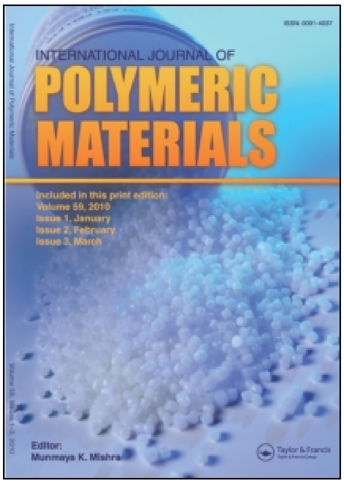

International Journal of Polymeric Materials
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713647664

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To cite this Article Eissa, M. F. , Tammam, M. T. and Abo-Elsoude, M.(2007) 'A Study on the Change in the Dielectric Properties of CR-39 Polymer Track Detector Due to α-Irradiation in the Frequency Range from 100 Hz to 100 kHz', International Journal of Polymeric Materials, 56: 10, 1015 — 1021

To link to this Article: DOI: 10.1080/00914030701215677

URL: http://dx.doi.org/10.1080/00914030701215677

International Journal of Polymeric Materials, 56:1015–1021, 2007

ISSN: 0091-4037 print/1563-535X online
DOI: 10.1080/00914030701215677

A Study on the Change in the Dielectric Properties of CR-39 Polymer Track Detector Due to α-Irradiation in the Frequency Range from 100 Hz to 100 kHz

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The dielectric properties in the frequency range from 100 Hz to 100 kHz of polyallyldiglycol carbonate "CR-39" samples before and after irradiations have been investigated. The irradiations were verified with 4.84 MeV α-particles at different irradiation times. The dependence of the dielectric properties of unirradiated and irradiated samples at room temperature (25°C) and constant frequency (10 kHz) on the total number of α-particles have been studied. It was found that the CR-39 can be used as a detector for high α-particles fluxes.

Keywords: α-particles fluxes, polyallyldiglycol carbonate "CR-39" samples, dielectric properties, different frequencies

INTRODUCTION

Most plastics are dielectrics (poor conductors of electricity) and resist the flow of a current. This is one of the most useful properties [1] of plastics and makes much of modern society possible through the use of plastics as wire coatings, switches, and other electrical and electronic products. In the presence of an electric field, the dipoles will attempt to move to align with the field. This will create "dipole polarization" of the material and, because a movement of the dipoles is involved, there is a time element to the movement. The alternating current frequency is an important factor because of the time taken to align the polar dipoles.

Received 19 December 2006; in final form 31 December 2006.
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Radiation effects on dielectric properties of polymers have been previously studied [2–5]. Due to the passage of α-particle in polyallyldiglycol carbonate, $C_{12}H_{18}$ O_7 (CR-39) dielectric polymer, used as a track detector, a damage zone is created. This zone is called latent track [6].

In conductor and semiconductor materials, the latent tracks are not stable [7]. The aim of this study is to investigate the change in the dielectric properties of CR-39 polymer track detector due to α-irradiation in the frequency range from 100 Hz to 100 kHz.

EXPERIMENTAL TECHNIQUE

Track detectors, CR-39, were normally irradiated in air by different fluxes of α-particles at energy 4.84 MeV emitted from 0.1 μCi ^{241}Am-source through a holder collimator [8]. The height of the holder is 7.25 mm. The incident flux (ϕ) was calculated from the following equation:

$$\phi = \frac{\mathrm{A}}{4\pi r^2} \tag{1}$$

where A is the activity of the ^{241}Am-source in Bq and r is the source-detector distance in centimeters.

The total number of α-particles (Φ) emitted from the collimator and incident on CR-39 per unit area in a certain irradiation time (t_e) is:

$$\Phi = \phi t \tag{2}$$

To measure the dielectric properties of the CR-39 samples after irradiation, an electric cell is used. The cell consists of two silver electrodes. The sample exists between the electrodes. The temperature is controlled by the use of a double wound electric oven.

The dielectric constant ϵ', dielectric loss ϵ'', and a.c. conductivity σ were measured using "Philips RCL bridge" at frequency range from 60 Hz–10^5 Hz at room temperature.

The values of the dielectric constant were determined using standard geometry techniques in which the capacitance C is assumed to be given by the usual expression for a parallel plate capacitor:

$$\epsilon' = \frac{Cd}{\epsilon_o A} \tag{3}$$

where ϵ_o is the permittivity of vacuum, A is the area of the sample, and d is the sample thickness.

