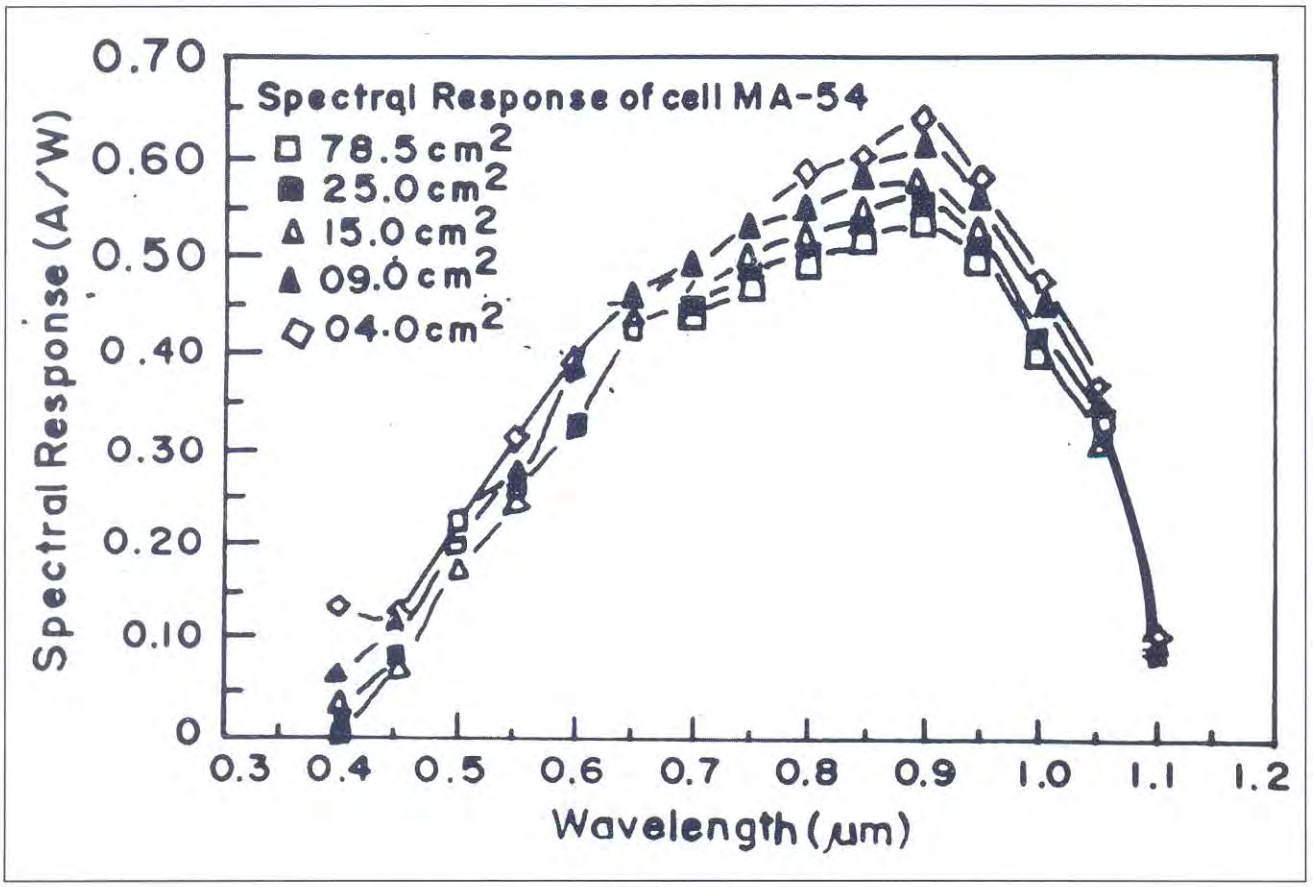


Fig. 4.4: Spectral response of a cell for four different concentric areas exposed to light

Luminescent Materials & Devices

Multichannel particle size analyser:

Design, fabrication and demonstration of the multichannel particle size analyser unit was completed. This computerised unit can analyse up to six samples simultaneously in six different settling liquids. Several demonstrations were given to prospective buyers/ entrepreneurs.

R & D in phosphors:

Work on alkaline earth aluminate phosphors was initiated. These are important for improved fluorescent lamps, plasma display and long decay phosphors. Of these compounds, mono-aluminates with the composition MAl_2O_4 and hexa-aluminates, $M\,Al_{12}O_{19}$ (M = Ca, Sr, Ba) are important phosphor materials.

$Sr\,Al_2O_4:Eu^{2+},Dy^{3+}$ is a very promising long decay phosphor having decay characteristics better than well established ZnS based long decay phosphor. Since strontium aluminate system is a complicated one and can exist in many compositions with different structures, its emission characteristics are expected to be influenced by synthesis parameters. A number of samples were prepared with varying compositions at different temperatures for different times with varying atmosphere. It was found that for the formation of $SrAl_2O_4$ lattice about 10 % flux is required. With other amounts of flux additional phases of strontium aluminate were formed as indicated by the presence of various emission peaks. The optimum amount of flux for higher brightness and long persistence was around 15%. Phosphorescence decay was hyperbolic and indicated presence of multiple traps. The trapping levels for exceptionally long decay was estimated to be around 0.78 to 0.80 eV attributed to Dy^{3+} in the lattice.

$SrAl_2O_4$:Eu gives emission in green region. There is a need for other emission colours as well. In this direction doping of the phosphor with manganese (Mn) was studied. Red emission with Mn as activator in strontium aluminate was obtained for the first time. Tetrahedral Mn^{2+} replacing Al^{3+} ions could be responsible for red emission in $SrAl_2O_4$.

Electroluminescent (EL) panels operated directly with mains supply (220 V, 50 Hz) were fabricated. These new type of EL panels do not require additional power supply with high voltages and higher frequencies and thus are low power consuming devices suitable for general displays as well as flat sources of light. Two types of such EL panels were developed which differ in their structure. Substrate for one was glass whereas the other was based on aluminium sheet. Life performance of the panels was also investigated with respect to the synthesis parameters of the phosphor.

Thin Film Optical Coating Technology

Silica-on-silicon integrated optical devices for wavelength division multiplexing applications:

As part of the above MIT funded project, detailed design of the Flame Hydrolysis Deposition (FHD) Facility was completed and given to a manufacturer for fabrication. This system comprises the FHD deposition chamber and its accessories and sub-systems, the constant temperature environment chamber to house the reactant vapours and liquids, the gas handling system and the scrubber for safe disposal of the toxic waste products. This system was custom-made since it was not commercially available and details about the system are not forthcoming from institutions abroad, who are commercialising their silica-on-silicon waveguide products. Preliminary runs were made in a makeshift facility, to gain initial confidence and experience while the complete system was being fabricated. A prism coupler set-up to characterise the waveguides by observing the guided modes were installed. A theoretical calculation procedure and the software to calculate the propagation losses of the guided modes in these waveguides was also developed.

High reflectance front surface mirror coating for rear view mirrors used in automobiles was developed. The reflectance is between 40 – 70 % meeting the specifications set by European Economic Community pertaining to rear view mirrors of motor vehicles. The coating successfully passed the prescribed tests on moisture resistance, temperature resistance and weather resistance.

Anti - glare and UV protective ophthalmic coating on spectacle lenses, for night driving applications:

While driving at night or in twilight, a vehicle driver faces problems in reading traffic signs, resolving colours and determining the size of an object in his vicinity due to glare from the headlights of oncoming vehicles, variation of luminous efficiency, ghost image formation and reduction in contrast because of multiple surface reflections from glass lenses etc. After having correspondence with various agencies like CGCRI, Calcutta, and Bharat Electronics Limited, Mumbai, and analysing DIN specifications, commonly acceptable optical specifications for anti-glare coatings for spectacle lenses suitable for night driving applications, were identified. A suitable optical coating meeting these specifications was developed for ophthalmic lenses. The light transmittance through the coated lenses is nearly uniform throughout the visible region (about 80 – 85 %) and, in addition, the entire UV radiation is cut off (transmittance less than 2 – 4 % in the UV region). Therefore, these coated lenses can be used during the day also for protection of the eyes from UV radiation (potential cause of cataract and macular degeneration), without affecting the visibility. The developed coating successfully passed all the abrasion and moisture resistance tests prescribed for these coatings. Samples of the coated lenses fitted in spectacle frames were given to several users, and their reactions were very favourable and satisfactory.

Amorphous Semiconducting Thin Films, Devices and Systems

Diamond like carbon films (DLC) :

Work was started on DST sponsored project entitled "Tetrahedral amorphous carbon (ta-C) deposited by a Filtered Vacuum Arc Discharge (FVAD) technique". These ta-C films have applications in field emission display devices. An improved FVAD set-up was designed and fabrication commenced. Field emission measurements of DLC films prepared by different techniques in our laboratory was carried out and their results analysed. A correlation between the observed stresses in these films and the Urbach energy was made.

DLC films grown by saddle field fast atom beam source technique was found to have a low dielectric constant which can be used as insulating material in multilevel metallisation for microelectronic applications. A dual fast atom beam technique has been suggested where carbon bearing precursors and diluted / reactive gases were separately passed through the two sources, and the material being deposited tailored for various desirable properties.

DLC films deposited in our sophisticated microwave plasma PECVD facility were characterised by Langmuir probe method to establish the correlation between the plasma parameters and the film deposition parameters. Further analyses and studies are continuing. Uniformity of the deposition of layers in this system could be correlated with ion density in a most convincing way through these experiments.

The low stress DLC films grown by various techniques was found to be successful on the cutting edges of stainless steel razor blades. Systematic work in this direction resulted in collaborative work with a leading blade manufacturer in the country for scaling up the DLC coatings for blade edges for commercialization.

DLC coatings were successfully deposited on the inside surfaces of plastic bottles of different shapes. The coatings were stable and uniform. Bottles so coated are considered to be safe for storing beer and similar products.

Special Ceramics

High temperature superconducting materials have opened the way for fascinating new applications in electronics, electrical engineering, high current applications etc. BSCCO rods and tubes are the first commercial applications in electrical power engineering as they offer major advantages over conventional metal leads. A heat reduction of more than a factor of 10 at 4K with a current of 500-1000A can be obtained for various applications. Small superconducting magnets of silver clad BSCCO tapes and cables of multifilamentory Ag-BSCCO are ready for commercialization. Keeping this in view special ceramic group has been working on HTSC BPSCCO long length tapes (monofilamentory and multifilamentory), tubes and rods as an in house project. After optimization of process parameters (in 1998-99) and demonstration of working devices at liquid nitrogen temperature 77K, many tube conductors of Bi2223, of 10cms length with 1cm O.D. and 0.9cm I.D. were tested at 4.2K for I>120A successfully with the minimum helium loss (1-2 litres per day). The contact resistance studies are in progress.

The fabrication of monofilamentory and multifilamentory silver clad Bi2223 tapes (maximum 32 filaments) of 20meters length were done successfully using the PIT method and were tested at 77K and 4.2K at zero field. It has been found that $Jc \sim 2x10^4$ A/cm^2 could be obtained with our optimized process. Basic studies of Bi2223 with magnetic and nonmagnetic impurities are in progress for their effect on flux pinning.

One inhouse project "Development of graded porosity porous ceramic for particulate filters" was initiated. This is aimed at improving the performance of high alumina (47mol% SiO_2, 23mol% MgO, 30mol% Al_2O_3) cordierite filters for, 10 BHP diesel engines. Another project, development of beta alumina tubes for sodium metal production, which was in collaboration with Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, with funding from Board of Research for Nuclear Studies

(BRNS), has been extended till June 2000. Under this project 35 numbers of 50mm(ϕ)X100mmX2mm wall thickness one end closed beta alumina tubes with an alpha alumina header joined by a special glass seal was supplied. The new work is on residual stress measurements on the joints of beta alumina tubes to alpha alumina header.

Microstructure Materials and Devices Group

This group has been working on novel semiconductor thin film materials based on compound semiconductor chalcogenides for photovoltaic and nano size quantum electronic devices and nitride group of wide band gap materials for optoelectronic and high temperature electronic devices. The research in these areas is strongly motivated by potential applications and emerging technologies of strategic importance. In photovoltaic research, the NPL program has advanced from prototype device stage. In other areas, the main focus of the NPL group is on basic research, material synthesis, understanding of physical phenomena and establishment of essential technology.

In the polycrystalline thin film solar cells NPL has demonstrated prototype CdTe based photovoltaic thin film solar cells of over 10% conversion efficiency and developed all important and critical technology steps in cell fabrication. NPL has also been developing new processes for cell area enhancement and fabrication of integrated submodules. NPL has developed host of technologies for CdTe absorber layer such as electrodeposition, organometallic decomposition and pulsed plating which have low cost cell fabrication potential. The new focus of the NPL programme has been to evolve novel technologies for solar cell fabrication and to develop new thin film solar cell materials. New ternary chalcogenides semiconductor such as CdPbTe, CdSnTe and dilute magnetic semiconductor CdMnTe, of variable composition are being studied with a view to develop homojunction CdTe based solar cells. Simultaneous work on $CuInSe_2$ (CIS) based cells is in progress where new studies on synthesis of other materials of the similar group are being done with a view to develop tandem cell structures based on CdTe on CIS group of new thin film materials. One of the fabrication techniques, namely the vapour selenization, which has been developed earlier by the NPL group, is being extensively investigated further for cell fabrication in such structures. The potential of the technique in developing solar cell materials with multiple chalcogen composition such as (Te, Se) is being evolved through research on novel group of metals, e.g. Pb, Sn, Cu, In, Ag etc. Extensive research is being done to investigate new window layer materials such as ZnSe exploring integrated approach to CIS solar cells. In depth scientific studies of optical and electronic properties of new photovoltaic thin film materials was carried out.

In further quest on thin film compound semiconductors, NPL group has initiated a major program on epitaxial growth of GaN thin films. GaN has emerged as potential new material for short wavelength optoelectronics and high temperature fast microelectronic devices. NPL has a state of the art Molecular Beam Epitaxy (MBE) equipment equipped with nitrogen ion beam source for synthesis of GaN epitaxial thin films. This group continues to investigate condition for GaN epitaxy with minimum defects. Development of p-type doped material to fabricate p-n junction blue LED is planned in the near future.

Nanocrystalline semiconducting thin films displaying quantum effects are emerging as potential materials for novel quantum electronic devices. NPL has been carrying out the synthesis of CdTe and Si nanocrystalline quantum dots. These nanophase materials are passivated in high band gap oxide matrix and show quantum confinement of charge carriers. Optical band edge shifts due to confinement of coupled exciton in nanocrystals of cdTe was studied. The effect of quantum dot size and density of distribution on optical properties as brought out by the studies revealed new information on anisotropic nature of confinement effects within the nanocrystal. CdTe growth islands, more specifically due to nano dot clustering. The effect of passivating matrix on optical edge shifts and associated absorption phenomenon was also studied.

This group has major research programme to develop oxides based electronics. The research projects in this area are in (i) ferro-magnetic oxides for recording media (ii) ferro-electric and pyroelectric oxides for nonvolatile memory gate dielectric and IR sensing applications and (iii) semiconducting sensor oxides. In ferro-magnetic oxides, chemical vapour deposition technology for synthesis of Co-doped yttrium iron garnet (YIG) thin films was developed. Various material phases such Ce compensated YIG, co-infiltrated YIG and multilayer Co-YIG/YIG structures were developed and their magnetic properties were investigated. In our search for new magneto-optic recording media, development of multilayer YIG and co-infiltrated YIG films are very significant. Currently nanophase barium hexaferrite thin film are being synthesized and investigated as potential high density information recording medium. This group has developed citrate complex based spray process for these films. Nano magnetic particle phase synthesising conditions were established. Predominantly perpendicular easy axis orientation and high coercivity of 5000 Oe of these film is extremely useful for recording medium. A significant observation of monotonic angular dependence of coercivity in these films established weaker inter nano grain interaction which is a useful indicator of low media noise for use in high-density magnetic recording media development.

The ferro electric, PZT, BST and SBT perovskite thin film have been investigated for NvRAM application. As a requirement for device use, assessment of dielectric and ferroelectric properties and dependence on synthesising parameters were done. The effect of secondary TiO_2 phase in diffused phase transition from ferro to paraelectric phase was investigated. So far this effect was seen in relaxor materials with B site defects. This significant data has further enhanced our knowledge on micro polar defects as main reason for diffusive phase transition. Since, in synthesis such phase formations are observed the new knowledge due to NPL group's work should be viewed as important for device application and basic understanding.

बहुलक व नर्म पदार्थ
POLYMERIC AND SOFT MATERIALS

अकार्बनिक अर्द्धचालकों/परावैद्युतों पर आधारित इलैक्ट्रॉनिक पदार्थ साधनों के डिजाइन और परिवृद्धि हेतु सीमित विकल्प प्रस्तुत करते हैं यह रिक्तता हाल के वर्षों में कार्बनिक अर्द्धचालकों और चालक बहुलकों के आगमन से अधिकांश रूप से भर गयी प्रतीत होती है। इन पदार्थों की चालकता को डोपिंग का प्रयोग करते हुए कई गुना बढ़ाया जा सकता है। सम्बद्ध बहुलकों का, जो अपने प्रोसेसिंग पर पराश्रित होते हुए धातु एवं अर्द्धचालक दोनों के अभिलक्षणों को प्रदर्शित कर सकते हैं, प्रयोग विस्तृत रूप से बहुत सी इलैकट्रॉनिक युक्तियों के निर्माण में किया जा रहा है। प्रकाश उत्सर्जक डायोड्स ऐसी ही युक्तियॉ हैं। इसी प्रकार लौह वैद्युत और अन्य प्रकारों के द्रव क्रिस्टल से नए अनुप्रयोग भी प्राप्त हो रहे हैं। विशेषकर, अपने बृहत प्रकाश वैद्युत और स्मृति प्रभाव के कारण सतही स्थायीकृत लौह वैद्युत द्रव क्रिस्टलस् पर एन पी एल में ध्यान केन्द्रित किया गया है। इनका प्रयोग विविध प्रदर्श अनुप्रयोग साधन तथा इमेज प्रोसेसिंग (OASLM) के लिए होता है। बहुलक पदार्थ नवीन स्वास्थ्य देख रेख युक्तियां एवं प्रणाली में प्रयोग के लिए भी उपयुक्त हैं। कोलेस्ट्रॉल निर्धारण व यूरिया जैव संवेदकों पर आवश्यक अन्वेषणों और विकास कार्यों का संचालन करते हुए जैव संवेदकों से सम्बन्धित गतिविधियों का कार्य क्षेत्र एन पी एल में बढ़ाया गया है। जैव सुसंगत बहुलक कम्पोज़िट पर कार्य का उत्तरदायित्व भी लिया गया है। पाया गया है कि पालीपिरोल/ सोडियम नाइट्रेट कम्पोज़िट्स से मानव एंडोथीलियल सैल्स सम्बद्ध हो जाती है और विकसित भी होती हैं । इसी प्रकार पानी में पोलियो-1 वायरस को पकड़ने के लिए चालक बहुलक झिल्ली प्रबन्ध के कार्य को आगे बढ़ाया है। इसके प्रारंभिक परिणामों की अखिल भारतीय आयुर्विज्ञान संस्थान, नई दिल्ली द्वारा पुष्टि की गयी है। सहबहुलक एनिलीन और फार्मेल्डीहाइड को समाविष्ट करते हुए बहुलक आधारित विभिन्न गैसों और सूक्ष्म जीवों की जांच करने वाले संवेदकों को दल समूह में उत्पादित किया गया है। 'विद्युत क्रोमिक विंडोज' में सुधार करने के लिए हमारे लगातार प्रयासों में बहुलक जैल विद्युत अपघट्य के अतिरिक्त पारदर्शी और चालक डोप्ड टिन आक्साइड परतों के विकास पर ध्यान केन्द्रित किया गया है। साथ-साथ विभिन्न प्रयोगशाला प्रक्रियाओं को बढ़ाने के लिए एक माइक्रो प्रोसेसर नियंत्रित निमज्जी विलेपन सुविधा का डिजाइन कर उसे विशेष रूप से निर्माण कर स्थापित किया गया है। ई एम आई परिक्षण और स्थिर वैद्युत आवेश के योग्य चालक बहुलक परत में और सुधार किया गया है। एक्सरे विकिरणी चित्रण में प्रयोग करने के लिए प्रकाशग्राही की एक्सरे संवेदनशीलता को बढ़ाने के प्रयास किए गए और बहुलक/सलीनियम संयोजन पर बड़े पैमाने पर अन्वेषण किया गया और साथ ही एक पोर्टेबल एक्सरे क्सीरोग्राफी यूनिट का भी सफलता पूर्वक प्रदर्शन किया गया। इंडो - यू एस सहयोगी परियोजना के अन्तर्गत इस अवधि के दौरान बहुलक ठोस अन्तरापृष्ठों पर पृष्ठीय क्रम व संरचनात्मक अध्ययनों के विषय में महत्वपूर्ण सहयोग किए गए। यह प्रदर्शित किया गया कि एक बड़ी सीमा तक अन्तरापृष्ठीय गुणधर्मों में संशोधन करके उसके द्वारा पुष्टि करते हुए किस प्रकार ए पी टी ई एस की दो एकाणु परतों को, एक दूसरे के ऊपर, स्वच्छ ग्लासप्लेट से संलग्न किया जा सकता है।

Electronic materials based on inorganic semiconductors/dielectrics offer limited choices for device design and development. This gap in recent years appears to have largely been filled by the advent of organic semiconductors and conducting polymers whose conductivity can be changed by many orders of magnitude using doping. Conjugated polymers, which can exhibit both metallic and semiconducting characteristics, depending upon their processing, are being increasingly used for fabricating many electronic devices, including light emitting diodes. Similarly, ferroelectric and other types of liquid crystals are finding new applications. Specifically, surface stabilized ferroelectric liquid crystals because of their large electro-optic and memory effects are drawing increasing attention for fabricating various display devices and also for image processing applications (OASLM). At NPL these materials and devices are receiving focussed attention. Polymeric materials are again very attractive for novel health care devices and systems. At NPL the scope of biosensors related activity has been enlarged by conducting necessary investigations and development work on lactate, cholesterol and urea biosensors has enlarged activity. In an interesting development, work on biocompatible polymer composite has been undertaken and human endothelial cells were found to be attaching and started growing on polypyrrole/$NaNO_3$ composites. Similarly, work on conducting polymeric membranes for arresting polio-1 virus from water has matured and our initial results were confirmed by AIIMS, New Delhi. Polymer based sensors, comprising of a copolymer aniline and formaldehyde, were batch produced and were found to identify various gases and microorganisms in a reproducible manner. In our continuing efforts to improve electrochromic windows, focussed attention was paid in developing polymeric gel electrolytes as well as transparent and conducting doped tin oxide films. Simultaneously, to scale up the various laboratory processes a sophisticated microprocessor controlled dip coating facility (for sol-gel process) was designed, custom fabricated and installed. Conducting polymeric coatings suitable for EMI shielding and dissipation of electrostatic charges were further improved. Attempts to enhance X-ray sensitivity of photoreceptors for use in xeroradiography continued to be made and polymer-selenium combinations were extensively investigated as also a portable X-ray xerography unit was successfully demonstrated.

Important contributions to the surface order and structural studies on polymer- solid interfaces, under a collaborative INDO-US project, were made during this period. It was demonstrated how two monolayers of APTES, one over the other, could be attached to a cleaned glass plate, confirming thereby modification of the interfacial properties to a great extent.

Liquid Crystal Physics and Applications

Surface order and structure studies on polymer-solid interface:

Significant progress could be made in the Indo-US project entitled "Surface order and structure studies on polymer-solid interface". As envisaged in the project, self assembled monolayer of alkyl-amine-silane, namely Amino-Propyl-Triethoxy-Silane (APTES) with high order and structure integrity could be deposited on glass and silicon substrates. The deposited monolayers were characterized by contact angle measurement, ATR-FTIR and other techniques. The dynamics of formation of monolayer was studied using the above-mentioned techniques. It was found that the complete monolayer formation depended critically on a variety of parameters, such as cleanliness of the substrate, time of immersion of the substrate in the silane solution, concentration of the silane in the solution, choice of the solvent and the moisture content therein and temperature of the solution etc. The deposited monolayer of APTES was treated with cinnamoyl chloride under catalytic and base conditions to attach the UV-chromophore of the cinnamoyl moiety to the deposited monolayer. In this way two monolayers one over other were attached to the glass substrates thus modifying the interface properties drastically. These substrates were polymerized with UV-polarized light leading to creation of anisotropic polymer surface interface. These substrates produced good planar orientation of the liquid crystals. The quality of planar orientation was examined under a polarizing microscope. A good planar oriented liquid crystal cell showed a strong variation in the transmission of the cell when the same was rotated between crossed polarizer. As such one observes four successive transmission intensity maxima and minima when the cell is rotated through an angle of 360°. Figure 5.1 shows the photographs of one such cell between crossed polarizer when the same is rotated from 0 to 90°. The transmission is minimum when one of the polarizing axes of the two-crossed polarizer coincides with the direction of planar orientation of the liquid crystal molecules and maximum when the same is at 45° to the polarizing axis. It was further observed that the direction of planar orientation of liquid crystals is controlled by the direction of the UV-polarized light. In this way the direction of planar orientation can be varied locally by varying the direction of UV-polarized light. It has been also observed that the direction of orientation of liquid crystal molecules is perpendicular to the polarization direction of the linearly polarized UV-light (Figure 5.2). This has been ascertained by monitoring the direction of orientation of the p-type dye doped liquid crystals vis-a-vis the direction of polarization of the linearly polarized UV- light.

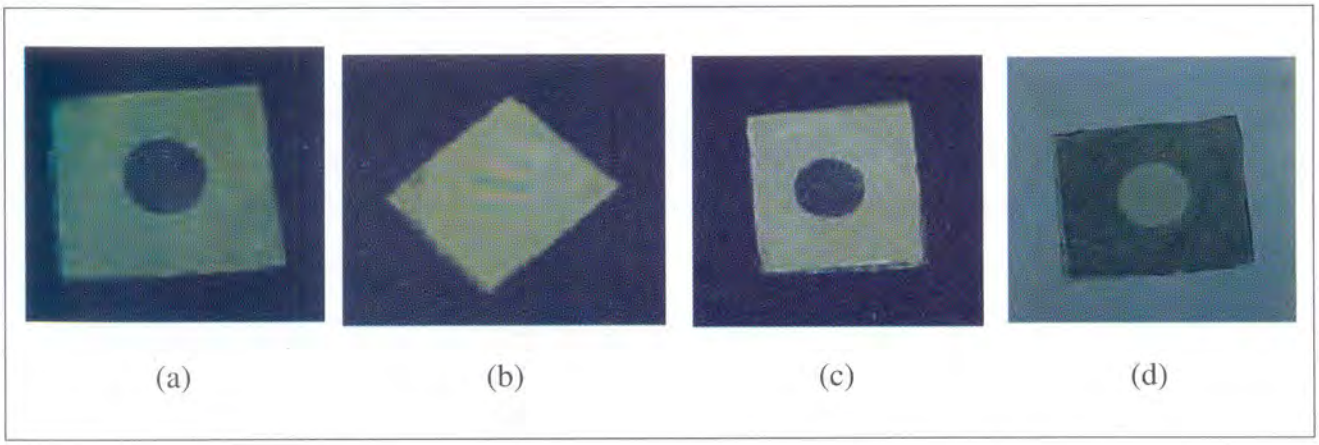


Fig. 5.1: Photographs of a planar oriented liquid cell produced by APTES + cinmoyl chloride treated glass substrates sandwiched between two crossed polarizers with orientation axis, a) parallel to one of the polarizer, b) at 45°, c) at 90°, respectively and d) the planar cell between parallel polarizer

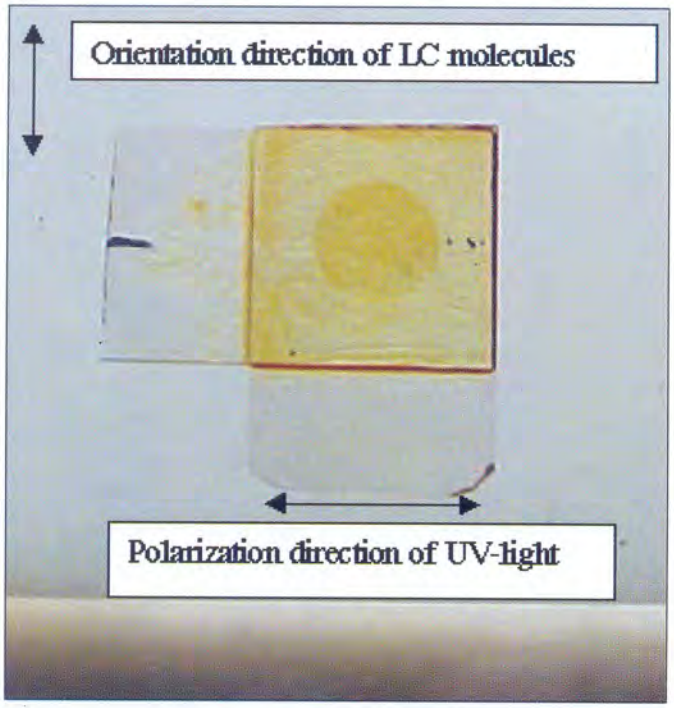


Fig. 5.2: Direction of the orientation of the liquid crystals is found to be perpendicular to the direction of polarization of the linearly polarized light

Ferroelectric Liquid Crystals

Ferroelectric liquid crystals (FLCs) due to their fast switching response have a big advantage over nematic counterpart for use in display devices. However, they are not widely used in such devices as yet because there exist a number of difficulties in their application. This also includes insufficient understanding (and control) of their alignment, switching mechanism etc.

The Surface Stabilised Ferroelectric Liquid Crystals (SSFLC) show a memory effect, which obviously can be exploited for interesting device applications. For preparing SSFLC devices, very thin samples of the order of 1-4 μm are to be used, where the surface anchoring effect plays a dominant role. There is no clear understanding on how the surface anchoring effect, particularly charge accumulation at the FLC /alignment layer interface, influences the switching dynamics of SSFLC devices. The charge accumulation phenomenon is very difficult to investigate owing to very low mobility of charges and hence the effect can be detected only at very low frequencies, where the conductivity effect dominates. Also, it increases very significantly on decreasing the frequency. Investigations relating to the dielectric behaviour were made on such thin SSFLC samples, at low frequencies and varying temperatures, in smectic C* and chiral nematic and also in isotropic phases. For the first time, the charge accumulation phenomenon between the alignment layer and the ferroelectric liquid crystal material at sub-hertz frequency range was detected using the dielectric relaxation method in SSFLC devices. Results are shown in Fig. 5.3.

Organic Light Emitting Devices

Considerable attention is being paid to the light emitting devices in recent years that utilise thin layers of organic materials as the electroluminescent medium. These Organic Light Emitting Diodes (OLEDs) are either based on molecular materials or polymers (PLEDs). The performance of these organic LEDs has now reached an efficiency level equivalent to that of a incandescent lamp of 20 lumens/watt. This technology appears to be on the verge of commercialisation. The main interest in the utilisation of the semiconducting organic and

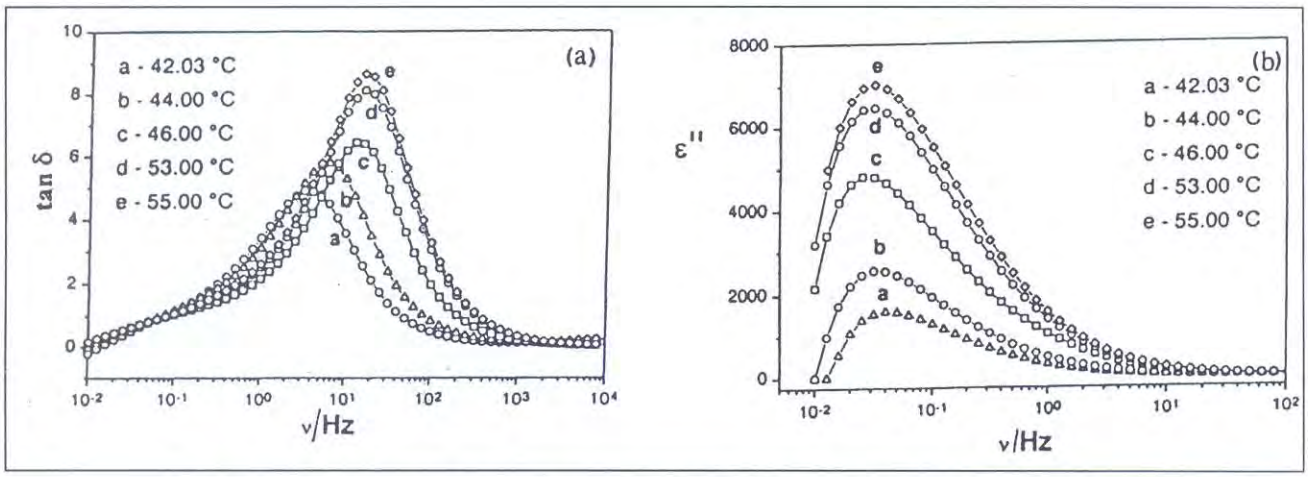


Fig. 5.3 (a): Loss factor(tanδ) vs frequency and (b) E" vs frequency at diffrent temperatures in smectic C and chiral nematic phases*

polymeric materials for the fabrication of LEDs is that it is easier to process them into large area displays, as compared to the conventional inorganic LEDs. It is also possible to vary the material properties a great deal to get light emission in the full range of visible spectrum. The prospects of making flexible, power efficient and colour tunable displays involving OLEDs have, indeed, become very bright. Recently, laser action and photovoltaic effect has also been reported in organic devices.

In general, there are two different approaches that utilize organic materials in the fabrication of light emitting devices. One employs organic dyes and metal chelates and the other utilizes polymeric materials as emitting elements. The schematic diagram of an OLED is given below (Fig. 5.4)

The device consists of an emitter layer and a hole transport layer which are sandwiched between a high work function transparent conducting electrode and a low work function cathode. Electrons and holes are injected from the cathode and anode respectively into the organic semiconductor where they are captured with the formation of excitons. These excitons decay radiatively giving out light, which comes out through the transparent conducting anode.

