Energy Loss and Dielectric Properties of γ-Irradiated PMMA Thin Film

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Abstract. The energy loss and dielectric properties of a polymer polymethylmethacrylate (PMMA) films was studied. The PMMA films were irradiated at a dose 8.5 kGy using the Co-60 source. The energy loss and dielectric properties of polymer films both before and after irradiation at room temperature have been studied. The dielectric constant of films after irradiation is found to be increased after irradiation this increase in the dielectric constant is mainly attributed to the creation of radiation induced charges in the film and the dielectric loss of the PMMA film is found to be decreased after gamma irradiation. The ac conductivity of PMMA films is found to increased after irradiation. The impedance of a PMMA is found to be decreased exponentially at lower frequency region and then it remained constant as the frequency increased. The impedance of the films increased after irradiation. The energy loss of α-particles with PMMA thin film at different pressures both before and after irradiation is found to be decreased with increase in the scattering chamber's pressure.

Keywords: Gamma Irradiation, Dielectric Loss, Dielectric Constant, Ac Conductivity and Polymer Films.

INTRODUCTION

The polymers have become the vital group of materials and are have the various applications in different areas of science and technology such as electronics, optics, biotechnology, space research and phonics(1-3). As polymers find the applications in the radiation environments nuclear power plants, like particle accelerator, spacecrafts etc. (4-5), it is essential to the investigate the modifications in the properties of polymers in ionizing radiations such as electron, ion beam, x-ray and γ- radiation. Generally, In the high energy radiation environment, the energy would be lost by in-elastic interaction along with the target material, which will then creates the cascade of the secondary electrons in solid micro-structure of polymers. Electrons would instigate the breaking of the chemical bonds and would create the excited as well as ionized species or the radicals along with the in-elastic scattering through contiguous molecules in polymers. It was observed that the different types of chemical change taken place in polymers in the process of irradiation like the formation of vacancy clusters, evolution of gases (H2, CO, CO2), generation of color centers, main chain scission(creation of new double bonds, C-C bond scission, radical combination (1,6). Usually, the cross linking method generates the chemical bonds between two adjacent polymer molecules, which would then results in the increase in molecular weight. While, the chain scission of polymer molecules decrease the molecular weight. These two reactions results in the modification in the physical properties of polymers primarily in its structural as well as optical properties.

MATERIAL AND METHODS

Polymer substance of Polymethylmethacrylate (PMMA) is purchased from SD Fine Chemical Limited, Mumbai. The PMMA thin films were prepared using the solution based method called as solution casting method with a 0.5 N. About a 10 ml of acetone was mixed to dissolve the beats and the solution was placed on the magnetic stirrer for 6 hours to form a homogeneous solution. The prepared solution was finally casted onto the glass plate having a uniform area and kept the same in RP for 1-2 days for drying. Later, the film was pealed off and used for further investigations. The films were mounted between on sample holders which has parallel type plates to give out the electrical connections. For Electrical measurements, the capacitance, phase angle, dissipation factor and impedance were measured as a function of frequency ranging from 50 Hz to 5 MHz at RT using PC connected LCR meter (Model: HIOKI 3532-50 LCR Hitester). The Gamma Irradiation was performed at *Gamma agro-Medical processing Private Limited Hyderabad*. The energy of γ-irradiation was 8.5 kGy which was fixed and it was obtained using the Co-60 source. Both interaction of charged particles and electrical characterization of the films were carried before and after irradiation.

THEORETICAL BACKGROUND

The dielectric properties were calculated as at different frequencies at RT. The dielectric constant values were calculated from the measured capacitances by Eq. (1).

$$\varepsilon' = \frac{Cd}{\varepsilon_0 A} \tag{1}$$

here *C* being capacitance of the sample, d being the thickness of the thin film, A being area of thin film and ε_o being the permittivity of the free space. The dielectric loss was calculated using Eq. (2).

$$\varepsilon'' = \varepsilon' \tan\delta \tag{2}$$

here ε' being dielectric constant, $tan\delta$ being dissipation factor.

The electrical conductivity (σ_{ac}) is calculated using Eq. (3).

$$\sigma_{ac} = \varepsilon' \varepsilon_0 \omega \tan\delta \tag{3}$$

here ε' being dielectric constant, ε_o being permittivity of free space, $tan\delta$ being dissipation factor and $\omega = 2\pi f$.

RESULTS AND DISCUSSION

The dielectric constant of unirradiated PMMA varies nonlinearly for unirradiated PMMA a dispersion in the dielectric constant is observed which could be due to the accumulation of charges at the grain boundaries and the interfaces which are generally referred to as the space charge polarization but whereas at higher frequencies more than 1 KHz the dielectric constant remains same and is independent of the frequencies as shown in figure 1. Further, after irradiation the dispersion in the dielectric constant at lower frequency is not observed which indicates that the charges which were accumulated at grain boundaries were affected by the γ-irradiation. After irradiation, both at lower as well as higher frequencies dielectric constant increased which could be due to the creation of radiation induced charges in the film. [6&7]. The dielectric loss of the films decreased γ-irradiation and it is ascribed to creation of free charges after irradiation which is reflected in conduction studies which is shown in figure 2.

