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Structural Response of Swift Heavy Ion Induced Poly (Methyl Methacrylate) PMMA

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Abstract: ***The structural modifications induced in PMMA due to swift heavy ion irradiation with Li^{3+} (50MeV), C^{6+} (85MeV), Ni^{10+} (120MeV) ions having the fluence range $1x10^{11}$ to $3x10^{12}$ions/cm^2 have been studied. Irradiation of polymer with different ion beams lead to its complete structural degradation.***

Keywords: Polymer films, swift heavy ion, irradiation, XRD, chain scission.

1. Introduction

The main advantage of polymer thin films is that they can be prepared easily at low cost. Polymethylmethacrylate (PMMA) is an excellent polymeric material because it is easy to produce and has the desired optical properties [1,2]. Modification of polymers by swift heavy ion irradiation, because of its technological implications is an expanding field of research and application. The use of ion beam irradiation is getting high impetus because both chemical composition and related physical properties of polymers can be modified in a controlled way by controlling the parameters like ion fluence and energy [3]. When a highly energetic charged ion strikes a polymer target, it loses most of its energy in exciting electrons and/or ionizing atoms. Target ionization causes bond cleavages; the formed free radicals are expected to come to rest and may react in a molecular site of a different type from their original site [4]. These radicals are responsible for most of the chemical transformations observed in the polymer films. Very high value of energy transferred induces an unusual density of electron–hole pairs close to the ion path and consequently the polymer modifications differ from those observed with low ionizing projectiles[5,6]. We have chosen polymethylmethacrylate (PMMA) polymer for our present investigation because PMMA is an important thermoplastic material, and has wide applications in many technological and productive fields. Earlier studies [7,8] have been undertaken by inert ion irradiation of higher energies.

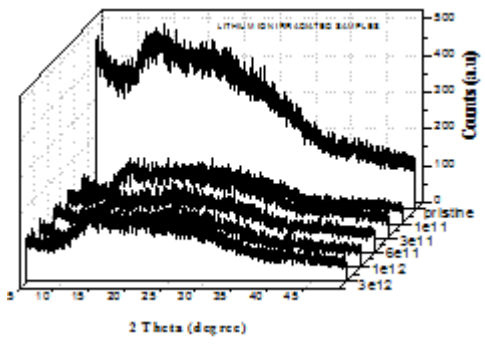
2. Experimental

The thin films of PMMA were procured from Good Fellow Ltd. (England) having thickness 50μm. These films were used as-received form without any further treatment in the size of 1 cm x 1 cm. The samples of PMMA were irradiated with lithium (50 MeV), carbon (85 MeV) and nickel (120 MeV) ion beams at Inter-University Accelerator Center, New Delhi after mounting on sliding ladder and using 15 UD pelletron facility for the general purpose scattering chamber (GPSC) under vacuum of ~10^{-6} Torr. The electronic energy loss of lithium (50 MeV), carbon (85 MeV) and nickel (120 MeV) ions in PMMA polymer is ~6.499, 26.25, 539eV/Å respectively [9]. The ion beam fluence was varied from 1 x 10^{11} to 3 x 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. The X-ray diffraction patterns were recorded from the Bruker AXS D8 diffractometer using the Cu-Kα (λ = 1.54 Å) radiation in θ-2θ locked couple mode with scan speed of 1degree min$^{-1.}$ The measurements were done under ambient pressure conditions at room temperature and the diffraction angle (2θ) had been varied from 5 to 50°.