Organic light emitting diodes fabricated:

Prototype Organic Light Emitting Diodes (OLEDs) were fabricated based on small molecules using transparent conductor Indium Tin Oxide (ITO) as the anode, N,N'-diphenyl-N-N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-

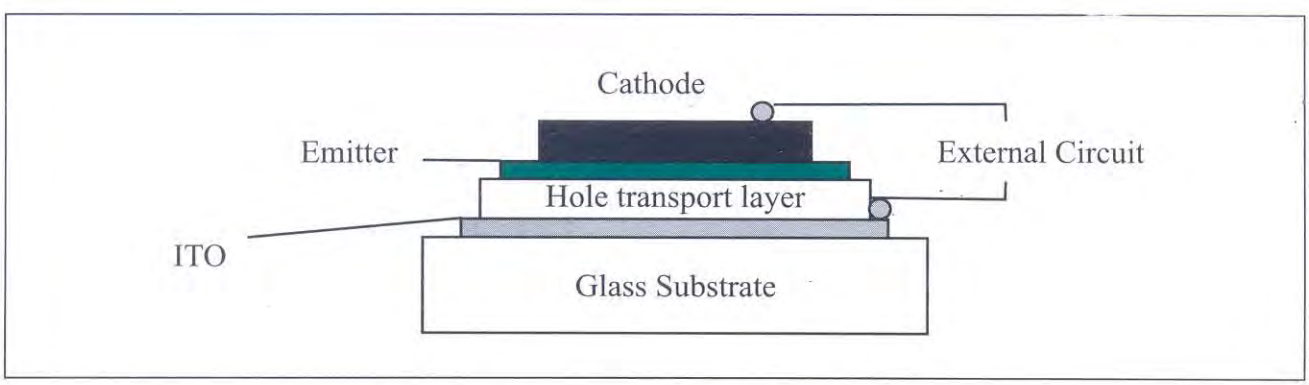


Fig. 5.4: Schematic diagram of an OLED device

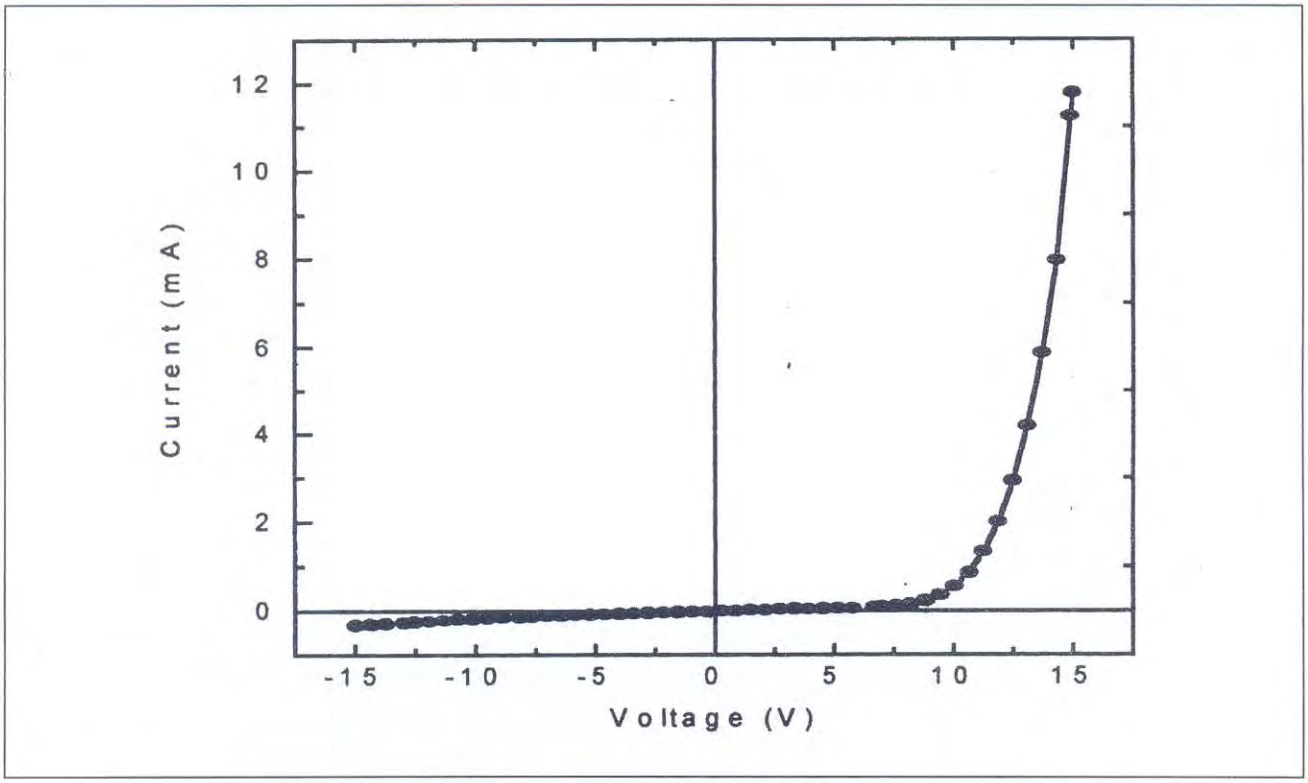


Fig. 5.5: I-V characteristics of Alq_3 based OLED

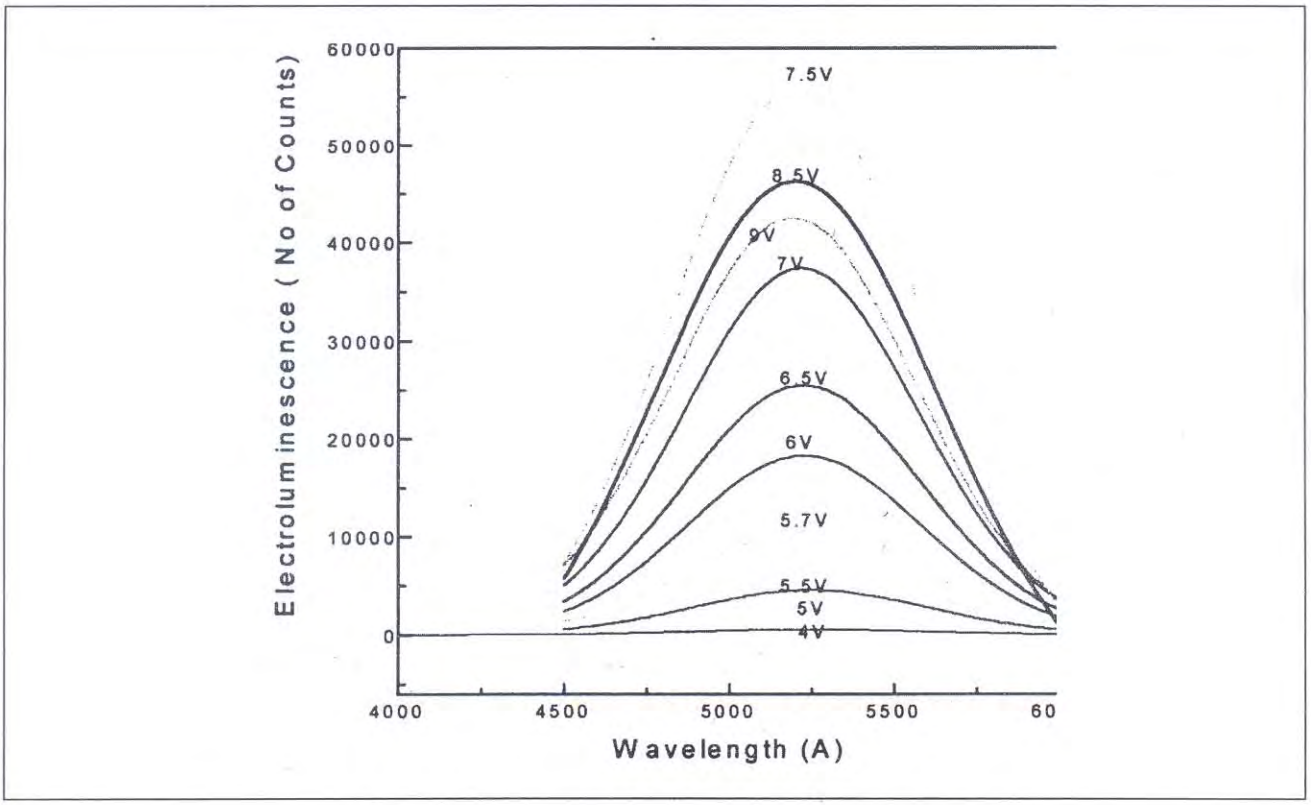


Fig. 5.6: OLED shows electroluminescence with a peak at 540 nm

diamine(TPD) as the hole transport layer and Aluminum tris(8-hydroxy qunoline) (Alq_3) as the emitter. The devices give bright green emission on application of about 7V. The electrical properties show typical diode characteristics with rectification factor of more than 50. (Fig. 5.5) The device show strong electroluminescence with a peak at about 540 nm.(Fig. 5.6)

Electrochromic Devices

In the work earlier carried out in this laboratory, emphasis was on improving WO_3 films to be used as electrochromic (EC) electrodes. Relatively fewer efforts were directed towards exploring polymeric gel electrolytes and counter electrodes, the other two basic components of an Electro Chromic Device (ECD). These were precisely the tasks that were additionally taken up during this period.

The addition of oxalic acid (OAD), in the optimum amount, to the peroxytungstic acid based precursor solution and a controlled post deposition thermal treatment were found to influence the physical, structural, electrical properties a great deal and ,as a result, EC properties of the (W_2O_3) films changed significantly. X-ray diffraction, electron microscopy and resistance measurements have revealed that such a chemical modification, with the optimum amount of oxalic acid accompanied with appropriate heat treatment can yield crack free thick films. These treatments were found to control resistance, crystallinity / amorphicity and as a result chemical stability of the films (Fig. 5.7 a & b). Fast ECDs with fairly long lifetime and excellent optical modulation (Fig. 5.8) can, thus, be prepared utilizing these films.

For doped tin oxide films, prepared by sol-gel peroxo route using $SnCl_2.2H_20$ as the starting material and metallic molybdenum powder as a dopant, the degree of crystallinity could be controlled by an appropriate post deposition thermal treatment and an optimum amount of the dopant incorporation. This process realized films with charge insertion capacity in the range 20-30, mC/cm^2, a value comparable to that of $W0_3$ films. The passive nature of these films has been evidenced by the fact that these films show negligible change in transmission characteristics upon charge intercalation/de-intercalation.

An important requirement of a polymeric gel electrolyte, for transmissive ECDs, apart from the high ionic conductivity that is invariant in a wide temperature range, chemical & electrochemical stability, is the high optical transmission in the visible spectral region. In designing highly conductive gel electrolytes, the primary step is to synthesize non-aqueous parent liquid

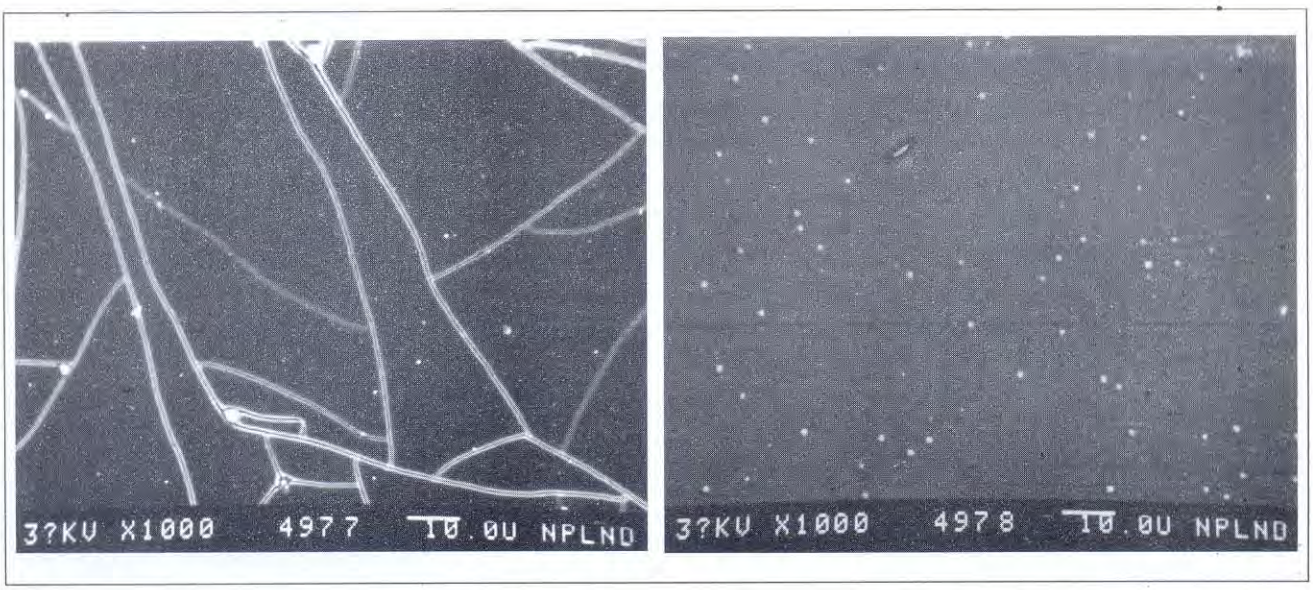


Fig. 5.7: Scanning electron micrograph of the films prepared with precursor solutions of (a) APTA and (b) APTA + OAD both heated at 250°C showing crack free nature of the films in the latter case

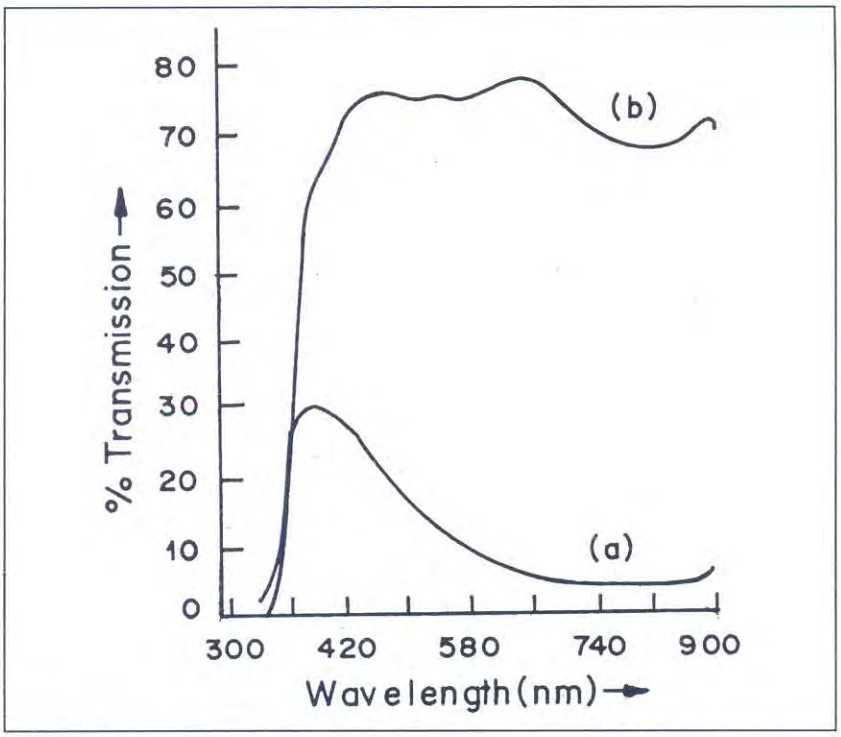


Fig. 5.8: Transmission spectra of a film with 5 wt.% of OAD with thickness 336 nm in a) coloured and b) bleached state.

electrolytes based on polar solvents with room temperature ionic conductivity of the order of 10^{-2} Scm^{-1}. Highly viscous gel electrolytes, comprising a novel class of highly polar solvents such as N-N-DMF and N-N-DMA as such and in conjunction with conventional plasticizing solvents like PC, EC and γ BL, Li salts with different anions and polymers like Polyacrylonitrile (PAN) and Polymethylmethacrylate (PMMA), were investigated. Gel electrolytes with good mechanical and adhesive properties, together with room temperature ionic conductivity of the order of $10^{-3}Scm^{-1}$ accompanied by good transparency in the visible region (even upon addition of 30-% by wt of PMMA) were realized. These appear to be good enough for the fabrication of transmissive ECDS. Further investigations, with a variety of solvents and their binary. ternary & quarternary mixtures, are in progress.

Another important consideration for the development of efficient transmissive ECDs, particularly for window applications, is the ability to deposit these thin films uniformly over large areas. A facility was, therefore, created for depositing these films by "Dip coating technique (Fig. 5.9). This custom made, fully microprocessor controlled Dip coating unit allowing wide variations in processing parameters like withdrawal speed, dipping time etc. is capable of depositing films up to dimensions of 300mm X 300mm.

Biomolecular Electronics and Conducting Polymers

Lactate biosensor:

For fabication of lactate biosensor, lactate oxidase and lactate dehydrogenase have been co-immobilized into electrochemically prepared polyaniline films by physical adsorption technique. Co-immobilization was carried out to detect lactate at lower concentrations lower than 1 mM. It has been seen that these polyaniline electrodes exhibit linear amperometric response (when measured at 0.2 V) from 0. 1 to 1 mM and are stable for about two weeks. Fig 5.10 shows the calibration curve for PANI/LOD and PANI/LDH electrodes as a function of lactate concentration. An attempt has also been made to immobilize lactate dehydrogenase on sol-gel

Fig. 5.9: A custom made Dip-Coating Unit installed at NPL. Substrates of dimensions up to the size 300 mm x 300 mm can be deposited using this facility.

matrix by physical adsorption and sandwich configuration. This lactate biosensor based on optical technique is found to have linearity from 0.5 -4 mM of lactate and is stable for about four weeks.

Cholesterol biosensor:

Amperometric cholesterol biosensor has been fabricated by co-immobilizing cholesterol oxidase and horseradish peroxidase onto sol-gel matrix by physical adsorption, sandwich configuration and micro-encapsulation techniques. The sensor can be utilized for cholesterol estimation from 2 to 10 mM and is stable for about 8 weeks at 25°C and about 12 weeks at 4-5°C.

Urea biosensor:

For urea biosensor urease and glutamate dehydrogenase have been co-immobilized on electrochemically prepared polypyrrole-polyvinyl sulphonate film. Urease catalyses the conversion of urea to ammonia and bicarbonate ions and the ammonium ion thus released is coupled with 2-oxoglutarate in the presence of glutamate dehydrogenase and NADH to form glutamate and in

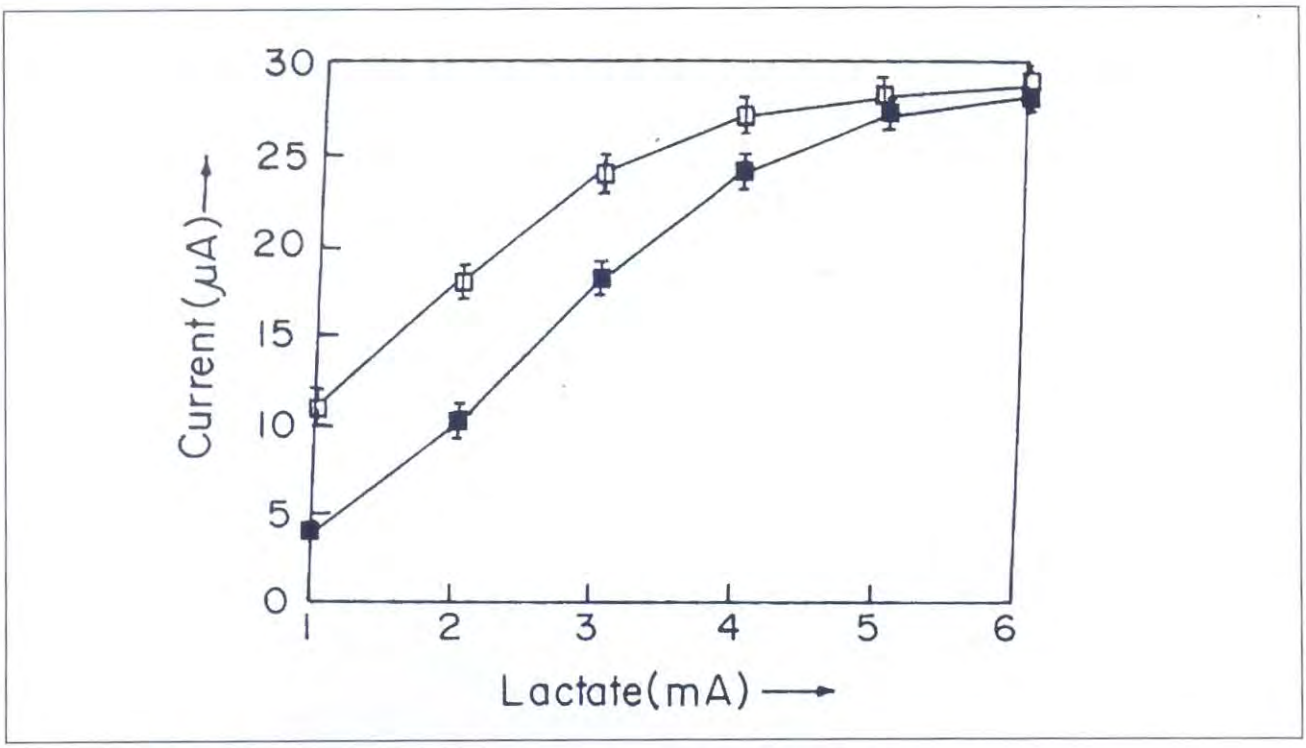


Fig. 5.10: Amperometric response curve for PANI/LOD electrodes (■) and PANI/LDH electrodes (□) in the presence of NAD (0.02 M) as a function of lactate concentration in 0.1 M phosphate buffer (pH 7.0)

the process NADH gets oxidised which is monitored at 340nm spectrophotometrically.

Thermal studies on polyemeraldine base:

Thermal characteristics of chemically synthesized polyemeraldine base were experimentally investigated using differential scanning calorimetry and thermogravimetric analysis, UV-visible and FTIR techniques, respectively. Results of TGA measurements have revealed that the chemically synthesized emeraldine base is thermally stable up to about 400°C. Analysis of reaction kinetics of cross-linking in polyemeraldine base reveals that a pseudo first order thermodynamic reaction occurs in this conducting polymer.

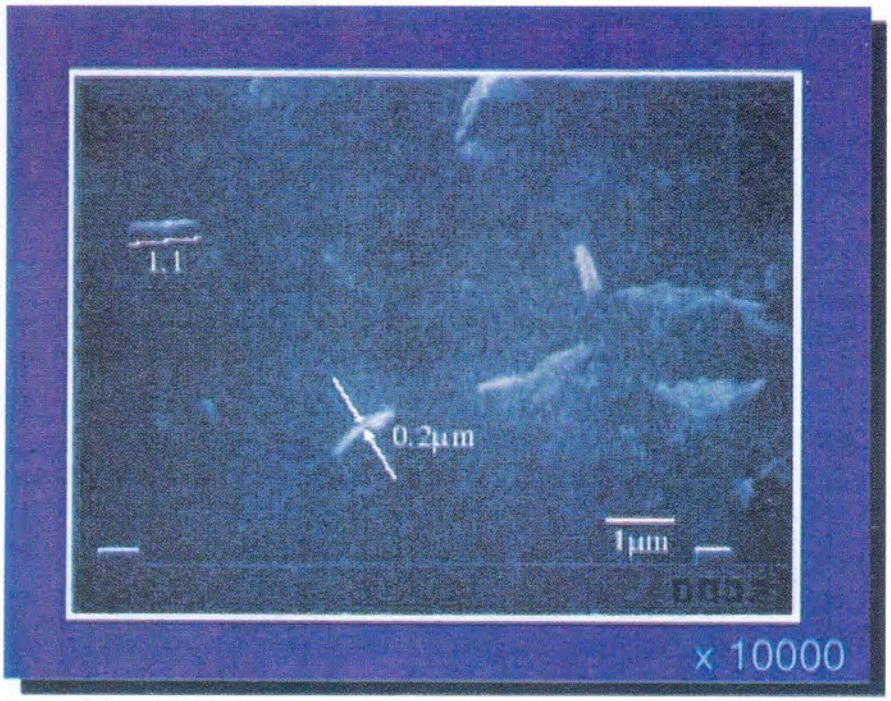
Poly (Aniline – co - fluoroaniline):

The copolymerization of aniline and 2-fluoroaniline was carried out by chemical method in an acidic medium. The characterization of the copolymer was done using FT infrared spectroscopy, UV-visible, differential scanning calorimetry (DSC) and scanning electron microscopy (SEM) techniques. Thermal analysis of copolymer reveals that the polymer degradation is about 8% in the temperature range of 50-400°C.

Langmuir Blodgett (LB) films of Poly(3-hexyl thiophene):

LB films of poly (3-hexylthiophene) were prepared by mixing with 66.5% stearic acid. The surface characteristics of these films were studied by scanning electron microscopy (SEM), atomic force microscopy and UV-visible analysis (Fig 5.11). The time- of-flight (TOF) measurements were carried out in annealed films at 50°C. The value of the TOF photo-carrier mobility obtained in P3HT-SA LB films sandwiched between metal (Al) and ITO glass is determined as 1.8×10^6 V/cm. It has been found that the value of the photocarrier mobility (Fig. 5.12) does not significantly vary with increasing electric field, reflecting the less dispersive

SEM Image



Trapping Mode AFM Image

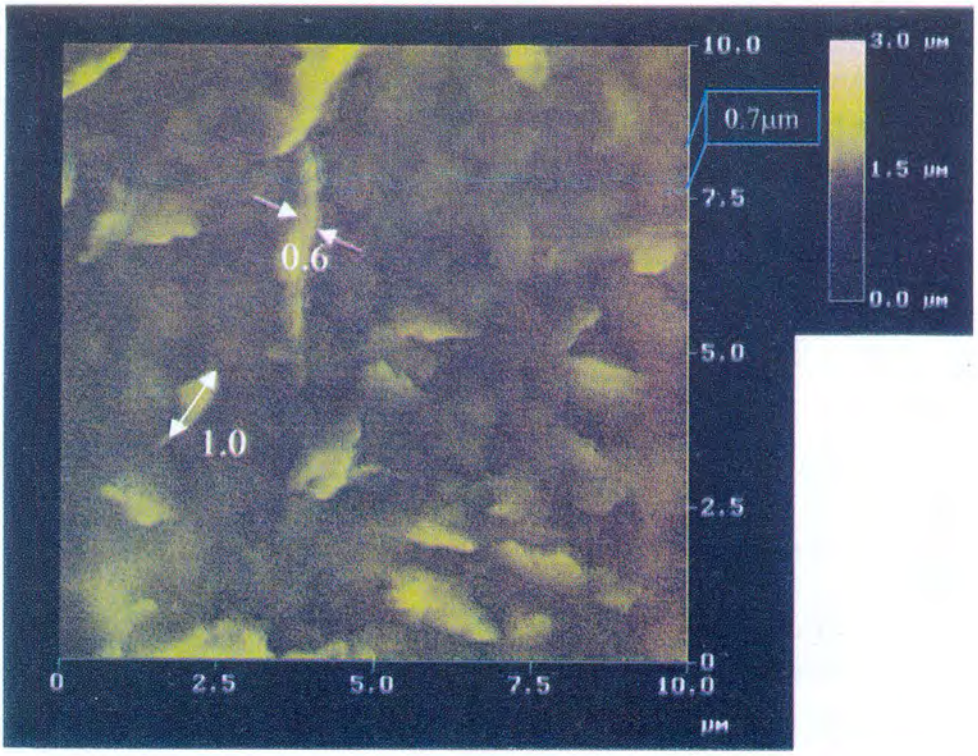


Fig. 5.11: Surface image of LB Film (PAT 12)

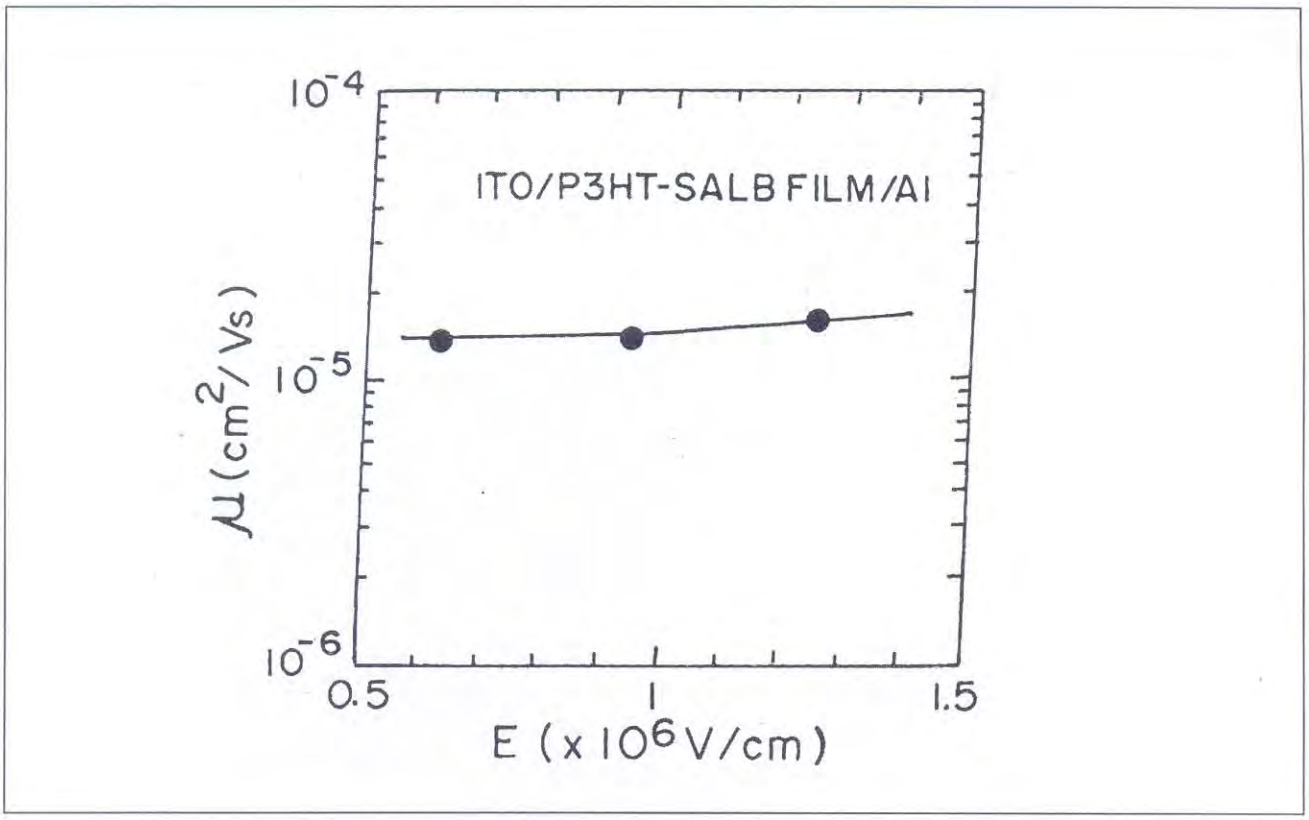


Fig. 5.12: Electric field dependence of photocarrier mobility in a P3HT-SA Langmuir Blodgett (LB) film at 298°K

nature of the transport of photocarriers in P3HT SA LB film.

Conducting Polymers I

The samples of Polypyrrole (PPY) family of polymers and HCl-doped Poly aniline were extensively investigated. It was found that the measured ac conductivity is substantially higher than the dc conductivity in these systems. Again Polyaniline polymer does not show well defined loss peaks. To learn more about the subtleties of the charge transport in Poly aniline, measurements of dielectric constant and ac conductivity have been made on lightly HCl-doped samples of Polyaniline, over the frequency range of 100 Hz -1 MHz and in the temperature range 77-410°K. At temperatures below 100°K, the ac conductivity data could be described by the relation; $\sigma(\omega)=A\,\omega^s$, where the parameter 's' is close to unity and its value decreases with the increasing temperature. The measured ac conductivity is substantially higher than the dc conductivity in the low temperature region and is mainly controlled by a process of dipolar origin. The observed dielectric behaviour does not exhibit well-defined loss peaks. In the absence of well defined loss peaks, another approach of dielectric modulus has been utilized. Analysis in terms of the dielectric modulus explains the conductivity behaviour of the system; although, it fails to explain the temperature variation of dielectric constant. The activation energies, calculated from dc, dipolar and modulus analysis, are found to be almost similar. This supports the existence of a thermally activated process in this system.

Poly (3-methyl thiophene) has been synthesized by the chemical oxidative polymerization technique, using ferric chloride as dopant in an inert atmosphere. The synthesis of the polymer has been confirmed by Fourier Transform Infra Red (FTIR) studies. Samples of different doping levels of poly(3-methyl thiophene) have been prepared and their FTIR spectra and Scanning Electron Micrographs (SEM) have been recorded. The shift and the disappearance of the characteristic bands in FTIR spectra, with an increase in the doping level, have been

analysed. It is evident from the SEM studies that the surface structure of the polymer becomes denser with the increase in the doping level. The dc conductivity, at room temperature, has been measured using four probe as well as two probe techniques. At one of the doping levels studied, namely, 0.4 M, samples of poly(3-methyl thiophene) were prepared at different temperatures, keeping the other synthesis parameters the same. The yield was found to increase as the temperature of synthesis decreased. The sample having dopant level of 0.4 M was annealed at 373°K for different intervals of time, viz., 0.5 to 120 hr. The effect of annealing time on the conductivity was examined and correlated with its surface structure.

In recent years the polypyrrole family of polymers, prepared by the electrochemical polymerization and chemical oxidation method, has been extensively studied for its different possible applications. Temperature sensors based on Schottky junctions, fabricated from copolymer of pyrrole and N-methyl pyrrole [P(NMPY-PY)] have been developed. Again, Polypyrrole (PPY) and its copolymer; poly(N-methyl pyrrole-pyrrole) [P (NMPY-PY)] have been used for the development of conducting polymeric membranes for monitoring water borne viruses. The membranes so developed have been examined for Polio I virus retention by the Department of Microbiology, AIIMS, New Delhi.

An exploratory project entitled "Development of biocompatible polymer composite" has been taken up keeping in view its far-reaching importance. Currently organ repair by direct stitching/implantation of "in vitro" engineered tissues, obtained by controlled growth of dedicated patient cell on biodegradable scaffolds (temporary substrates), is seen as the ultimate cost-effective global solution warranting a full biocompatibility and a "zero-risk" in terms of disease transmission. Keeping this in view, polypyrrole/sodium nitrate (PPY/$NaNO_3$) and polypyrrole/heparin (PPY/HEP) composites were developed for their possible application as biodegradable scaffolds. Human endothelial cells were found to be attaching and started growing on PPY/$NaNO_3$ composite as shown in Figure 5.13 (a & b). These preliminary results were encouraging.

Conducting Polymers II

Conducting polymers for EMI shielding and dissipation of electrostatic charges:

Conducting polymers acquire importance over inorganic semiconductors and metals in their applications because of their high strength to weight ratio, low cost, ease of processing and environmental stability. At NPL conducting polymer based composites have been investigated and one is able to graft conducting

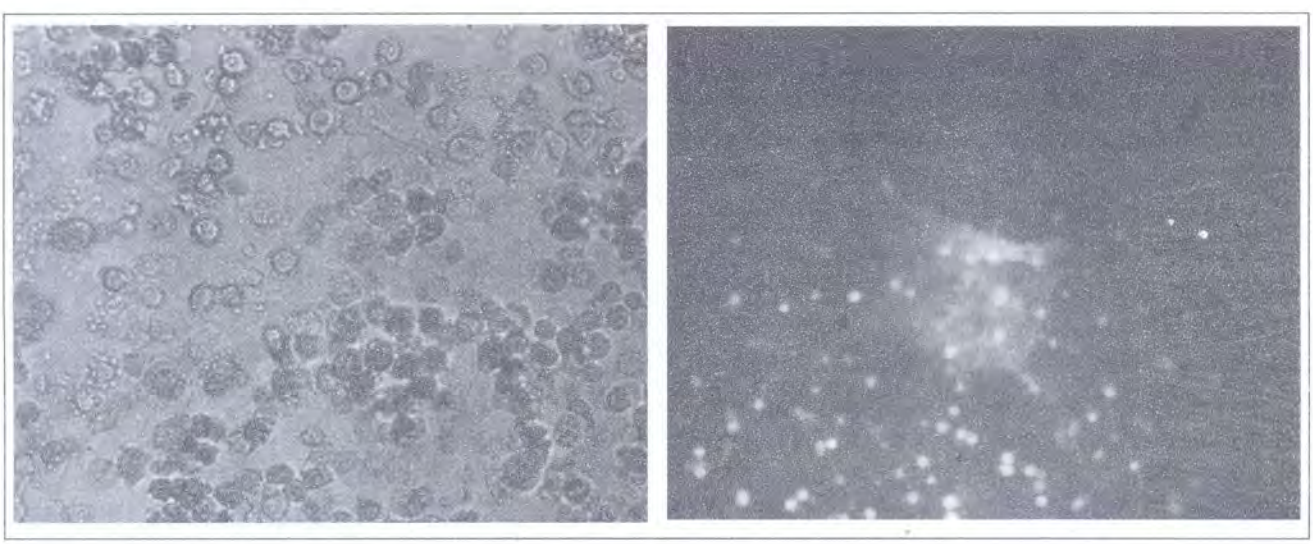


Fig. 5.13 (a): Photographs show human endothelial cells seeded on polypyrrole/$NaNO_3$ composite and (b) cells that prefer to attach and start growing on the composite (72 hours later)

polymers on insulating surfaces, which can then find applications as: (i) antistatic material for the dissipation of electrostatic charge (ESD) (ii) for the shielding of electronic equipment which are susceptible to electromagnetic interference in the radio frequency range, as well in the microwave range from 7 - 12 GHz and 101 GHz range and (iii) for the storage of IC chips in electronic packaging industries as also in various other sensitive situations.

