

# Study on crystallization and AC conductivity behaviour of gamma Irradiated PVC and POM

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**Abstract:** In the present investigation, Effect of gamma radiation on Poly vinyl chloride (PVC) and Polyoxymethelene (POM) has been studied for various doses varied from 0Mrad to 50Mrad. PVC and POM is an engineering plastic product with excellent electrical properties. Characterization of the polymer using XRD and AC electrical conductivity was done both before irradiation and after irradiation in each step. Present investigation clearly indicates that though the crystallinity increases in the material, it undergoes degradation and shows brittleness due to irradiation and A.C. Electrical conductivity study of gamma irradiated PVC and POM were carried out in frequency range from 10 kHz to 2MHz at room temperature.

**Key words:** Polyvinylchloride (PVC), Polyoxymethelene (POM); Crystallinity; Crystal size; AC conductivity, Gamma irradiation.

## I.INTRODUCTION

Irradiation with X-rays, alpha, beta and gamma radiation also have a significant effect on properties of polymers and some physical properties are usually modified. The vigorous development of polymer science and the extensive utilization of polymeric materials in all fields of technology have led, in recent years, to the increased interest in the various problems of physics and chemistry of polymers. It is known that one of them a in objectives of polymer physics is the elucidation of the relationship between the chemical and physical structure and the physical properties of the polymers. The majority of polymeric materials are electric insulators in nature. Many experiments aimed to increase the crystallinity and electrical conductivity of polymer by ion irradiation has been reported and discussed [1-3]. Interaction between electromagnetic radiations with polymer chains is different from that of ions because of the high value of energy loss and the spatial distribution of deposited energy.

## II. EXPERIMENTAL

The Polyvinylchloride (PVC) and Polyoxymethelene (POM) samples which were received from POLYPENCO Ltd (UK), in the form cylindrical rods of 1.2cm diameter. These polymer samples were irradiated by Co<sup>60</sup> source with a dose rate of 0.25 Mrad/hr in the presence of air at CTRL (Cotton Textile Research Laboratory), Mumbai. The PVC and POM samples were irradiated for different doses of gamma irradiation like 10 Mrad, 20 Mrad, 30 Mrad, 40 Mrad, and 50 Mrad. They were cut into discs of 6mm radius & 1mm thickness. The unirradiated PVC & POM sample and irradiation POM and PVC samples were characterised using X-Ray diffraction respectively. The percent of crystallinity was calculated using XRD pattern as follows [4].

$$\% \text{ of crystallinity} = \frac{Ac}{Ac + Aa} \times 100$$

Similarly, the percent of Amorphous was calculated using XRD pattern as follows.

$$\% \text{ of Amorphous} = \frac{Aa}{Ac + Aa} \times 100$$

Where, "Ac" is area under crystalline peaks. "Aa" is area under amorphous back ground.

## III. RESULTS AND DISCUSSION

### A. Crystallinity Analysis

The analysis of crystallinity of the PVC and POM materials was carried out to look at the change in crystallinity of the PVC and POM material on exposure to gamma radiation. The increase in the crystallinity and the decrease in the amorphous nature of the PVC and POM material with an increase in the dosage of gamma irradiation is given in Table 1 and 2 respectively. From the tables are clear that as the dosage of gamma irradiation increases on the PVC and POM samples, the

materials tends to move from amorphous nature to crystalline nature. The graphical representation of the increase in crystallinity and decrease in amorphous nature of the PVC and POM material on exposure to gamma radiation is given in Fig.1 and 2.

Dosage (Mrad)	PVC		
	% of Crystallinity	% of Amorphous	Crystal size(nm)
0	15.5405	84.4595	0.0495
10	28.5714	71.4286	0.0854
20	35.1852	64.8148	0.0858
30	41.7476	58.2524	0.0859
40	54.5455	45.4546	0.0865
50	63.4409	36.5591	0.0869

Dosage (Mrad)	POM		
	% of Crystallinity	% of Amorphous	Crystal size(nm)
0	18.4168	81.5831	0.135
10	21.0019	78.9980	0.138
20	28.4182	71.5817	0.155
30	34.2756	65.7243	0.159
40	52.2471	47.7528	0.160
50	68.5039	31.4960	0.163

Table 1 and 2. Crystallinity, Amorphous nature and Variation of crystal size with different dosage of gamma irradiation on PVC and POM respectively.

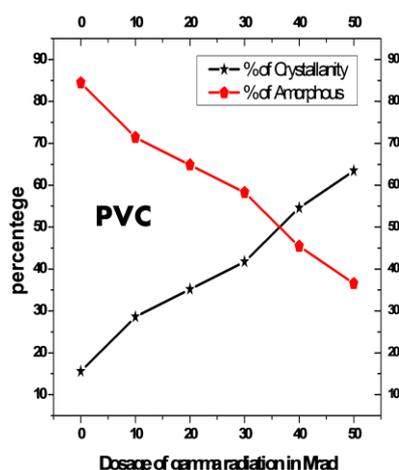


Fig.1 Variation of percentage of Crystallinity and percentage of amorphous v/s increase Dosage of Gamma radiation on PVC samples.

