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Modification of dielectric and structural properties of PVC by gamma irradiation

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ABSTRACT

This paper presents the changes induced in the dielectric constant and structural properties of the poly vinyl chloride (PVC) sheets due to gamma radiation. PVC sheets were irradiated for different doses like 0 Mrad, 10 Mrad, 20 Mrad, 30 Mrad, 40 Mrad, 50 Mrad by Co^{60} source with a dose rate of 0.25 Mrad/hr at room temperature. FTIR spectra of the PVC samples before and after irradiation indicate that the gamma irradiation results in the formation of free radicals. In turn they bring in changes in the dielectric properties of PVC samples. It has also been observed that crystallinity of the sample changes due to gamma irradiation.

KEYWORDS

Dielectric constant;
FTIR;
Crstallinity;
Gamma irradiation.

INTRODUCTION

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 the main objectives of polymer physics is the elucidation of the relationship between the chemical and physical structure and the physical properties of the polymers[1]. The majority of polymeric materials are electric insulators in nature[2]. It is well known that electrical conduction in polymers can be considerably enhanced by irradiation[3]. The increase in conductivity of irradiated polymers may be attributed to the formation of conjugated structures[4]. Also, the irregularity in the polymer chain may give rise to a hopping mechanism that will enhance the conductivity[5]. High-energy radiations, such as gamma rays, change the physical properties of the materials they penetrate. The changes are strongly dependent on the internal structure of the absorbed substances. It is believed that ionizing radiation causes structural defects leading to their density change on the exposure to gamma rays[6]. The influence of radiation depends on both the dose and the parameters of the films including their thickness: the degradation is more severe for the higher dose and the thinner films[7].

PVC is widely used due to its resistance to fire and water. Due to its water resistance it is used to make raincoats and shower curtains, and of course, water pipes which are commonly used everywhere these days. Since chlorine atoms are released when PVC is burnt, and chlorine atoms inhibit combustion, PVC is flame resistant and finds several applications. Structurally, PVC is a vinyl polymer having structure similar to polyethylene, but on every alternate carbon in the backbone chain, one of the hydrogen atoms is replaced with a chlorine atom. It is produced by the free radical polymerization of vinyl chloride. Proton irradiation is found to cause changes in the Dielectric properties of the PVC[8]. It is thus interesting to see the effect of gamma irradiation on the polymer PVC. Because, several materials made of PVC are used in the environment having gamma radiation. With this in view, in the present study, effect of gamma radiation on the Dielectric and structural properties of the PVC has been carried out using XRD, FTIR and Dielectric constant measurements.

EXPERIMENTAL

In the present study commercially available PVC sheets were cut into discs of 6 mm radius & 1mm thickness and were irradiated by Co^{60} source with a dose rate of 0.25 Mrad/hr at C.T.R.Laboratory, Mumbai. The PVC samples were irradiated for different doses like 0 Mrad, 10 Mrad, 20 Mrad, 30 Mrad, 40 Mrad and 50 Mrad. The XRD patterns of the gamma irradiated samples and unirradiated sample were done using MiniFlex II available at the Central College, Bangalore University, Bangalore. The FTIR spectra were recorded for the samples in the wave number region 4000 cm^{-1} - 500 cm^{-1} using Perkin Elmer FTIR Spectrum 60 instrument available at the Research centre of the Post Graduate Department of Physics, Government Autonomous College, Mandya. The sample holder of the instrument has provision for the measurement of blank KBr as well as for the sample. The specimen sample was prepared by mixing PVC thoroughly with KBr in the ratio of 1:100. The background measurements were recorded for the blank KBr before measuring for the sample. The dielectric constants of the samples were recorded using the LCR bridge in high frequency range of 10 MHz to 100 MHz at room temperature.

RESULTS AND DISCUSSION

X - ray diffraction

Figure 1 represents the XRD patterns of PVC on exposure to different dosages of gamma irradiation. Variation of percentage of crystallinity v/s dosage of gamma irradiation has been shown in Figure 2.