Thin films of conducting polymer composites were also developed that can be used as a sensor material for aqueous ammonia. Some specific conducting polymer formulations have been synthesized which can be used as effective corrosion inhibitor for iron and mild steel in highly corrosive medium like 1.0 N HCl and 3.5 % NaCl. Studies are also being directed towards developing polymers that can be used for clearing the effluents from the dyeing, electroplating and printing industries (safe waste water management).

Polymer Electronics

Development of polymeric sensors:

A process for the batch preparation of the polymeric sensors was standardised. A copolymer of aniline and formaldehyde was prepared by a chemical process. The copolymer powder so obtained was used for the fabrication of pellets and also for the preparation of polymeric films by vacuum evaporation on glass substrates. Sensors based on undoped and doped polymeric pellets were prepared. The optical absorption characteristics for various types of polyaniline thin films doped with Fe and Al are shown in Fig. 5.14. The vacuum deposited gold contacts were provided to these thin films. The current voltage characteristics of the polymeric thin film doped with some specific dopants were obtained, with and without exposure to various gases and microorganisms . The average operating voltage of such sensors was ~ 1.54 volts. A particular doping combination in the polymer enabled specific sensor for a particular specy. A sensor responding optimally to a particular gas / microorganism was not found to respond to other species, and as such allowed the desired selectivity to be achieved.

Highly efficient polymer based sensing devices were fabricated on macroporous silicon substrates in collaboration with CNR Italy. Advantages of these polymeric devices are the ease of fabrication, high sensitivity to microorganisms, fast response time and room temperature operation. In this work current voltage characteristics, dielectric loss and capacitance variation

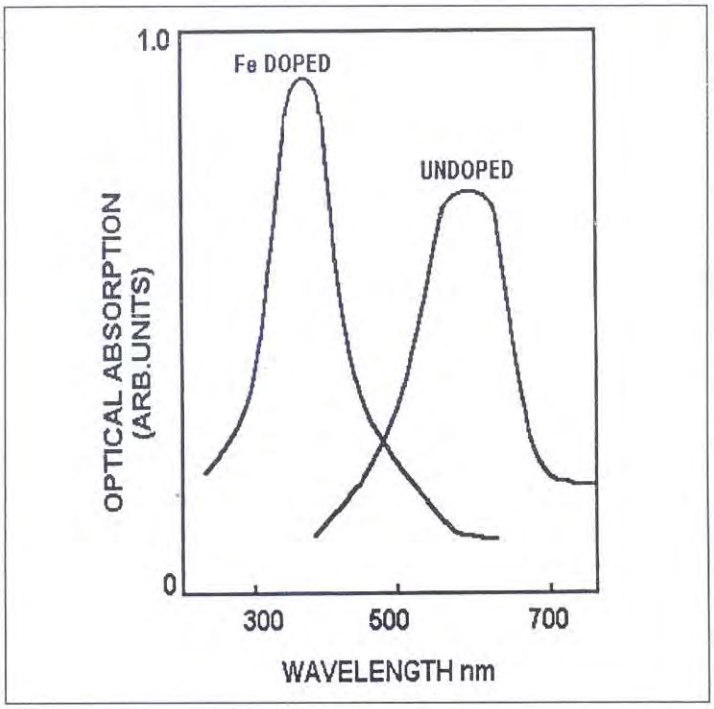


Fig. 5.14: Optical absorption characteristics for various type of polyaniline thin films doped with Fe and Al

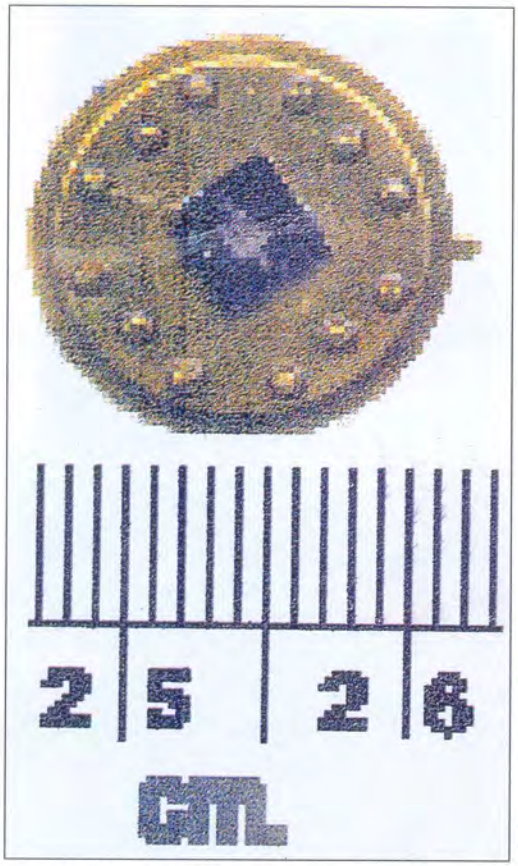


Fig. 5.15: Structure of a polymeric sensor device

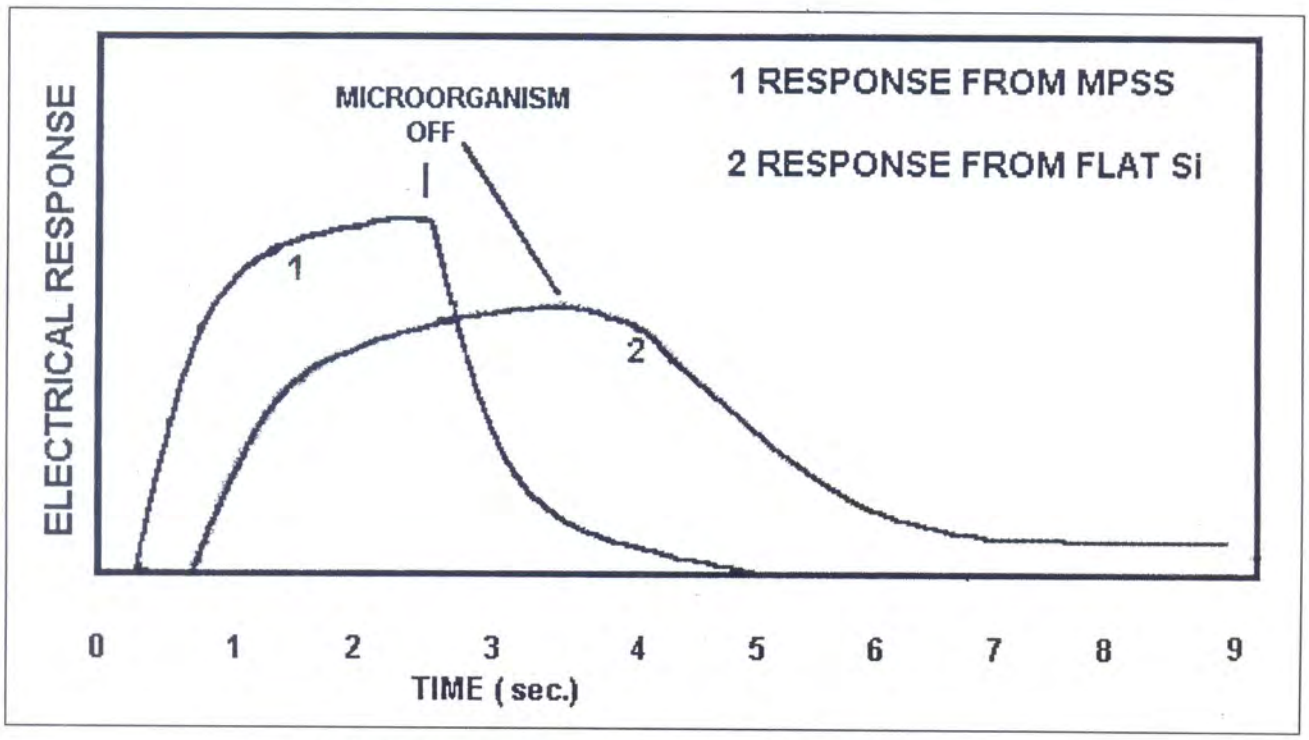


Fig. 5.16: Electrical response of polymeric/MPSS structure sensors

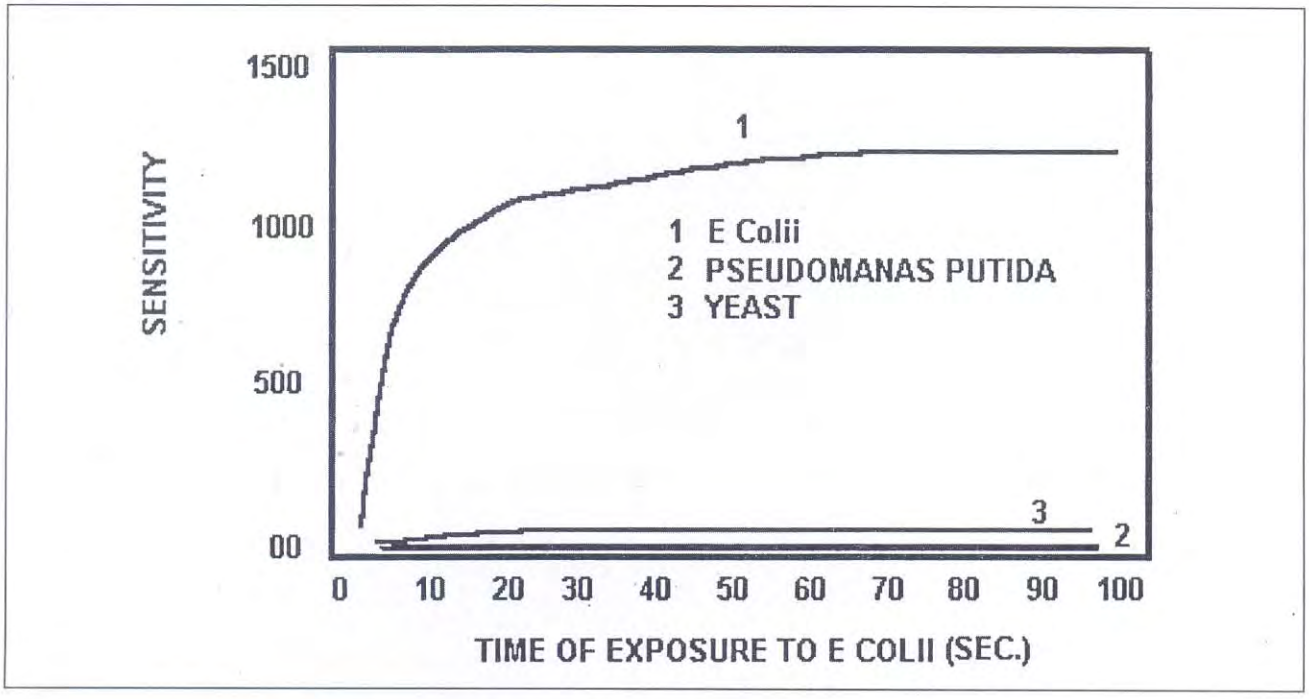


Fig 5.17: Comparative response of polymeric thin film sensors on glass and MPSS

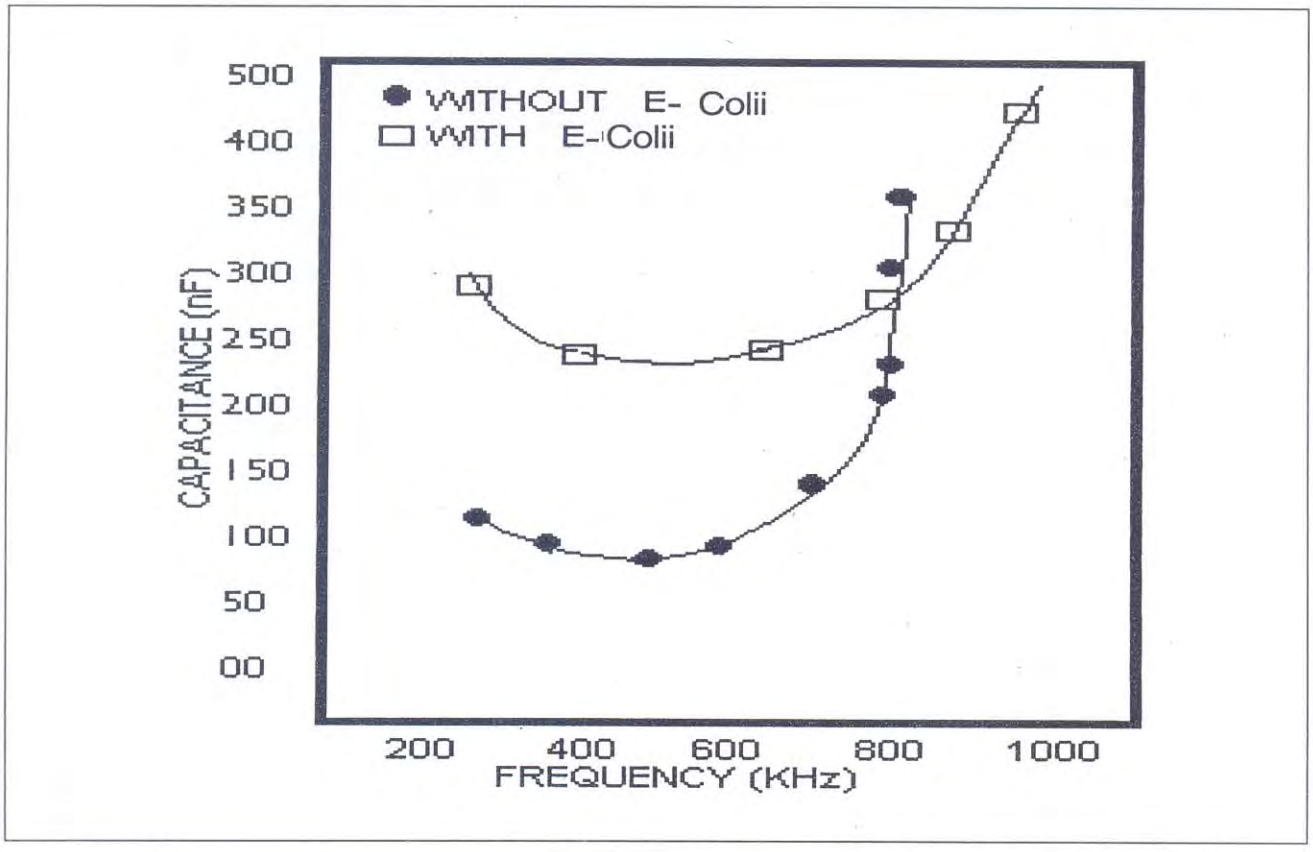


Fig. 5.18: Variation of capacitance with frequency for polyaniline / MPSS sensor upon exposure to E.Colii

of the specifically doped polymeric thin films, deposited on silicon macroporous membranes ,upon exposure to E. Colii, were studied. . A particular dopant incorporation in the polymer makes the sensor specific for the detection of E. Colii. The sensitivity of the devices, defined as the ratio of current from the sensor upon exposure to E. Colii with respect to the current without exposure to the microorganism, is found to be reasonably high. The device structure is shown in Fig. 5.15. The performance characteristics, of the polymer /MPSS sensor structure, are depicted in Fig. 5.16. The comparative response of polymeric thin film sensors on glass and MPSS are shown in Fig. 5.17. The macroporous silicon substrate allows one to obtain a polyaniline thin film with high specific surface area and good crystallinity, as evidenced, respectively, by SEM and X-ray investigations. Both the high surface area and the crystallinity of the polyaniline film, deposited on the macroporous silicon substrates, are believed to be responsible for the excellent sensor performance. The effect of the exposure of a particular microorganism on the capacitance of the polymer/ MPSS sensor structure is shown in Fig. 5.18.

Non-linear electro-optic devices:

A process for the preparation of polymeric thin film non-linear electro-optic devices has been developed under this program. The constituent polymeric thin films have been characterized for their electrical, optical and structural properties. Polymeric thin films of poly (methylmethacrylate) with aminobenzophenone side chains have been observed to exhibit strong electrical and optical non-linearity. The electrical, optical and structural characterization of these films suggests that they have strong potential for use as frequency doubler for optoelectronic applications. A collaborative work was also taken up under UISTRF program , with the University of Strathclyde, UK. The identification of target small charge transfer molecules , definition of model system(s) and preparation of polymeric thin films by various methods constituted the main tasks under this program. The spin cast thin films of aminobenzophenone doped with suitable amount of PMMA were prepared. The poling conditions have been investigated and an assessment of the second harmonic generation efficiency made. For a comparative assessment of the different technologies, the second harmonic generation efficiency has also been studied in a system where p - amino benzophenone is a guest doped into a methyl methacrylate backbone.

Inorganic thin films:

Thin films of ZnSe, ZnTe; ZnSe/ZnTe and CdZnTe/Se were prepared and their stichiometry, thickness uniformity etc. were optimized for possible use as active elements in various optoelectronic devices.

Polymeric thin film optical waveguides:

Polyacrylate and polycarbonate thin films were prepared by solution casting, dip coating and vacuum deposition techniques for use as optical waveguiding devices. A detailed study of the optical parameters of polyacrylate thin film waveguides was carried out. Particularly, the temperature dependence of the propagation modes in the polycarbonate thin film optical waveguide was studied in detail.

Xeroradiography

Enhancement of sensitivity of xeroradiography photoreceptors:

With a view to develop better x-ray sensitive imaging materials for xeroradiography, a variety of polymers and polymer-selenium combinations have been studied. This comprehensive study allowed a depth of understanding of the subtleties of the mechanisms that control charges storage, photoconductivity and x-ray sensitivity etc in these films. It was found that by incorporating a thin film of PVK (Polyvinyl Carbozale), as an interfacial barrier layer, charge storage characteristics of the selenium photoreceptors as also their residual potential can be tailored a great deal. It appears to be a very significant result and is expected to lead to the development of a series of new and better x-ray sensitive imaging materials for XR photoreceptors.

Development of portable X-ray xerography unit:

In order to develop a portable x-ray xerography unit, design and developmental work pertaining to various constituent parts and subsystems were undertaken. The components developed and tested successfully for achieving this objective include image development triboelectric chamber, image development electrodes, Venturi generator for image development, etc. A suitable trolley for mounting various constituent parts was designed and fabricated. A portable x-ray xerography unit has since been demonstrated and tested for its performance. Fig. 5.19 is the photograph of such a unit.

Fig. 5.19: Portable X-ray radiography machine developed by NPL

पदार्थ अभिलक्षणन
MATERIALS CHARACTERIZATION

इस प्रभाग द्वारा एन पी एल तथा बाह्य प्रयोक्ताओं को संयोजन लेश अशुद्धियां, ढांचा और एकल क्रिस्टल की दोषहीनता से सम्बन्धित पदार्थ अभिलक्षणन सुविधाएं उपलब्ध कराई जाती हैं। बायोमास बर्निंग (जैवमात्रा दहन) और सम्बन्धित गैस उत्सर्जन, डोपित (मादित) पॉलीएनिलीन, बोरो वेनेडेट ग्लासेज़, गैलियम टेल्यूराइड (GaTe) की संरचना, गैलियम् एन्टीमोनाइड/गैलियम आर्सिनाइड (GaSb/GaAs)-विषम संरचनाओं की वास्तविक संरचना, बी जी ओ (BGO) क्रिस्टल की दोषहीनता [अतिनिम्न कोण परिसीमा, तापीय एनिलीकरण (तापानुशीतन) प्रभाव], एम बी ए एन पी (MBANP) में गतिकीय विवर्तन, कैडमियम् जिंक टेल्यूराइड (CdZnTe) क्रिस्टल का संरचनात्मक विश्लेषण के लिए तथा इंडियम् एन्टीमोनाइड एवं एल्यूमिनियम एन्टीमोनाइड (Insb व AlSb) को तैयार करने के लिए इनकी सूक्ष्म संरचना पर अनुसंधान एवं विकास किया गया।

उच्च विभेदन एक्स-रे विवर्तन प्रयोग हेतु एक निम्न ताप संलग्नी को विकसित किया गया। पाउडर एक्स-रे विवर्तनमापी के स्वचालित यंत्र के विकास कार्य को पूर्ण किया गया। पश्चिम बंगाल में भू-जल की गुणवत्ता निर्धारण को मॉनीटर कर किया। परामर्श एवं अनुबंध अनुसंधान परियोजनाएं जारी रखी गयीं। द्विपक्षीय करार (अनुबंध पत्र) के अन्तर्गत क्रिस्टल विकास व उच्च विभेदन एक्स-रे विवर्तन क्षेत्र में अनुसंधान एवं विकास परियोजनाएं की गईं।

Facilities for characterization of materials regarding composition and trace impurities, structure, and perfection of single crystals are being provided to users from NPL and outside. R&D investigations had been carried out on: biomass burning and related gas emissions; doped polyanilline; boro-vanadate glasses; structure of GaTe; real structure of GaSb/GaAs – hetero structures; perfection of BGO crystals (very low angle boundaries, effect of thermal annealing); dynamical diffraction in MBANP; structural evaluation of CdZnTe crystals; and preparation and microstructure of InSb and AlSb

A low temperature attachment for high-resolution X-ray diffraction experiments was developed. Automation of powder X-ray diffractometer was completed. The quality of As determination in ground water (W. Bengal) has been monitored. Consultancy and contract research projects were continued. R&D projects under bilateral agreements were pursued in crystal growth and high resolution X-ray diffraction.

NPL, right from its foundation, had laid emphasis on development and applications of advanced materials in important industrial sectors. As a part of this continuous effort a strong group on materials characterization is active at the laboratory. This group covers all aspects of materials characterization, namely determination of major constituents (chemical composition) and minor constituents (trace impurities), structure (identification of crystallographic phases) and evaluation of perfection of single crystals (identification and characterization of all types of crystal defects). Facilities have been established for characterization of materials in vapour phase, liquid phase as well as solid phase. Thin films as well as nano-materials can be characterized. The range of facilities include graphite furnace, atomic absorption spectrophotometer, ICP emission spectrometer, gas chromatography, ion chromatography, FTIR spectrometer, UV-visible spectrophotometers, EPR spectrometer, X-ray fluorescence spectrometer, energy dispersive spectrometer attached with a SEM, powder X-ray diffractometer, transmission electron microscopy, scanning electron microscopy. In addition, a series of multi-crystal X-ray diffractometers have been developed in the laboratory for high resolution X-ray diffraction experiments. These include a five crystal X-ray diffractometer with state-of-the-art level resolution. These facilities are being used to provide services to NPL groups as well as outside users. Research and development work is pursued in different areas of materials characterization. Consultancy and contract research project are also in progress. Several collaborative projects with advanced research institutes in countries like USA, Germany and Russia are under way in areas of considerable significance.

Crystal Growth and Characterization

Structural characterization of bulk single crystals, thin epitaxial films and devices:

The versatile five crystal X-ray diffractometer was employed for a systematic study of highly mismatched GaSb/GaAs heterostructures. These heterostructures had been grown by molecular beam epitaxy (MBE). Effect of film thickness and a buffer layer on the perfection of GaSb layers and interface regions has been investigated. The diffractometer was employed in a three crystal configuration (+,-,+) with MoMKα_1 radiation as the exploring beam. Increase in film thickness led to substantial improvement in perfection of films, as shown by half widths of their diffraction curves (HW), which were: 483 ($\pm$14) arc sec, 306 ($\pm$4) arc sec and 305 ($\pm$5) arc sec and 166 ($\pm$2) arc sec, for film thickness: 0.5 μm, 1.5 μm, 2 μm and 5 μm, respectively. Insertion of a buffer layer [5 nm AlAs + 500 nm AlSb] between 1.5 μm thick GaSb film and substrate led to a notable improvement in film perfection; HW decreased from 306($\pm$4) arc sec to 263($\pm$3) arc sec. The film and the substrate diffraction peaks were separated by large angles due to fairly big lattice mismatch. The as observed mismatch values were in the range: 3634-3860 arc sec. However, there was a finite orientational mismatch Δa in addition to the usual lattice mismatch $\Delta d/d$. The values of Δa were found to be in the range: 34.5 – 103 arc sec. The specimen with buffer layer, had largest value of Δa (103 arc sec). The smallest value of Δa was for the thinnest film, which exhibited highest level of strain at the interface. After making corrections for Δa, compositions of all the films were determined. The Sb percentages were in the range: 89.52 – 90.68%. If corrections for Δa were not made, the compositions could have been in error by as much as 2.74 % in some cases.

Study of effect of thermal annealing on perfection of bismuth germanate single crystals containing boundaries:

Crystalline perfection of bismuth germanate(BGO) single crystals having low degree of crystalline perfection has been investigated. These crystals were grown by low thermal gradient Czochralski method. A double crystal X-ray diffractometer designed and developed at NPL and set in (+,-) configuration with a well collimated and monochromated MoKα_1 beam as exploring beam has been employed. In this study the specimen crystals of low degree of crystalline perfection were deliberately selected. Their diffraction curves contained several peaks separated from each other by angles lying in the range: 6 to 88 arc sec. This showed that in addition to the low angle boundaries, there were several very low angle boundaries also present in these specimens. Each peak represents a subgrain. The half widths of the

individual diffraction curves of the subgrains were in the range: 15 to 39 arc sec. It was found that annealing at 1000 °C for 8 h or more can remove some of the low angle boundaries. The annealing temperature was selected to be close to the melting point of BGO (1040 °C). However, some of the very low angle boundaries could not be removed even when annealing was carried out for 80 h. To examine in details the region of the specimen around the very low angle boundaries, a series of diffractometric experiments were performed around the boundary in a systematic manner. Diffraction curves recorded for either of the two subgrains surrounding the boundary showed one well defined peak. Half widths of the diffraction curves of the two subgrains were in the range 14 to 24 arc sec. However, as the explored area approached the boundary, diffraction from both the subgrains was observed from the same irradiated area of the crystal. Two well resolved peaks of almost equal intensities were observed when the central region of the boundary was irradiated with the exploring beam. The angle of the tilt between the two subgrains was found to be 40 arc sec. Morphological features of the boundaries were also investigated. Secondary ion mass spectrometry (SIMS) measurements were made to see if the boundary was decorated because it was not possible to anneal it out. Overall survey spectra showed that there was variation in impurity concentration through out the specimen surface around the boundary. Silicon was found to be one of the main impurities present in the specimen. Silicon imaging was carried out. The region of high silicon concentration in the BGO crystal coincides with the region, which showed the very low angle boundary. Therefore, it was concluded that the very low angle boundaries, which could not be annealed out were decorated with silicon.

Observation of features typical of dynamical diffraction of X-rays in MBANP single crystals:

Systematic studies carried out in the group had shown that important features of crystals could be observed with 'thin' ($\mu t << 1$; t being the thickness) diamond crystals of varying degree of perfection. These were the direct observations of a forward diffracted X-ray beam with nearly perfect (diffraction curve half widths ~ 10 arc sec) as well as quite imperfect (half widths of hundreds of arc sec) diamond crystals with $\mu t << 1$. Also a loss in absorption at and near Laue diffraction peaks had been demonstrated. Normally one expects dynamical diffraction of X-rays from nearly perfect and 'thick' ($\mu t \geq 10$) crystals. An attempt has been made to observe the dynamical X-ray diffraction phenomenon in an organic single crystal. A solution grown MBANP {2-(α)-methylbenzylamino)-5-nitropyridine} single crystal having dimensions: ~15mm x 15mm x 5mm was used as specimen. A double crystal X-ray diffractometer developed at NPL was set in (+,-) geometry with $CuK_{\alpha 1}$ radiation as the exploring beam. To determine the degree of crystalline perfection, high resolution X-ray diffraction curves as well as topographs were recorded, with the specimen set in the Laue geometry. The diffraction curves for (110) reflection had two well defined peaks with an inter-sub grain angle of ~250 arc sec showing the presence of a low angle boundary. Stationary topographs were recorded individually from both the sub-grains. These results showed that the crystal possessed a low degree of perfection.

High resolution stationary X-ray topographs recorded in the direct beam direction showed a flag like feature close to the direct beam, similar to the observations made in the case of diamond [Lal, Goswami and Verma, Solid State Commn. 81(1992)461] and silicon [Lal and Goswami, and Verma, Solid State Commn. A52 (1995)33] crystals. By employing the technique earlier developed by Lal, Goswami and Verma, the residual direct beam was masked with a carefully aligned straight edge. This enables to record images of the forward diffracted beam and also to record its diffraction curves. The half widths of the diffraction curves of the forward diffracted beam were measured as ~ 110 arc sec. The intensity of this peak was approximately one third of the normal Laue diffracted component. The plots of total transmitted beam intensity, diffracted beam intensity and the intensity of the forward diffracted beam as a function of glancing angle showed some interesting features. The peak positions of the diffracted beam and forward diffracted beam were shifted with respect to each other by ~ 40 arc sec. The total transmitted beam (normal diffracted + forward diffracted + residual direct

beam) showed a broad maximum near the Laue diffraction peak position clearly showing a reduction in the magnitude of the linear absorption coefficient (μ) at and near the Laue diffraction condition. Experiments are being carried out with other diffracting planes.

These results reported above, obtained with MBANP crystals with 'μt' $\cong$ 3 and low degree of crystalline perfection are in agreement with the earlier conclusions drawn from the study of diamond single crystals that, if a high quality exploring beam is employed, one can observe dynamical diffraction features like in forward diffracted beam even in imperfect crystals whose $\mu t << 10$.

Characterization of CdZnTe single crystals:

A variety of cadmium zinc telluride (CZT) single crystals have been characterized under a consultancy project "Characterization of Semiconducting Crystals and Epitaxial Layers," for Solid State Physics Laboratory, Delhi. The perfection of these crystals varied in a wide range. Some of these were of high quality giving sharp diffraction curves with half widths comparable to that expected for an ideally perfect crystal (9.5 arc sec). Some samples contained low angle and very low angle boundaries with tilt angles ranging from fraction of an arc minute to few arc minutes. A typical crystal was annealed and its diffraction curves obtained before and after annealing were compared with each other

Development of sophisticated instruments:

A low temperature attachment for structural investigation of single crystals at temperatures lower than room temperature was designed and developed. This employs thermo-electric cooling elements. The device is designed in such a way that the cooling element as

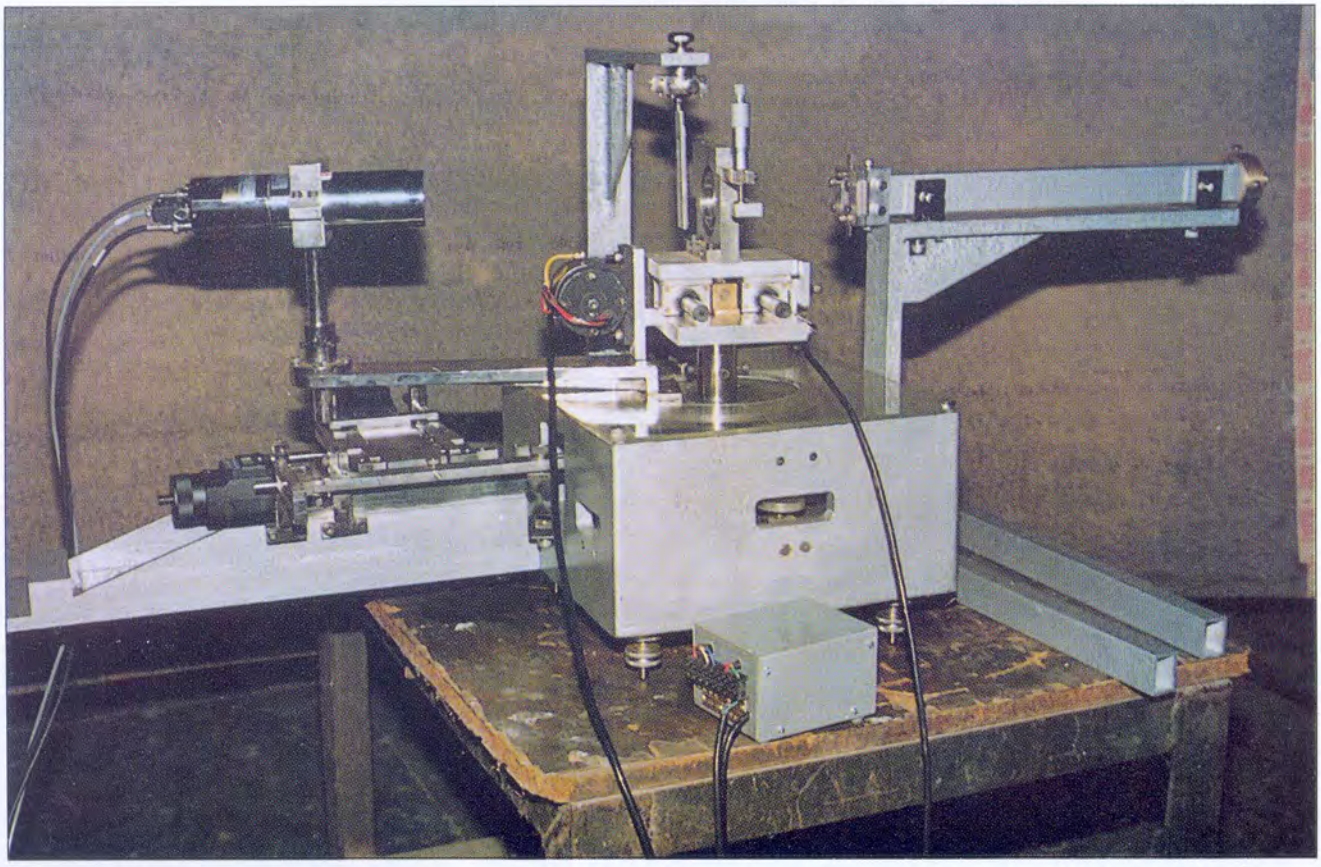


Fig.6.1: An X-ray diffraction topography system (Lang camera) designed, developed and fabricated at NPL and supplied to RRL, Thiruvananthapuram

well as the crystal can be placed in vacuum to minimize the radiation losses and to avoid condensation of moisture. The device is compact and it can be coupled to the existing goniometers.

Under a joint collaborative project between NPL, New Delhi and RRL, Thiruvananthapuram under sponsorship from DST, an X-ray diffraction topography system, as per the design developed at NPL, was fabricated. It involved precision made parts of X-ray diffractometer like turn table, vertical circle goniometer (VCG), traversing mechanism, collimators, slits etc. After successful testing the system was supplied to RRL, Thiruvananthapuram (Fig. 6.1)

Indian Reference Materials

Work on preparation, certification and dissemination of Bharatiya Nirdeshak Dravyas (BNDs) i.e. Certified Reference Materials was continued. In addition to the preparation of BNDs of toxic elements in water, scope of the activity was enhanced in the area of pesticide and gas standards. These are extensively being used in calibration of analytical equipment and validation of analytical methods. By the use of certified reference materials precise and accurate measurement data traceable to national measurement system can be generated. The measurement data generated with the use of certified reference material are globally acceptable. Its usage enhances the quality of industrial products and increases global trade. The users of mono and multi-element certified reference materials are State Pollution Control Boards, State Public Health Laboratories, R&D laboratories of private and public sectors and industries. BND of methane in nitrogen will be used at R& D Laboratories and academic institutes for measurement of methane in air for global warming studies. BND of chlorpyriphos pesticide would be used to monitor the quality of agricultural products. All these BNDs are being used for development of quality system in the country as per ISO 9000 and also for laboratory accreditation under National Accreditation Board for Testing & Calibration Laboratories. Sixteen national laboratories including Bhabha Atomic Research Centre, R&D Centre Indian Oil Corporation, and R&D Centre National Thermal Power Corporation are participating in the programme of preparation and dissemination of certified reference materials of toxic elements in water. Solutions of three new mono-element standards of zinc, iron and copper were prepared at National Physical Laboratory and distributed to the participating laboratories for measurement. Third and second batch of earlier batches of BNDs i.e. solutions of lead, cadmium, chromium and arsenic were also prepared in the concentration range of 1-2 mg/l. The measurement data is being generated at sixteen participating laboratories at an interval of fortnight over six months. Seven laboratories including four foreign laboratories had participated in pilot studies of BNDs of methane in nitrogen. Now, material is ready for round-robin test for certification. Six laboratories including Indian Agricultural Research Institute and R&D Centre Indian Oil Corporation had participated in pilot dies of BNDs of chlorpyriphos pesticide. Material had been sent to 12 laboratories for round-robin test for certification.

