Abstract

Irradiation induced modification in polymeric materials is an active area of research from the scientific and technological perspective. When an ionizing radiation passes through a polymer, the incident energy is transferred to the medium as a result of primary ionization and excitation of the target molecules. Charged particles lose their energy to the stopping materials, mainly via two independent processes i.e. elastic collisions (ion atom interaction) and inelastic collisions (ion electron interaction). The former is the dominant mechanism at low energies region (~keV/nucleon), whereas the inelastic collisions dominant at high energies (>1MeV/nucleon). Thus, for heavy ions the electronic energy loss leads to the deposition of incident energy on the target material, which creates defects and atomic displacement due to the formation of tracks in terms of cylindrical zones of the order of some nanometers in diameter in the material.

Irradiation induces bond breaking, main chain scission, creation of unsaturated bonds, intermolecular cross linking, radical formation and loss of volatile fragments. All these processes are responsible for the modification of chemical, electrical, optical and mechanical properties of polymers leading to their applications in different scientific and technological fields viz. microelectronics, sensors, dosimetry, catalysis, light-emitting diodes, electromagnetic interference shielding, super capacitors and so on. The effectiveness of these transformations produced in the polymeric materials predominantly depends on the structure and the ion beam parameters such as ion energy, linear energy transfer, fluence/dose, mass, charge etc. and the nature of the target material itself.

It is obvious from literature survey that a systematic study of the effects of irradiation on the properties of polymeric materials is needed to check the role of radiation agents in the modification process. At the same time, the actual physico-chemical changes taking place inside the polymers are yet to be ascertained with specific and definite accuracy by using different techniques. The aim of this research work is to study the effects of swift heavy ions (SHI), neutrons and gamma rays on optical, chemical and
structural properties of metal conducting polymer composites and non-conducting polymers, and for further exploring their applications in different fields. The main focus and key objectives of this particular research work are:

1. To optimize various process parameters (viz. concentration of monomers and dopant, applied current density, deposition time, etc.) for the electrochemical synthesis of metal conducting polymer composites (Au-polypyrrol and Ag-polyaniline) on conducting substrate. And to study the effects of heavy ion beam irradiation on morphological and structural properties of these composite films.

2. To study the effects of swift heavy ions i.e. charged particles, neutrons and gamma rays on the optical, chemical and structural properties of non conducting polymers i.e. polyallyl diglycol carbonate (PADC), polyethylene terephthalate (PET), Makrofol-KG and PM-355.

3. To characterize the samples by using micro-Raman, scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), X-ray diffraction (XRD), UV-visible and Fourier Transforms Infrared (FTIR) spectroscopic techniques.

The work presented in the thesis deals and describes about the following studies:

Swift Heavy Ions Induced Modifications in Polymeric Materials: The effects of swift heavy ions of Li$^{3+}$ and C$^{5+}$ ion beams on the morphological and structural properties of Au-polypyrrol (Au-Ppy) and Ag-polyaniline (Ag-PANI) composite films are investigated at various fluences. The composite films are irradiated at Material Science Beam Line from the 15 UD Pelletron at the Inter University Accelerator Center (IUAC), New Delhi using various fluences ranging from $1\times10^{11}$ to $1\times10^{13}$ ions/cm$^2$. The composite films are studied by using SEM, EDS and micro-Raman spectroscopy before and after irradiation of the composite films. The reasonable improvement has been found after irradiation on the composites which indicates their proper use in chemical as well as bio-sensing applications. Interestingly, the experimental result of the Raman spectra and deconvoluted Raman spectra with Gaussian fitting shows the similar behavior. This clearly indicates a structural change in Au-Ppy and Ag-PANI films after heavy-ion beam irradiation. The effects of heavy ion beam irradiation on the composites are reported for the first time in the present investigation.
High electronic excitation induced modifications by 100 MeV O^{7+} and 150 MeV Ni^{11+} ions in Makrofol-KG polycarbonate films which is a non conducting polymer are also investigated in the present work. The effects of irradiation parameters such as energy, mass, linear energy transfer (LET) and ion fluence on the optical, chemical and structural properties of the Makrofol-KG films are reported in detail. The effects of 55 MeV C^{5+} ions beam irradiation on the properties of polyallyl diglycol carbonate (PADC) and polyethylene terephthalate (PET) polymer films are also investigated at various fluences. The pristine as well as ion beam irradiated samples were subjected to UV-visible, photoluminescence (PL), FTIR and XRD spectroscopic techniques. It has been found that ion irradiation induces defects in the polymers due to cross linking and chain scission which are responsible for changes in the properties of polymers.

**Neutron-Irradiation Induced Effects in Polymer:** The effects of neutron-irradiation on the optical, chemical and structural properties of PADC polymer films (a non conducting polymer) are studied at various fluences varying from 2.36×10^{6} to 5.94×10^{7} n/cm^{2}. All samples of PADC polymeric detector were irradiated at ambient condition at IUAC, New Delhi. One side of these samples was exposed to fission fragments from 500 mCi Am-Be neutron source having yield of 0.96×10^{6} n/sec and average energy of 4 MeV. The changes in this polymer induced by the neutron-irradiation are investigated by using UV visible, PL, XRD and FTIR spectroscopic techniques. The behaviors of the band gap and the Urbach energy with increasing neutron fluence have been investigated. The numbers of carbon atoms in a cluster were also calculated. The aim of these studies is to obtain the information about the modifications induced by interaction of neutron with PADC. In addition, the studies about the feasibility of using modifications as an application in neutron dosimetry were carried out.

**Gamma-Irradiation Induced Modifications in Polymers:** The effects of gamma radiations on the properties of plastic bottle sheets and PM-355 solid state nuclear track detector (SSNTDs) were investigated. Detectors are irradiated using 1.25 MeV gamma radiation (the average energy of the two {^{60}Co} photons) source of {^{60}Co} in the gamma chamber (1200 GC) with dose rate of 7.328kGy/h at IUAC, New Delhi. Doses from 150kGy to 675kGy were used in the present study. The changes in the polymer films induced by gamma-irradiation are investigated by using XRD, micro-Raman and UV-
Visible spectroscopic techniques. The effects of gamma dose on the crystallinity and crystallite size of the irradiated plastic bottle sheets and PM-355 SSNTDs films have been studied by using XRD measurement. In addition, the interchain distance \((r)\), interplanar distance \((d)\), micro strain \((\epsilon)\), dislocation density \((\delta)\) and distortion parameters \((g)\) are also calculated. Further, chemical changes in these polymer films due to gamma irradiation are studied by using micro-Raman spectroscopy. The peaks, their shifting and broadening observed in UV Visible spectra are explained on the basis of gamma induced changes in the plastic bottle sheets and PM-355 SSNTDs films along with the simultaneous existence of direct and indirect band gap energy. Raman spectra show the change in the peak intensity. The values of an indirect band gap were found to be lower than the corresponding values of the direct band gap. The interchain and interplanar distances changed marginally. Lattice and micro strain changes with an increase of gamma dose. Therefore, the decreases in optical band gap energy are in line with the results of Raman and XRD studies. The studies demonstrate the applicability of these polymer films as a cost-effective gamma dosimeter.