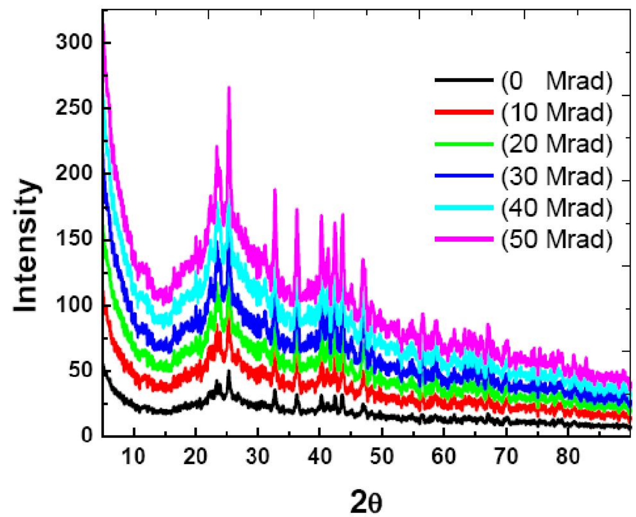

Figure 1 : XRD of PVC at different gamma radiation dosages

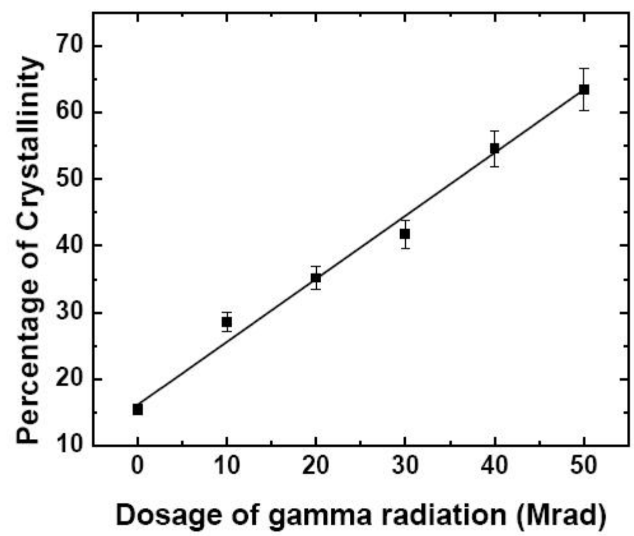

Figure 2 : Percentage of crystallinity v/s gamma irradiation dosage

XRD patterns of PVC which were irradiated up to 50 Mrad show very clear prominent peaks which clearly depict that the sample is becoming more and more crystalline. This is clear from the XRD patterns that there is a slight increase in the area under the peaks, with the increase in irradiation dosage. 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[9-12]. Similar increase in percentage of crystallinity in the matrix of Polyoxymethylene has been reported by our group earlier[13].

FTIR measurements

FTIR spectra of un-irradiated PVC and gamma irradiated PVC samples are shown in Figure 3.