S&T Services:

Monitoring the quality of measurements of arsenic in ground water were carried out at NEERI, Zonal Laboratory, Calcutta, SOES Laboratory, Jadavpur University, Calcutta and PHED Department of West Bengal Government, Barasat under Rajiv Gandhi National Drinking Water Mission Programme (RGDWMP). Also, conducted proficiency test programme for measurement of arsenic and iron in water for these three laboratories. These laboratories are involved in a project sponsored by RGDWMP to give a solution to the problem of high arsenic contents in underground water at West Bengal. This quality check is being done by the use of certified reference material of arsenic solution (BND 301) prepared under BND programme.

X-ray Analysis

Elemental analysis using X-ray fluorescence technique was carried out for 10 samples of materials that included metal coating on mirror, M_m-Ni-Al powder and samples from M/s Subros Ltd., New Delhi and M/s Polyplex Corporation Ltd., New Delhi.

In the Ga-Te system, X-ray powder analysis of GaTe semiconducting chalcogenide material was completed. This material crystallizes in monoclinic system with a = 17.35 Å, b = 10.09 Å, c = 4.05 Å and γ = 104.4°. The results on the single crystal precession studies on Ga_2Te_3 observed earlier were evaluated. The mirror like reflecting faces of the crystal were found to be {111} of cubic zinc blende with a_o = 5.9005 Å. The translation period was calculated as 10.22 Å. This refers to the cube diagonal [111] of zinc blende and also parallel to [0001] of the hexagonal form. The primitive lattice was determined as rhombohedral (trigonal) with axial length 4.1723 Å and angle 60°.

Powder X-ray diffraction data of CuInSeTe, collected on a diffractometer with long horizontal soller slits, was analyzed to obtain structural information parameters such as atomic positions, occupancy, thermal parameters, interatomic distances, angles and atomic coordination using advanced Rietveld refinement program RIETAN developed by NIRIM, Japan. Similarly, the neutron diffraction data of solid electrolyte K-Li-Sn-O collected at NIRIM was analyzed to obtain structural information, particularly on the Li ions. The electrical properties of $CuGa_{0.5}In_{0.5}Se_2$ polycrystalline thin films, prepared earlier by thermal evaporation method, was investigated in the temperature range 300° to 475°K. It was found that the conductivity, hole and mobility activation energies exhibit exponential dependence on the inverse temperature which are indicative of grain boundary scattering mechanism.

The quality of results of measuremments and the extent of their reliability for the purpose for which they are used is extremely important. This requirement is fulfilled by indicating uncertainity of measurement which gives a measure of confidence that can be placed on the result irrespective of the method used. In continuation of our work in this direction, uncertainity of measurement was evaluated as per ISO guidelines for estimation of manganese in steel by spectrophotometric method. The percentage of Mn in one of the standard steel sample no. 20.02 obtained from NML, Jamshedpur was estimated as 0.56 ± 0.03% m/m. The reported expanded uncertainity of measurement is stated as the standard uncertainity of measurement multiplied by a coverage factor of 2. This gives a coverage probability of approximately 95%.

In the field of ferrofluid, the development of ferrofluid inclination sensor have been initiated for measuring tilt angle that plays a very important role in the areas like drilling technology and precission measurement. For this purpose, a quartz tube of I.D. 10 mm and length 80 mm half filled with the kerosene based ferrofluid was used. Copper windings around the tube were used to measure potential difference at various tilt angles. A linear increase in the potential difference with tilt angle upto approximately $30x10^3$ arc second was observed. Further work is in progress for design and fabrication of the system.

Development of grazing angle incidence diffraction set up for structural characterization of thin films had been continued. A soller slit assembly having 0.36° angular aperture was designed and fabricated. This was installed in the existing old goniometer, converted from vertical to horizontal mode. Modifications in the specimen holder, detector arm which carries soller slit assembly & detector were carried out. Complete system was aligned on an X-ray generator using CuK_α radiation. A preliminary X-ray diffraction pattern of Si sample was recorded and the XRD data matched well with the ICDD file.

The automation of X-ray powder diffractometer (sponsored project by DST) was completed in collaboration with M/s Vinytics Peripherals Pvt. Ltd., New Delhi. This involved precise movement of θ, 2θ, zero settings of goniometer, acquisition of data, display of diffraction pattern, data analysis and display of table containing interplanar spacing, intensity ratio, half width etc. Necessary hardware and software were installed and incorporated with the main system. Several trial runs were made and necessary changes in the software incorporated. As a final test, several XRD powder patterns of Si sample were recorded in the auto-mode. The results were compared with the standard one and found to be very close. Fabrication of three more diffractometers is in final stages. Radiation shield has

also been designed and fabricated using special aluminium channel and 12 mm thick glass.

Also, under the Indian Reference Material program work on the new XRD standard reference material α-Al_2O_3 was initiated

Analytical Chemistry

A number of samples received from Industries, Research Organisations and from sister divisions of NPL were analysed for their constituents by classical and instrumental methods. A number of polyaluminium chloride samples received in batches from Delhi Jal Board were analyzed for their aluminium content. Other samples which were analyzed included piezoelectric ceramic materials for Ministry of Defence and Graphite carbon impregnated with silver for silver determination received from M/s Industrial Carbon Pvt.Ltd. Gujarat.

Indelible ink samples received regularly through Election Commission were analyzed for their composition and performance to be used for election purposes.

In the area of Indian Reference Materials evaluation of solutions of zinc, iron and copper and the second batch of lead, cadmium, chromium and arsenic solutions, in the concentration range 1-2ppm, were evaluated by flame Atomic Absorption Spectroscopy from time to time to study the stability of these solutions for their certification as reference materials.

Pilot studies of methane gas in nitrogen medium was carried out during the year in collaboration with laboratories within India and outside India and evaluation of methane was carried out by gas chromatography. The gases are ready for intercomparison for certification as reference materials.

In order to improve quality of measurements it has become mandatory to give uncertainty of measurement along with the result. In this direction uncertainty of measurement in the determination of fluoride in water by Ion chromatography has been worked out for a concentration of 1-2 mg/litre fluoride in water as fluoride determination is very important from the human health point of view.

Study of greenhouse gas emissions/sink measurements is an ongoing programme. Study in the area of aerosols, precursor gases and precipitation measurments with linkage to INDOEX programme is being carried out.

Also study on biomass burning and related gas emissions using IRS-P3 Satellite data is being carried out in collaboration with NRSA Hyderabad.

In addition to the above developing methods for trace elements analysis in the ppm and ppb level in different materials, consultancy and innovative work to generate patents is being done.

Electron Microscopy

Synthesis and characterization of semi conducting thin films:

The semiconductor compounds of InSb and AlSb have been grown by Bridgman technique. The X-ray diffraction study of the as-grown ingots of InSb showed very sharp lines of InSb, indicating the formation of the single phase (cubic) compound. The formation of any other phase could not be detected. Using EDS technique, the composition of the ingots was determined and it was observed that the stoichiometry of the compound is maintained through out the crystal. However in case of AlSb the X-ray analysis showed the formation of AlSb compound with extra reflections of Al and Sb. The elemental analysis of the as-grown AlSb ingots was carried out with EDS and the results showed a difference in the stoichiometry compared to the starting material.

InSb compound grown by Bridgman technique was used for the preparation of thin films of InSb. The films were deposited on to Corning glass, KCl and NaCl crystal substrates, maintained at ambient temperature, 200, 350 and 430°C. The films were removed from the substrates by suitable methods and examined with the help of TEM. The electron diffraction patterns of the films showed the formation of single phase having cubic structure. The films formed at higher substrate temperatures showed oriented growth leading to

epitaxy. It was noted that the films deposited at lower temperatures, especially on KCL substrate, led to the formation of InSb particles of cubic structure in nanometer scale. These particles have led to some interesting results, like Moire fringes and dislocation network throughout the microstructure. These results on the films grown at various temperatures are being analyzed.

Thin films deposited on different substrates were further characterized for their electrical behaviour. Resistivity measurements were conducted from ambient temperature to 200°C. Subsequently, the band gap was calculated from the plot of resistivity – temperature curves. It was noted that with increase in film deposition temperature, the band gap was decreased. A correlation between microstructural features on electrical resistivity is underway.

S&T Services of SEM and EDS facilities:

PC controlled Scanning Electron Microscope (SEM), make and model LEO 440 accessed with Link ISIS 300 Oxford Instruments EDS, was installed in January 1999. SEM has a resolution of 3.5 nm, accelerating voltage variable from 300 V to 40 kV and magnification varying from 5X to 300,000X. EDS can detect elements from atomic no. 5 to 92 with the resolution of 133 eV. The facility is fully functional and operative, since February 1999.

The facility has been extensively utilized by scientists in NPL, other R&D organizations as well as Industries. About 400 samples were analyzed using this instrument. Response from Industries was also enthusiastic. Some of the Industries, which have actively utilized the present facility include:

1. M/S Gulshan Sugar & Chemical Industries, Delhi
2. M/S Nupore Filtration System Pvt. Ltd., New Delhi
3. M/S SWIL Ltd., Calcutta
4. M/S Double A Sig Contacts Pvt. Ltd., Delhi
5. M/S Gabriel India Ltd., Parwanoo (H.P.)
6. M/S SEMTEL Electron Devices Ltd., Parwanoo
7. M/S Teletube Electronics Ltd., Ghaziabad

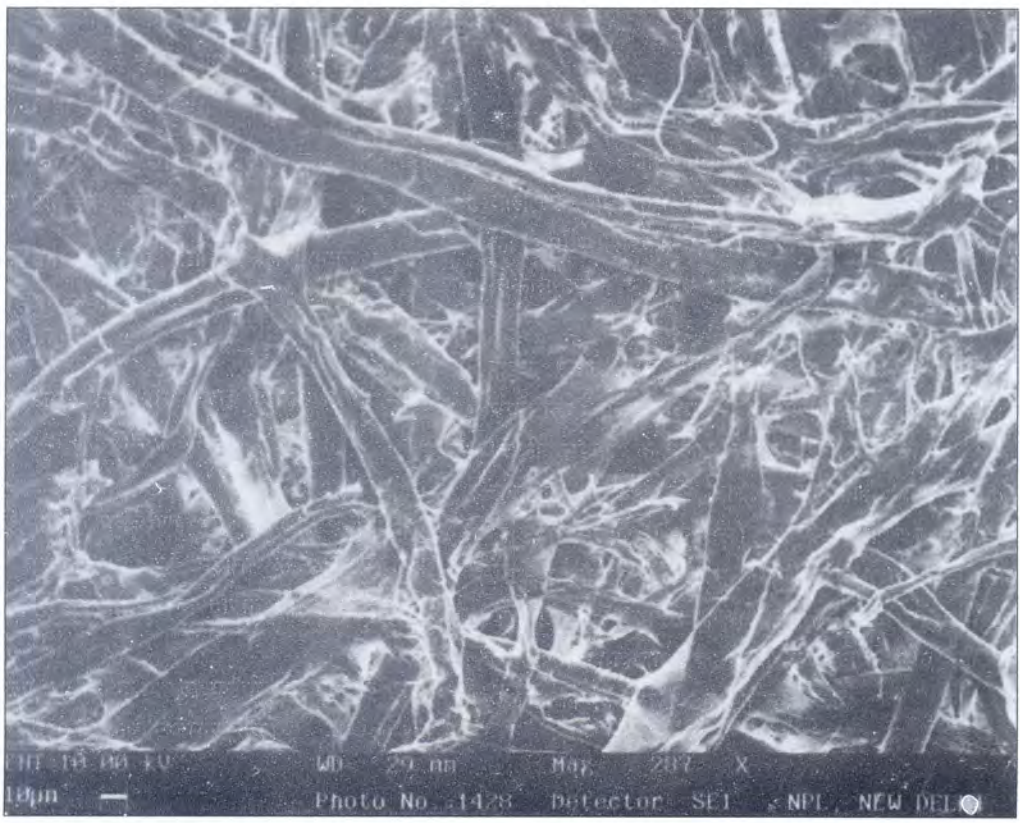


Fig. 6.2: Microstructure of porosity of a filter paper recorded by SEM

Due to its versatile capabilities and utility in various detection modes, SEM can analyze large variety of materials, e.g., polymers, nano-materials & nano-tubes, fibres, thin films and bulk materials. Materials could be conductors, semiconductors or insulators. Samples received from industries were of different types and form. For example, one of the tasks undertaken is analysis of size and distribution of porosity in a sample of filter paper provided by an industry. A typical microstructure observed in this specimen is illustrated in Fig. 6.2.

EPR Spectroscopy

Electron Paramagnetic Resonance (EPR) spectroscopy is a very powerful and specialised technique to get information about unpaired electrons associated with molecules/atoms and to relate such informations to macroscopic behaviour of the materials. Characterization of different materials for such paramagnetic centres was provided to different NPL research groups and outside organisations. In collaboration with conducting polymer group of NPL, EPR study of polymer polyaniline doped with different protonic acids was undertaken. Detailed EPR analysis showed that polarons formed at low doping level and polaron-bipolaron equilibrium established in high doping region along with the enhanced mobility of these charge carriers are responsible for the observed electrical behaviour of this material. EPR study of microstructure of many ternary oxide glasses was also continued. In boro-vanadate glasses $M_2O.V_2O_5.B_2O_3$ (M = Li, Na, K), VO^{2+} ions were found to exist in octahedral coordination with tetragonal compression. It was observed that $3d_{xy}$ orbit of the unpaired electron of vanadyl ion dilates with increase in V_2O_5:B_2O_3 ratio keeping M_2O constant. In lithium molybdenum borate glasses $xLi_2O.(30\text{-}x)MoO_5.70B_2O_3$, the octahedral symmetry on V^{4+} site was found to improve when diamagnetic modifier Li^+ was replaced by paramagnetic modifier Mo^{3+} keeping the concentration of glass network former B_2O_3 constant.

रेडियो एवं वायुमण्डलीय विज्ञान
RADIO & ATMOSPHERIC SCIENCES

इस प्रभाग ने इस वर्ष लद्दाख क्षेत्र में अधिक ऊँचाई पर हो रहे पर्यावरणीय परिवर्तन के अध्ययन के लिए पहली बार सूर्य की किरणों, ओज़ोन, एरोसॉल, जल वाष्प आदि का मापन किया। पर्यावरण अध्ययन हेतु पूर्ण सूर्य ग्रहण के दौरान प्रयोगात्मक अभियान संचालित किए तथा इन्डोइएक्स (INDOEX) कार्यक्रम व 18 वें अंटार्कटिक अभियान और एरोसॉल डाटा सिंथेसिस व सेसकॉम (SASCOM) के एकीकरण (Integration) प्रोग्राम में इस प्रभाग ने भाग लिया।

सेटेलाइट से प्राप्त डाटा का प्रयोग करते हुए रेडियो वातावरण अभिलक्षण, एम एस टी रेडार, रेडियो सिस्टम एप्लीकेशन हेतु एल अे एस LOS माइक्रोवेव लिंक्स और आयनसोंद भी आर ए एस डी की महत्वपूर्ण गतिविधियां हैं। जी पी एस अनुप्रयोगों के लिए आयनमंडलीय टाइम विलम्बक मॉडल्स, सैटेलाईट सिगनल्स् पर लीओनिड उल्कावर्षण का प्रभाव, माइक्रोवेव लिंक्स पर वर्षा का प्रभाव, चलती हुई रेलगाड़ी से मोबाइल कम्यूनिकेशन प्रयोग भी कुछ मुख्य अध्ययन हैं।

Monitored solar UV-B radiations, ozone, aerosols, water vapour etc. for the first time in Ladakh region for studying high altitude environmental variations, conducted experimental campaigns during total solar eclipse for studying environment, participated in INDOEX programme and 18TH Antarctic expedition and in the Asian aerosol data synthesis and integration programme of SASCOM.

Characterization of radio environment using data from satellites, MST Radar, Ionosondes and LOS microwave links for radio system application is an important activity at RASD. Ionospheric time delay models for GPS Applications, Leonid meteor showers effects on satellite signals, Rain effects on microwave links, mobile communication experiments from a moving train are some of the major studies.

Atmospheric Environment and Global Change

High altitude environmental monitoring at Leh/Hanle (Ladakh):

For the first time experiments in a campaign mode were conducted at Hanle (32°43' N, 77°34' E) and Leh (34°77' N, 77°36' E) located in the high altitude Ladakh region of our country to measure levels of solar UV-B, erythemal dose, atmospheric aerosols, surface ozone, atmospheric total ozone and atmospheric water vapour. These locations which are free from anthropogenic air pollution are uniquely suited for obtaining information on background levels of various environmental parameters mentioned above. The measurements were made at Indian Astronomical Observatory, Hanle (Mount Saraswati), the highest observatory located anywhere in the world situated 4467 meters above mean sea level (amsl) and also at Leh (3311 amsl) during the period July 13-31,1999. These measurements were compared with those obtained for Delhi which has high levels of anthropogenic air pollution and also with those from Antarctic region which is free from such air pollution. Some of the important results are given below.

Erythemal dose at Hanle:

UV-biometer, which measures the Ultra-Violet radiations (UV-B) in the form of erythemal doses showed that they are higher by 100-120% at Hanle and by 60-80% at Leh as compared to those at Delhi. Normally the Minimum Erythemal Dose (MED/Hour) in July is around 2.0 – 3.0 at Delhi and was found to be around 4.0 at Leh and around 5.0-5.5 at Hanle as shown in Fig.7.1. The interesting feature of these results is that the MED values at Leh and Hanle are higher than those of Antarctica where the UV-B values are expected to be quite high due to ozone depletion. Another interesting feature observed is time periods for which the values remain above the dangerous thresholds. While at Leh and Hanle these thresholds are reached almost after sunrise and continue after sunset, at Delhi these dangerous levels appear with some delay after sunrise

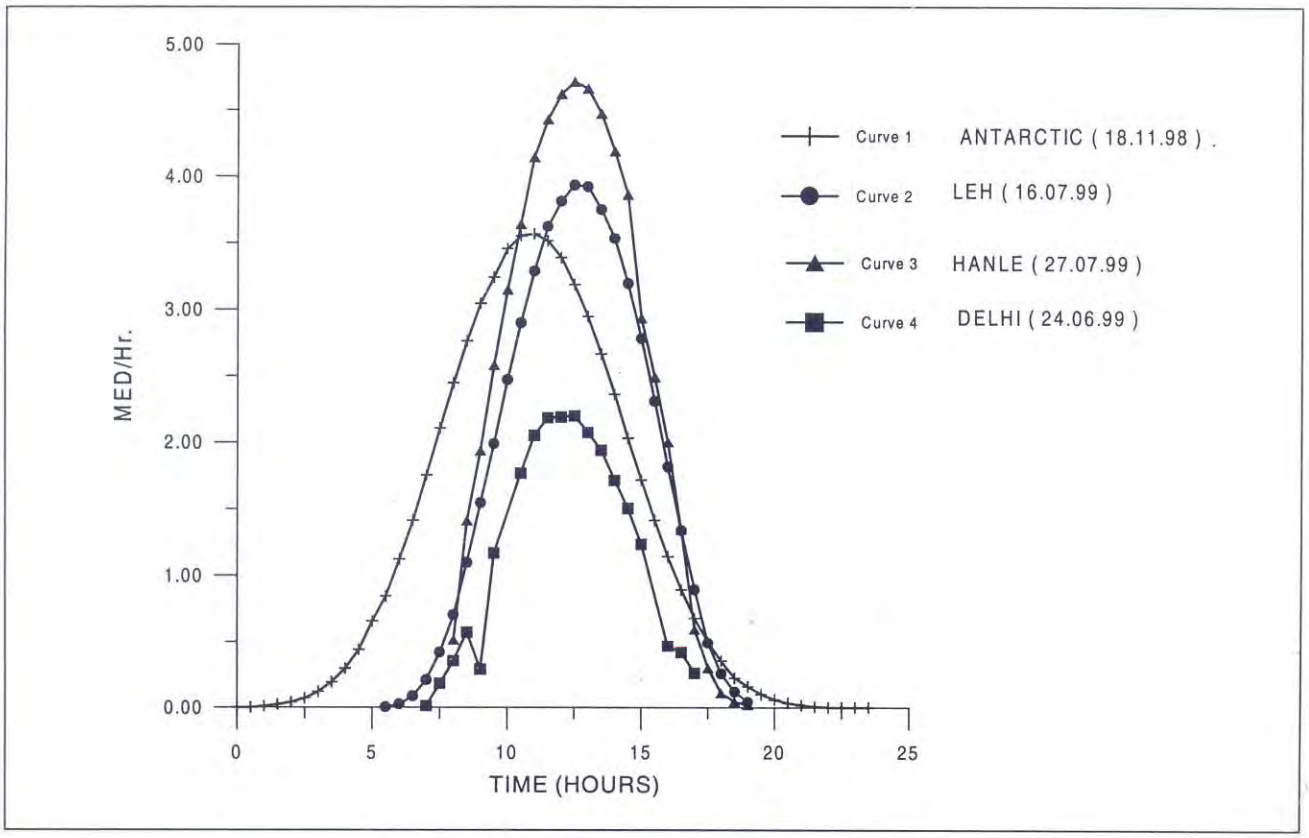


Fig. 7.1: Local time variation of erythemal dose at Delhi, Leh, Henley and Antarctica

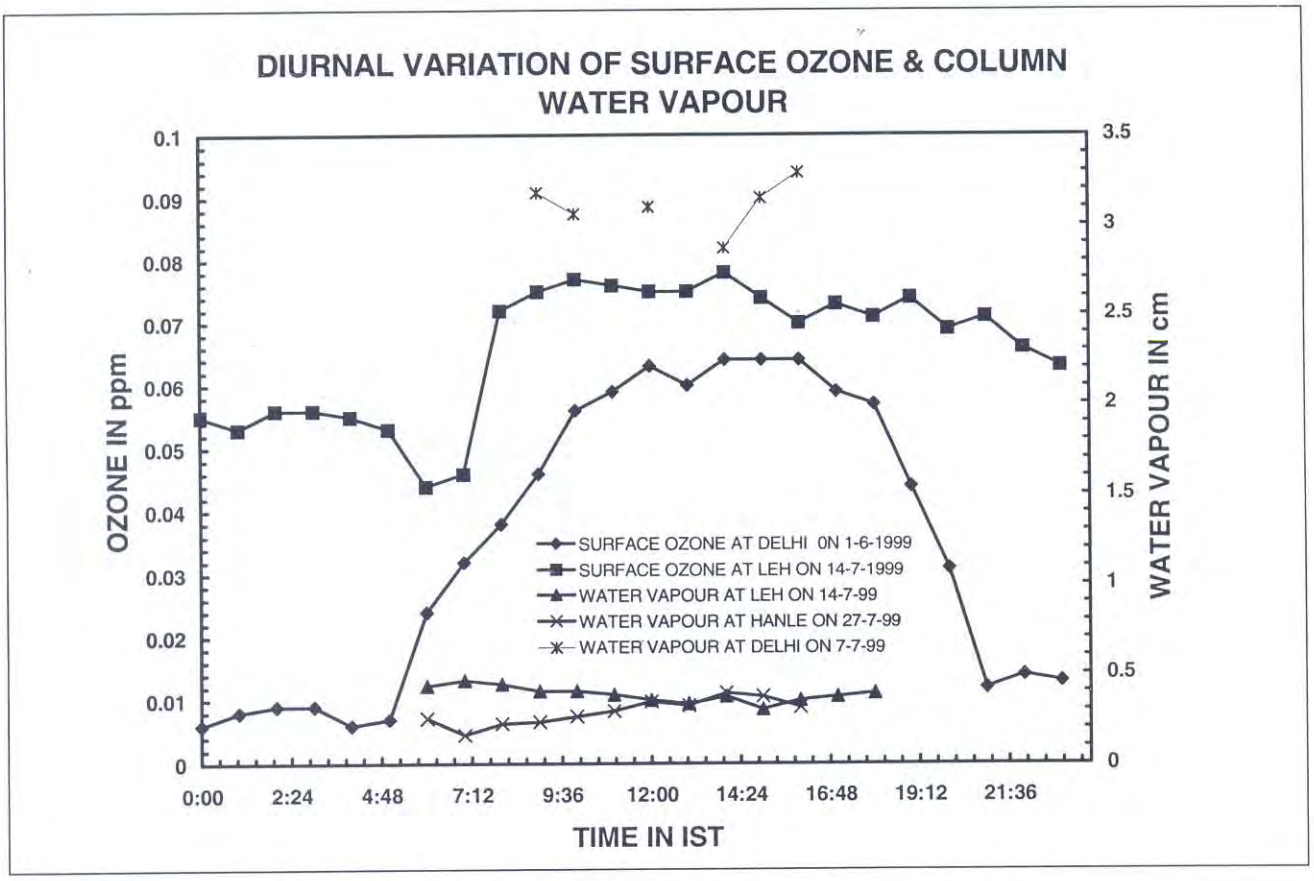


Fig. 7.2: Diurnal variation of surface ozone and column water vapour

and end much before sunset. This happens due to the fact that the pollution levels in Delhi is higher than those at Leh and Hanle. The higher pollution levels are able to inhibit the solar UV-B radiation levels from reaching to lower levels at high solar zenith angle conditions around sunrise and sunset. Though the Erythemal action standards for Indian skin are not set up so far, the MED/HR values at Leh and Hanle are definitely much higher than any tolerable standards. The direct effect of this can be seen during summer by the tanned skin of the people staying around Hanle.

Aerosol optical depth at Hanle:

The spectro-radiometer, used for deriving aerosol optical depth (at 400, 450, 500, 590, 700, 750, 800, 850, 935 & 1025 nm) was operated at Leh and Hanle. It is found that overall aerosol optical depth remains around 0.2 and 0.1 at Leh and Hanle, respectively, except at 750 nm where abnormal values were observed and need further investigation. It is quite interesting to note that the aerosol optical depths obtained at Hanle are smaller than even those obtained at the Indian Antarctic Station, Maitri. However, the main difference between Hanle and Maitri is that the latter is about 100 meters above msl while Hanle is 4500 meter above msl. The aerosol optical depths at Leh are, as expected, higher than those of Antarctica.

Surface ozone at Hanle:

The surface ozone measurements were carried out at Leh and Hanle on round the clock basis using ozone analyser. The surface ozone was found to have less diurnal variation both at Leh as well as at Hanle as compared to low altitude urban location, like Delhi, as shown in Fig.7.2 . This may be attributed to anthropogenic activity over Delhi especially to higher emission level of NOx. Surface ozone was found to show a minimum soon after the sunrise and that may be due to local dynamics of the atmosphere. The surface ozone is found to be anti correlated with relative humidity.

The three year data as depicted in Fig.7.3 shows that the concentration of surface ozone is also dependent on wetness. Delhi experienced less rain fall during 1999 rainy season, as compared to 1997 and 1998. This is anticorrelated with the ozone concentration during the corresponding years. It may be noted that the ozone analyzer used for these studies is an in situ type system wherein air sample is sucked in and is analyzed by employing UV source.

Sunphotometer measurements:

The measurement of total ozone, water vapour, aerosol optical depths etc, at Henle and Leh were made using Sun-photometer (MICROTOP). The total ozone at Hanle and Leh was found to be around 300 Dobson units and to be higher than that over Delhi. The diurnal variation is not well defined at these high altitude locations.

Water vapour is found to be very low as expected and varies from 0.15 cm to 0.40 cm, which is nearly one tenth of the Delhi values as shown in Fig. 7.2. It was also found that water vapour and relative humidity show normal behavior at Hanle, but, the behaviour at Leh is abnormal. This may be attributed to the topography of Leh. To draw a definite conclusion extensive data are required.

Solar eclipse experiments:

The last total solar eclipse of the millennium occurred on 11 August 1999. NPL team conducted various experiments at the M.S. University, Vadodra, which falls within the totality belt. Totality was for 62 seconds while partial eclipse was visible for nearly two hours. A set of instruments i.e., surface ozone analyser, micro-barograph, microtop-II, UV-B biometer (280 – 340 nm), erythemal dose (UV-B 291 – 311 nm) and humidity/ temperature sensor were installed at roof of technology faculty building at M.S. University, Vadodra. The measurements were started on 8th August and continued until 12th August 1999 covering controlled as well as eclipse days. Observations show that there was a 20% decrease in surface ozone, 1.8°C decrease in ambient air temperature, a decrease in erythemal dose, nearly 100 times drop in global diffused radiation. A decrease in water vapour content during the solar

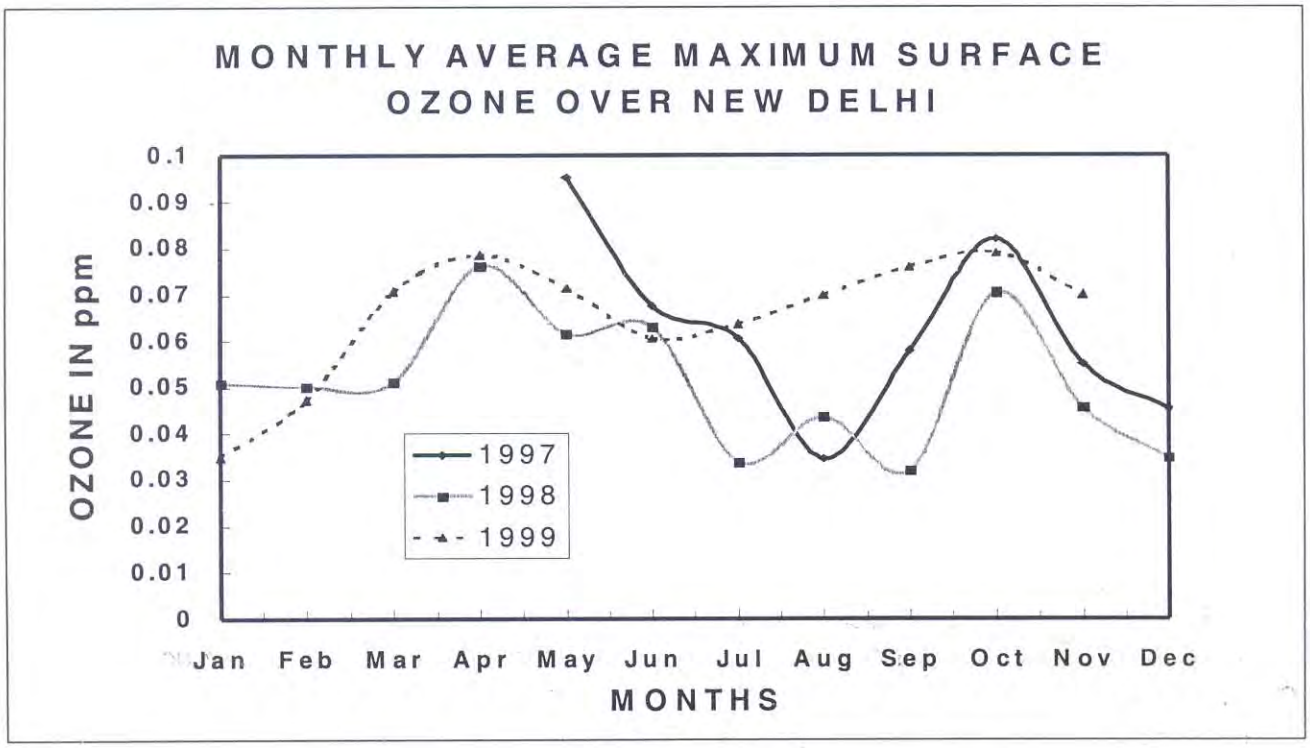


Fig. 7.3: Monthly average maximum surface ozone over New Delhi

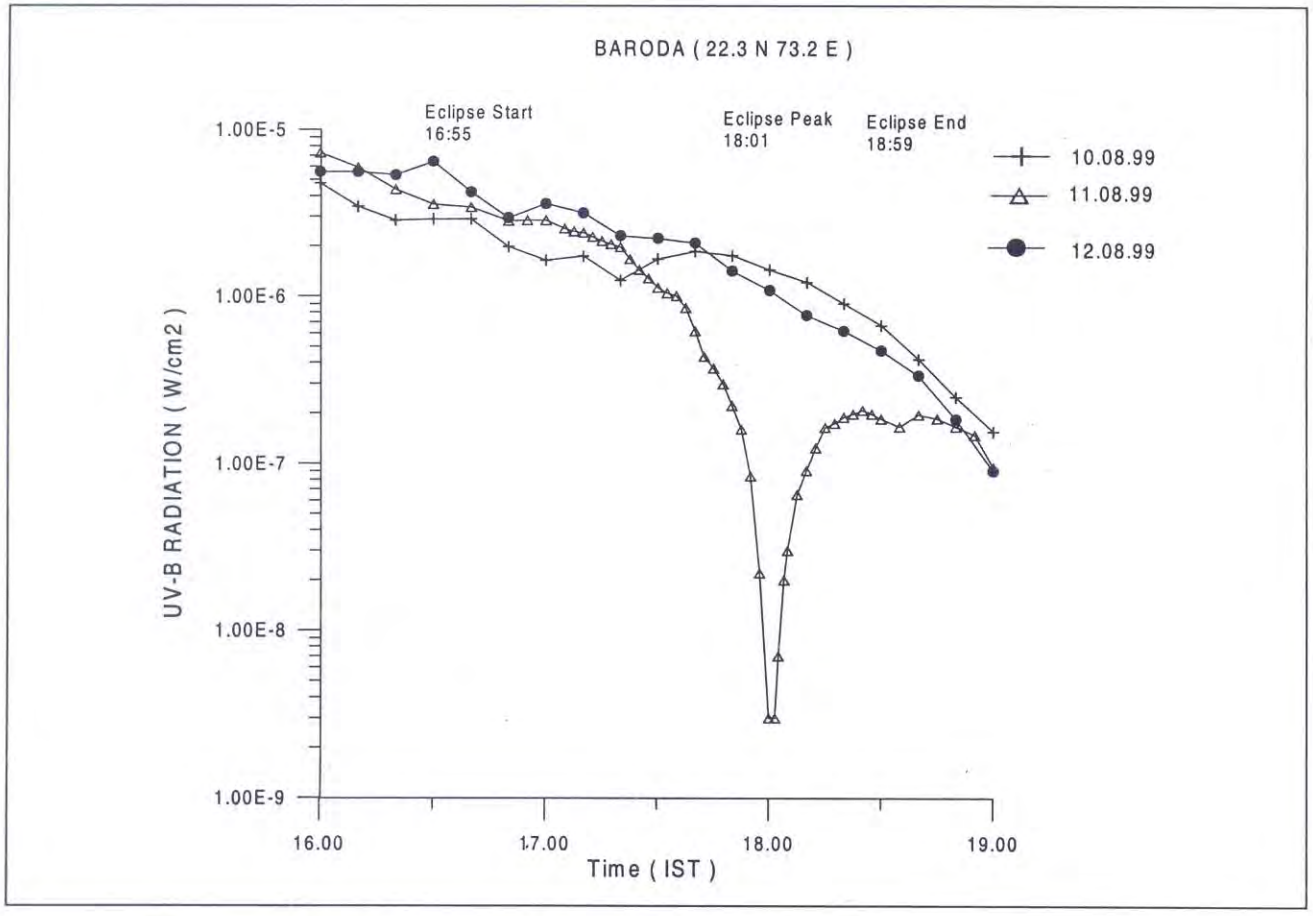


Fig. 7.4: Variation of UV-B radiation during eclipse and control days

eclipse was also observed. Values as low as 2.79gm/cm^2 were observed on eclipse day (11th August, 1999) while these were around 3.30gm/cm^2 on control day. The total ozone varied between 281 D.U. to 310 D.U. on 11th August 1999 while they varied between 279 and 283 D.U. on 12th August 1999, a normal day.