The A C conductivity of γ-irradiated PMMA thin films is obtained as a function of frequency from the measured values of dielectric permittivity at room temperature, which are shown in Fig 3. The A C Conductivity of PMMA increased after irradiation which could be due to creation of extra charges which take part in conduction. The similar nature was seen dielectric loss. We have also studied the impedance as a function of frequency for the irradiated films of PMMA. The impedance of the composite film decreases exponentially at lower frequencies up to 10 KHz and onwards it remains constant. Here it has been observed that the values of impedance of PMMA films have been increased after irradiation. The observed modifications in the irradiated film were ascribed to the modifications in the grain structure due to the high value of electronic energy loss as shown in figure 4.

The energy loss of alpha particles with PMMA thin film at different pressures both before and after irradiation is shown in figure 5.a. As the scattering chamber's pressure is increased, the energy loss is found to be decreased. It was ascribed to the lesser interaction of the particles with PMMA thin film. While, at higher pressure, higher energy loss of alpha particles with PMMA thin film was observed. Further, it is also observed from figure 1 that after the γ-irradiation(8.5kGy), the energy loss was found to be slightly increased. The transmitted energy of alpha particles is high at lower pressure of 4 mbar but whereas at higher pressure of 7 mbar the transmitted energy is less. after the γ-irradiation(8.5kGy), the energy loss was found to be slightly decreased.

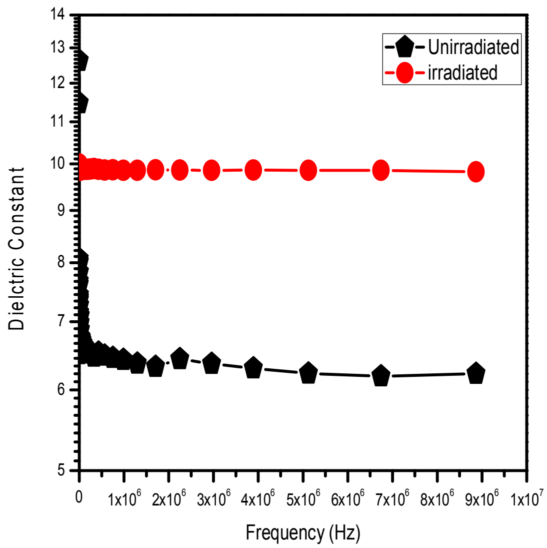

FIGURE 1. Plot of dielectric constant of γ-irradiated PMMA as function of frequency.

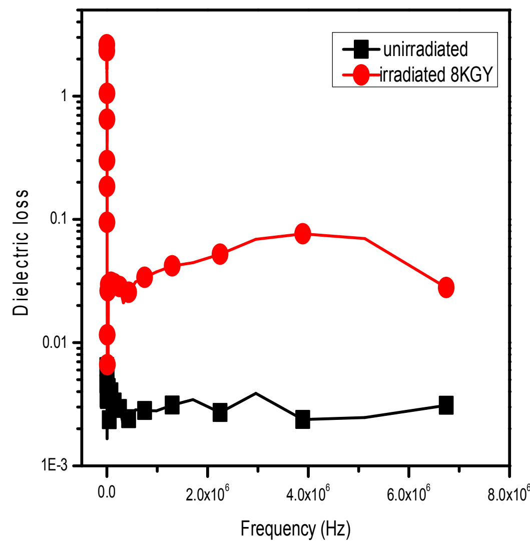

FIGURE 2. Plot of dielectric loss of γ-irradiated PMMA as function of frequency.

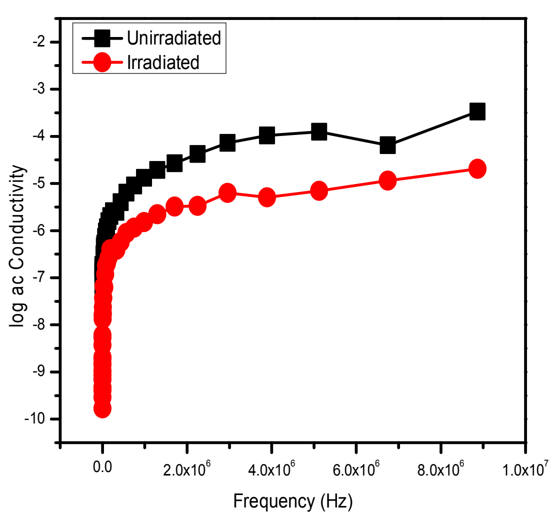

FIGURE 3. Plot of ac conductivity of γ-irradiated PMMA as function of frequency.

