Optical Study of carbon ion irradiated Poly (methyl methacrylate) films

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Abstract --The alterations induced in Poly methyl methacrylate (PMMA) due to C\textsuperscript{6+} ions (85MeV) irradiation having the fluence range 1x10\textsuperscript{11} to 3x10\textsuperscript{12} ions/cm\textsuperscript{2} have been studied. The irradiated samples of PMMA were characterized using UV-Visible spectroscopy. The optical energy gap was reduced for carbon ion irradiated samples of PMMA as compared to the pristine sample.

Keywords: PMMA, irradiation, Swift Heavy Ion, C\textsuperscript{6+} ion, Polymer

I. INTRODUCTION

The alterations induced in polymers due to swift heavy ion irradiation are of great curiosity. The spectacular alterations acquainted in the irradiated polymers are due to main-chain scission and cross linking [1]. The changes stimulated in the polymers not only depend upon the energy of the irradiating ions, but also on the ion species [2]. After the collisions of irradiating ions with target particles, the ions lose their energy by ionization, excitation, and collision processes [3]. The irreversible changes activated in the polymer, due to ion irradiation, are quite different from those stimulated by low ionizing particles [4]. At very high ion fluences, carbon clusters are created [5]. Earlier reports, on irradiation of PMMA included studies of the physical and chemical changes induced by 70 MeV carbon ions [6] and the effect of 145 MeV Ne\textsuperscript{6+} ions on physico-chemical and structural properties of PMMA was also presented [7]. The effect of temperature on the mechanism of radiation stimulated degradation of PMMA was reported [8]. The ion induced degradation of the polymer, with release of volatile fragments, scission of side chains and polymeric backbone, formation of conjugated double bonds, ensuing increased absorption of the UV part in the UV–Vis spectral region was described [9]. The response of the irradiated samples towards biomedical applications was also demonstrated by the improved antimicrobial activity, haemocompatibility and cytocompatibility [10]. In the present study we have observed the alterations introduced due to irradiation on PMMA films with C\textsuperscript{6+} (85MeV) ions. The irreversible changes produced in the optical properties of PMMA due to ion irradiation were studied using UV-Visible techniques.

II. EXPERIMENTAL

The specimens of PMMA were procured from Good Fellow Ltd. (UK) in the form of flat, polished thin films (50 µm). These films were used as-received in the size of 1 cm x 1 cm without any further treatment. The samples were irradiated with carbon (85 MeV) ion beams after mounting on a sliding ladder and using the 15 UD Pelletron facility and the general purpose scattering chamber (GPSC) under a vacuum of ~10\textsuperscript{-6} Torr at the Inter-University Accelerator Center, New Delhi, India. The Ion range, electronic energy loss and Nuclear Energy loss of carbon (85 MeV) ions in the PMMA polymer was as shown in table 2 [11].

Table 1: Electronic, Nuclear Energy Loss and Ion Range of polymer

<table>
<thead>
<tr>
<th>Ion Beam</th>
<th>Ion range (µm)</th>
<th>Electronic Energy loss (eV/Å)</th>
<th>Nuclear Energy loss (eV/Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon (85MeV)</td>
<td>240.48</td>
<td>26.25</td>
<td>1.151 E-02</td>
</tr>
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</table>
The beam was scanned in the x-y plane in order to expose the whole target area (1 cm²) and the total fluence of the ion beam over the target was varied from 1 x 10^{11} to 3 x 10^{12} ions cm⁻². UV-VIS spectroscopy, using a Lambda 35 Perkin Elmer UV-Vis spectrophotometer (USA), was used to observe the variation in optical energy gap and cluster size in the range 200-800 nm. Doses for the given fluence and ion type were calculated and provided in Table 1 using the formula as given below [12].

\[
\text{Dose} = 1.602 \times 10^{-10} \times \frac{1}{\rho} \times \frac{dE}{dx} \times \phi \tag{1}
\]

\( \phi \): Ion fluence, \( \rho \): Density of polymer, \( \frac{dE}{dx} \): Stopping power of ion

<table>
<thead>
<tr>
<th>Ion Fluence (ions/cm²)</th>
<th>Pristine</th>
<th>1 x 10^{11}</th>
<th>3 x 10^{11}</th>
<th>6 x 10^{11}</th>
<th>1 x 10^{12}</th>
<th>3 x 10^{12}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon (85 MeV) (kGy)</td>
<td>0.00</td>
<td>35.90</td>
<td>107.69</td>
<td>215.38</td>
<td>358.97</td>
<td>1076.92</td>
</tr>
</tbody>
</table>

### III. RESULTS AND DISCUSSION

Figures 1 show the optical absorption spectra of pristine and C₆⁺ ion irradiated samples of PMMA. The absorption band edge for the PMMA irradiated with the higher fluences showed significant shift, than the case of PMMA irradiated with the lower fluences. The band edge shifted towards lower energies with the enhance in ion fluence as shown in figures 1, which may be due to creation of carbonaceous clusters or defects (e.g. vacancy clusters, anions, cations, radicals and organic species etc), in the irradiated PMMA samples due to the irradiation [9,13,14].

![Figure 1: UV-Visible spectra of PMMA irradiated with C₆⁺ ions](image)

These defects produce new energy levels, which can be associated with the change of color of the pristine PMMA from transparent to pale yellow after irradiation.
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REFERENCES