UV-B measurement results during total solar eclipse 1999 are shown in the fig 7.4. Results show that reduction in the global intensities during the totality of the eclipse is almost by three orders of magnitude as compared to the intensities observed on control days (10th and 12th August) at the same local time. When these are compared with the similar observations taken during the total solar eclipse at Neem Ka Thana (Rajasthan) on 24th October 1995, it is seen that there the reduction in the intensities was by about two orders of magnitude. This difference could be due to different weather conditions prevailing on these two occasions. Vadodra observations were taken under thin cloudy conditions (both Eclipse and control days), while Neem Ka Thana observations were taken under clear sky conditions on both eclipse and control days. The conclusion thus can be that the total radiation is reduced by two orders of magnitude during the totality of the eclipse and that the diffused radiation is further curtailed by one order of magnitude by the presence of clouds during the totality at Vadodra.

Microbarograph studies:

Measurements of infrasonic pressure variations using microbarograph were made both at Vadodra in the path of totality and also in Delhi which falls in 83% of Maximum Obscuration (M.O.). Significant decreases in pressure variations have been observed only after the

totality of the eclipse at Vadodra with no significant changes during the increasing phase of the eclipse. However, in case of Delhi significant pressure variations were observed as the eclipse was in progress. This is unlike what was observed at Vadodra. Also, pressure variations seen after the totality show an opposite trend as compared to Vadodra. Instantaneous change in pressure around M.O. of 600 μbar at Delhi and 320 mbar at Vadodra were recorded. At Vadodra amplitude fluctuations in pressure were observed within + 100 mbar after the totality. This is similar to 1991 eclipse in USA. Power spectra shows time periods of 62 minutes at Delhi and 21 minutes at Vadodra as compared to normal time period of 1 .5 to 17 minutes. As such this higher time period is the evidence of gravity wave generation.

SASCOM activity:

Under the Memorandum of Understanding (MoU) signed between NPL and the START Secretariat Washington, in January 1997 NPL hosts and operates the South Asian START Regional research center (SAS-RRC). START is a System for Analysis, Research and Training for the Study of Global Change, supported by ICSU and UN. START, works towards capacity building in developing regions of the world to enable scientific communities in these countries to take part in internationally co-ordinated scientific research initiatives to understand the global change processes, their causes and impacts. Activities of SAS-RRC benefit Bangla Desh, India, Maldives, Mauritius, Nepal, Pakistan and Sri Lanka and are overseen by the South Asian START Planning Committee (SASCOM). The nature of activities includes workshops cum training programmes, exchange of visits, publications to help growing cooperation in scientific activities of mutual interest to these countries. Some of the SASCOM activities are given below

Global change data centre:

The SASCOM has a data center located at the Centre on Global Change, National Physical Laboratory. The center stores and dissiminates data related to activities in the area of global change. The data stored in the center is being collected through major initiatives in this region namely, the Indian Ocean Experiment (INDOEX), Greenhouse and trace gas measurement and estimates, aerosol synthesis and integration, space related data collected through various agencies, meteorological parameters.

Web page development:

The centre now has a 64 kbps radio link and a WEB site has been developed for SASCOM during this period. The address of this page is: http://npl-cgc.ernet.in/sasrrc_front.html. The contents of the web page include its organization, activities of SASCOM, publication, datasets, and recent announcements.

SASCOM regional synthesis report:

A major initiative that has been undertaken during this period is the "SASCOM regional Synthesis Report". This report focuses on the following issues of the region :

- Changing atmosphere
- Monsoon change and extreme climate events
- Climate variability and agriculture
- Oceans, coastal zone and inland waters
- Indo-Gangetic plains land use planning for sustainable food security
- Integrated impact assessment

Participation in 18th Antarctic expedition and data analysis:

NPL was represented by Shri K.H. Gajanad as a winter team member, in the 18th Antarctic Expedition. UV-B biometer, sunphotometer and UV-B filter photometer were operated at Antarctica for data collection from Jan. 1999 to Feb. 2000. The data analysis of UV-B intensities, erythemal dose and aerosol optical depth were continued and the results from the 17th expedition i.e. Jan. 1998 to Feb. 1999 were communicated to DOD (Department of Ocean Development).

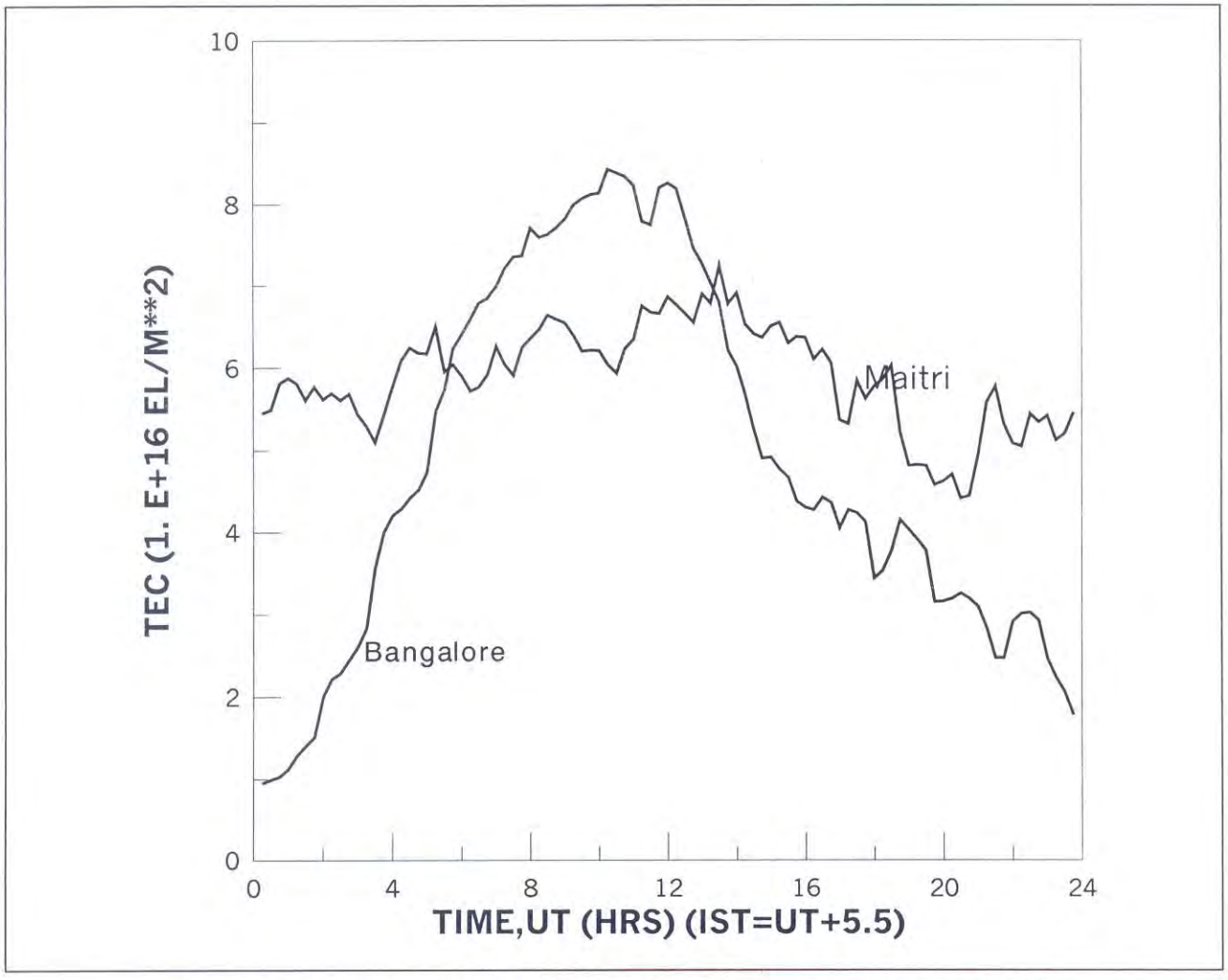


Fig. 7.5: Diurnal variation of total electron content at Maitri and Bangalore on 20-1-98

The PBL data collected by SODAR at Maitri, Antarctica during 1996 is analysed and printed in a report form. The same was sent to Australian Antarctica Data Centre (AADC) for usages by a wider community. The data were accepted by AADC for printing on its web site.

TEC observations at Antarctica:

Observations of Total Electron Content (TEC) of the ionosphere were carried out for the first time at the Indian station Maitri, in Antarctica from Jan.12,1998 to Feb. 6,1998 during the 17th Indian scientific expedition to Antarctica. For this purpose signals from Global Positioning System (GPS) orbiting satellites were monitored. A software for deriving TEC from GPS observations was developed at NPL. The values so derived for Maitri along with values obtained for Bangalore from IGS (International GPS Service) are presented in Fig. 7.5. As expected the TEC values for Maitri do not exhibit large diurnal variation however signatures of large scale disturbances are seen superposed on the diurnal variation of TEC.

Radio Environment

Rain height for satellite communication and radar propagation:

Knowledge of rain rates and rain heights is important for determining the radio attenuation over earth-space paths over a location with a good degree of accuracy. It is also important to obtain the information on the distribution of rain height and rainfall rate over as many locations as possible for rain attenuation estimation. This

information is necessary for designing highly reliable earth-space communication systems over different regions. Using the radiosonde observations over Port Blair, Vishakhapatnam and Jodhpur rain height results have been derived. It is seen that 0°C isotherm height during the year varies from 2.1 km to 6.8 km over these stations. The variation in the rain height during winter is appreciable. During summer months it varies between 2.15 and 6.4 km. The one way attenuation over Jodhpur for 5 %, 0.1 % and 0.01% probability levels are found to be 5 dB, 20 dB and 47 dB at 20 GHz.

Rain induced cross polarization (comparison of existing models):

The performance and reliability of a dual polarized LOS links operating around 10 GHz are degraded due to rain. Among the degrading effects important ones are attenuation and depolarization. Three models that estimate depolarization have been compared. The cross talk levels are estimated for various drop size distributions, canting angles and vertical and horizontal polarizations. These results indicate that the performance of dual polarized links will be degraded to unacceptable levels during rain.

Mobile train radio measurements in northern India:

Some mobile train radio measurements were conducted in the UHF band in northern India in urban, sub urban and open environmental zones. The base stations used in this study are New Delhi, Ghaziabad, Meerut, Muzzafarnagar and Saharanpur. The path losses deduced from the experimental observations are compared with different path loss prediction techniques.

An attempt is also made to extend Hata's method for prediction of path loss into the microwave region by adding appropriate losses due to oxygen and other parameters. Also the coefficients in the Hata's method are derived using adaptive propagation techniques. The coefficients thus obtained are characteristic of a particular region and can be used for the design of mobile communication systems in the microwave and millimeter wave bands in that region.

Results from SROSS C2:

RPA experiments flown aboard Indian SROSS C2 satellite have been providing, since May 1994, valuable

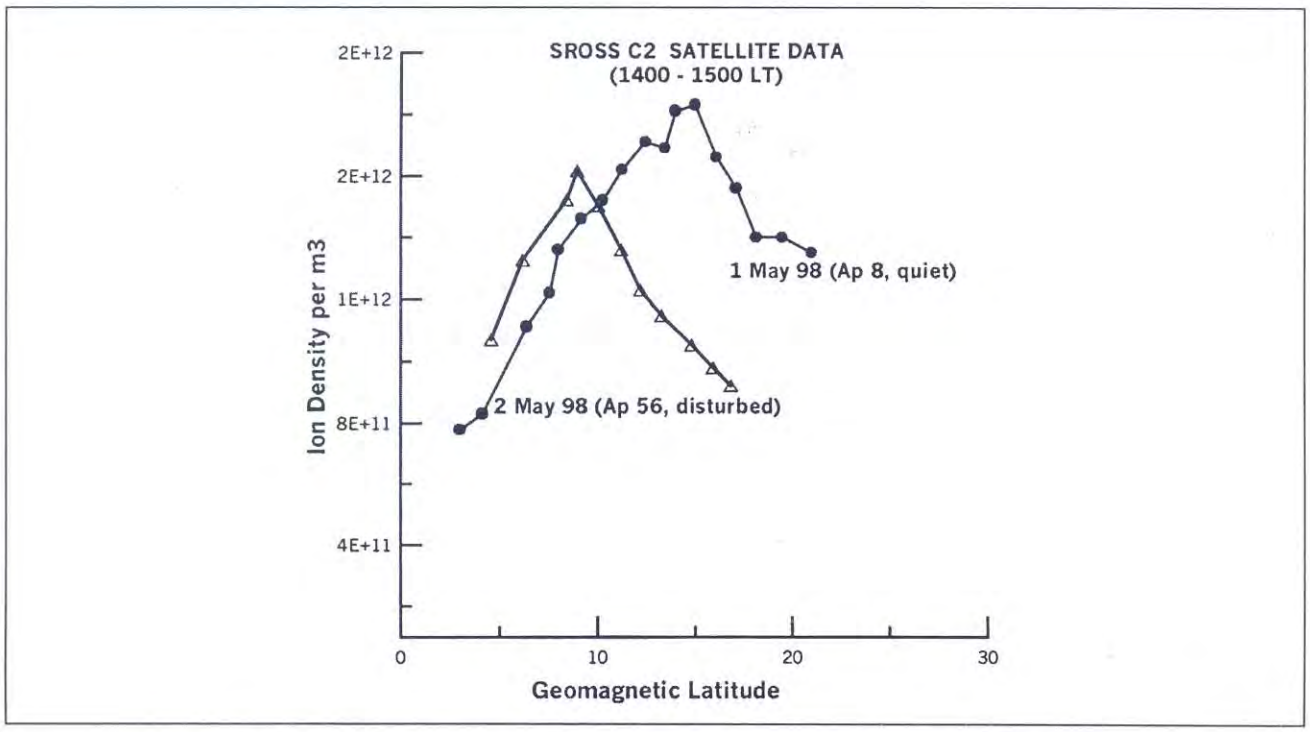


Fig. 7.6: Latitudinal variation of O^+ during daytime for quiet and disturbed days

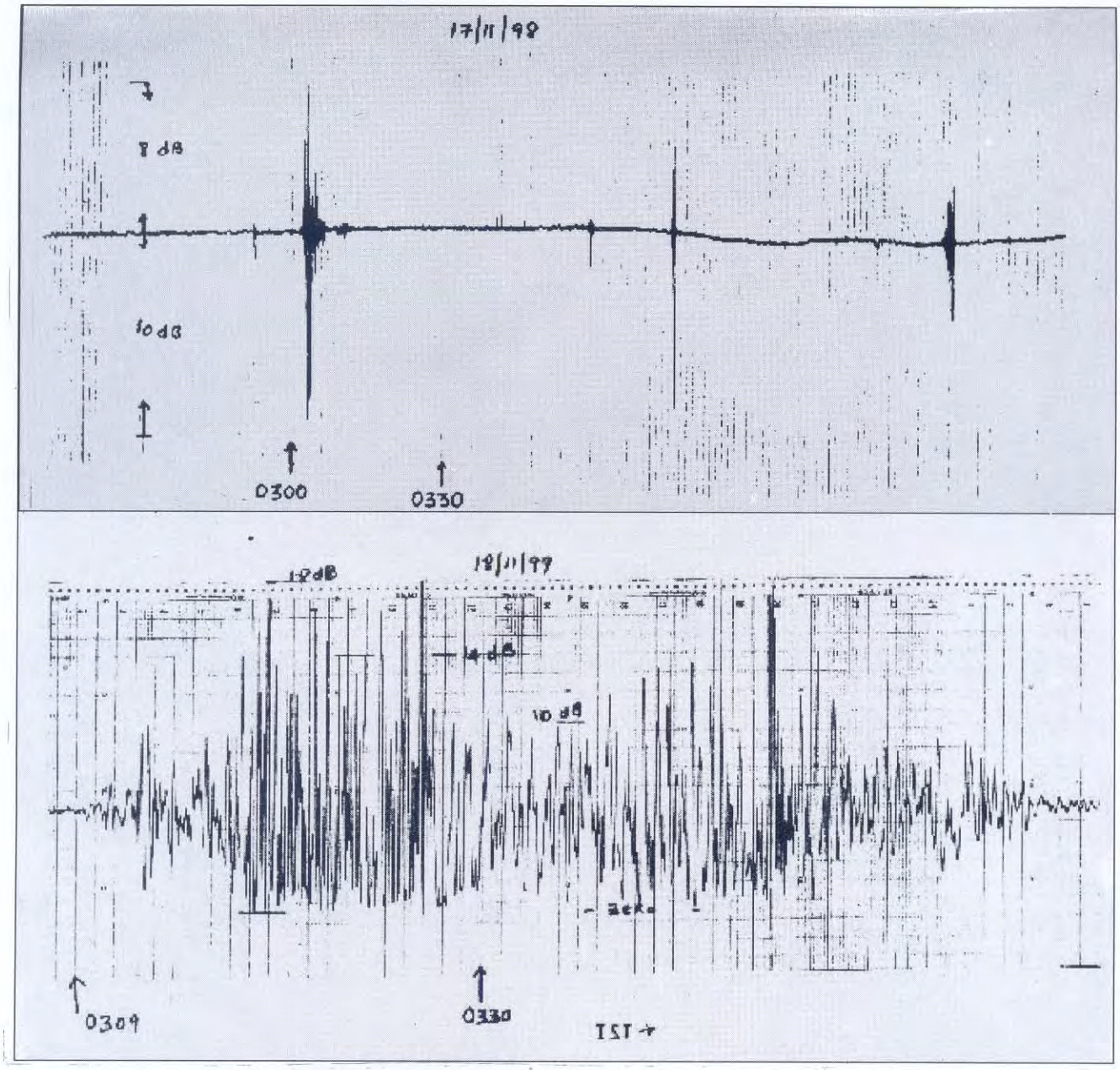


Fig. 7.7 : Scintillation records of Fleetsat 250 MHz signals during Leonoid shower Events of 17th November 1998 and 18th November 1999

information on electron and ion temperatures and ion densities over Indian region in the altitude range of 430 - 630 km. These data sets are used for a comprehensive study of the various low latitude ionospheric features and their variations over the Indian region. Simultaneous variations examined in topside plasma temperatures and in plasma densities from SROSS C2 data pertaining to a few severe magnetic storm events yielded some interesting results on low latitude ionospheric behaviour during magnetically disturbed periods. Electron temperature showed substantial rise and latitudinal variation during such events. Fig. 7.6 shows latitudinal variation of ion density (O^+) during daytime for a magnetically quiet and a highly disturbed day during May 1998.

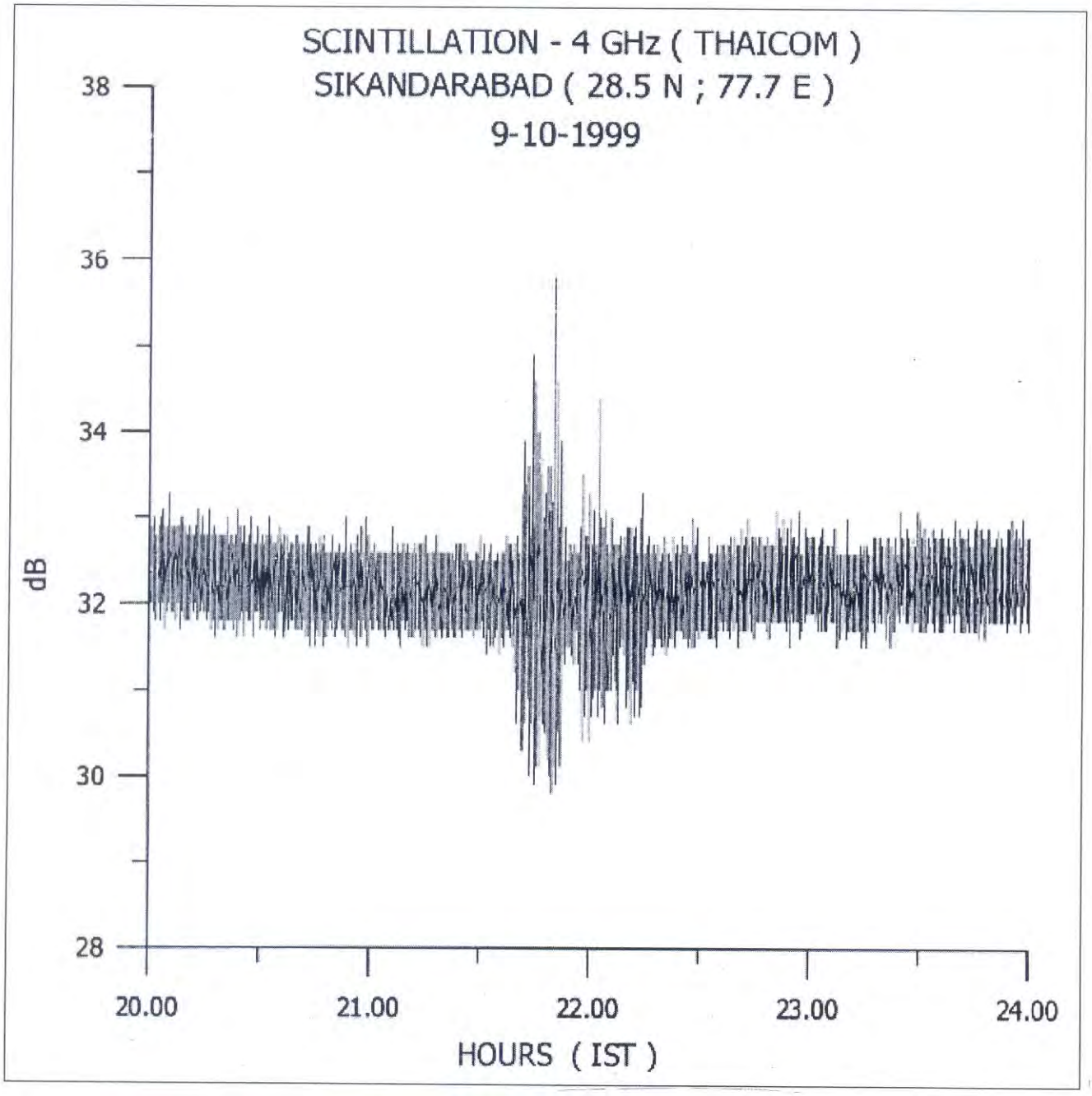


Fig. 7.8: Scintillation pattern observed at 4 GHz

Leonoid Meteor shower effects on FLEETSAT VHF signals:

November months of 1998 and 1999 have witnessed peak activity of Leonoid meteor showers which recur with a 33 year periodicity. A study has been undertaken to see the effect of meteor showers on VHF signals using the amplitude records of Fleetsat (73° E) signals at 250.35 MHz. Contrasting scenarios of signal fading patterns were observed at Delhi, during these two November shower periods. The signal fading observed in the early morning hours of 17 Nov.1998 (type-I) is in the form of discrete, isolated-patches showing quasi-periodicity. The patch duration being of the order of 1 to 5 minutes. The peak-to-peak fluctuation of the largest patch is about 15 dB. In contrast, the signal

fading in the early morning hours of 18 Nov.'99 (type-II) is observed as three long-duration patches varying in time extent from 45 minutes to 90 minutes (fig. 7.7). The signal fading in each patch is continuous, and of random nature. Again, the peak to peak fading is about 15-18 dB. It is strongly believed that type-I fading is due to drifting of isolated, discrete-irregular structures created at the meteoric heights of 80-110 km. The timings of these scintillation events were found to coincide with the peak activity of the meteor showers and also there were no other scintillation observations during these months.

Observations of ionospheric scintillations in GHz:

To study the physical and dynamical characteristics of equatorial ionospheric irregularities, scintillation observations at 4 GHz have been started at two Satellite Earth Stations namely Chenglepet (12.7° N; 79.9° E) and Sikandarabad (28.5° N; 77.7° E) in September 1999 and data is being collected since then. These observations (fig. 7.8) were carried out using the C-band pilot carrier of Thaicom geostationary satellite at 94° E. Several cases of scintillation occurrences were recorded at both these locations. Figure 7.8 shows a record of scintillations observed at Sikanderabad with 6 dB peak-to-peak activity. A study conducted using scintillations observed at Sikanderabad show that there was good correlation between the day time equatorial electrojet strength and night time scintillation intensity. This result has a predictive potential for scintillation activity.

Plasma hole in the nightside Venus ionosphere:

An examination of nightside electron density profiles showed that there are three basic ionospheric states in which the nightside ionqsphere exists, (a) the "full up" normal ionosphere - a state which is generally seen at times of low solar wind conditions, (b) the 'holed" ionosphere - a state which is seen during moderate solar wind conditions and (c) the "disappearing" ionosphere a state which is seen during very high solar wind conditions. We found that holes are nothing but manifestations of the nightside ionopause. During low solar wind conditions, the ionopause occurs at very high altitudes and therefore one does not see any plasma hole in the ionosphere. However, during moderate solar wind conditions, the ionopause occurs at altitudes above the periapsis but well below the upper limit of ionopause seen during "full up" ionospheric conditions exhibiting a State of "holed" ionosphere. And during very high solar wind conditions, the ionopause occurs below the periapsis, thus providing a state of disappearing ionosphere. The question however arises as to what causes the formation of the nightside Ionopause. And a possible explanation is the penetration of ionosheath -ionotail magnetic fields to altitudes within the nominal nightside ionosphere. We have provided evidence for this by showing that thermal plasma depletions (i.e. holes) are directly correlated with intruding magnetic field enhancements. These depletions occur at the ionopause altitudes and their locations (altitudes) are related to solar wind condition.

MST radar studies:

In recent years efforts have been concentrated on the "Generation mechanism of quasi-periodic echoes" observed on MST radar signals from E region altitudes. These echoes were first observed by us at the tropical station Gadanki with the Indian MST radar along with echoes that were also observed simultaneously. The quasi periodic echoes appeared over the altitude range between 102 to 116 km and the continuous echoes between 97 and 101 km. The period of QP echoes was in the range of 2-4 min. Analysis of time series of the line of sight Doppler velocity associated with continuous echoes between 97 and 101 km altitude showed that the waves of period 3-5 min dominate in this altitude range. This is quite close to the period of QP echoes observed between 102 and 116 km. The amplitude profile for the wave of period 3-5 min indicates that wave amplitude increases with height from about 2.5 ms^{-1} at 98.5 km to 4 ms^{-1} at 101 km. These observations are consistent with the theory of increase in wave amplitude with height and provide the first experimental evidence to the theory proposed by Huang and Kelly on differential modulation of Es layer with height.

Ionosphere Modelling

Total electron content and slab thickness:

The high resolution electron density profiles from Arecibo Incoherent Scatter Radar data were used to obtain the profile shape parameters by comparing the observed profiles with the IRI bottomside profile function. Median values of these parameters are used to generate empirical models and we have suggested to the IRI community to implement our model. The comparative studies of TEC (100 - 500 km) derived from Arecibo measurements and the IRI model showed some discrepancies between the observed and the predicted TEC and these discrepancies were maximum in summer and equinox months. During winter, these discrepancies are minimum. Since most of the contribution to TEC comes from around F2 peak, the studies indicated that these discrepancies occur mainly due to inadequate representation of profile shapes above and below the F2 peak.

The examination of the variability of Equivalent Slab Thickness (EST) in relation to measured peak height of the F layer and electron temperature revealed that EST showed good correlation with F layer peak height during nighttime, while during daytime it showed linear relationship with the electron temperature. The IRI predicted EST overestimates the observed values during all the seasons.

RWC and Forecast Services

Short term forecasting and data exchange activities of Indian RWC operating from NPL continued this year. Short term forecasts on solar and magnetic activities were provided to a number of user agencies including MCF, Hassan, ISTRAC, Bangalore, radio communications units of the Indian Navy etc.

Special ionospheric predictions were also provided to the Indian Defence Services to aid in planning of HF links to countries where Indian troops are stationed as a part of international peace keeping force. NPL has also been providing HF prediction for links operating in certain strategic region to Indian Army and Air Force.

अतिचालकता
SUPERCONDUCTIVITY

अतिचालकता प्रभाग की गतिविधियों का मुख्य केन्द्र असामान्य अतिचालक और सामान्य अवस्था आचरण (Normal State Behaviour) व उच्च Tc संवृति (Phenomenon) की अधःस्थ यंत्रावली को समझना है। अधिकांश प्रतिस्थापनी अध्ययनों द्वारा इन विवरणों को अनावृत करने का प्रयास किया गया है। एच टी एस सी (HTSC) क्यूपरेट्स में मुख्यतः धनायनिक प्रतिस्थापन त्रुटियों एवं अव्यवस्था (व्यतिक्रम) की उत्पत्ति को प्रेरित करता है। अधिमान्य स्थल अवलम्बित विलक्षणता विभिन्न परस्पर प्रतिस्पर्धात्मक संवृति (Phenomenon) यथा स्थानीयकरण, विमितीय परिवर्तन, अस्थिर चालकता व आर्डर पैरामीटर रूपान्तरण, इलैक्ट्रॉनिक प्रोपर्टीज में स्थानीय परिवर्तनों को प्रेरित करती है। LaSrCuO पद्धति में विवट सघनता सहित रसायनिक विभव के आचरण को समझने के लिए सैद्धान्तिक अध्ययन भी किया गया। t-t'-j माडल ने अतिमादित (overdoped) प्रवृत्ति में आचरण को सफलतापूर्वक स्पष्ट (व्याख्या) किया है। विश्वविद्यालयों तथा मुख्य अनुसंधान एवं विकास संस्थानों के साथ सहयोग और प्रमुख आर एण्ड डी संस्थान बहुत अधिक लाभप्रद रहे हैं।

The main focus of the activities of the Superconductivity Division is to understand the unusual super conducting and normal state behaviour and the underlying mechanism of high T_c phenomenon. Host of substitutional studies have been attempted to unveil such details. Cationic substitutions in HTSC cuprates essentially leads to the generation of' defects and disorders. Preferential site dependant singularities lead to various mutually competing phenomena like localization, dimensionality changes, fluctuation conductivity and order parameter variations and local changes in the electronic properties. A theoretical study has also been undertaken to understand the behaviour of chemical potential with hole density in LaSrCuO system. The t-t'-J model is found to successfully explain the behaviour in the overdoped regime. Collaboration with universities and premier R & D institutes has been most fruitfully continuing.

We have synthesized the single phase sample of $Cu_xC_{1-x}Ba_2Ca_3Cu_4O_8$ (x=0.2~0.9). Transport and magnetic measurements and iodometry titration analysis were carried out for these materials. From these results we discussed the correlation between T_c , the Hall number, copper valance and oxygen content. The effect of substituted M ions on T_c in (CuC,M)-1234 (M=Ni,Zn,Al,Tl,Mg) is also discussed. We proposed a unique selective carrier doping mechanism in (CuC)- and (CuC,Mg)-1234 systems.

Single phase systems with the composition of $(Cu,M)Ba_2Ca_3Cu_4O_8$ (CuM-1234; M=C, Al,Tl, Mg, Zn) have been synthesized using high pressure technique. We have measured the pressure dependence of superconducting transition temperature (T_c) through insitu resistivity measurements upto 8 GPa for these samples, reproducibly. These samples exhibit almost the same Tc enhancement by applied pressure, inspite of their different ambient T_c values. The enhancement values of 8-10 K at 8 GPa pressure for these samples are found to be comparable to those of Hg- systems and (B,C)- system.

Scanning Tunneling Microscopy (STM) and Spectroscopy (STS) studies, at atomic level resolution have been carried out on single crystals of $Y_{1-x}Pr_xBa_2Cu_3O_7$, i.e. Y(Pr)-123, to understand the striking differences in the behaviour of Pr-123 from Y-123, both having an identical crystal structure. With the incorporation of Pr, the twin-boundary density gets systematically reduced which is found to be consistent with the observed decrease in the orthorhombicity. Furthermore, Pr substitution at the Y-site produces a striking effect on the defect structure as well as on the electronic structure of CuO_2 planes, where the superconductivity is believed to reside. The peculiar features and their impact on the superconductivity are found to fit in the general framework of the explanation proposed by Blackstead(1996) and Mazin(1998),where the disorder plays a crucial role in the suppression of superconductivity.

A t-t'-J model has been employed to study the variation of the chemical potential shift with the change in the density of doped holes in high T_c cuprates. The model Hamiltonian incorporates the nearest neighbour hopping, the next neighbour hoping and the fictitious Coulomb interaction(U'). The fictitious Coulomb interaction is treated within the Hubbard self energy approximation. U' limit is taken to avoid the double occupancy. The Hamiltonian also includes the antiferromagnetic exchange energy J. This term is treated within the mean field approximation. The density of states (DOS) is calculated and it depends upon t,t',J and hole density nH. It is found that the t-t'-J model is successful in explaining the doping dependent DOS and the shift in the chemical potential is only in the overdoped regimes of the $La_{2-x}Sr_xCuO_4$ system. For low and moderate dopings the agreement is not good. Reasons for the failure of the model for low doping regime are mentioned.

Three $BiSrCaCu_2O_{8+x}$ (BSCCO) single crystals were irradiated with 250 MeV Ag +17 ions, with fluences of 2.5, 5,10 x 10^{10} ions/cm^2 respectively, to create columnar (linear amorphous tracks) type defects in them. The defect structure was characterised at nano level using scanning tunneling microscope. Low ac field (B_{ac}) succeptibility measurements in a frequency range of 0.016-1kHz and field range of 0.01- 10 Gauss, were performed on the crystals before and after the irradiation. Considerable frequency dependence of the susceptibility transitions is observed. Using an Arrhenius-like expression flux creep activation barriers were determined, which shows a $B_{ac}^{-0.7}$ dependence. Introduction of defects leads to a shift of susceptibility transitions to higher temperatures and an increase in activation barrier. The results show the dominance of bulk pinning, rather than surface/geometrical barriers, in determining the flux line dynamics at low fields and temperatures very near to critical temperature.

Changes in the physical properties of Pb doped and Pb-Sn doped polycrystalline Bi-2223 high temperature superconductor irradited by 100 $MeV^{0.7}$ were studied. All the samples were prepared by usual solid state reaction method. The parent compound was single phase with a $T_c(0)$ value of 106 K for the Pb doped batch and 107 for Pb-Sn batch. The samples were irradiated at various influences in the range of 10^{12} to 10^{14} ions/cm^2. For both the cases it was observed that

the maximum damage have been produced at optimal fluence value varying between 10^{13} to $5x10^{13}$ ions/cm^2. The phase transitions probably due to oxygen disordering are evident from X-ray analysis, which is supported by R-T measurements. AC susceptibility studies shows changes in the real part of χ. A shift in the imaginary part of the ac susceptibility, with various fluences is also observed.

Step height of growth spiral on CdI_2 crystals, unambiguously measured for the first time by STM, do not turn out to be integral multiples of the unit cell height, as normally expected, unless enhanced by a constant value of 0.31 nm. The discrepancy primarily arises from the weak Van der Walls bondings between the neighbouring molecular sandwiches I-Cd-I constituting the structure and from the dangling bonds exciting at the edge of a growth step and at the crystal surface. The result is significant from the problem of surface physics and surface chemistry.

Flux dynamics studies of swift heavy ion irradiation on high T_c $RBa_2Cu_3O_7$, (R-123 where R is Y or Dy) thin films with high c-axis orientation which were grown using pulsed laser deposition and DC magnetron sputtering technique are reported. The characterized films were irradiated with 25 MeV Ag ion beam at different fluence equivalent to $B\phi$ in the range 1T to 20T. The nature of columnar Amorphization and structural symmetry changes produced by swift heavy ions in these films were investigated by STM which provided the information regarding the columnar track diameter in these materials. The flux dynamics studies were performed using magnetization and electronic transport measurements. We have observed a remarkable enhancement in critical current density and pinning force in the materials upto an optimal value of ion fluence and after that the decline in them. The critical magnetization results analyzed using critical state models and the magneto transport results were analyzed in the frame-work of Bose-glass model.

The fluctuation conductivity studies have been carried out in pure and doped 123 HTSC systems . Possible carrier modification and the related correlations due to low content of preferential Cu-site doping have been explored. The possible effect of changing the planar Cu-site substituent by a chainer Cu-site substituent Fe of nearly the same content, on the order parameter dimensionality and the associated correlation have been investigated.

TGA and DTA analysis of the precursor material for casting sol-gel based tungsten oxide films have been carried out. Such analysis have also been performed on various types of polymers like APTA and APTA-ester families, Besides those on Hg doped 123 and Ln based superconductors. Preliminary TGA analysis of bio-degradable polymers have been performed with a view to determine its composition for exploring its synthesis. Moisture content determination by TGA is also being attempted.