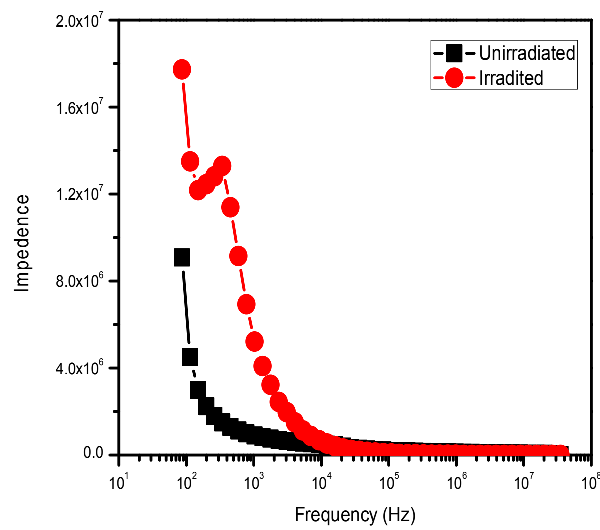

FIGURE 4. Plots of Impendence of gamma irradiated PMMA as function of frequency.

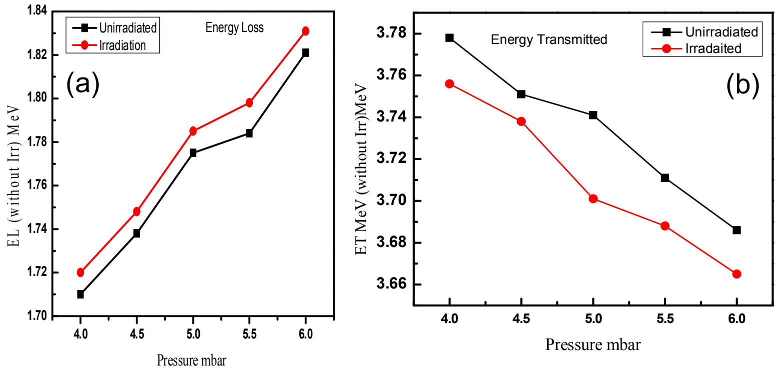

FIGURE 5. Plots of (a) Energy loss, (b) Transmitted energy of Alpha particles in PMMA film.

CONCLUSIONS

Gama Irradiation study on PMMA films was carried at a dose of 8.5kGy using the Co-60 source. The Dielectric constant of the film increased after irradiation while loss decreased it is ascribed to creation of free charges after irradiation. AC conductivity and impedance of the film increased after irradiation. The observed changes in the impedance properties are ascribed to the modifications in the grain structure due to the high value of electronic energy loss. As the scattering chamber's pressure increases, the energy loss is found to be decreased. It was ascribed to the lesser interaction of the particles with PMMA thin film. While, at higher pressure, higher energy loss of alpha particles with PMMA thin film was observed. Further, it is also observed that after the γ-irradiation(8.5kGy).

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REFERENCES

1. Ismayil, Ravindrachary, V. Bhajantri, R.F. Praveena, S.D. Poojary, B., Dutta, D. Pujari, Polymer Degradation and Stability. **95**, 1083-1091 (2010).
2. Ennis, C.P. Kaiser, R.I. Phys. Chem. Chem. Phys. **12**, 14902-14915 (2010).
3. Fowzy, Y.H.A. Amr El-Hag, G.F. Radwan, R.M. Word J. Cond. Matt. Phys. **1**, 12-18 (2011).
4. H. Kudo, S. Sudo, T. Oka, Y. Hama, A. Oshima, M. Washio, T. Murakami, Rad. Phys. and Chem. **78**, 1067-1070 (2009)..
5. H.V. Subramanyam, S.V. Subramanyam, 1987. Polymer **28**, 1331-1333 (2009).
6. U.H. Hossain, V. Lima, O. Baake, Severin, D. Bender, M. Ensinger, Nucl. Inst. and Meth. in Phys. Res B. **326**, 135-139 (2014).
7. J. Meyer, Polymer Engineering and Science, 13(6), 462–468.M. P. Brown and K. Austin, *The New Physique* (Wiley publications, London, 2005), pp. 25–30.
8. H. Devendrappa, Radiation Physics and Chemistry **98**, 124–131(2014).
9. S. A. Nouh and A. S. Abdel-Naby, Radiation Effects & Defects in Solids, **158**, 553 – 560 (2003).
10. N. Bohr. Kgl. Danske Videnskab, Mat. Fys, . Fys, Medd-**18** no.8 163-166 (1948).
11. M. C. Holloway and M. S. Livingston, Phys. Rev. **54** 18 (1938).