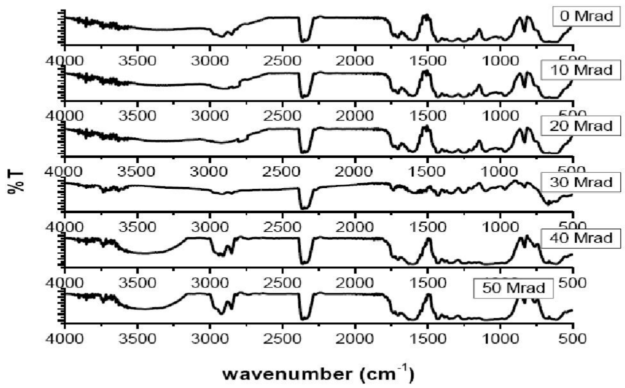

Figure 3 : FTIR spectra of unirradiated and irradiated PVC at different dosages

Strong absorption peak found at 2360 cm^{-1} is due to C – C stretching. This peak appears in all specimens with same intensity. It simply indicates that there is no effect of gamma irradiation on the C – C bonds of the polymer. Strong absorption peaks found at 1427 cm^{-1} and 1337 cm^{-1} are due C – H bending. They are more prominent in samples irradiated for 40 Mrad and 50 Mrad. As the dosage of gamma irradiation increases, a prominent absorption appears at 2914 cm^{-1} at higher dosages of 40 Mrad and 50 Mrad. This peak corresponds to C – H stretching mode of vibration in the polymer[14]. These observations clearly indicate that the irradiation is resulting in the increase of C – H bending and C – H stretching mode of vibration in PVC. This clearly indicates the formation of free radicals in the polymer due to gamma irradiation[15].

Dielectric constant

The dielectric properties of the samples irradiated to different doses at different frequencies range from 10 KHz to 100 KHz were measured using LCR meter at room temperature. The graph plotted against dielectric constant v/s frequency for samples irradiated for different doses of irradiation is shown in Figure 4.

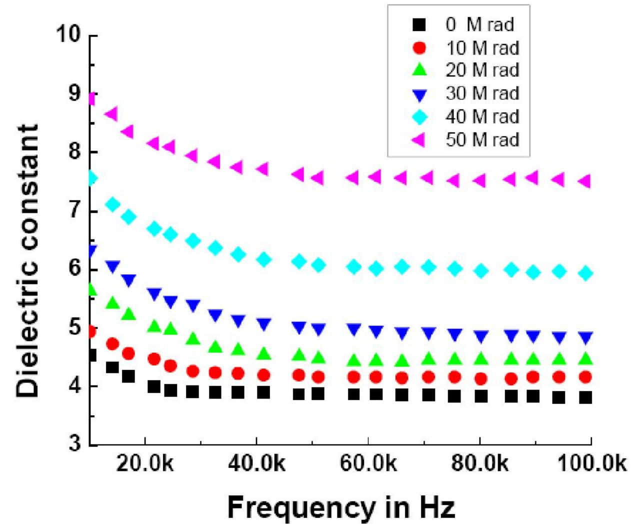

Figure 4 : Dielectric constant v/s Frequency for samples with gamma irradiation dosage from 0 to 50 Mrad

From the graph shown in Figure 4 it is clear that, as the dosage increases the dielectric constant increases at room temperature. A similar increase in the value of Dielectric constant has been observed due to proton irradiation of PVC[8]. It is observed that the dielectric constant gradually decrease at lower frequency range and then it remains constant at higher frequencies. From the structural point of view, the dielectric relaxation involves the orientation polarization which in turn depends upon the molecular arrangement. So, at higher frequencies, the rotational motion of the polar molecules of dielectric is not sufficiently rapid for the attainment of equilibrium with the field, hence dielectric constant of the PVC seems to be decreasing with increasing frequency and stays constant at higher frequencies at room temperature.

CONCLUSIONS

The XRD study clearly reveals that as the dosage of gamma irradiation increases there is an increase in the crystallinity of the polymer matrix. From FTIR studies it has been found that a strong absorption peak due to C – C stretching is found at 2360 cm^{-1} in all specimens with same intensity indicating that there is no effect of gamma irradiation on the C – C bonds of the polymer. Prominent strong absorption peaks due to C – H bending are found at 1427 cm^{-1} and 1337 cm^{-1} in samples irradiated for 40 Mrad and 50 Mrad. As the dosage of gamma irradiation increases, a prominent absorption appears at 2914 cm^{-1} at higher dosages of 40 Mrad and 50 Mrad indicating that the irradiation is resulting in the increase of C – H bending and C – H stretching mode of vibration in PVC. This clearly indicates the formation of free radicals in the polymer due to gamma irradiation. Gamma irradiation is bringing changes in the dielectric properties of the polymer. The dielectric constant of the PVC increases with increase in dosage of gamma irradiation and seems to be decreasing with increasing frequency and stays constant at higher frequencies.

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