क्रायोजेनिक्स
CRYOGENICS

क्रायोजेनिक्स प्रभाग पर उच्च Tc अतिचालकों और विकसित अतिचालक चुंबक प्रणाली पर आधारभूत अध्ययन पूरा किए जाने की जिम्मेदारी है । आर्द्रता मानकों व हीलियम प्लांट का अनुरक्षण इस विभाग की अन्य जिम्मेदारियां हैं । इस वर्ष के दौरान प्रतिस्थापन अध्ययनों ने इन पदार्थो के व्यवहार (आचरण) पर बहुमूल्य सूचनाएं देना जारी रखा। समरूप क्रिस्टल संरचना सहित Pr-123 व Y-123 दोनों के बीच प्रभावशाली अन्तर को समझने के लिए Y(Pr)-123 पर STM अध्ययन पूरे किए गए । एक नवीन अस्थायी (क्षत्रिक) हाटस्ट्रिप प्रक्रिया को इस्तेमाल करते हुए पैरोवस्काइट मैंग्नाइट (80-300 K) पर थर्मल चालकता अध्ययन किए गए । फ्लक्स पिनिंग पर जोसेफसन जंक्शन के एक व्यूह (array) में स्तंभ दोष के प्रभाव पर अध्ययन किया गया । इससे यह पता चलता है कि अनुप्रस्थ परिच्छेद (cross- section) से युक्त लघु उच्च करंट के नेटवर्क में पिनिंग (Pinning) अत्यधिक प्रभावशाली है । वर्ष के दौरान इस प्रभाग सात 7T मैंग्नेट जो कि एक रिकार्ड है। इन में से एक Nb_3 Sn इन्सर्ट के उपयुक्त है और 11T चुम्बकीय क्षेत्र प्रस्तुत करता है।

Cryogenics Division has the responsibility to carry out basic studies on high T_c superconductors and develop superconducting magnet systems. Maintenance of humidity standard and helium plant are other responsibilities. During this year substitution studies continued to give valuable information on the behaviour of these materials. STM studies on Y (Pr) 123 were carried out to understand striking difference between Pr-123 and Y-123 both with identical crystal structure. Thermal conductivity studies on perovskite manganites (80-300K) have been carried out using a new transient hot strip method. Effect of columnar defects in an array of Josephson Junction on flux pinning has been studied. It turns out that pinning is more effective in a network of smaller high current carrying cross section. During the year we built a record number of 7T magnets (seven) including one which is capable of having a Nb_3Sn insert and produce a field of about 11T.

Superconducting Magnet Technology

Systems development of six units of 7T superconducting magnet:

NPL has been making Nb-Ti based 7T magnets for many years for a variety of applications. During this year six 52 mm working bore, 7T magnets, complete with support system, quench protection and the liquid helium cryostats were fabricated. It is proposed to supply these magnet systems to various R & D organizations. The motivation being that such magnets need not be imported at huge cost unless it is a complex magnet. One such prototype magnet produced a field of close to 8T.

All these magnets have been wound in two sections so as to make optimum use of conductors. Both the sections run on the same current but on different current densities compatible with the field experienced. Both sections are individually protected against quench. The magnet uses conductors of the sizes 0.75 mm and 0.54 mm dia., the copper to superconductor ratio is 1.35 to 1. Å total of 4.1 km of conductor length has been used. The design field homogeneity is 0.072 % over 10 mm SDV. The operating current at highest field (~8T) is 100 Å. Our magnet systems will be available to R & D institutions shortly. The superinsulated dewars are being tested for performance. A computer program was earlier developed with parameters like working bore, field strength and homogeneity. The photograph shows six magnets without their support systems in a row (Fig.9.1).

Development of a 11 Tesla 52mm bore superconducting magnet:

Superconducting magnet based on Nb-Ti conductor technology has a limitation of 8T. For higher fields additional incremental field is provided by a Nb_3Sn insert. Nb_3Sn is however an inter- metallic compound which is

Fig.9.1: Six units of 52 mm bore superconducting magnets designed and fabricated by NPL to produce a field of more than 7 Tesla at 100 amp

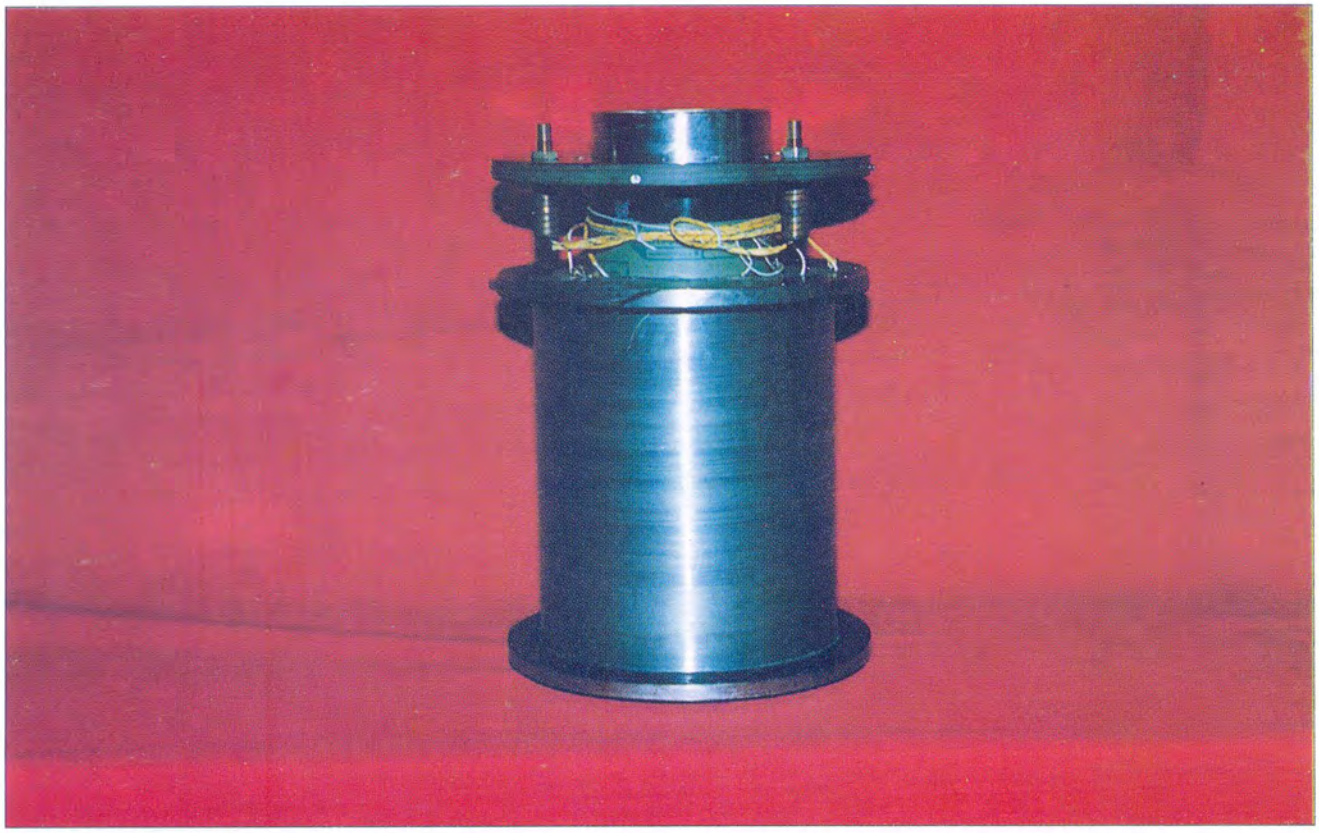


Fig. 9.2: A large bore 104 mm, 7 Tesla superconducting magnet wound with Cu/Nb-Ti conductor. The magnet will be used as a background field magnet. It will have a Cu/Nb_3Sn conductor insert coil for producing a central field of 11 Tesla

Table 9.1 Design parameters of 11T superconducting magnet
(Working bore dia. = 50 mm)

S.No.	Parameter	Inner Coil	Outer Coils	
			Inner coil	Outer coil
1.	Inner Winding Dia.	56.4 mm	110.1	152.6 mm
2.	Outer Winding Dia.	100.4 mm	152.2 mm	191.2 mm
3.	Winding Length	170 mm	220 mm	220 mm
4.	Conductor Used	Nb3Sn	Nb-Ti	Nb-Ti
5.	Cu : SC ratio	1.1 :1	1.35 :1	1.35 : 1
6.	Conductor Dia.	0.8 mm	0.75 mm	0.54 mm
7.	No. of Filaments	5000	54	45
8.	No. of Layers	22	22	26
9.	Total No. of Turns	4674	6453	10554
10.	Conductor Length	1.16 Km	2.67 Km	5.7 Km
11.	Field at 100 Amp.	3.1 T	3.15 T	4.75 T
12.	Homogeneity Over 10 mm SDV	0.06 %		
13.	Total Central Fild	11 T at 100 Amp.		
14.	Interlayer Material	Fibre Glass Cloth		
15.	Impregnating Material	Bees Wax		
16.	Quench Protection	Through Dump Resistor		

very brittle and difficult to handle. The conductor is thus manufactured in the form of multi-filaments of pure Nb in a Cu-Sn matrix. A 'wind and react' method is thus followed for winding the magnet. The magnet is reacted in a controlled inert atmosphere at high temperature for several days. During this reaction Sn migrates form the matrix to diffuse into Nb to form Nb_3Sn. This reaction brings forth several technical problems which have to be solved before it can be used as insert. NPL has developed this expertise and during early nineties made two Nb_3Sn inserts with working bores of 45 mm and 33 mm. A total field of 11 T was produced when these coils were used in hybrid form. Nb-Ti magnet provided a background field of 7.8T and the Nb_3Sn insert an additional field of 3.2 T. This year yet another 11T magnet has been designed with a working bore of 52mm. The background Nb-Ti magnet is ready. It has a winding bore of 114 mm and the winding length 200-mm. It is again wound in two sections using a total of 8.25 km of conductor length. The Nb_3Sn insert has been designed and the arrival of Cu-Sn/Nb conductor is being awaited (Fig. 9.2). The table 9.1 shows the parameters of the complete hybrid magnet. The Nb_3Sn magnet technology can in fact be transferred to any institution or a company if such an opportunity is available in future.

High Temperature Superconducting Materials

A new technique of preparing Y-Ba-Cu-O superconductor using HgO:

Bulk superconductivity in $YBa_2Cu_3O_{7-x}$ superconductor system depends on the non-stoichiometric oxygen 'x'. For maintaining proper oxygen concentration within the bulk, techniques like, slow cooling and annealing under oxygen atmosphere at 450-700°C are normally adopted. It has recently been observed, however, that HgO added YBCO superconductors show good 90 K superconductivity even when the samples are quenched directly to room temperature. The thermal studies (Thermogravimetric analysis), X-ray diffraction and resistivity measurements provide evidence of stability of the oxygen within the lattice. The activation barrier of oxygen out-diffusion at higher temperature appears to be higher in the case of HgO added samples. This is due to stronger bonding of nascent oxygen released from the dissociation of HgO at ~476°C,with copper.

Thermal conductivity of perovskite manganites:

The thermal conductivity of a series of $La_{1-x}Ca_xMnO_3$ ($0.2<x<0.5$) has been measured over a temperature regime of 80-300 K using transient hot strip method. In this method, a Ni foil is attached with the bulk manganite sample and is heated through a power supply. The heat is, then, transmitted to the bulk of the sample. Depending on the rate of variation of the voltage across the Ni foil with time, one can evaluate the thermal conductivity of the bulk sample. This transient technique is suitable for samples with poor thermal conductivity. The values, thus obtained, are found to be tallying with the reported results. The pattern of variation of thermal conductivity with temperature undergoes changes from above to below T_c (Curie point). Since, the thermal conduction is taking place mostly through phonons, a change in lattice dynamics could be noted around T_c.

Flux pinning in an array of Josephson junctions with columnar defects:

The presence of periodic columnar defects at the Josephson junction gives rise to sharp peaks in the current (I)-field (B) structure at a commensurate vortex-defect concentration (Fig.9.3). The defects at the junction block the supercurrent tunnelling across the electrodes. The improvement observed in a single junction, however, is found to be smeared across an array. But, the overall current density (J_c)-field (B) characteristics show improvement depending on the ratio of defect and junction dimensions. For smaller values of the ratios, the J_c-B characteristics are improved over the entire field regime while with the increase in the ratios, the improvement is found to be restricted within the low field regime. These features are all the more prominent in the array of smaller zero-field junction coupling energy E_{J0}. It has also been found that the flux pinning energy U, defined as the variation in the junction coupling energy, is higher in arrays having smaller E_{J0}. In other words, pinning is more effective in a network of smaller high current carrying cross-section.

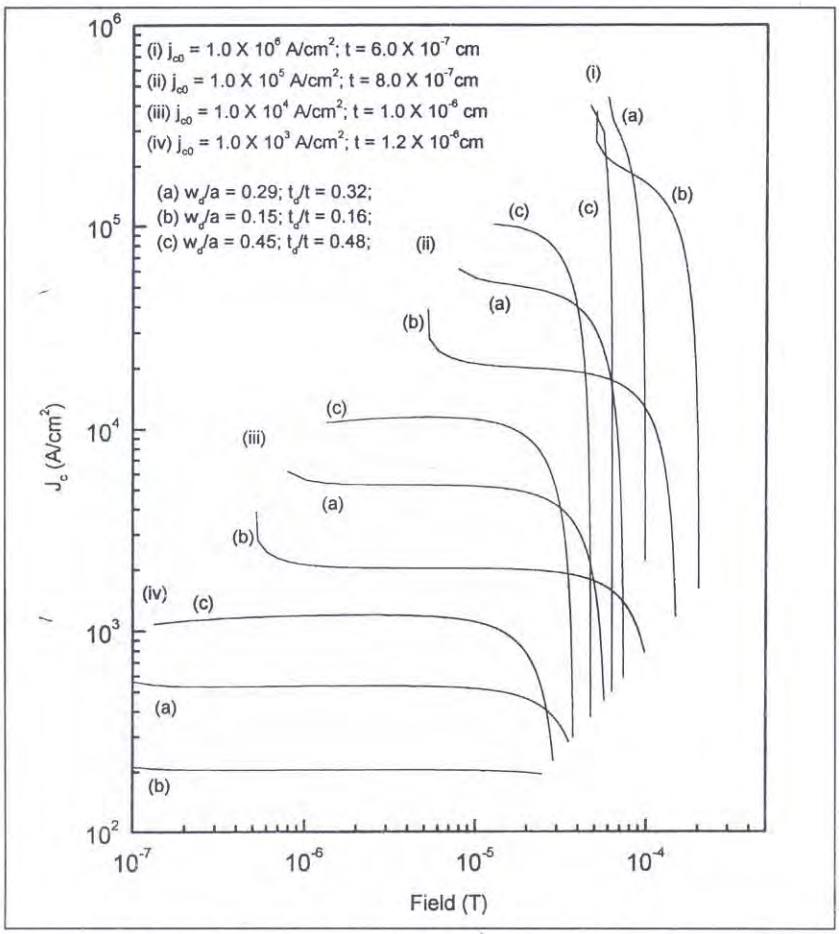


Fig.9.3: J_c-B characteristics of Josephson junction array with different columnar defect parameters

Basic investigations on high temprature superconductors

Studies on dopant-effect of magnetic impurities were confined mainly to the Bi-2212 series prepared by adding Pb and Ag to the system. Both these additions give rise to a much faster reaction for the formation of relevant phases which results in a lower T_c ~ 65K superconductor in case of Pb-added material whereas for samples prepared by the addition of Ag, the T_c remains more or less identical (~ 80 K) to the un-doped Bi-2212 superconductor. The striking feature of the present studies was that the effect of f-level magnetic dopants on both these materials was again similar to the Bi-2223 series investigated previously, i.e. indications of formation of VBS (virtual bound state) and the possibility of T_c getting affected by the same for some dopants of the 4f series. Impact of the above results on other superconducting parameters (J_c , and H_{c2}) as well as the magnetic properties of these doped superconductors is presently being investigated.

Module Hydride Air-Conditioner

This group has a DST funded project entitled "Development of Module Hydride Air-conditioner" of 250 to 500 watts cooling capacity. This is a joint collaborative project between BHU and NPL groups. The BHU group has supplied 1 kg each of both hydrides (HTH & LTH). The P-C-T curves of these materials after characterization were used as the guiding factor for the initial charging with hydrogen gas. A modified version of the electronic sequential timer using 11 solenoid valves has been tested rigorously. The proto-type cooling device was tested and the temperatures at various stages were measured using PRTs. The feasibility concept of the hydriding and dehydriding of this unit was demonstrated. The project completion report has been submitted to the DST. Figure 9.4 shows the proto-type cooling device.

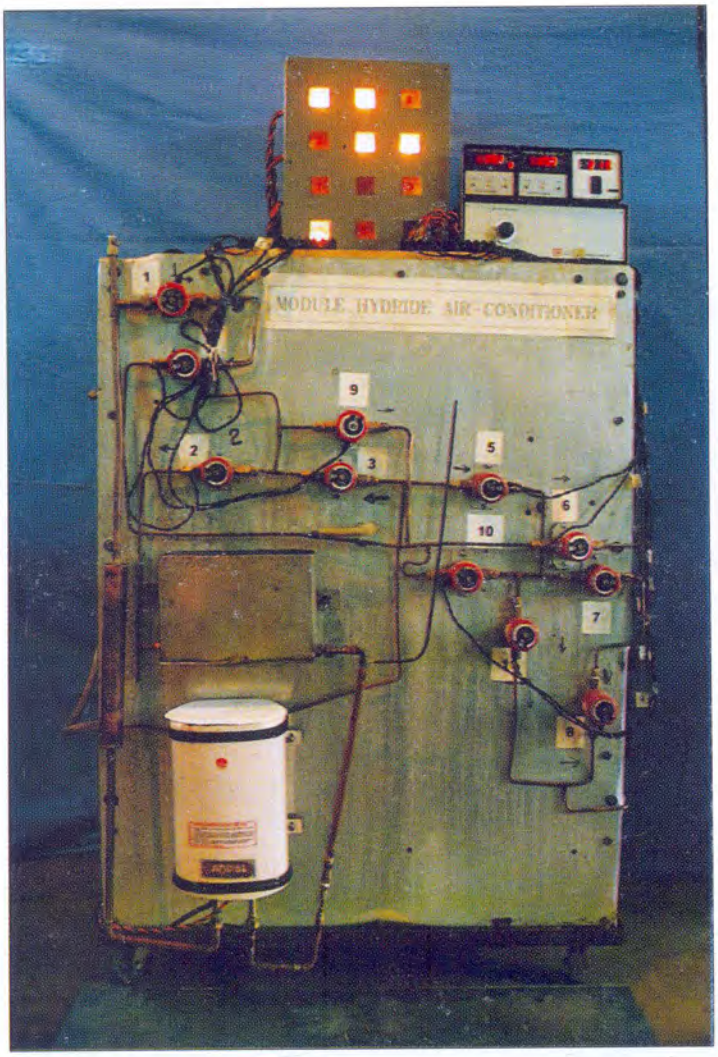


Fig.9.4: Prototype Hydrogen-Hydride based cooling device

Liquid Nitrogen and Helium Facilities

The storage cryo-container (6000 litres capacity) has been installed. During this year more than 16,000 litres of liquid nitrogen was consumed out of which about 3,500 litres has been produced from our own plant, rest has been procured or purchased. Regarding liquid helium 500 litres has been purchased from M/s Pure Helium, Mumbai and supplied to various R&D groups for carrying out their experiments.

Humidity Standards

Setting up of national humidity standard:

It is one of the recent activities of the laboratory with an objective to provide calibration service to various industries. In its first year itself the group offered calibration services to several industries. Besides, the following techniques have been developed.

Setting up of secondary humidity standard using two matched and precise quartz thermometers (aspirated psychrometer) RH range 10 % to 95 % RH with an accuracy of ± 1 % RH. Installation of humidity oven for calibrating different RH sensors at various temperatures. Generation of different RH using saturated salt solutions. Insitu calibration facility of RH sensors using capacitance type hygrometer. A proto- type unit for RH generation using two-flow method. Humidity generation using glycerine-water mixtures. Preliminary studies on the feasibility of portable RH generator using two-pressure techniques. Figure 9.5 shows the humidity oven being used in an experimental set up for the

Fig.9.5: Experimental set up using humidity oven for calibration of relative humidity(RH) sensors

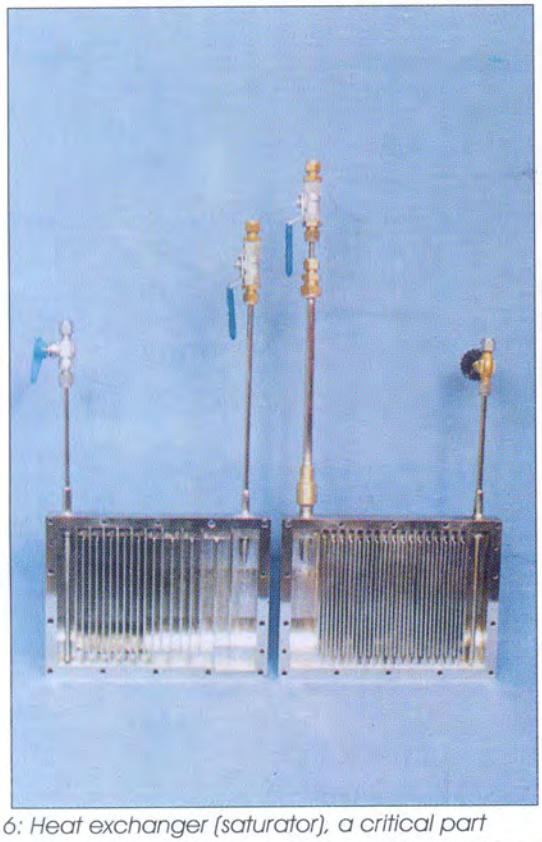


Fig.9.6: Heat exchanger (saturator), a critical part of the two-pressure cum two temperature RH generator

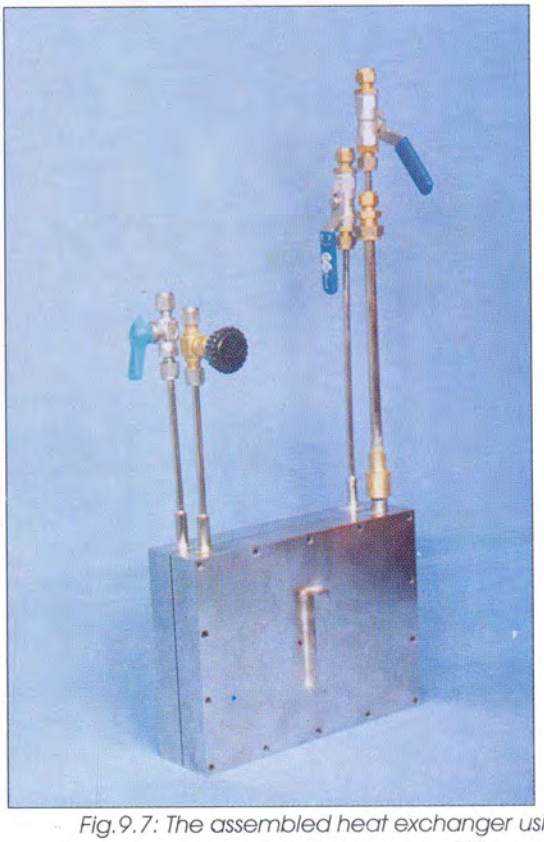


Fig.9.7: The assembled heat exchanger using two-pressure cum two temperature RH generator

calibration of industrial RH sensors. Efforts are being pursued to develop a laboratory model of two-pressure cum two-temperature relative humidity generator laboratory model. This is practically a humidity standard which is used in almost all the standard laboratories of the world. Fig. 9.6 displays the heat- exchanger (saturator), a critical part of this device. Fig.9.7 shows the assembled heat exchanger after it was put to rigorous leak testing.

APPENDIX : 1
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APPENDIX : 2

PATENTS

S.No.	Title	Countries	Project
1	A process for the preparation of highly stable solid precursor material useful for tungsten oxide based electrochromic coating	India, UK	GIA
2	An improved process for the production of green coke based high density monolithic graphite	India	Sponsored
3	A method for the preparation of polymer coated long duration optical memory device	India, USA, UK, Germany, South Korea, France, Japan	In house
4	A process for the preparation of compensated polyaniline as a water soluble polymer useful for corrosion inhibition	India, US Germany, Japan, UK, France, Italy	In house
5	An improved process for the preparation of multiple bilayers of high coercivity yttrium iron garnet thin films useful for magnetic and magneto optic recording	India	In house
6	A novel method of fabricating improved standard platinum resistance thermometer and improved standard platinum thermometer made thereby	India	In house
7	A novel composition useful for removing organic coating from solid surfaces and a process for preparing the said composition	India	In house
8	A process for the preparation of water repellent chemical useful for cellulosic materials and a method for the fabrication of the water proof cellulosic textiles	India	In house

APPENDIX : 3
R & D COLLABORATIONS

Collaborating Agency	Title of Project

Physico-Mechanical Standards

Indian

Archaeological Survey of India	Applied acoustics
Bhabha Atomic Research Centre, Mumbai	Laser cooling of atoms
Central Pollution Control Board, New Delhi	Applied acoustics
CNR-IFA, Italy; IPCL, Dhahej	Applied acoustics
Delhi Metro Rail Corporation Ltd., New Delhi	Applied acoustics
Indian Association for the Cultivation of Science, Calcutta	Surface characterization of thin films
Indian Institute of Technology, Kharagpur	Surface and interface characterization of semiconductor devices
Indian Institute of Technology, New Delhi	Surface and interface characterization of thin films, ultrasonic studies
Indira Gandhi Centre for Atomic Research, Kalpakkam	High pressure R&D
KADAM Environ. Consultants, Baroda	Applied acoustics
Nuclear Science Center, New Delhi	Surface analysis (collaborative project funded by DST)
Rajiv Gandhi Cancer Institute and Research Centre, New Delhi	Detection of cancerous tissue by near infrared techniques
Sugar Technology Mission, TIFAC, Deptt. of Science & Technology, New Delhi & Sriram Industrial Enterprises Ltd., New Delhi	Online determination of sugar contents in sugar cane solids., juices & sugar, by near infrared techniques.
Steel Authority of India , Ranchi	Applied acoustics
Uttar Pradesh State Observatory, Nainital	Steller interferometry

Collaborating Agency	Title of Project
Overseas	
Instituto di Metrologia "G. Colonnetti" (IMGC), Italy	Vaccum & leak standards
National Research Laboratory of Metrology,Japan	Pressure & vacuum standards
National Institute of standards & Technology NIST), Gaithersburg, USA	Development of diffuse reflectance transmittance & emittance standards of infrared standards and bilateral intercomparison
PTB, Germany	

Electronic Materials

Indian

Bhabha Atomic Research Centre, Mumbai	Silicon photodiodes
Solar Energy Centre, Ministry of Non-Conventional Energy Sources, Gurgaon	Mechanical load tester for PV modules

Polymeric & Soft Materials

Indian

Centre for Biochemical Technology, Delhi	Biosensor and related material
Indian Association for the Cultivation of Science, Calcutta	Biosensor and related material
IRDE(DRDO), Dehradun	Development of optically addressed spatial light modulators for defence applications
GND University, Amritsar	PAN/PMMA based solid polymer electrolytes
VSSC (ISRO), Thiruvananthapuram	Metallization of fabrics as a shield against electromagnetic interface (EMI)
Deptt. of microbiology, AIIMS, New Delhi	Conducting polymers
University of Delhi, Delhi	Conducting polymers

Collaborating Agency	Title of Project
Overseas	
Fukuoka Industry: Science and Technology Foundation, 1-1-1 Tenjin, Fukuoka, Japan	Biosensor and related material
Institute of Physical Chemistry, Technical University, Dermstadt, Germany	Dielectric studies of surface stabilized ferroelectric liquid crystal cells
Kyushu Institute of Technology,Fukuoka, Japan.	Biosensor and related material
National Institute of Standards and Technology, USA	Biosensor and related material
Naval Research Laboratory, Washington, D.C., USA	Surface order and sturcture studies of polymer solid interface
GE Research And Development, Schenectady, New York, USA	Conducting polymer composites for the shielding of electromagnetic interference and as antistatic materials
Sophia University, Tokyo, Japan	Biosensor and related material

Materials Characterization

Indian

Solid State Physics Laboratory, New Delhi	Characterization of semiconducting crystals and their epitaxial layers
University of Delhi, Delhi	Experimental and theoretical investigations of the effect of asphericity of electron density distribution in crystals on diffracted X-ray intensities
Indian Agricultural Research Institute, Pusa, New Delhi	Research on the origin and nature of colour, structure and technological properties of naturally coloured cotton
Regional Research Laboratory, Thiruvanathapuram	X ray diffraction study of solid state electrolysis in quartz
Indian Association for Cultivation of Science, Calcutta	Electron microscopy
Indian Institute of Technology, Delhi	Electron microscopy

Collaborating Agency	Title of Project
Pantnagar University	Electron microscopy
National Remote Sensing Agency, Hyderabad	Biomass analysis
Bhabha Atomic Research Centre, Trombay, Mumbai	Preparation and dissemination of Bharitiya Nirdeshak Dravya
Central Building Research Institute, Roorkee.	Preparation and dissemination of Bharitiya Nirdeshak Dravya
Central Food Technological Research Institute, Mysore	Preparation and dissemination of Bharitiya Nirdeshak Dravya
Central Glass & Ceramic Research Institute, Calcutta	Preparation and dissemination of Bharitiya Nirdeshak Dravya
Central Salt and Marine Chemicals Research Institute Bhavnagar.	Preparation and dissemination of Bharitya Nirdeshak Dravya
Gharda Chemicals Limited, Dombivili, Mumbai	Preparation and dissemination of Bharitiya Nirdeshak Dravya
Indian Agricultural Research Institute, New Delhi	Preparation and dissemination of Bharitiya Nirdeshak Dravya
Indian Institute of Chemical Technology, Hyderabad	Preparation and dissemination of Bharitiya Nirdeshak Dravya
Indian Institute of Petroleum, Dehradun	Preparation and dissemination of Bharitiya Nirdeshak Dravya
Indian Oil Corporation, R & D Centre, Faridabad	Preparation and dissemination of Bharitiya Nirdeshak Dravya
Industrial Toxicology Research Centre, Lucknow	Preparation and dissemination of Bharitiya Nirdeshak Dravya
National Aerorspace Laboratory, Bangalore	Preparation and dissemination of Bharitiya Nirdeshak Dravya
National Chemical Laboratory, Pune	Preparation and dissemination of Bharitiya Nirdeshak Dravya
National Environmental Engineering Research Institute Nagpur	Preparation and dissemination of Bharitya Nirdeshak Dravya

Collaborating Agency	Title of Project
National Geophysical Research Institute, Hyderabad	Preparation and dissemination of Bharitiya Nirdeshak Dravya
National Institute of Oceanography, Goa	Preparation and dissemination of Bharitiya Nirdeshak Dravya
National Metallurgical Laboratory, Jamshedpur	Preparation and dissemination of Bharitiya Nirdeshak Dravya
National Thermal Power Corporation, R & D Centre, NOIDA	Preparation and dissemination of Bharitya Nirdeshak Dravya
Regional Research Laboratory, Bhopal	Preparation and dissemination of Bharitya Nirdeshak Dravya
Regional Research Laboratory, Jorhat.	Preparation and dissemination of Bharitya Nirdeshak Dravya
Physics Department, M.D. University, Rohtak	Preparation and dissemination of Bharitya Nirdeshak Dravya for Characterization of materials
Overseas	
Institute of Inorganic Chemistry, Siberian branch of the Russian Academy of Sciences, Novosibirsk, Russia	Crystal growth and high resolution X-ray diffraction
Technical University of Darmstadt, Germany	High resolution X-ray diffraction
Naval Research Laboratory Washington, DC, USA	High resolution X-ray diffraction
National Institute of Standard and Technology, Gaithursburg, USA	High resolution X-ray diffraction
Central Research Institute for Food , Crops, Bogor, Indonesia	Preparation and dissemination of Bharitya Nirdeshak Dravya
Institute of Atmospheric Physics, Beijing, China	Preparation and dissemination of Bharitya Nirdeshak Dravya
International Rice Research Institute, Manila, Philippines	Preparation and dissemination of Bharitya Nirdeshak Dravya
Institute of Meteorology and Hydrology, Hanoi, Vietnam	Preparation and dissemination of Bharitya Nirdeshak Dravya

Collaborating Agency	Title of Project

Radio and Atmospheric Sciences

Indian

Indian Agricultural Research Institute, New Delhi	Free Air CO_2 enrichment studies on crops and gas emissions using OTC and FACE facilities.
Indian Meteorological Department, New Delhi	Rain effects on microwave communications
Indian Statistical Institute, Calcutta,	Estimation of rain characterization using X-band radar
ISRO Tracking and Ranging Centre, Bangalore	SROSS-C2 satellite tracking and RPA payload operations for ionospheric data collection over Indian region.
Ministry of Environment, Forest and Wildlife, CPCB, Govt. of India	Fog monitoring
National Institute of Oceanography, Goa	Antarctic expeditions
National MST Radar Facility, Tirupati	Studies on lower atmosphere
NERTU, Osmania University, Hyderabad	VHF and mobile communications
Roorkee University, Roorkee and B.H.U., Varanasi	SROSS data analysis
S.V.University, Tirupati	VHF/UHF propagation studies
Satellite Application Center, Ahmedabad	Ionospheric corrections in sea surface radiometer data on board indian satellite

Overseas

Asia Pacific Network for Global Change Research, Tokyo, Japan	Crop growth under elevated CO_2 conditions and aerosol scoping
National Centre for Atmospheric Research, Washington, USA	Indian ocean experiment (INDOEX)
Participating institutes of SASCOM Programmes in Bangladesh, Maldives, Nepal, Pakistan and Sri Lanka and START	South Asian level co-ordinated activities to study global change and impacts

APPENDIX : 4
SPONSORED R&D PROJECTS

New Beginnings

Agency/ Client	Title	Funds Received 1999-2000 (Rs. in Lakhs)
DST	Rain characteristics and estimation using X-band radar for rain attenuation in microwave and millimeter wave bands	5.750
Indo-UK	Role of matrix precursor in the development of high thermal conductivity carbon-carbon composites	1.000
Indo-Russia	Growing by MBE Method epitaxial structure on the basis of compound AIII BV Ga As, Al In Ga As in different compositions for various applications	3.600
DST	Dimensional metrology coordinate measurement	0.850
DST	To develop 10 pF capacitor using ULE quartz for use by accredited calibration laboratories	10.000
DST	Study of doped rare earth manganese oxide films for enhancing low field magnetic-resistance effect	2.700
RGNWDM (Rajiv Gandhi National Water Development Mission)	One year village level trial of filter tablet for arsenic removal from ground water	1.500
DST	Tetrahedral amorphous carbon (ta-c) films deposited by a filtered vacuum arc discharge (FVAD) technique	21.572
DST	Studies on surface layer in relation to turbulent kinetic energy budgeting	2.500
APN (Asia Pacific Network for Global Change Research)	Effect of atmospheric CO2 enrichment on rice varieties grown under various cropping ecosystems and their biogenic emissions using several open top chambers (OTC)	22.000

Agency/ Client	Title	Funds Received 1999-2000 (Rs. in Lakhs)
DST (NABL)	Planning, preparation and dissemination of Certified Reference Materials for quality assurance in analytical measurements	6.000
HAL	Development of oval shape tubes as skid landing gear for Advanced Light Helicopter (Phase II)	6.500
NMRL	Development of porous conducting carbon paper	10.000
NRSA	Studies on biomass burning and related trace gas emissions using IRS-P3 satellite data	0.500
ISRO	SROSS-C2 satellite RPA aeronomy payload data management	1.700
CPCB (Central Pollution Control Board)	Studies on fog occurrence in Delhi	20.000
Continuing Projects		
DST	Calibration service programme under the NABL programme	0.000
DST	Investigations aimed at producing stress relieved diomond like carbon film of high IR transmission	0.000
Indo-US	Research and development on (a) atomic hydrogen masers and (b) precision frequency metrology	7.200
DST	Development of a post earthquake rescue system by EM wave Cw Doppler technique	1.500
DST	Development of an acoustic wind profiler (with multi-beam acoustic array antenna) for remote atmospheric wind measurement	2.000
NIST (USA)	Programme of technical collaboration and cooperation in metrology with NIST (USA)	0.000
DST	Testing and evaluation of a superconducting magnet for making it a compatible unit of FT-NMR spectrometer	2.200
INDO/UK Fund	Development of polymeric optoelectronic devices	1.300

