बहुलक व नर्म पदार्थ

POLYMERIC AND SOFT MATERIALS

अकार्बोनिक अर्द्धचालकों/पराबैंडरूपों पर आधारित हल्कोनिक पदार्थ साधनों के डिजाइन और परिवर्तन हेतु शीर्षित विकास प्रस्तुत करते है। यह रिसर्च और विकास के वर्गों में कार्बोनिक अर्द्धचालकों और चालक बहुलकों के आगमन से अधिकांश लूप से भर गयी प्रगति होती है। इन पदार्थों की चालकता को डिजाइन का प्रयोग करते हुए कई गुणा बढ़ाया जा सकता है। समस्त बहुलक का, जो अपने प्रोसेसिङ पर प्रभावित होते हुए दायु एवं अर्द्धचालक दोनों के अभिन्नता को प्रभावित कर सकते हैं, प्रयोग विश्वसनीय रूप से बढ़ता है। हल्कोनिक पदार्थों के निर्माण में किया जा रहा है। प्रक्रिया उस्ताद्विक आयोजित और स्वीकृत होती है। इसी प्रकार लोह बैलून और अन्य प्रकारों के घन क्रिस्टल से नए अनुप्रयोग भी प्राप्त हो रहे हैं। विशेषकर, अपने बुद्धि क्रिस्टल और रूढ़ि प्रभाव के कारण सतही स्थायीता लौह बैलून द्वारा क्रिस्टलस्पे पर एन थी एल नन्हा कैंसिन किया गया है। इसका प्रयोग विविध प्रक्रिया अनुप्रयोग साधन तथा हल्कोनिक प्रोसेसिङ (OASLM) के लिए होता है। बहुलक पदार्थ नबीन स्वास्थ्य देख रेख रूढ़िविवेक एवं प्रणाली में प्रयोग के लिए भी उपयुक्त है। कॉलेस्ट्रॉल निधारण व तुरिका जैव संवेदनों पर आवश्यक अब्जुल्लाहों और बिकास कार्यों का संचालन करते हुए जैव संवेदनों से सम्बन्धित गतिविधियाँ का कार्य क्षेत्र एन थी एल में बढ़ाया गया है। जैव सुसंगत बहुलक कम्प्यूटर पर कार्य का उत्तरदायित्व भी लिया गया है। पाया गया है कि पालिपिरोला/ संडिएम नाइट्रॉट्रीक के द्वारा रो मामा बुद्धि करता है और विकसित भी होती है। इती प्रकार अनपूर्ण मीलों में पीली-1 वारस को पकड़ने के लिए चालक बहुलक घिसली प्रवाह के कारण का आगे बढ़ाया गया है। इसके द्वारा अपरिष्ठ ज्वाला अधिक में संक्षण, नई विकल्पों द्वारा पूर्ण की गयी है। सबबहुलक एनसीसी और फॉर्मिनीट को समावेश करते हुए बहुलक आधारित विभिन्न गैतराय और सुरु जीवों की जांच करने वाले संवेदनों को दम समूह में उत्पन्न किया गया है। ‘बिबंदु कमीक विवोड’ में सूचार करने के लिए हमारे लगतार प्रयासों में बहुलक जैल विभाग अनुदाय के अतिरिक्त प्रबलों और चालक दोष टिन आंकड़ा पर तस्कर के विकास पर ध्यान केंद्रित किया गया है। साथ-साथ विभिन्न प्रयोगशाला प्रक्रियाओं को बढ़ाने के लिए एक माइक्रो प्रोसेसर नियंत्रित निम्नलिखित विवेदिता का डिजाइन कर उसे विशेष लूप से निर्माण का विवेदिता किया गया है। इस में इस प्रक्रिया विशेष और स्पर्श बाली आपत्ति के घोर चालक बहुलक पर नॉय या नॉय किया गया है। एक्सर स्किरपी चित्रण में प्रयोग करने के लिए प्रक्रियापत्र की एक्सर संचालनशीलता को बढ़ाने के प्रयास किए गए और बहुलक/नारिनिम संयोजन पर व्यापी पूर्ण प्रवृत्ति किया गया। इसको या एक सकारात्मक प्रवृत्ति से प्रभावित प्रक्रिया को अधिक तोड़ अन्तर्गत पूर्ण प्रबन्धन किया गया। इंडो - यूएस संयोजनों के अंतर्गत इस वार्ता के दौरान बहुलक को दो अन्तरागुल्ल पूर्ण क्रम संरचनात्मक अंतर्गतों के विषय में महत्वपूर्ण सहयोग किया गया। यह प्रश्नानुसार किया गया कि एक बड़ी सीमा तक अन्तरागुल्ल पूर्ण क्रम और संशोधन करने उसके द्वारा पूर्ण करते हुए किस प्रकार ए ए पी इ डिस की दो एकांग पर्यतन को, एक उद्योग के अलावा, त्वचाग्ना स्थान से संजोधन 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/NaNO₃ 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-assembly 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 + cinnamoyl 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.

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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
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. 5.5: 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 quinoline) (Alq3) 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 WO3 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 Chrome 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 peroxy tungstic 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 (WO3) 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/amorphism 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 SnCl4·2H2O 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/cm², a value comparable to that of WO3 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](image)
electrolytes based on polar solvents with room temperature ionic conductivity of the order of $10^{-3}$ 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 γBL, Li salts with different anions and polymers like 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 30-80% 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 fabrication 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 PANILOD and PANILDH electrodes as a function of lactate concentration. An attempt has also been made to immobilize lactate dehydrogenase on sol-gel
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
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 $1.8 \times 10^{-6}$ 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
Fig. 5.11: Surface image of LB Film (PAI 12)
nature of the transport of photocarriers in P3HT SA LB film.

**Conducting Polymers**

The samples of Polypyrrrole (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 Poly aniline 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 Poly aniline, 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 ac, 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 feric 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 \([\text{P(NMPY-PY)}]\) have been developed. Again, Polypyrrole (PPY) and its copolymer; poly(N-methyl pyrrole-pyrrole) \([\text{P(NMPY-PY)}]\) 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/NaNO₃) 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/NaNO₃ 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
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 specey. 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

![Graph showing optical absorption characteristics for various type of polyaniline thin films doped with Fe and Al](image)

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.Coli
of the specifically doped polymeric thin films, deposited on silicon macroporous membranes, upon exposure to E. Coli, were studied. A particular dopant incorporation in the polymer makes the sensor specific for the detection of E. Coli. The sensitivity of the devices, defined as the ratio of current from the sensor upon exposure to E. Coli, 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 stichometry, 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 Carbazole), 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 X Ray 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