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Full Length Research Article

SILVER ION INDUCED CONDUCTIVITY OF POLYETHYLENE NAPHTHALATE (PEN)

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ABSTRACT

The conductivity of Polyethylene Naphthalate (PEN) pristine and irradiated with silver ions (120MeV) having fluence range of 1x10^{11} ions/cm^2 to 6x10^{11} ions/cm^2 have been studied using dielectric studies. The analysis of dielectric studies point toward that hopping process is the main mode for electronic conduction in the polymer.

INTRODUCTION

The irrevocable changes due to irradiation occurring in the structure and electrical properties of polymeric material are of great interest (Hall *et al*., 1982; Martin, 1994). Ion bombardment of the polymer materials, in particular, induces significant chemical transformations, depending on the energy deposition mechanisms (Venkatesan *et al*., 1987; Marletta, 1990). The transfer of energy from the ions to the polymeric material leads to polymer chain scissoring, covalent bond breaking and cross-linking. The application of irradiation with swift heavy ions in polymeric material is of great significance with a view to attain some desired advances in polymer properties. In 1948 Cook *et al*. described the synthesis method of a new aromatic polyester poly (ethylene-2,6-naphthalate) (PEN) in which the benzene ring in poly (ethylene terephthalate) (PET) is substituted by a naphthalene ring (Cook *et al*., 1948). In late 80s the increasing interest in PEN appears probably due to its excellent mechanical properties and thermal stability (Cheng and Wunderlich, 1988; Nakamae *et al*., 1993; Hill and Walker, 1948). Poly (ethylene-2,6-naphthalate) (PEN) is one of high temperature semi crystalline thermoplastic polymers and was commercialized by Eastman Chemical Company in 1994 as a high-performance thermoplastic for engineering applications. It exhibits superior physical and mechanical properties and chemical resistance than widely used polyesters, along with low permeability with excellent dielectric properties (Hardy *et al*., 2001; Morse, 1997; Tonelli, 2002). This paper deals with the study of conductivity of PEN Polymer irradiated with silver ions with varyers flueuces.

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MATERIALS AND METHODS

The specimens of Poly ethylene naphthalate (PEN) in the form of flat polished thin films (25μm) were procured from Good Fellow Ltd. (England). The samples were mounted on the sliding ladder and irradiated with silver (120 MeV) ion beams using 15 UD pelletron facility for the general purpose scattering chamber (GPSC) under vacuum of ~10^{-6} Torr at Inter-University Accelerator Center, New Delhi. The electronic energy loss, nuclear energy loss and ion range of polymers of characterize silver (120 MeV) ions in PEN polymer is ~5.49, 965.5 and 2.353 E+01 eV/Å respectively (.Ziegler, 2008). The beam current was kept low to suppress thermal decomposition and was monitored intermittently with a Faraday cup. The ion beam fluence was varied from 1 x 10^{11} to 6 x 10^{11} ions cm$^{-2.}$ Doses (Table 1) for the given fluence were calculated using the formula (Geiβ *et al*., 1998) as given below:

$$\text{Dose} = 1.602 \times 10^{-10} \times \frac{1}{\rho} \times \frac{dE}{dx} \times \phi \qquad \text{.......(1)}$$

ϕ : Ion fluence,

ρ: Density of polymer,

$\frac{dE}{dx}$: Stopping power of ion

The Precision impedance analyzer 6500B is used to measure dielectric loss of pristine and irradiated samples of PEN films at room temperature in the frequency range 20Hz-1MHz.

RESULTS AND DISCUSSION

Figure 1 depicts the graph between log frequency and ac conductivity ($\log\sigma_{ac}$) for pristine and ion irradiated samples (irradiated with 120 MeV silver ions).

large amount of energy is deposited along the trajectory of the ion. The ion loses energy in two different ways; either the energy is lost due to the ionization and excitation of atoms and is called as electronic energy loss S_e or due to elastic and inelastic nuclear collisions and is called as nuclear energy loss S_n. Generally the electronic energy loss S_e is greater than nuclear energy loss S_n, hence large number of disordered regions are formed in the polymer. As the ion fluence increases, these disordered regions overlap and results to establishment of ion caused defects and induces a modification in the *ac* conductivity. From the graph it is clear $\log\sigma_{ac}$ versus log frequency obeys linear relationship and hence the

Table 1. Doses for given fluence of silver ion of studied polymer

Polymer	Ion Fluence (ions/cm^2)	Silver (120 MeV) (kGy)
	Pristine	0.00
PEN	1 x10^{11}	1137.26
	3 x10^{11}	3411.78
	6x10^{11}	6823.57