Agency/ Client	Title	Funds Received 1999-2000 (Rs. in Lakhs)
DST	Development of an automatic self locking NMR Gaussmeter	0.000
UGC	Interaction with universities/laboratories in the area of superconductivity (UGC)	0.000
NGRI, Hyderabad	Hydrogen maser for VLBI studies	0.000
NSTL	Fabrication and supply of an underwater pinger unit	1.589
AIT (Asian Institute of Technology, Thailand)	A study of biomass as energy source and technical option for greenhouse gas emission reduction	0.000
DOE-DRDO	Studies on potentialities of Glonass for positioning and timing vis-a-vis application of GPS	0.000
HAL	Development of oval shape tubes as skid landing gear for Advenced Light Helicopter (Phase-I)	0.000
ADB (Asian Development Bank)	Study of Least Cost Greenhouse Gas Abatement Strategy for Asia (ALGAS Project)	2.998
Indo-US	High resolution X-ray diffraction imaging for advanced materials characterization	0.000
DST	Development of six HTSC rf SQUID basic systems suitable for operation at liquid nitrogen temperatures	0.000
DST	On line determination and systematic recording of sugar content in sugarcane, sugarcane Juice and sugarcane solids	0.000
DST	Laboratory level technology development of some biosensors and related biomaterials	1.100
DST	Electron paramagnetic resonance optical absorption and electrical conductivity investigations in glasses	0.000
DST	Measurement of thermospheric wind and temperature with ground based Fabry-Perot interferometer	0.000

Agency/ Client	Title	Funds Received 1999-2000 (Rs. in Lakhs)
ISRO/NCAR (USA)	Indian Ocean Experiment (INDOEX) - Indian Programme	25.720
DST	Deposition and properties of mixed composition infrared optical thin films	0.000
Indo-US	Standardization of techniques for immobilization of proteins and enzymes in conducting polymers	0.000
DAE (BRNS)	Development of the β-alumina tubes for sodium metal production	0.000
MoEnF	Continuous measurement, updating, modeling and assessment of greenhouse gases	0.000
MoEnF	Ozone over India: Change in the past & future	0.000
Indo-ISRAEL	Studies of organic and inorganic thin films: Self assembled monolayer templates for metal oxide film processing	0.000
DST	Intensifying screen - a new dimension in X-ray xeroradiography	2.000
DST	Carbon composite ring based Ilizarov fixator for orthopaedic application	0.000
DST	A study of optically addressed spatial light modulators based on nematic and ferroelectric liquid crystals	0.600
DST	Transport behavior of strongly correlated electron systems	0.000
ISRO	Metallisation of fabrics as shield against electromagnetic interference (EMI)	0.000
DRDO (DTSR)	Fabrication and characterization of real time image processing devices.	1.250
Indo-US	Total spectral reflectance, total spectral transmittance and spectral emittance study in the infrared region of various materials in thin and thick films and bulk samples	2.513
DAE (BRNS)	A major up gradation of the standard time and frequency Signal (STFS) broadcast via INSAT satellites	0.000
NIST (USA)	Improved pressure standards in the range 10-360 kPa	3.200

Agency/ Client	Title	Funds Received 1999-2000 (Rs. in Lakhs)
DST	Non-linear dynamics and vertex flows in AC-driven Josephson Junction Arrays	0.000
Intl. START Secretariat, Washington	SASCOM activity: Meeting on Indo-Gangetic Plains (IGP) research efforts	0.000
DST	Investigation of materials under ultra high pressure metrological applications (Phase - II)	2.500
DST	To compose monographs on noise pollution	0.500
Intl. START Secretariat, Washington	Operation of the South Asian Regional Research Centre for Study of Global Change (SAS-RRC) under SASCOM	26.757
Indo-US	Surface order and structure studies of polymer solid interfaces	2.792
NIST	To improve frequency stability of atomic time and frequency standards by suppressing quantum noise through squeezed states	6.357
DST	A study of flare triggering and associated hard X-ray emissions and other flare-related phenomena for modeling of flares	1.400
DST	Asbestos free brake material for automobile tailoring characterization & evaluation	1.775
HAL	Development of titanium fasteners using warm forging	0.000
ISRO	A study of QUAS: Horizontal and vertical transport of air from tropical upper troposphere and stratosphere	0.000
ARDB	Development of carbon monofilament suitable for CVD-based SiC fibres	0.000
DAE	Low temperature scanning tunneling microscopy and spectroscopy of rare earth	0.000
DAE	Development of frequency stabilized diode laser for laser cooling of alkali atoms	0.000
DST	Study of droplet dynamics and heat flow characteristics during spray atomization and deposition	0.000

Agency/ Client	Title	Funds Received 1999-2000 (Rs. in Lakhs)
IPR (Institute for Plasma Research)	Development of high thermal conductivity special graphite for first wall components of SST-1 TOKAMAK	6.170
DOE	Silica-on-silicon based integrated optic components for wavelength division multiplexing (WDM) application (Partial)	0.000
DST	Development of a portable analytical X-ray imaging instrument for bio-materials	0.000
DST	Development of ultrasonic nebulising spray system for medical application	0.000
IOC	Feasibility study on various petroleum refinery streams as precursor for high performance carbon fibre	2.220
DOD	Planetary Boundary Layer (PBL) problems over Antarctica	5.730
Completed Projects		
DST	To investigate a new category of catalyst used for the synthesis of diamond under high pressure and temperature	0.600
DST	Characterization of tropospheric and ionospheric media to aid in radio communication	0.000
ARDB	Spray deposition & property evaluation of aluminium matrix composites	0.000
DST/RRL	X-ray diffraction study of solid state electrolysis in quartz crystals	0.000
ARDB	Development of SiC incorporated carbon-carbon composites	0.000
Indo-French	Influence of surface energetics of microstructure of matrix and fibre/matrix interactions in composites	0.560
DST	Development of tungsten oxide based electrochromic (EC) films by sol-gel technique	0.500
	TOTAL	229.206

APPENDIX : 5
RECEIPTS THROUGH CONSULTANCY

Client	Title	Amount
GTB Hospital	Accoustic treatment of auditorium under construction at GTB hospital	0.500
Ministry of Defence (R&D), Lucknow	Charcterization of semiconducting crystals and epitaxial layer	2.500
M/s Real Scientific Engg. Corpn.	Assistance to establish laboratory for calibration of force proving devices for 1 MN as per IS: 4169-1988	3.000
M/s Real Scientific Engg. Corpn.	Assistance in project planning to establish laboratory for calibration of force proving devices for 1 MN as per IS: 4169-1988	1.750
Delhi Metro Rail Corpo-ration Ltd.	Real time data acquisition from Metro operation in Calcutta to assess the potential of damage to historical monuments	0.750
Election Commision of India	To identify an unknown sample used to remove indelible ink	0.100
M/s Secure Meters Limited	Consultancy/guidance for procedure for calibration of power/energy measurement set-up at higher currents using 3 phase precision CT	0.200
M/s Unitech Machines Ltd.	Development, modelling and development of Core Cavity Electrode for housing (Mirror Bajaj)	0.800
Central Board of Irrigation & Power	Consultancy/guidance regarding AC/DC magnetic field strength and its influence on energy meters	0.300
M/s Samtel Color Ltd.	Designing, modelling and CNC machining of 20"CPT MF-Jig-Retainer for colour picture tube.	0.750
M/s AIMIL Ltd.	Consultancy in the area of instrumentation and automation	0.500

Client	Title	Amount
M/s Bhilai Steel Plant	Consultancy in developing a technique for evaluating dimensional accuracy of blind holes	2.566
R&D Centre for Bicycle & Sewing Machines	Development of caliration facilities and methodology in dimensional metrology	1.550
M/s Amex Machine Tools	Modelling and CNC machining of turning components	0.220
BARC	Isotoropic and radiationally stable carbons	2.000
M/s GE BEL Pvt. Ltd.	Characterization of penning gauge	0.610
Central Board of Irrigation & Power	Studying the effect of AC/DC magnetic induction on performance of various types of energy meters	0.050
Central Board of Irrigation & Power	Studying the effect of AC/DC magnetic induction on performance of various types of energy meters.(extension of old project CNP/990832)	0.350
Regional Testing Center	To design. develop and fabricate the piston gauge pressure standard	2.990
M/s Unitech Machine Tools	Design, modeling and CNC machining of Mould Base Winker Lamp for Hero-Honda	0.500
M/S ADTRANZ, New Delhi	Locomotive strain gauge and displacement measurements	4.624
NSIT, New Delhi	Acoustic evaluation and selection of suitable sound reinforcement system of the auditorium at NSIT	0.500
Sophisticated Test & Instru-mentation Centre	To improve upon the accuracy in the pressure measured by the piston gauge pressure standard.	1.410
Tool Room Training Centre	Harmonic analysis & power factor improvement	3.800

Client	Title	Amount
M/s Canon Testing Services	Guidance to prepare the quality manual as per NABL criteria	0.500
Election Commission	To identify an unknown sample used to remove indelible ink	0.250
M/s Ravika Engineers	Establishment of a pressure standard laboratory in the hydraulic region	1.800
M/s Canon Testing Services	Assistance to maintain National Traceability in force measurements through Force Proving instruments used for verification of testing m/c	1.000
Ministry of Non-Conventional Energy Resources	Design and development of a mechanical load tester for determining the ability of a PV module to withstand wind snow and ice loads.	3.500
Total		39.37

APPENDIX : 6
EARNINGS FROM CALIBRATION/TESTING

Calibration

Physico-Mechanical Standards

Activity	Gr. Code	Reports	Charges (Rs.)
Length Standards	1	20	138600
Dimensional Metrology	2	622	3142050
Mass, Density, Volume & Viscosity	3	633	1861450
Force & Hardness Standards	4	590	4108900
Pressure & Vacuum Standards	5	164	1965000
Temperature Standards	6	506	1931600
Optical Radiation Standards	7	314	1749050
UV Radiation Measure Standards	8	17	70000
IR Radiation Standard	9	02	22000
Acoustic Standards	10	137	671950
Ultrasonics Standards	11	08	79800
Humidity Standards	12	27	72800
Fluid Flow Standards	13	10	76200
Total		3050	15889400

Electrical & Electronic Standards

AC & LF Standards (up to 1 kHz)	20	301	1717200
AC & LF Standards (CT/PT)	21	38	430600
D.C. Standards	22	61	516600
HF & Microwave Attenuation and Impedance Standards	23	03	20500
LF & HF Impedance Standards	24	59	261000
HF & Microwave Standards of Power, Voltage, Frequency & Noise	15	68	846600
Magnetic Measurement Activity	26	49	133000
Time & Frequency Standards	27	32	122350
Total		570	36977600

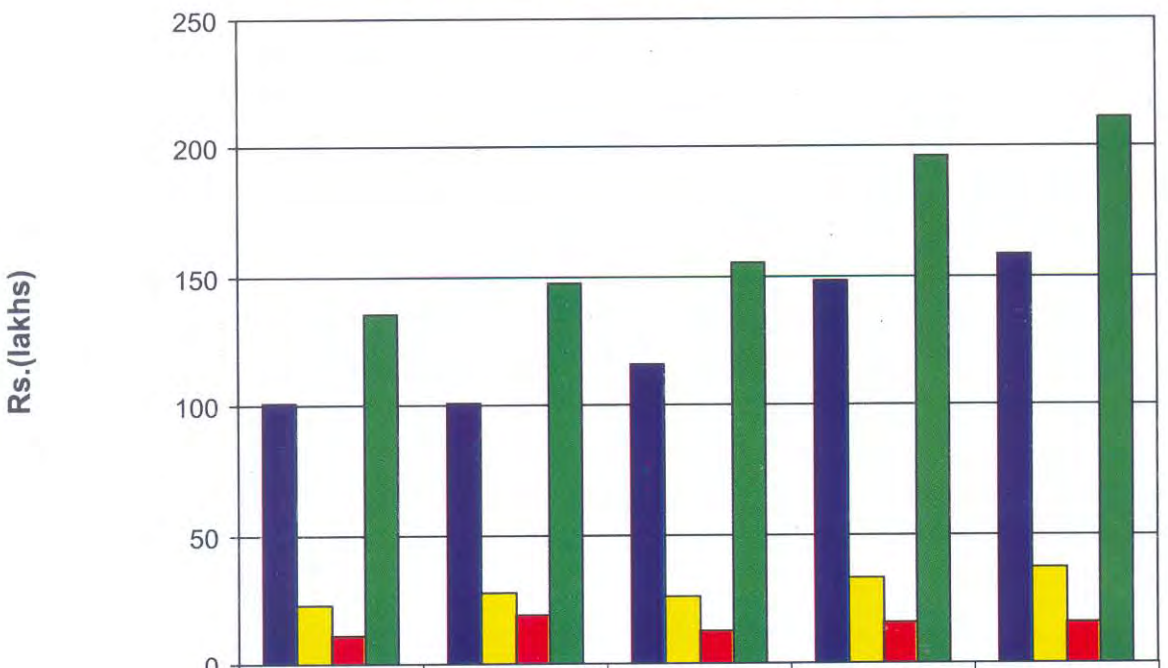
Testing

Activity	Gr. Code	Reports	Charges (Rs.)
Material Characterisation	30	0	3000
Chemical Analysis	31	80	514300
Indian Reference Material	32	10	171500
X-ray Analysis	33	02	16000
Electron Microscope Analysis	34	06	39800
EPR Analysis	35	01	60000
Materials Division	40	01	8000
Carbon Technology	42	02	6000
Metal & Alloys Group	43	20	48000
Electric Engineering	45	04	5000
Total		126	871600

Job Work

Piezoelectric Accelerometer	46	01	12600
Central Workshop	47	24	519900
Thin Film	48	01	22500
PSM	49	0	100000
Computer Centre	50	01	4000
ACR	51	01	3500
Total		28	662500
Grand Total		3774	21121100

YEARWISE FINANCIAL GROWTH FROM TESTING AND CALIBRATION SERVICES

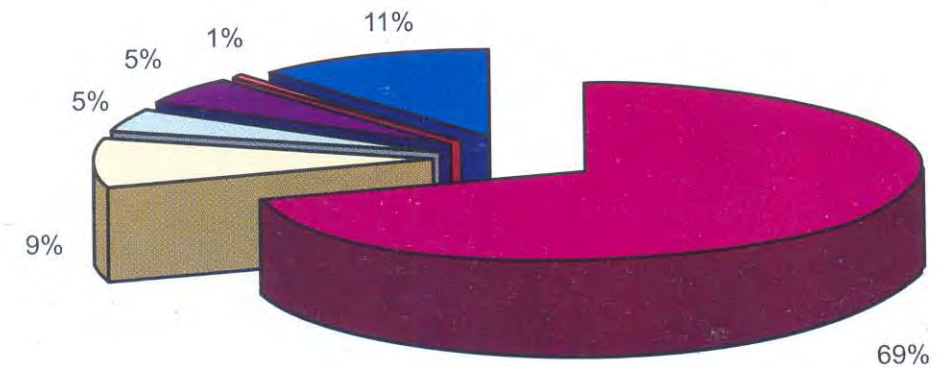


	1995-96	1996-97	1997-98	1998-99	1999-00
Phy.Mech. Std.	101.3	100.9	116.3	147.9	158.2
Elect.Std.	23.2	27.7	26.3	33.4	37
Other services	11.1	18.7	12.9	15.4	16.1
Total	135.8	147.8	155.5	196.6	211.3

APPENDIX : 7
ACTUAL EXPENDITURE

Budget Head	Rs (Lakhs)
Salaries (Pay & Allowances)	1773.128
Contingencies	225.826
Maintenance	113.828
Chemicals	115.540
Works & Services	15.533
Equipment	279.775
Total	2523.630
Sponsored Projects	252.265

ACTUAL EXPENDITURE (PIE DIEGRAM)



APPENDIX : 8
HONOURS & AWARDS RECEIVED

1999 CSIR Technology Shield was awarded this year to the Advanced Carbon Products Group for the development of advanced carbon products at NPL.

Physico-Mechanical Standards

Santa Chawla was awarded STA fellowship for three months by Japan Government.

Electrical & Electronic Standards

Dr. V.R.Singh won an Award for best research paper, at IEEE-EMBS Int Conf., Atlanta, Georgia (USA), Oct 13-16, 1999.

Dr.V.R.Singh was elected as a Member of the Senate of Thapar Institute of Engineering & Technology, Patiala

Materials Characterization

Dr. Krishan Lal, was invited by International Union of Crystallography to serve as Member, Programme Committe for the International Congress and General Assembly, Glasgow, Aug. 1999 and was also invited by INSA to lead the national delegation to this congress.

Dr. A.K. Agrawal honoured as Chartered Chemist by Institution of Chemists (India), Calcutta.

Dr.(Ms) Rashmi was awarded the STA fellowship, Japan.

Dr. O. P. Bahl (third from left), Head Advanced Carbon Products Group receiving the CSIR Technology Shield, 1999 from the honourable minister of State Sh. B.S. Rawat (second from left) and Prof. A.K. Raychaudhuri, Director, NPL (extreme left)

Radio and Atmospheric Sciences

Dr. S.L. Jain is a Member Programme committee AE04 SPIE's International Symposium on 'Optical Science & Technology', San Diego, USA, July 30-Aug 4, 2000.

Dr. S.L. Jain was invited to Chair Second International Asia-Pacific Symposium on: Remote Sensing of the Atmosphere, Environment, and Space, during 9 - 12 October 2000 at Sendai International Ctr., Sendai, Japan.

Dr. D.R. Lakshmi, member, Research Advisory Council, Indian Inst. of Geomagnetism, Bombay.

Dr. M.K. Tiwari was Co-Convenor along with Prof. Y.P. Abrol for the International Workshop on 'Historical Perspectives of Land-Use Land-Cover Changes in the Indo-Gangetic Plains Region in the Context of Study of Global Change' held during April 11-13 at Surajkund organised by South Asian START Regional Research Network for Study of Global Change, 1999.

Dr. M.K. Tiwari was Co-Convenor along with Dr. I. P. Abrol for the International Workshop on' Data Related Issues: Indo Gangetic Plains Region Land-Use Land-Cover Change in the Context of Study of Global Change' held during Oct. 3-7 at Gurgaon organised by European Network for Global Change Research (ENRICH) under its NELDA Programme.

Dr. K.K. Mahajan is

- Member COSPAR/URSI *Working* Group on IRI.
- Member, Editorial Board, Indian Journal of Radio & Space Physics.
- Member, Editorial Board, Indian Journal of Physics.
- Member, Governing Council, National MST Radar Facility, Deptt. of Space.

APPENDIX : 9
VISITS ABROAD

Sl. No	NAME		COUNTRY	DURATION	PROGRAMME
1.	Dr. R.B. Mathur	Sc.EII	USA	2.4.99 to 1.8.99	Raman Research Fellowship
2	Dr. Rashmi	Sc.EI	JAPAN	10.5.99 (45 days)	Govt. STA Fellowship, Japan
3	Dr. Harish Bahadur	Sc.EII	FRANCE	10.4.99 to 22.4.99	Attended the joint meeting of 13th European Frequency & Time forum & IEEE Int. Freq. Control Symposium
4	Dr. A. Sen Gupta	Sc.F	FRANCE	12.4.99 to 23.4.99	- do -
5	Dr. A. K. Bandyopadhyay	Sc.EII	ITALY	5.5.99 to 7.5.99 10.5.99 to 12.5.99	1) On Business development 3rd CCM Int. Conf. on pressure metrology at Italy 2) Working group meeting of CCM Paris
6	Dr. B. D. Malhotra	Sc.EII	JAPAN	16.5.98 to 19.6.98	Done Research in Kyushu
7	Dr. Ram Kishore	Sc.EII	UK	10.5.99 to 27.5.99	1) Equipment training on the operation of LEOSE 2) Visit to Univ. of Cambridge Oxford
8	Dr. K.N. Sood	T.O. A	UK	10.5.99 to 21.5.99	Equipment training on the operation of LEOSE
9	Dr. Santa Chawla	Sc.EII	JAPAN	22.5.99 (3 months)	STA fellowship, Japan
10	Dr. G.M. Saxena	Sc.EII	ITALY FRANCE	24.5.99 to 29.5.99 31.5.99 to 01.6.99	Attended Int.conf.on squeege states & uncertainty, held at Naples, Italy

Sl. No	NAME		COUNTRY	DURATION	PROGRAMME
11	Prof. A. K. Raychaudhuri	Director	RUSSIA	4.6.99 to 11.6.99	As a member of Indian deleg--tion under ILTP progs
12	Mr. A. C. Gupta	Sc.F	USA	14.6.99 to 16.7.99	Under USIF Project
13	Dr. S. K. Agarwal	Sc.EI	JAPAN	17.6.99 to 8.7.99	Carried out research work on high temp. superconductivityat Electro-Tech laboratory
14	Dr. O. P. Behl	Sc.G	USA	11.7.99 to 16.7.99	Attended 24th Biannual Conf. On carbon
15	Dr. S. C. Garg	Sc.G	BANGLADESH	10.7.99 to 14.7.99	To visit Bangladesh Res. Council & Nepal Agriculture Res. Council associated Institute.
16	Dr. Krishan Lal	Sc Director Gr.	JAPAN	14.7.99	2nd Int. Workshop of species 2000 COPAM 99 DST workshop 14th Global Environment at Tsukuba, Japan
17	Dr. S. M. Shivprasad	Sc. EI	GERMANY	16.7.99 to Dec. 99	To work with Prof. R.J.Bahm in the field of surface physics using STM
18	Dr. Krishan Lal	Sc Director Gr.	U.K.	4.8.99 to 13.8.99	As a member of INSA delegationto attend the 18th IC & General Assembly
19	Dr. N. Goswami	Sc C	U.K.	8.8.99 to 13.8.99	To Attend the 18th Int. Union of crystallography congress & General Assembly at Scotland
20	Dr. K.K. Mahajan	Sc G	USA CANADA	9.8.99 to 21.8.99	To Attend IRI Workshop at Lowel & Canada to attend URSI General Assembly at Toronto
21	Dr. P. Banerjee	Sc F	CANADA	13.8.99 to 24.8.99	To Attend the 26th General Assembly of Int. Union of Radio Sc.(URSI)at Toronto & Visit L&F Symp at NRC, Ottawa

Sl. No	NAME		COUNTRY	DURATION	PROGRAMME
22	Dr. A. Basu	Sc EII	FRANCE	22.9.99 to 25.9.99	To Attend Indo-French seminar on guided wave optics and applications to telecommunications at NICE France
23	Dr. Ram Kishore	Sc EII	USA	15.9.99 (1 year)	On sabbatical leave to Univ. of Arkansas USA
24	Dr. A. Sen Gupta	Sc F	SOUTH KOREA	29.9.99 to 2.10.99	To present lectures of Stds. Time & Freq. Signal Broadcast visiting Insat & others Geo satellite at SEOUL
25	Dr. Anil K. Gupta	Sc F	JAPAN	16.10.99 to 11.11.99	To work on Project No.1 of CSIR AIST SST cooperation under ITI framework
26	Dr. Rajiv Sikand	T.O. C	- do -	- do -	- do -
27	Dr. A. K. Raychaudhuri	Director	FRANCE	11.9.99 to 15.9.99	To attend BIPM Meeting
28	Dr. S. P. Verma	Sc F	TAIWAN	15.11.99 to 19.11.99	To participate in APMP General Assembly and Workshop at Ind. Technology Res.Institute
29	Dr. Ajay Dhar	Sc EI	CANADA	19.11.99 (1 Year)	On EOL to visit Queen's Univ. Canada as a Visiting Scholar
30	Dr. A. Sen Gupta	Sc F	USA	15.1.2000	Ongoing USIF project on Std Technique
31	Dr. B. D. Malhotra	Sc EII	USA	03-02-2000 to 24-02-2000	Immobilization of Projective/anzymes in semiconducting polymers
32	Dr. Krishan Lal	Sc Director Gr.	GERMANY	8.2.2000 to 6.3.2000	Under NPL-FZJ joint project
33	Dr. S. C. Garg	Sc G	BANGLADESH NEPAL	16.2.2000 to 23.2.2000 24.2.2000 to 29.2.2000	Visit Bangladesh Ag. Res. & Associt Inst. Nepal Agri. Res. Council Institutes

Sl. No	NAME		COUNTRY	DURATION	PROGRAMME
34	Sh. H. K. Maini	Sc EII	BANGLADESH	16.2.2000 to 21.2.2000	- do -
35	Sh. Alok Mukherjee	Tech. Assist	BANGLADESH	18.2.2000 to 23.2.2000	Under SASCOM planning Meet & CO2 Environment Workshop
36	Dr. M.K. Tiwari	Sc F	NEPAL	21.2.2000 to 1.3.2000	Participate in South Asian Rice Growth Res. under elevated CO2 conditions
37	Sh. T. K. Chakraborty	T.O. B	TAIWAN	1.3.2000 (6 months)	As Guest Researcher under Int. Scientific Instrument training prog
38	Dr. B. D. Malhotra	Sc EII	USA	30.6.2000	Technique immobilization of Projective/enzymes in semiconducting polymers

शोध सुविधाएँ व सहायक सेवाएँ

RESEARCH FACILITY AND SUPPORT SERVICES

यह प्रभाग निदेशक की अध्यक्षता में वर्ष 1997-98 में गठित किया गया था । क्रायोजोनिक्स व अन्य अति विशेष सुविधाएँ, तांत्रिक संगठन : उदाहरणार्थ केन्द्रीय कम्प्यूटर सुविधा, मुख्य वर्कशॉप, ग्लास टेक्नोलोजी वर्कशॉप, विद्युत वितरण, पम्पिंग, वातानुकूलन, सिविल वर्क्स, कैम्पस रख-रखाव, दूरभाष, फैक्स, फोटोग्राफी, लाइब्रेरी, आर.एण्ड. डी. व प्रशासन इकाइयों का प्रबन्धन व अन्य ऐसी सुविधाएं जिनका उपयोग सभी प्रभागों द्वारा होता है, इस प्रभाग के अधीन आते हैं । इसी का एक भाग तकनीकी सचिवालय (टेक्नीकल सेक्रेटरियट) कहलाता है। आंतिरक व बाह्य संयोजन प्राप्त अनुसंधान एवं विकास परियोजनाओं का नियोजन व समन्वयन, मार्केटिंग व तकनीकी ज्ञान का हस्तान्तरण, विभिन्न विदेश कार्यक्रमों में भ्रमण, पेटेंटों का निवेदन व पंजीकरण, मानवीय संसाधनों का संवर्धन, प्रयोगशाला के डाटाबेस का प्रबन्धन, राजभाषा विषयक प्रसारण व प्रयोगशाला के तकनीकी प्रकाशन ये सभी इकाइयां तकनीकी सचिवालय के अंतर्गत कार्यरत हैं। क्रायोजेनिक्स के क्षेत्र की गतिविधि पिछले अध्याय में प्रस्तुत की गई है । इस प्रभाग की अन्य गतिविधियां संक्षेप में यहां दी गई हैं। गत् वर्ष में स्थापित एन पी एल-लैन के प्रयोगकत्ताओं के लिए एन पी एल वेबसर्वर पर वेबसाइट की सुविधाओं का प्रावधान इस वर्ष कर दिया गया है।

This Division was constituted during 1997-98, with Director, NPL as its head. Cryogenic and some other sophisticated instruments facilities, technical infrastructure - such as, central computer facility, main workshop, glass technology workshop, electrical supply, pumping, air-conditioning, civil works, campus maintenance, phones, fax, auditorium, photography, library, R&D management and administration units, that provide support to and are shared by all the other divisions, whose R&D activities are given in the preceding chapters of this report, function under this division. The Technical Secretariat, one of the units of this Division is responsible for planning and coordination of all in-house and externally supported R&D projects, marketing and transfer of technological know-how developed indigenously, processing of deputation under various international collaborative programmes, filing of patent, human resource development programmes, maintaining laboratory information data bases, propagation of Rajbhasha and bringing out technical publications of the laboratory. Activities in the area of cryogenics were described in the previous chapter. The rest of the activities of this Division are briefly presented here. Website for internal users of Intranet was established by creating webserver on NPL-LAN.

Central Computer Facility

The CCF provides services through an array of PC's, workstations and a library of software that serve as common user facility. It also administers NPL-LAN and Internet services through satellite via a VSAT. Facilities added during the year include the following:

- Intranet facilities were set up over the NPL-LAN installed last year with approximately 275 nodes distributed over the campus. An Apache webserver was configured and set up on a Sun workstation and an NPL Website launched for internal users.
- A Database server using PostgreSQL was set up on a LINUX machine. It was Web enabled for ease of use by all NPL users. Events and Announcements, Library information, and Manpower information are provided on this Intranet site.
- Servers were upgraded. The Name Server was speeded up by installation of the same on a LINUX machine and introducing caching.

On Y2K a laboratory wide exercise was undertaken to check, identify and correct all computer equipment, software and embedded systems for Y2K compliance. The exercise was completed successfully in time.

Library and Technical Information Services

NPL library is a leading repository of publications in physics and related sciences in the country. During the year it strengthened its collection by acquiring new books and journals on need basis. It spent Rs. 85.16 lakhs for this purpose – Rs. 80.65 lakhs on journals and the rest Rs. 4.51 lakhs on books. During the year it subscribed to 140 journals and purchased 145 books. Its collection by the end of the year stood at 43192 books and 65000 volumes of bound journals.

Named as KSK Library, in the honour of the first director of the laboratory, late Sir K S Krishnan, the NPL Library is gradually transforming itself into an electronic library. During the year it has started dial-up service for Internet access as a central facility in the library and has also created a web page on the NPL intranet. The library web page provides Internet access to information on journals of current subscription, new issues received in the current week, current contents of electronic journals, impact factor of journals, etc. It also provides links to electronic journals, electronic libraries, publishing houses of electronic journals, etc. The page is updated weekly. The page also provides to its users Internet access for performing e-mail, www, ftp and telnet functions. It also subscribed to four leading CD-ROM databases in physical sciences - Current Contents: Physical, Chemical & Earth Sciences, Current Contents: Engineering, Technology and Applied Sciences (both with reference additions), Material Science Citation Index and INSPEC. The library continued to perform its house keeping function on computer using a Library Information Package developed in house.

The library also continued to provide services like selective dissemination, literature search, access to bibliographical databases available in-house, inter-laboratory loan, document supply, photography, etc.

Technical Services

Responsibility of general maintenance of infrastructure like electricity, pumping, air conditioning, telephones, fax, photography service, auditorium, maintenance of campus and colony, civil works, etc. lies with this section.

Workshops

Central Workshop:

Different types of machining facilities have been established in NPL to extend support to laboratory's R&D need and to outside orders. Its mechanical workshop has milling machine, lathe machine and welding etc., for normal fabrication and machining of mechanical jobs. NPL workshop has established a CNC milling facility backed up by a CAD-CAM facility. The machine has high precision German 'Deckel FP4A' universal milling machine, CNC rotary table. In addition to CNC milling machine workshop has Gildemeister CT-200 CNC lathe machine capable of producing turned components.

Workshop has also AutoCAD based drawing and tracing facilities. This year Central Workshop has completed 1216 jobs for NPL users and 26 for outside users. Rs. 7 lakhs has been generated as ECF this year.

In addition to this NPL has high pressure and metal extrusion shops, which cater services to in-house and outside world on contract basis.

Glass Technology Unit:

In addition to NPL job, this unit also undertakes job work from outside users. This year GTU has processed 201 jobs for NPL and 39 jobs for outside users and earned Rs. 2.95 lakhs as ECF. The highlight of activities this year was the challenging task of erecting at an external site, namely, the R & D Centre of IOC at Faridabad, a large glass flow set up usable in dual solid studies (Fig. 10.1).

Technical Secretariat

Planning and Coordination:

This Group coordinates all the projectised activities of the laboratory, including in-house, collaborative, sponsored and grant-in-aid projects. It keeps track of current manpower deployment. On these it collects information, analyses it and places it to top

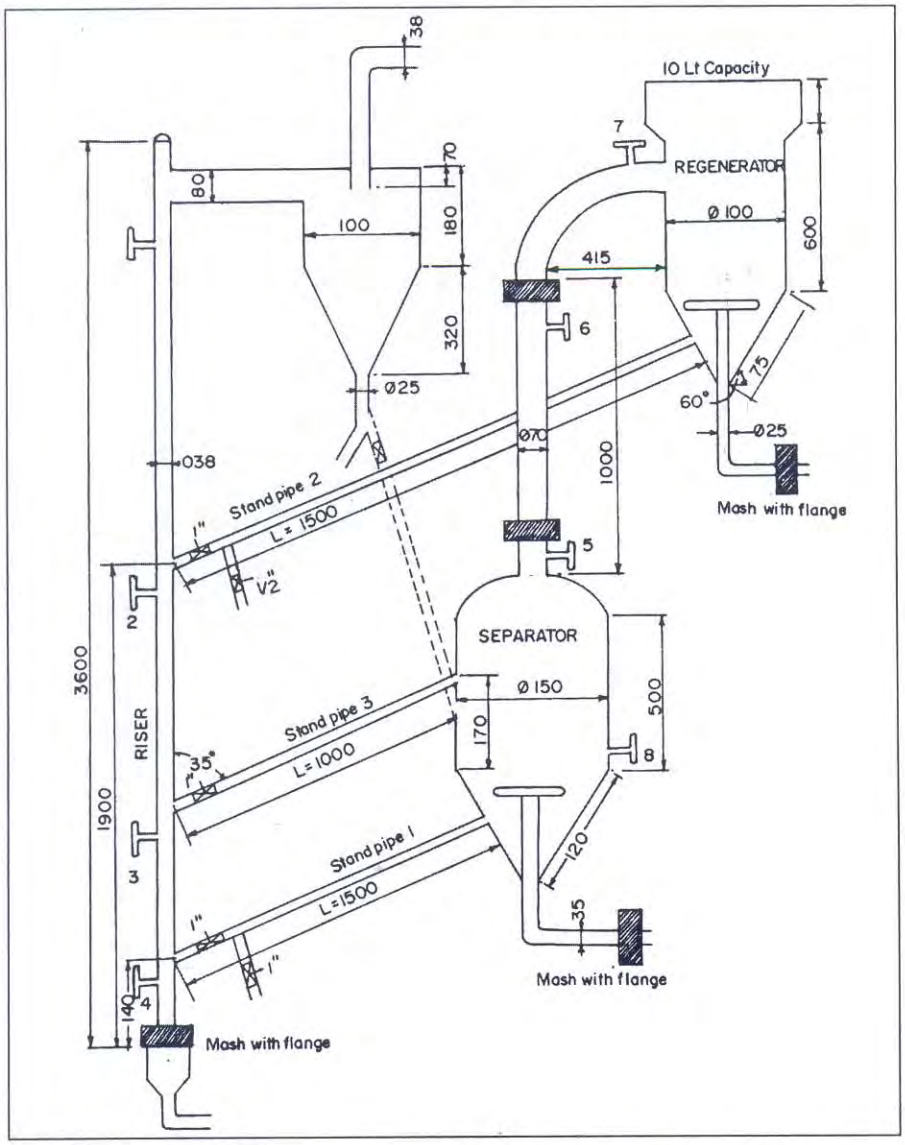


Fig 10.1 : Schematics of the 4 metre tall large glass flow set up erected by NPL's Glass Technology Unit at IOC, Faridabad

management for decision making. During the year the group handled 48 grants-in-aid and 32 collaborative projects. The group also handles coordination in matters related to the Research Council.

Intellectual Property Right:

Realizing the strategic importance of intellectual property in the ever-changing global economic scenario, this totally independent cell was created last year. Its main thrust is to manage in totality the IP portfolio of the laboratory. This includes not only to help scientist to file patent of the R&D outputs but also to scout around and look for the possibility to protect any R&D output, which otherwise might be missed by the scientists for taking protection.