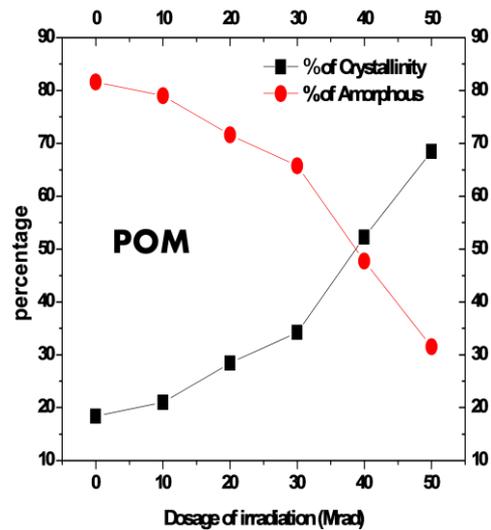


Fig.2 Variation of percentage of Crystallinity and percentage of amorphous v/s increase Dosage of Gamma radiation on POM samples.

**B. Crystal Size Analysis**

Crystal size analysis was carried out to look at the change in the grain size of the material on exposure to the gamma irradiation at different dosage level. The crystal size of the material was calculated using Scherrers’s formula follows [5].

$$t = \frac{K\lambda}{B\cos\theta}$$

Where t is the averaged dimension of crystallites, K is the Scherrers’s constant, somewhat arbitrary value that falls in the range 0.87-1.0 (it is usually assumed to be 1), λ is the wavelength of X-ray and B is the integral breadth of a reflection (in radians 2θ) located at 2θ. B is also called as full width half maxima of crystalline peak.

The results obtained for crystal size of unirradiated and irradiated PVC and POM samples are given in Table1. From the Table, we conclude that the size of the crystal increases with respect to an increase in the dosage of gamma irradiation. It is observed that the size of the crystal were 0.135 nanometer, when exposed to 0 Mrad (un-irradiated), where as when the dosage increases from 10 to 50 Mrad, size of the crystals has varying from 0.0495nm to 0.0869nm and 0.138 nm to 0.165nm for PVC and POM respectively. By the analysis we can conclude that as the irradiation dose increases the crystallinity of the sample increases in this polymer. The increase in crystallinity is due to the alignment of small chain

polymer fragments produced due to irradiation. The increase in percentage of crystallinity of the polymer can be attributed to the scission of side chains and decrease of free volumes in the polymer matrix [1].

C. Study of AC conductivity

The Fig 3 and 4 shows the dependence of conductivity of PVC and POM sample on frequency at room temperature for unirradiated and irradiated samples. A gradual increase in conductivity was observed as the frequency increases. It is also observed that as the dosage of gamma irradiation increases the AC conductivity increases. The increase in conductivity due to irradiation may be attributed to scissioning of polymer chains and as a result, increase of free radicals, unsaturation and AC field sufficiently high may cause a net polarization, which is out phase with field. This result concluded increase of conductivity at higher frequency [6]. The ac conductivity ( $\sigma_{ac}$ ) was obtained from the data of dielectric constant ( $\epsilon'$ ) and loss tangent ( $\tan \delta$ ) using the relation.

$$\sigma_{ac} = \omega \epsilon' \epsilon_0 \tan \delta$$

Where,  $\epsilon_0$  is the permittivity of free space  
 $\omega$  is the angular frequency =  $2 \pi f$

III CONCLUSIONS

The investigation clearly shows that the percentage of crystallinity of the sample increase as a function of radiation dosage. The crystallinity of the PVC and POM material increases from 15.54% to 63.44% and 18.41% to 68.50% respectively.

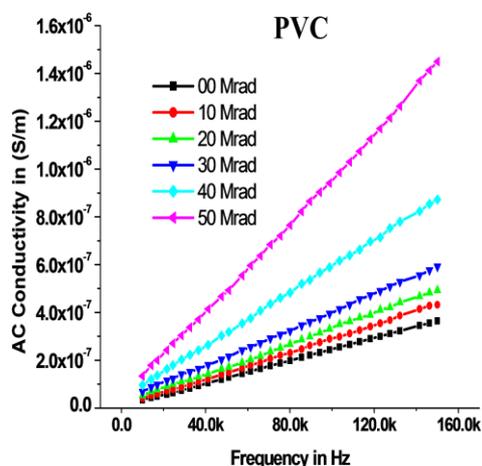


Fig3.Comparative study of AC conductivity verses frequency at different dosage of gamma irradiation on PVC.

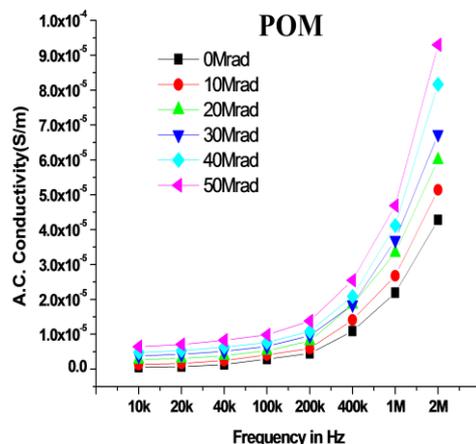


Fig4.Comparative study of AC conductivity verses frequency at different dosage of gamma irradiation on POM.

Also, clearly observed that the size of the crystal were increase from 0.0495nm to 0.0869nm and 0.135 nm to 0.163 nm respectively. It undergoes degradation and shows brittleness due to gamma irradiation. Hence it is suggested to take more care while using the products made of this material in the radiation environment. The results of AC conductivity study clearly show that when the PVC and POM exposed to 0Mrad to 50 Mrad were subjected to a variation of frequency in a range 10 kHz to 160 KHz and 10KHz to 2MHz respectively, there is increase in AC conductivity when the material is exposed to higher dosage compared to the values for the unirradiated sample.

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