3. X-Ray Diffraction (XRD) Analysis

X-ray diffraction (XRD) analysis is used by to characterize the change in the crystal structure parameters such as: the degree of crystal orientation, the apparent crystal size and the lattice strain along the axis of the crystal unit cell [10]. PMMA falls in the category of polymer materials that consist mainly of amorphous regions with some crystalline region in different proportions. XRD peaks with ion fluence to observe loss of crystallinity with irradiation Fig 1presents the XRD pattern for virgin PMMA films and also for those irradiated with lithium (50 MeV), carbon (85MeV) and nickel (120MeV) ions to various fluences. The diffraction pattern of pristine sample shows partial crystallinity. The most intense peak occurs at 2θ = 21.8°. The irradiated samples also exhibit identical diffraction patterns. Diffraction pattern of virgin PMMA sample also shows a broad peak around 13.3° indicating that polymer is mainly amorphous in nature. However, no considerable change in the peak position is observed, which reveals that the lattice parameters do not change significantly [11]. The average crystallite size (L) for pristine and irradiated samples was calculated using Scherrer's formula [12]

$$\beta = K\lambda / L\cos\theta$$



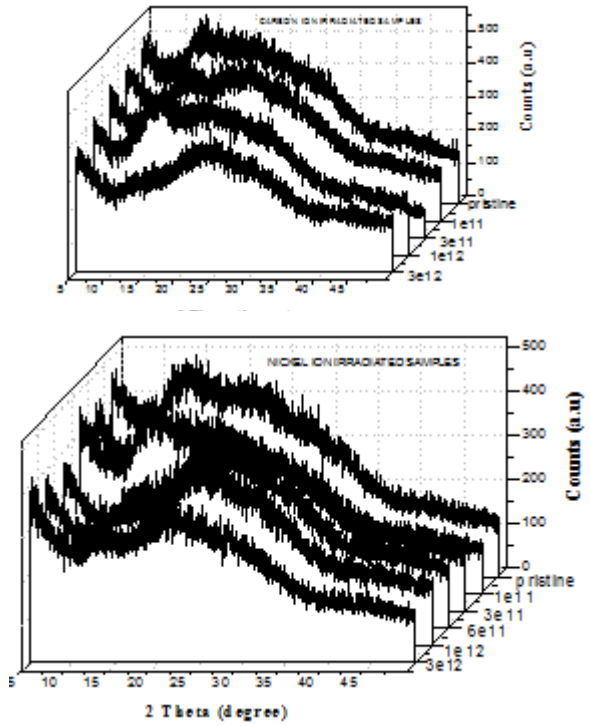


Figure1: XRD patterns of Li, C and Ni ions irradiated PMMA at varying fluence.

Table 1: Relevant data for XRD spectra of pristine, Li, C and Ni ions irradiated PMMA at different ion fluences

Ion	Ion fluence	Full Width at Half Maximum	2Θ	Θ	cosΘ	Crystallite size L(A°)
LITHIUM	pristine	32.1212	21.85	10.9	0.98	0.044
	1e11	17.8633	23.80	11.9	0.98	0.079
	3e11	24.50	22.18	11.09	0.98	0.057
	6e11	25.78	21.5	10.75	0.98	0.055
	1e12	21.16	23.0	11.5	0.98	0.067
	3e12	23.88	20.57	10.28	0.98	0.60
CARBON	1e11	34.56	21.0	10.85	0.98	0.040
	3e11	44.52	13.9	6.95	0.98	0.032
	1e12	29.93	21.9	10.95	0.98	0.047
	3e12	30.73	23.36	11.68	0.98	0.046
NICKEL	1e11	29.93	22.4	11.2	0.98	0.047
	3e11	33.45	19.9	9.5	0.98	0.042
	6e11	28.19	23.25	11.62	0.98	0.050
	1e12	28.32	23.25	11.62	0.98	0.050
	3e12	44.24	22.4	11.20	0.98	0.047

where β is FWHM in radians, λ is the wavelength of X-ray beam (1.5418 Å), L is the crystallite size in Å, θ is the angle between the atomic plane and both the incident and reflected planes, K is a constant which varies from 0.9. From table1 it is clear that the variation in crystallite size L is not significant. Although the intensity of the diffraction peak decreases with ion fluence, this behavior may be attributed to chain scissioning taking place, which may results in the alignment of the polymeric chains.

4. Conclusion

The paper concludes that the swift heavy ion irradiation of PMMA led to its structural modification and degradation at different doses.

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Author Profile

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