The dielectric loss was calculated from the measurements of loss factor ($\tan\,\delta$) using the following relationship:

$$\epsilon'' = \epsilon' \tan\delta \tag{4}$$

Also, the conductivity was calculated using the relationship

$$\sigma = \epsilon'' \omega \epsilon_o \tag{5}$$

where $\omega = 2\pi$f and f is the applied frequency.

RESULTS AND DISCUSSION

The dielectric properties of CR-39 samples depend on the applied frequency and environmental temperature. In this article, the frequency dependence will be briefly studied.

Frequency Dependence

The dependence of the dielectric constant, dielectric loss and conductivity on the frequency for unirradiated (bg) and irradiated samples are shown in Figures 1, 2, and 3, respectively. It is clear from the figures that the dielectric constant gradually decreases and then increases with frequency for bg and irradiated samples at 4.84 MeV with different irradiation times 0.17, 0.50, 0.75, 2.00, 3.00, 4.00, 5.00, and 6.00 min. The dielectric constants for 0.25, 1.00, and 1.50 min increase to constant value and then increase. The conductivities rapidly increase with increasing the frequency to 1000 Hz and then increases at a far lower rate. If the dipoles have sufficient time to align with the applied field before it changes direction, the dielectric

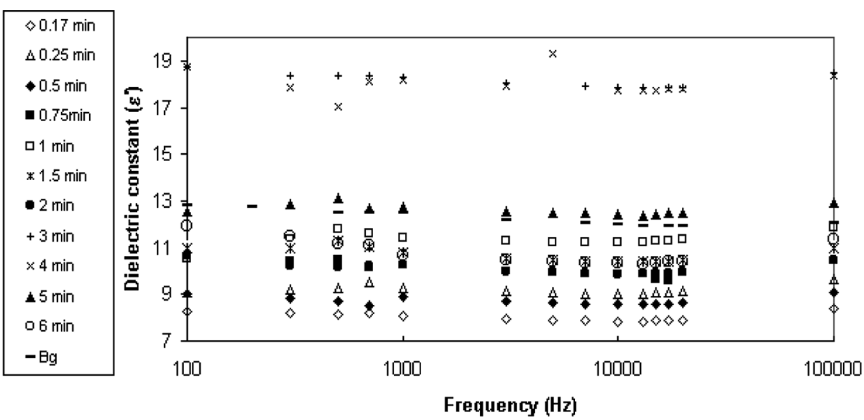

FIGURE 1 The frequency dependence of dielectric constant (ϵ') at room temperature for unirradiated and irradiated CR-39 samples.

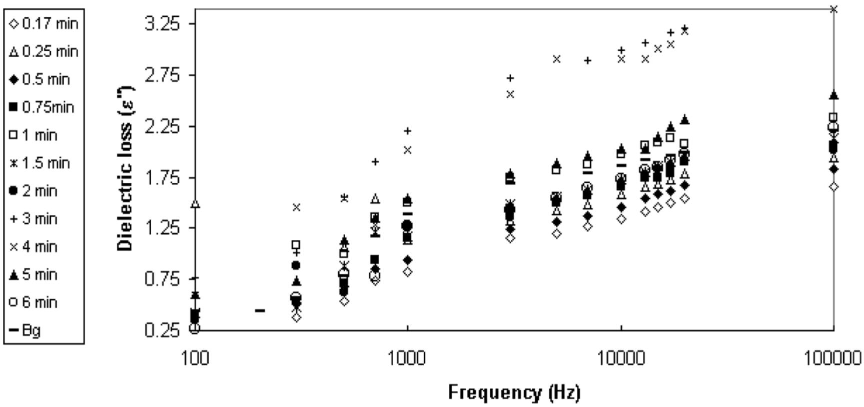

FIGURE 2 The frequency dependence of dielectric loss (ϵ'') at room temperature for unirradiated and irradiated CR-39 samples.

constant will be high. This appears in the region of low frequency. Also, if the dipoles do not have time to align before the field changes direction, the dielectric constant will have lower value.

