PHOTOLUMINESCENCE AND DIELECTRIC STUDIES OF ION INDUCED POLYETHYLENE NAPHTHALATE

By

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ABSTRACT

Dielectric properties along with photoluminescence phenomenon of ion induced Polyethylene naphthalate (PEN) were analyzed. Li^{3+}, C^{6+}, Ni^{10+} ion beams were used to analyze the modifications induced by swift heavy ions as a function of ion fluence, ranging from $1x10^{11}$ to $3x10^{12}$ ions/cm^2. Blue shift is observed in PL behavior. Dielectric constant (ε') for pristine and irradiated samples has also been calculated, which increases with the increase in ion fluence.

Keywords: Dielectric Constant, Irradiation, Photoluminescence, Swift Heavy Ions.

INTRODUCTION

Swift heavy ion loses its energy by interacting with target nuclei (nuclear stopping) and by interaction with target electrons (electronic stopping). In case of polymers, electronic stopping process due to ion irradiation is more eminent, which contributes to the scissoring of original bonds, production of radicals and excited atoms. At higher ion fluences, cross linking and rearrangement of bonds occur. All these processes are accountable for the modifications in structural, optical, thermal and chemical properties of the polymer due to creation of defects in the polymer [1]. The analysis of properties of PEN has been reported in number of research papers [2, 3], however, a little about the results of irradiation on PEN have been found in literature. PEN film showed a moderate decrease in luminescence intensity at 440 nm [4]. Track to bulk etch ratio in radiation stimulated PEN films were studied for producing micro and nanostructures [5].Thermally Stimulated Depolarization Current (TSDC) measurements of gamma ray irradiated PEN films were studied by Mackersie et al [6]. With the increase of dose of irradiation, both the capacity of surface charge and the rate of charge decay decreases [7]. An intense photo yellowing resulting from the conversion of the naphthalate units, accompanied by the formation of gel, was observed by Scheirs and Gardette [8], but tensile properties of TEMs of PEN films were studied by Buczkowski et al [9]. Therefore, the aim of the present investigation is to study the alterations in structural properties of PEN films caused by lithium (50 MeV), carbon (85 MeV) and nickel (120 MeV) ion irradiation with the help of Photoluminescence (PL) and Dielectric techniques.

1. Experimental Details

The specimens of Polyethylene naphthalate (PEN) in the form of flat polished thin films (25m) were procured from Good Fellow Ltd. (England). These films were used as-received form without any further treatment in the size of 1 cm x 1 cm. The samples were mounted on the sliding ladder and irradiated with lithium (50 MeV), carbon (85 MeV) and nickel (120 MeV) ion beams using 15 UD pelletron facility for the General Purpose Scattering Chamber (GPSC) under vacuum of $\sim 10^{-6}$ Torr at Inter-University Accelerator Center, New Delhi.

The electronic energy loss of characterized lithium (50 MeV), carbon (85 MeV) and nickel (120 MeV) ions in PEN polymer is ~6.96, 27.85 and 563.3 eV/Å respectively [10]. The range of all ions is more than the thickness of polymer films. The ion beam fluence was varied from 1×10^{11} to 3×10^{12} ions cm^{-2}. In order to expose the whole target area, the beam was scanned in the x-y plane. The beam current was kept low to suppress thermal decomposition and was monitored intermittently with a Faraday cup. Flouromax-3 (Jobin-Yvon, Edison, NJ, USA) equipped with a photomultiplier tube and a xenon lamp was used for (PL) analysis of samples at 300K. The Precision impedance analyzer 6500B is used to measure dielectric constant (ε') of pristine and irradiated samples of polyethylene naphthalate at room temperature in the frequency range of 20Hz-1MHz.

2. Results and Discussion

2.1 PL Analysis

Figures. 1(a), (b) and (c) show the PL spectra of pristine and irradiated samples of Polyethylene Naphthalate (PEN) with different fluences of lithium, carbon and nickel ions respectively. The samples were excited at wavelength λ =350 nm. A prominent peak was observed at 448 nm for pristine sample. The spectra shown by samples irradiated with heavier ions (nickel ions) have intensity quite smaller than the pristine ones, which show that after irradiation, the luminescent centers such as impurities, defects have disappeared [11]. The PL spectra of irradiated Polyethylene naphthalate (PEN) samples show shifting of peaks towards the lower end of wavelength (448nm-425nm) i.e. towards higher energies which is known as blue shift that might be due to compressive stress. This may be due to the reason that with irradiation, there is increase in defect concentrations in polymers [12].The PL intensity of PEN samples irradiated with lighter ions (lithium and carbon ions) decreases, when irradiated at lower fluence ($1x10^{11}$ions/cm^2), but at intermediate fluences there is increase in intensity, which may be due to increase in concentration of defects after irradiation. At higher fluences the intensity again decreases, which is due to the degradation of sample with irradiation.