During this year two seminars were organised for the benefit of scientists. Deliberations were made by external experts in the field like Mr. Shanti Kumar, ex-controller of patents and patents attorney from M/s Anand and Anand, , Mrs. L. Balasubramanyan, Head, and Mr. A.K. Bose, Mr. R.K. Gupta , Dr. Indra Dwivedi, Scientists, IPMD, CSIR, New Delhi.

During this year 8 patents have been filed in India of which three patent applications have been filed in foreign countries also.

Marketing Group:

This cell is totally responsible for marketing and liasoning of technological know-how transfer of the laboratory. This group have arranged the participation in iITF-99 at Pragati Maidan, New Delhi,14-27 Nov.1999, and Swadeshi Mela at IIT, Delhi, 2-6 Feb. 2000, to exhibit NPL developed R&D Prducts.

International Science & Technology Affairs Group (ISTAG):

This group is responsible to maintain and process application of scientists for deputation abroad. This cell also arranges K. S. Krishnan Memorial lectures, invited talks, and special lectures for scientists by visitors. ISTAG have processed applications for deputations of NPL staff to various international seminars/conferences/visits/ exchange programmes, etc. Dr. K. S. Krishnan memorial lectures and other special lectures were also organized These are listed in respective appendices.

Human Resource Development Group (HRDG):

This Group arranges various training programmes for the benefit of NPL staff and also the training courses offered by NPL for the benefit of industries in various areas of calibration. The group also supports organization of various symposia, conferences etc. by NPL staff at NPL. It also attends to various PR activities and follows up various MoUs with educational institutions in respect of doctoral, post-graduate and summer training on reciprocal basis. It processes induction of JRFs, SRFs and Research Associates for NPL programmes. The Group also pursues other schemes of CSIR on EMR and HRD activities. List of training programmes and other events organized by the group is given in the Appendix.

Publication and Documentation:

This cell is responsible for compiling, editing, printing and distribution of Annual Reports and other documents informing about laboratory's activities. A monthly circular 'NPL-Info' for internal consumption is also being brought out in printed form. This unit also compiles monthly and annual inputs to go from NPL for CSIR level reports.

Rajbhasha Unit:

This unit is looked after by both the office of COA and also the Technical Secretariat and helps scientists in Hindi transcription of their papers, articles, reports, etc. This year also the Hindi unit arranged various training programmes. Hindi fortnight was celebrated in the month of September to encourage use of Hindi in all official proceedings and also to encourage writing of R&D outputs in Hindi for the benefit of the society. As per Govt. of India directives the Unit arranges selection of, for cash awards, NPL employees who contribute most to the propagation of Hindi in office work. Cash awards are given to winners in various categories. Detailed report of the Unit is given in Hindi in the following pages.

वर्ष 1999-2000 के दौरान राष्ट्रीय भौतिक प्रयोगशाला में राजभाषा की प्रगति

PROGRESS OF RAJBHASHA IN THE LABORATORY

वर्ष के दौरान प्रयोगशाला ने कार्यान्वयन की दिशा में उल्लेखनीय सफलता प्राप्त की है । राजभाषा नीति के अनुपालन और कार्यान्वयन हेतु इस प्रयोगशाला द्वारा निरंतर प्रयास किए जा रहे हैं। प्रयोगशाला के लगभग सभी अधिकारी/कर्मचारी हिन्दी का कार्यसाधक ज्ञान रखते हैं ।

राजभाषा अधिनियम 1963 की धारा 3(3) के अन्तर्गत जारी किए जाने वाले सभी परिपत्र, आदेश, ज्ञापन आदि द्विभाषी रूप में जारी किए गए ।

वर्ष के दौरान प्रत्येक तिमाही में कार्यान्वयन समिति की बैठक बुलाई गई तथा बैठक में लिए गए निर्णयों पर सफलतापूर्वक अनुवर्ती कार्यवाही की गई । राजभाषा विभाग गृह मंत्रालय द्वारा तैयार किए गए वार्षिक कार्यक्रम पर विस्तार से चर्चा हुई तथा निर्धारित लक्ष्यों को प्राप्त करने का पूरा-पूरा प्रयास किया गया ।

प्रयोगशाला में 7.7.1999 को एक दिवसीय विज्ञान संगोष्ठी का आयोजन किया गया । इस संगोष्ठी में प्रयोगशालाओं में लगभग 40 वैज्ञानिकों/अधिकारियों ने सक्रिय रूप से भाग लिया । संगोष्ठी में लगभग बीस वैज्ञानिकों द्वारा हिन्दी में अपने क्षेत्र से संबंधित लेख प्रस्तुत किए गए ।

राजभाषा के प्रगामी प्रयोग के अनुपालन हेतु राष्ट्रीय भौतिक प्रयोगशाला में 1.9.1999 से 14.9.1999 तक हिन्दी पखवाड़ा मनाया गया । इस अवधि के दौरान विभिन्न प्रतियोगिताओं का आयोजन किया गया । प्रयोगशाला के लगभग 110 सदस्यों ने इसमें सक्रिय रूप

चित्र 10.2: हिन्दी पखवाड़े के समापन समरोह पर पुरस्कार वितरण करते हुए निदेशक महोदय डा. कृष्ण लाल (बाएं से तृतीय)

से भाग लिया । दिनांक 14.9.1999 को पुरस्कार वितरण के अवसर पर कार्यकारी निदेशक डा. कृष्ण लाल ने कर्मचारियों से अपील की कि हमें संविधान में प्रतिष्ठित राजभाषा हिन्दी के विकास संबंधी सभी उद्देश्यों की पूर्ति में अपना भरपूर सहयोग देना चाहिए । राजभाषा कार्यान्वयन समिति के सदस्य डा. नीरज खरे ने धन्यवाद देकर कार्यक्रम का समापन किया (चित्र-10.2)।

वर्ष के दौरान तिमाही हिन्दी पत्रिका 'समीक्षा' के चारों अंकों का प्रकाशन किया गया । विभिन्न वैज्ञानिकों ने मूलतः हिन्दी में वैज्ञानिक लेख लिखे जिनकी जांच करना, टाइप करना, उसके सम्पादन का कार्य व अन्य सभी औपचारिकताएं राजभाषा यूनिट द्वारा सम्पादित की गईं। वर्ष के दौरान प्रत्येक तिमाही में हिन्दी में किए गए कार्य की प्रगति रिपोर्ट 1999-2000 (अप्रैल-जून, जुलाई-सितंबर, अक्तूबर -दिसंबर, जनवरी-मार्च) सी.एस.आई.आर. मुख्यालय भेजी गई ।

वर्ष 1999-2000 में वैज्ञानिकों के अपार के फार्मों का अनुवाद किया गया, जिससे कि वे द्विभाषी रूप से तैयार किए जा सकें । विभिन्न अनुभागों से प्राप्त नामपट्ट व रबड़ की मुहरों को द्विभाषी रूप से तैयार किया गया ।

प्रयोगशाला में प्रयुक्त होने वाली टेलीफोन डायरेक्टरी का हिन्दी अनुवाद कर उसे द्विभाषी रूप से प्रकाशित किया गया जो वास्तव मे एक बहुत बड़ी उपलब्धि है । राजभाषा यूनिट द्वारा किया गया यह प्रयास सराहनीय रहा क्योंकि यह डायरेक्टरी राजभाषा विभाग, गृह मंत्रालय द्वारा तैयार किए गए वार्षिक कार्यक्रम में निहित लक्ष्यों को पूरा करने के साथ-साथ प्रयोगशाला के अधिकारियों/कर्मचारियों के लिए भी उपयोगी सिद्ध हुई है ।

APPENDIX : 10
Ph.D. AWARDS BASED ON RESEARCH WORK AT NPL

Title	Awardee	University/Institute	Guides
Studies of Hot Extruded Characteristics of 2124 Al – Si Cp MMCs	R. K. Goswami	University of Delhi, Delhi	Dr. Anil K. Gupta, NPL
Experimental and theoretical studies of some conjugated polymers and their interface with metals	N.N. Beladakere	Jamia Milia Islamia, New Delhi	Dr. B.D. Malhotra, NPL Prof. Pankaj Sharan, Jamia Milia Islamia
Multiphase Measurements of Atmospheric Acidity in Delhi region	Monica Jain	Dr. Bhim Rao Ambedkar University, Agra	Dr. D.C. Parashar, NPL Dr. Ashok Kumar, Agra
Electrical and Magnetic Behaviour of MBE Grown Thin Films of Pervoskite Materials	Hazi Shirin Zadeh	University of Delhi, Delhi	Dr. V. S. Tomar, NPL Dr. Shahnawaz, University of Delhi, Delhi

APPENDIX : 11
TRAINING PROGRAMMES ARRANGED

Training Courses Organised For Industries

- Training course on Mass Metrology, 28 Jun-2 July '99
- NPL- Industry Interaction, 23 October '99
- Training Course on Dimensional Metrology, 25-19 October '99

Training Programmes Organized for NPL Staff:

- In house training programme for Admn. Staff on administrative rules & regulations, 19-25 May '99
- Training course on Windows 98 , MS Office 97, Internet & E-Mail, 4-15 October '99
- Training course on Windows 98, M/S Office 97, Internet & E-Mail, 1-12 November '99
- Awareness Programme on IPR issues, 16 December '99
- Training course on windows 98, MS Office 97, Internet & E-Mail, 21 Feb-3 Mar '00
- Course on C++ , 13-24 March '00
- Course on Vacuum Technology, 27-29 March '00

Post Graduate Dissertation Work Completed at NPL

- "Measurement of microwave parameters and study of Gunn oscillator" a M. Tech Dissertation by Shri A.K. Sethi, of the post-graduate course in Microwave electronics, University of Delhi, guided by Dr. Ram Swarup, Electrical and Electronic Standards, NPL.
- "Sodar measurement of atmospheric stability classes", a M. Tech Dissertation by Shri Kh. Gajananda of Department of Environmental Science & Engineering, Guru Jambheshwar University, Hisar, May, 1998 guided by Dr.H.N. Dutta, RASD, NPL (Co-Guide Prof. Asha Gupta, G. J. University).
- One M.Sc. (Physics) final year student of Dayal bagh Educational Institute, Agra took training on Porous Si as Anti-reflection coating on Si solar cells during the period 31.5.99 to 25.6.99.

APPENDIX : 12
CONFERENCES, SYMPOSIA AND WORKSHOPS ORGANISED BY NPL

15-16 April '99

Workshop on SROSS-C2 Data Analysis.

16-17 September '99

National Symposium on Bimolecular Electronics Interfacing Physics and Chemistry with Biology.

17-19 November '99

Workshop on Modern Quartz working Techniques & Associated Problems.

22November'99

User-researcher Interaction Seminar in the area of 'Fixed and Mobile Communications.

25 November '99

National Conference on Carbon.

International Conference & Exhibition on Ultrasonics (ICCU - 99).

22 - 23 February '00

Workshop on Frontiers of Precision Forging.

APPENDIX : 13
SPECIAL LECTURES

S. No.	Speaker's Name and Affiliation	Topic	Date
1.	Dr. Ragis Vanderhghen France	Use of in-situ Ellipsometry & RMC for the knowledge of Micro-Crystalline properties	14.6.99
2.	Dr. V. T. Chitnis On deputation from NPL	India-Japan Science and Technology Cooperation	10.9.99
3.	Dr. Loh & Ms Chaua Al Ming, Singapore	Shimadzu Thermal Analysis Instrument DSC	13.9.99
4.	Dr. Kalaga Murli Krishna Nagoya, Japan	Semiconducting Carbon-New Approaches, Properties and Applications	29.10.99.
5.	Prof. W. Haase, Germany	Characterization of Polymers for electro-optical applications	02.12.99
6.	Prof. M.S. Valiathan*	Conquering Heart Disease	10.12.99
7.	Prof. M.M.Sharma (FRS)*	Role of innovation in the context of chemical technology	14.12.99
8.	Prof. J. V. Narlikar*	Some outstanding problems on the frontier of Physics and Astronomy	20.12.99
9.	Prof. C.N.R. Rao (FRS)*	New directions in the design of exotic materials	13.1.2000
10.	Prof. Hiroshi Kobayashi	Display technology and science including CRT, PDP and EL	17.1.2000
11.	Prof. Eduard Nagev	Magnetroimpurity Theory of the colossal magnet resistance materials	19.1.2000
12.	Prof. Tamio Endo, Japan	Why oxygen plasma is more effective on crystal growth of Ca – doped Bi 2201 thin films	28.1.2000

* These lectures formed Krishanan Birth Centenary Lecture Series.

S. No.	Speaker's Name and Affiliation	Topic	Date
13.	Dr. Tsuruta, Japan	Greenhouse gas emissions from terrestrial ecosystem	07.2.2000
14.	Dr. J. E. Bouree, Frane	Thin film microcrystalline sillicon for photovoltaic applications	09.2.2000
15.	Dr. E. K. Smith, Japan	VHF Sporadic-E in Japan	10.2.2000
16.	Dr.St. Even Lorentz, USA	NIST Electrical Substitution Radiometer for improved accuracy in radiometry	15.2.2000
17.	Dr. Robert Saunders	Optical Temperature Measurement & Research	16.2.2000

Prof. J.V. Narlikar (speaker), Prof. A.K. Raychaudhuri, Dr R.G. Sharma (L to R)

Dr. R.G. Sharma, Prof. S.K. Joshi, Prof. R.A. Mashelkar, Prof. C.N.R. Rao (speaker) Prof. A.K. Raychaudhuri (L to R)

Prof. M.S. Valiathan (speaker)

KRISHNAN BIRTH CENTENARY LECTURE SERIES

Prof. M.M. Sharma (speaker)

APPENDIX : 14
HUMAN RESOURCES

As on March 31, 2000

S.No.	Category	Grade	Number
(A).	*Scientific & technical Staff*		
1	Scientific Staff	Group IV	247
2	Technical Staff	Group III	134
	Sub-Total	1 + 2	381
3	Engineering Cadre Staff	Group V	---
4	Supporting Technical Staff	Group II	296
5.	Supporting Technical Staff	Group I	103
	Total S&T Staff		780
(B).	*Administrative & Non-Technical Staff*		
6	Administrative (Gazetted)	Group A	7
7	Administrative (Gazetted)	Group B	17
8	Administrative (Non-Gazetted)	Group B	69
9	Administrative (Non-Gazetted)	Group C	70
10	Non-Technical Staff	Group D	111
	Total Administrative & Non-Tech. Staff.		274
	GRAND TOTAL (A) + (B)		1054

Scientists and Officers as on 01. 04. 2000

(listed in order of Gr. IV to Gr. III.)

Director
A K Raychaudhuri

Standards

Chief Metrologist
B S Mathur

Physico-Mechanical Standards Division

Head
Dr. S. P. Verma

LENGTH

Scientist E-II
V G Kulkarni

Scientist E-I
Santa Chawla

Scientist B
Rina Sharma

TO E-I
B K Roy
A K Kanjilal

DIMENSIONAL METROLOGY

Scientist F
R P Singhal

Scientist E-I
K P Chaudhary
M Karfa

TO E-I
V Roonwal
N K Aggarwal

TO C
S L Thind

MASS

Scientist E-II
S N Nangia
Tripurari Lal
M L Das

Scientist C
S Sinha

Scientist B
T K Parameshwaran

FLUID FLOW

Scientist E-II
J N Som
Raj Singh

TO E-I
Virendra Babu

TO A
I S Tak

FORCE

Scientist F
K K Jain

Scientist E-II
S K Jain
J K Dhawan
M K Chaudhuri

Scientist E-I
Ganga Prasad
Anil Kumar

Scientist B
S S K Titus
Rajesh Kumar

TO B
V D Arora

TO A
H K Jain

PRESSURE & VACUUM

Scientist F
A C Gupta

Scientist E-II
A K Bandyopadhyay
D R Sharma
B R Chakraborty
Pardeep Mohan
S M Shivaprasad

Scientist B
D Arun Vijay Kumar
Sanjay Yadav
Nita Dilawar

TEMPERATURE

Scientist E-II
Y P Singh

Scientist E-I
N K Srivastava

TO C
S K Nijhawan
J K Gupta

TO A
Gurcharanjit Singh

OPTICAL RADIATION

Scientist F
J S Vaishya

Scientist E-II
H C Kandpal

TO C
Jai Bhagwan

ULTRAVIOLET RADIATION

Scientist E-II
R S Ram
Om Prakash
R K Garg

INFRARED RADIATION

Scientist F
S P Verma

Scientist E-II
D Gupta

Scientist E-I
Ranjana Mehrotra

ACOUSTICS

Scientist F
V Mohanan

Scientist E-II
BS Gera
Omkar Sharma

Scientist E-I
R M Khanna

Scientist C
Mahavir Singh

TO B
V K Ojha

TO A
Gurbir Singh

ULTRASONICS

Scientist F
Janardan Singh

Scientist E-II
Ashok Kumar
Ved Singh
Mukesh Chandra

TO C
Subhash Chandra

TO B
Reeta Gupta
N C Soni

TO A
G S Lamba
V K Hans
Yudhisther Kumar

ELECTRICAL & ELECTRONIC STANDARDS DIVISION

Head
Dr. A. K. Gupta

TIME & FREQUENCY

Scientist G
B S Mathur

Scientist F
P Banerjee
A Sen Gupta

Scientist E-II
G M Saxena
A K Hanjura

Scientist E-I
M Saxena
A Chatterjee

Scientist B
C Sri Kumar

TO B
Gurdial Singh
A K Suri

DC STANDARDS

Scientist E-II
S K Mahajan

Scientist C
Ajeet Singh

TO C
P K Mittal

JOSEPHSON VOLTAGE STANDARD & SUPER-CONDUCTING DEVICES

Scientist G
A K Gupta

Scientist E-II
N D Kataria
V N Ojha

Scientist E-I
Vijay Kumar
Neeraj Khare

Scientist C
M M Krishna

TO A
A K Goel

HF IMPEDANCE & AC, LF STANDARDS

Scientist E-II

O N Khanna
S R Gupta
M K Mittal
A K Saxena

Scientist E-I
Kewal Krishan
Naib Singh

Scientist C
J C Biswas

TO C
A R Kaushik

TO A
Mohammad Saleem

HF & MW VOLTAGE POWER, POWER FREQUENCY & ATTENUATION

Scientist F
R S Yadava
Ram Swarup

Scientist E-II
V K Rustagi
A K Govil
Ritander Aggarwal

Scientist E-I
P S Negi
Ranjit Singh *
(* Abroad on EOL)

TO C
R L Mendiratta

MAGNETIC STANDARDS

Scientist F
P C Kothari

Scientist E-I
R K Kotnala

INSTRUMENTATION

Scientist F
V R Singh

Scientist E-II
R B Tripathi

TO C
Y P S Negi

NABL PROGRAMME

Scientist E-II
Mahesh Chander

Scientist E-I
J L Pandey

TESTING & CALIBRATION

Scientist E-II
H S Dahiya
M L Sharma

TO B
S P Sharma
P C Sharan

TO A
G K Kapoor
J N Prasad

ENGINEERING MATERIALS DIVISION

Head
Dr. A. K. Gupta

METALS & ALLOYS GROUP

Scientist F
Anil K Gupta

Scientist E-II
R C Anandani

Scientist E-I
Ajay Dhar

Scientist B
A K Srivastava

TO E-I
I A Mallik

TO C
Rajiv Sikand

TO B
H B Singh

TO A
Rakesh Khana

ADVANCED CARBON PRODUCTS

Scientist G
O P Bahl (sperannuation on 31-10-99)

Scientist F
Gopal Bhatia

Scientist E-II
R B Mathur
R K Aggarwal
Vasantha Raman
T L Dhami

Scientist E-I
C Lal

Scientist C
S R Dhakate

TO B
P R Sen Gupta

HIGH PRESSURE GROUP

Scientist E-II
B P Singh

S K Singhal
Rajeev Chopra

TO B
K D Sharda

ELECTRONIC MATERIALS DIVISION

Head
Dr. B. K. Das
(technical resignation 28-12-99)

Scientist G
B K Das
P K Ghosh

Scientist F
R Bhattacharya
S N Singh
A C Rastogi

Scientist E-II
S N Ekbote
S T Lakshmi Kumar
Virendra Shanker
Harish Chander
Mohan Lal
B C Chakravarty
P K Singh
B S Verma
A Basu
P N Dixit
M Kar
O S Panwar
S S Rajput

Scientist E-I
Kiran Jain
N K Arora

Scientist C
K M K Srivatsa
C M S Rauthan

Scientist B
G K Padam
V K Shankarnarayanan
T D Senguttuvan
Santosh Singh

TO E-I
H S Kalsi
R C Goel

TO C
S K Sharda
B S Khurana
M K Banerjee
Ravi Kumar

TO B
T K Chakraborty
T K Bhattacharya
Mukul Sharma

POLYMERIC & SOFT MATERIALS DIVISION

Head
Dr. R. Bhattacharyya

Scientist G
Subhas Chandra
(superannuation on 31-1-2000)

Scientist F
S C Jain
S S Bawa

Scientist E-II
MN Kamalasanan
S C K Misra
Suresh Chand
A M Biradar
S A Agnihotri
Ramadhar Singh
B D Malhotra
C P Sharma

Scientist E-I
S Dwivedi
R K Sharma
S K Dhawan

Scientist C
K K Saini

Scientist B
K L Yadav

TO B
G D Sharma

TO A
Chander Kant

MATERIALS CHARACTERIZATION DIVISION

Head
Dr. Krishan Lal

CRYSTAL GROWTH AND CHARACTERIZATION

Sc. Dir. Grade
Krishan Lal

Scientist E-II
R V Anthamurthy
S K Haider
G Bhagavannarayana

Scientist E-I
S N N Goswami

Scientist B
K K Maurya

TO A
S K Rastogi

INDIAN REFERENCE MATERIALS

Scientist E-II
A K Agarwal

TO A
R K Saxena
Abha Bhatnagar

X-RAY ANALYSIS

Scientist E-II
D K Suri

Scientist E-I
Rashmi
R P Pant

TO A
D P Singh

ANALYTICAL CHEMISTRY

Scientist E-II
A K Sarkar
R. Ramachandran
Prabhat Kumar Gupta

Scientist B
Nahar Singh

TO B
R C Sharma
M K Das Gupta
Niranjan Singh

ELECTRON MICROSCOPY

Scientist G
S K Sharma

Scientist E-II
Ram Kishore
Kasturi Lal

Scientist C
Sukhvir Singh

Scientist B
A K Srivastava

TO B
K N Sood

EPR SPECTROSCOPY

Scientist E-II
S K Gupta

TO A
Manju Arora

RADIO AND ATMOSPHERIC SCIENCES DIVISION

Head
Sh. S. C. Garg

Scientist G
S C Garg

Scientist F
D R Lakshmi
M K Tiwari
S L Jain
P K Banerjee
A B Ghosh
H N Dutta
R C Saksena

Scientist E-II
S K Sarkar
Lakha Singh
R K Pasricha
K S Zalpuri
M C Sharma
P N Vijaya Kumar
M K Goel
Mahendra Mohan
Madhu Bahl
S D Sharma
R S Dabas
D R Nakra
P Subrahmanyam
M V S N Prasad
B C Arya
R S Arora
J K Gupta
V K Pandey
N K Sethi
S K Singhal
H K Maini

Scientist E-I
V K Vohra
P Chopra
Thomas John
Jayanta Kar
Risal Singh
C B Tandel
Meena Jain

Scientist C
R S Tanwar

TO C
S K Shastri

TO B
D B Sharma
Raksha Marwah
D B Singh
V S Yadav
Iqubal Ahmed
S K Bhatia
R Kohli

TO A
D S Chaunal
Shambu Nath
A K Goghar

CRYOGENICS FACILITIES

Head
Dr. R.G. Sharma

Scientist E-II
Hari Kishan
R B Saxena
S S Verma

Scientist E-I
B V Reddi
P L Upadhauya

Scientist B
M A Ansari
Dipten Bhattacharya

TO A
Bhikam Singh
M C Singh

SUPERCONDUCTIVITY DIVISION

Head
Dr. R G Sharma

Scientist G
R G Sharma

Scientist E-II
B V Kumaraswamy
P K Dutta
Ramji Rai

Scientist E-I
S K Agarwal

Scientist C
U C Upreti
Ratan Lal

Scientist B
Anurag Gupta

TO C
S B Samanta

TO B
V S Yadav

RESEARCH FACILITY & SUPPORT

P & C, MARKETING AND ISTAG

Scientist E-II
P K Ashwini Kumar
N K Babbar
F C Khullar

Scientist E-I
T K Chakraborty
S K Sharma
Shikha Mandal
Indra Tewari
D P Bhatt

TO C
K Chibber

TO A
A K Suri

LIBRARY

Scientist F
SM Dhawan

Scientist E-I
DK Tewari

Scientist B
NK Wadhwa

TO B
Hasan Haider
Jagdish Prasad

TO A
S Bhatnagar

CCF

Scientist E-II
Ravi Mehrotra

Scientist B
Sher Singh

TO A
Kanwaljit Singh
Ashok Kumar
Vijay Sharma

WORKSHOP

Scientist F
S C Gera

Scientist E-II
H N P Poddar

TO C
Ravi Khanna
Ram Swarup

PUBLICATION & REPORTS

Scientist E-II
V S Tomar

Scientist C
N S Verma

TO A
V K Sharma

GLASS WORKSHOP

TO E-I
Mohan Lal

TO C
Karnail Singh

TO A
R K Saxena
Abha Bhatnagar

X-RAY ANALYSIS

Scientist E-II
D K Suri

Scientist E-I
Rashmi
R P Pant

TO A
D P Singh

ANALYTICAL CHEMISTRY

Scientist E-II
A K Sarkar
R. Ramachandran
Prabhat Kumar Gupta

Scientist B
Nahar Singh

TO B
R C Sharma
M K Das Gupta
Niranjan Singh

ELECTRON MICROSCOPY

Scientist G
S K Sharma

Scientist E-II
Ram Kishore
Kasturi Lal

Scientist C
Sukhvir Singh

Scientist B
A K Srivastava

TO B
K N Sood

EPR SPECTROSCOPY

Scientist E-II
S K Gupta

TO A
Manju Arora

RADIO AND ATMOSPHERIC SCIENCES DIVISION

Head
Sh. S. C. Garg

Scientist G
S C Garg

Scientist F
D R Lakshmi
M K Tiwari
S L Jain
P K Banerjee
A B Ghosh
H N Dutta
R C Saksena

Scientist E-II
S K Sarkar
Lakha Singh
R K Pasricha
K S Zalpuri
M C Sharma
P N Vijaya Kumar
M K Goel
Mahendra Mohan
Madhu Bahl
S D Sharma
R S Dabas
D R Nakra
P Subrahmanyam
M V S N Prasad
B C Arya
R S Arora
J K Gupta
V K Pandey
N K Sethi
S K Singhal
H K Maini

Scientist E-I
V K Vohra
P Chopra
Thomas John
Jayanta Kar
Risal Singh
C B Tandel
Meena Jain

Scientist C
R S Tanwar

TO C
S K Shastri

TO B
D B Sharma
Raksha Marwah
D B Singh
V S Yadav
Iqubal Ahmed
S K Bhatia
R Kohli

TO A
D S Chaunal
Shambu Nath
A K Goghar

CRYOGENICS FACILITIES

Head
Dr. R.G. Sharma

Scientist E-II
Hari Kishan
R B Saxena
S S Verma

Scientist E-I
B V Reddi
P L Upadhauya

Scientist B
M A Ansari
Dipten Bhattacharya

TO A
Bhikam Singh
M C Singh

SUPERCONDUCTIVITY DIVISION

Head
Dr. R G Sharma

Scientist G
R G Sharma

Scientist E-II
B V Kumaraswamy
P K Dutta
Ramji Rai

Scientist E-I
S K Agarwal

Scientist C
U C Upreti
Ratan Lal

Scientist B
Anurag Gupta

TO C
S B Samanta

TO B
V S Yadav

RESEARCH FACILITY & SUPPORT

P & C, MARKETING AND ISTAG

Scientist E-II
P K Ashwini Kumar
N K Babbar
F C Khullar

Scientist E-I
T K Chakraborty
S K Sharma
Shikha Mandal
Indra Tewari
D P Bhatt

TO C
K Chibber

TO A
A K Suri

LIBRARY

Scientist F
SM Dhawan

Scientist E-I
DK Tewari

Scientist B
NK Wadhwa

TO B
Hasan Haider
Jagdish Prasad

TO A
S Bhatnagar

CCF

Scientist E-II
Ravi Mehrotra

Scientist B
Sher Singh

TO A
Kanwaljit Singh
Ashok Kumar
Vijay Sharma

WORKSHOP

Scientist F
S C Gera

Scientist E-II
H N P Poddar

TO C
Ravi Khanna
Ram Swarup

PUBLICATION & REPORTS

Scientist E-II
V S Tomar

Scientist C
N S Verma

TO A
V K Sharma

GLASS WORKSHOP

TO E-I
Mohan Lal

TO C
Karnail Singh

TECHNICAL SERVICES

Scientist F
C S P Kumar

Scientist E-I
J C Sharma
H L B Bhaskar

Exe. Engr.
S K Jha

TO E-I
Shashi Bhushan
R S Singh

Scientist C
S K Kulshrestha

TO C
S L Sharma
K L Ahuja

Asstt.Ex.En.
Harbans Singh

Scientist C
S K Kulshrestha

TO B
B S Negi
Damodar Prasad

TO A
Krishan Kant
Deepak Bansal
Hitesh Jan
P S Tripathi

ADMINISTRATION, ACCOUNTS, STORES & PURCHASE

COA
H R Gupta

Senior F & AO (SG)
S C Santosh

AO
Hari Mohan

Deputy SPO
S N Gupta
P D Aggarwal

SO (F&A)
Ramesh C
Satish Kumar
H Chongloi

SO
D Rajashekher
D K Salone
O P Meni
C Tobden
Bijendra Kumar
Beena Kulu

TO C
A K Ghosh

TO B
K G M Pillay

Hindi Officer
Shakuntala Sharma

PS
R K Bhasin
Paramjit Kaur
Mange Ram
S A Joseph
Shish Ram

Security Officer
Vijay Kumar
Lakhpat Singh

STAFF ON DEPUTATION

V T Chitnis
(transferred to HQ on 7-1-2000)
A R Jain(left)
R P Tandon (left)

SCIENTIST FELLOWS, RESEARCH ASSOCIATES & POOL OFFICERS

Homi Bhabha Fellow
A P Mitra

Emer. Scientist
D C Parashar

Sr. Scientist
T R Anantha Raman

Young Scientist
R Murli Krishna

UGC Res. Scientist
Vikram Soni

RAs & Pool Officers
Ashish Aggarwal
Archana Gulati
Ananika Gulati
Alka Gupta
Arvind Paandey
A S Grover
B Veenadhari
Deepak Varandani
Dillp Singh Mehta
G S Okram
Hari Om Upadhyay
Jagjiwan Mittal
Jaya Naithane
Kanchan Saxena
MR Srivastava
Mitali Shah
Manju Gerad

Neeraj Saxena
Pradeep Varshney
Rajesh
Rajesh Kumar
Ranu Godi
R K Choudhary
R Jaya Kumar
Sandeep Singh
Sanjay Srivastava
Swati Haldar
Sushil Kumar
Suchitra Ghosh
T K Manual
Vibha Rani
V C Bagar
V K Parashar

LIST OF RETIRED PERSONS

Lakhi Ram, W/S Asstt.VII
Hari Singh, W/S Asstt. VII
A D Raheja, SMA
R S Khanduja, Sc.F
T R Pushpangadan, TOC
Charan Singh, Tech.VIII
Prithvi Raj, Tech.VIII
U Dhawan, Sc.EII
Ram Gopal Kashyap, Tech.VII
S.N. Vaid, SMA
O.P. Khowal, SMA
M.S. Tyagi, Sc.F
Kundan Lal, W/S Asstt. VII
B K Chopra, SEO
Ram Kishan, Tech.VIII
S K Phull, Sc.F
J P Khanna, Sr. Steno
Munna Lal, Tech.VIII
S S Dillan, SMA
Ram Kishan, Sc.EI
O P Bahl, Sc.G
P Rana, Asstt.G
B M Sharma, SMA
Gulshan Kumar, SMA
S S Bhakhari, TOB
Prem Prakash, TOC
K S Balakrishnan, TOC
Joginder Singh, Sc.EII
K K Mahajan, Sc.G
Parmanand, SMA
Pavitra Singh, Tech.VII
Roshan Lal, Tech.VIII
Kewal Krishan, TOC
Didar Singh, TOB
Jaswant Singh, TOB
Subhas Chandra, Sc.G
M K Raina, Sc.EII
V S Panwar, Sc.EI
Trilochan Bhatt, Tech.VIII
Balgovind, Tech.VIII
K M Sharma, SMA
N K Kohli, TOC
Mehram Singh, SMA
A V Narlikar, Sc.Dir.Gd.
J RAnand, Sc.G
K S Saxena, SMA

OBITUARIES

Ram Sathan, W/S Asstt.VII
Bansi Lal, Tech.VIII
Yadvendra, Sr.Steno
Roshan Lal, Tech.VIII
Bageshwar Prasad, SMA

APPENDIX : 15
RESEARCH AND MANAGEMENT COUNCILS OF NPL IN 1999-2000

Research Council

Name	Position
Name	Chairperson
Dr. R. Chidambaram Chairman AEC & Secretary Department of Atomic Energy Anushakti Bhawan Chhatrapati Shivaji Marg Mumbai-400039	
Prof. V.S. Ramamurthy Secretary Department of Science & Technology Technology Bhavan New Mehrauli Road New Delhi-110016	Member
Dr. R.R. Kelkar Director General Indian Metrological Department Mausam Bhavan Lodi Road, New Delhi-110003.	Member
Mr. P.S. Das Director General Bureau of Indian Standards Manak Bhavan 9, Bahadur Shah Zafar Marg New Delhi-110002	Member
Prof. Dipankar Chakravarty Director Indian Association for Cultivation of Science 2A & B, Raja S.C. Mullick Road Jadavpur Calcutta-700032.	Member

Name	Position
Dr. N. Srinivasan Deputy Director General Confederation of Indian Industry Gate No. 31, North Block Jawahar Lal Nehru Stadium Lodhi Road New Delhi-110003	Member
Mr. M.K. Mittal Director (E& RD) BHEL BHEL Headquarter Sirifort, New Delhi-110049	Member
Dr. S. Ahmad Acting Director Central Electrical & Electronics Research Institute (CEERI) Pilani-333031 (Rajasthan)	Member Sister Laboratory
Dr. S.P. Vassi Reddy CMD Vimta Laboratories Limited 142, IDA Phase II Cherlapally Hyderabad-5000519(AP)	Member
Dr. A.K. Raychaudhuri Director, NPL	Member
Mr. T.K. Chakravarty Scientist E-I P & C Group, NPL	Non-member secretary
Dr. H.R. Bhojwani Head Research, Planning & Business Development (RPBD) Council of Scientific & Industrial Reesearch (CSIR) Anusandhan Bhawan Rafi Marg, New Delhi-110001.	

Management Council

Name	Position
Dr. A. K. Raychaudhuri Director National Physical Laboratory New Delhi-110012	Chairman
Dr. R.P. Singhal Scientist National Physical Laboratory New Delhi-110012	Member
Dr. (Smt) N. N. Goswami Scientist National Physical Laboratory New Delhi-110012	Member
Dr. Jayanta Kar Scientist National Physical Laboratory New Delhi-110012	Member
Dr. T.D. Senguttuvan Scientist National Physical Laboratory New Delhi-110012	Member
Shri Ashok Kumar Technical Officer National Physical Laboratory New Delhi-110012	Member
Dr. B.S. Mathur Scientist National Physical Laboratory New Delhi-110012	Member
Dr. N.K. Babbar Scientist National Physical Laboratory New Delhi-110012	Member

Name	Position
Sr. FAO National Physical Laboratory New Delhi-110012	Member
COA National Physical Laboratory New Delhi-110012	Member Secretary