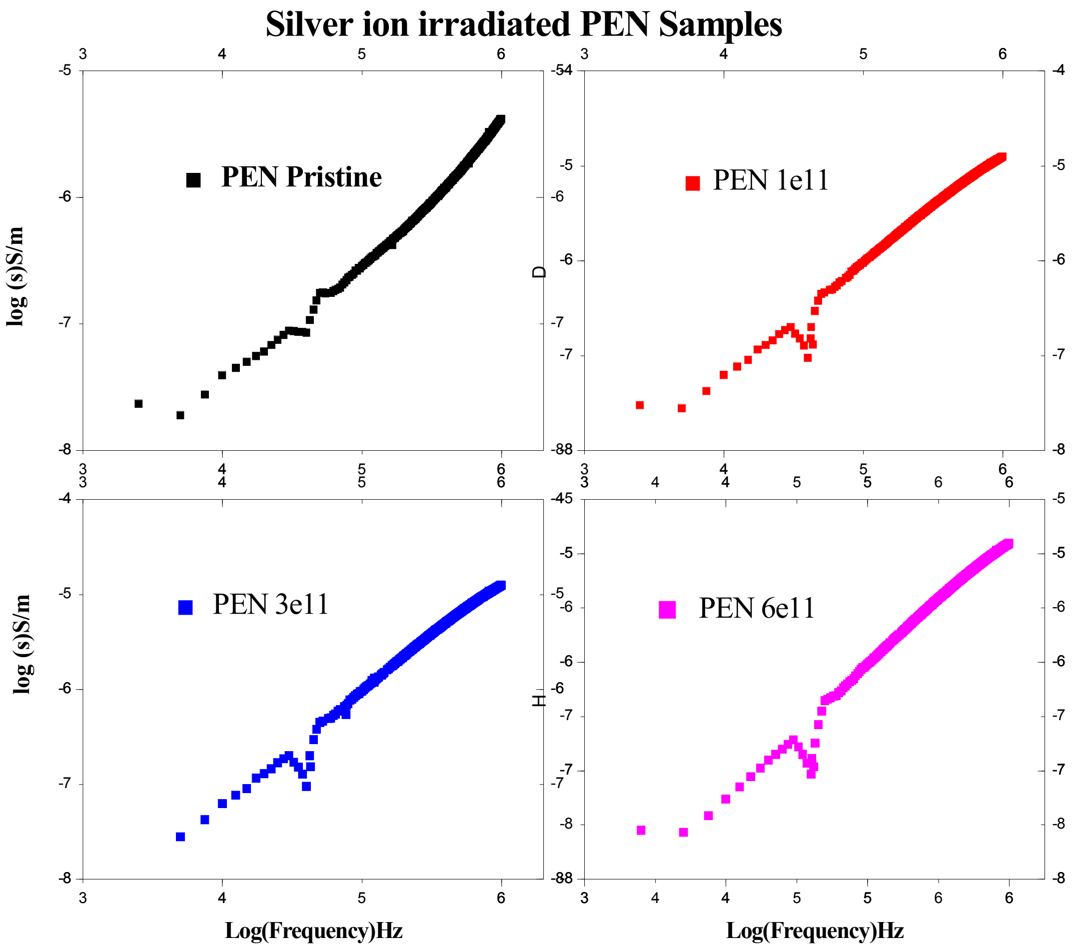

Fig. 1. Conductivity spectra of Poly ethylene naphthalate (PEN) samples irradiated with varying fluences of silver ions

Due to the formation of ion induced defects along the path of incoming ions a substantial change is detected in the *ac* conductivity. When swift heavy ions enter into the material, a

ac conductivity follows the $\sigma_{ac} \alpha\ f^n$ relation, where n can be worked out from the slope curves of Figures 1 and is known as the frequency exponent.

The linear relation of *ac* conductivity with frequency and the value of $n<1$ depict for the electronic conduction via hopping process.

Conclusion

Specimens of PEN polymer have been irradiated with 120 MeV silver ions at different fluencies in the range from 1 x 10^{11} to 6 x 10^{11} ions cm^{-2}. Due to the formation of ion induced defects, the irradiated PEN samples illustrate a remarkable change in the *ac* conductivity. The plot of log *ac* conductivity is depicts the proportion relation with f^{n} in pristine and irradiated samples of PEN polymer, with a slope $n<1$ which points that electronic conduction occurs through hopping process.

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