2.2 Dielectric studies

The dielectric constant of pristine and irradiated samples of polyethylene naphthalate (PEN) was calculated using the relation $\varepsilon' = C_p/C_0$, where C_p is capacitance measured using impedance analyzer; $C_o=\varepsilon_o A/t$, where ε_o is the permittivity in vacuum. The plots for variation of dielectric constants with frequency for pristine and irradiated samples of polyethylene naphthalate (PEN), irradiated with

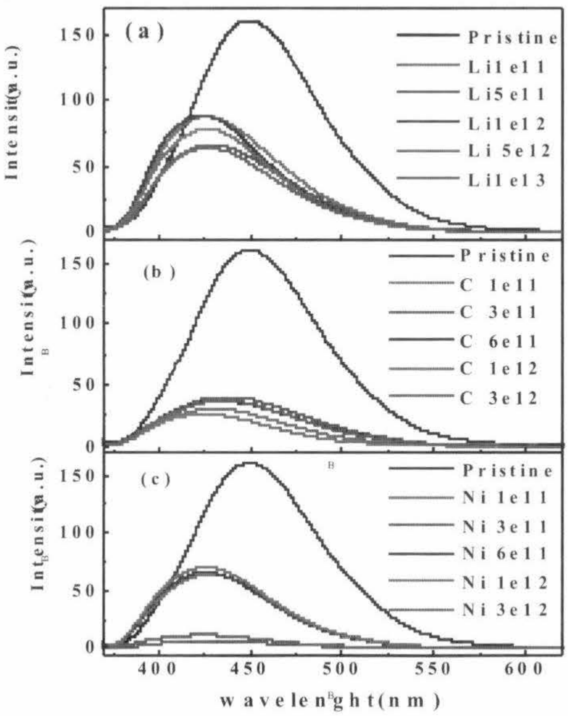

Figure 1. PL spectra of Polyethylene Naphthalate samples irradiated with different fluences of (a) lithium (b) carbon and (c) nickel ions.

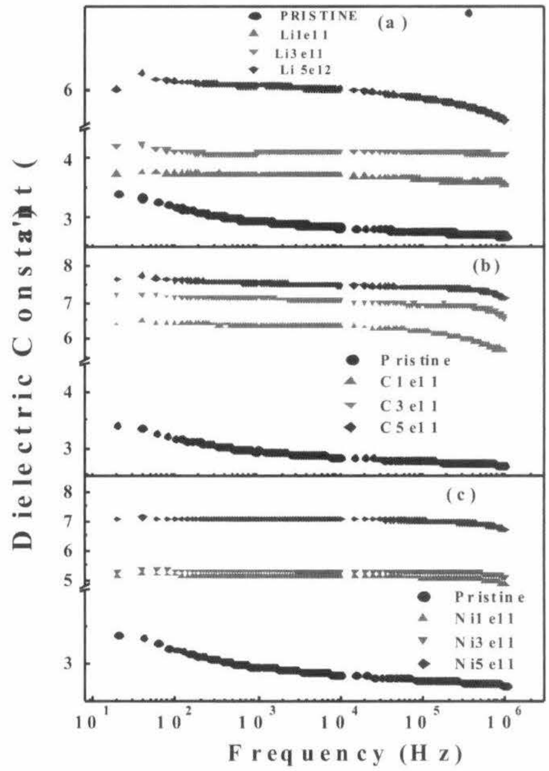

Figure 2. Dielectric spectra of Polyethylene Naphthalate samples irradiated with different fluences of (a) lithium (b) carbon and (c) nickel ions.

lithium ions, carbon ions and nickel ions are shown in Figure 2(a), (b) and (c) respectively. It is observed that dielectric constant (ε') decreases with increase in frequency. This is due to the fact that the charge carriers migrate through the dielectric and get trapped against a defect site, where they induce an opposite charge. Hence motion of charge carriers slow down, which in turn decreases the value of dielectric constant (ε'). It is also observed from Figure 2 that the value of dielectric constant (ε') of irradiated samples of polyethylene naphthalate (PEN) is more as compared to dielectric constant (ε') of pristine sample. This may be due to chain scission process due to which there is an increase in the number of free radicals [13]. The increase in dielectric constant (ε') with increase in ion fluence leads to the increase in rigidity of polymer due to irradiation [14].

Conclusion

The irradiated samples of Polyethylene naphthalate (PEN) show shifting of peaks towards the lower end of wavelength (448nm-425nm) i.e. towards higher energies due to compressive stress. The increase in dielectric constant (ε') with increase in ion fluence leads to the increase in rigidity of polymer due to irradiation.

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