The dependences of the dielectric constant, dielectric loss, and conductivity for unirradiated and irradiated samples at room temperature (25°C) and constant frequency (10 kHz) on the total number of alpha particles (Φ) are represented in Figures 4, 5, and 6. It is observed from the three figures that the dielectric parameters studied

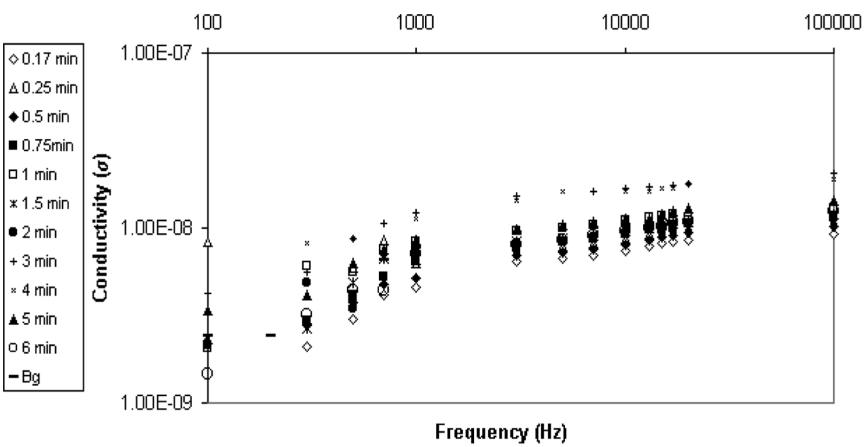

FIGURE 3 The frequency dependence of conductivity (σ) at room temperature for unirradiated and irradiated CR-39 samples.

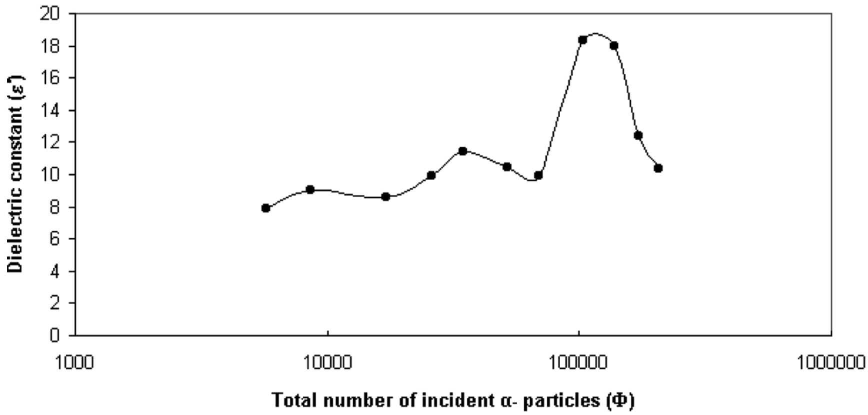

FIGURE 4 The variations of Dielectric constant (ϵ') with the total number of α-particles (Φ) incident on CR-39 samples.

sharply increased and then sharply decreased with increasing the Φ-value (for irradiation times 2.00, 3.00, 4.00, 5.00, and 6.00 min). The fitting equation for the dielectric constant (ϵ') for the irradiation times (2.00–6.00 min) is:

$$\epsilon' = -57.69 + 0.0016(\Phi) - 1.11 * 10^{-8}(\Phi)^2 + 2.31 * 10^{-14}(\Phi)^3 \qquad (6)$$

The correlation factor (r^2) is 0.99 for the fitting Eq. 6. This equation makes it possible to use CR-39 as a good sensor (dosimeter) for counting

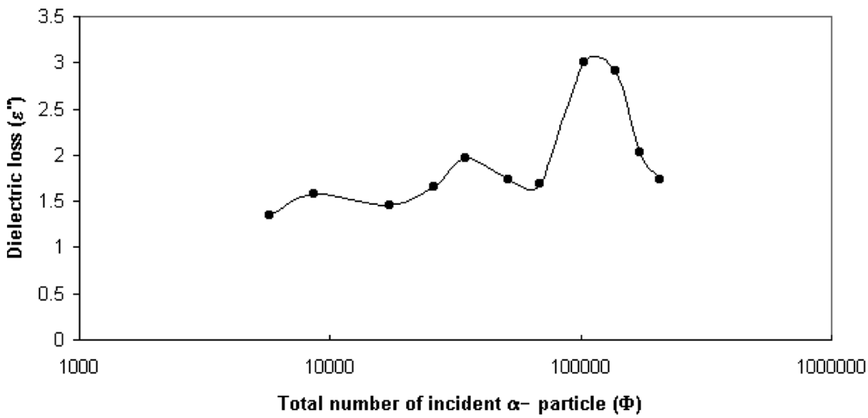

FIGURE 5 The variations of Dielectric loss (ϵ'') with the total number of α-particles (Φ) incident on CR-39 samples.

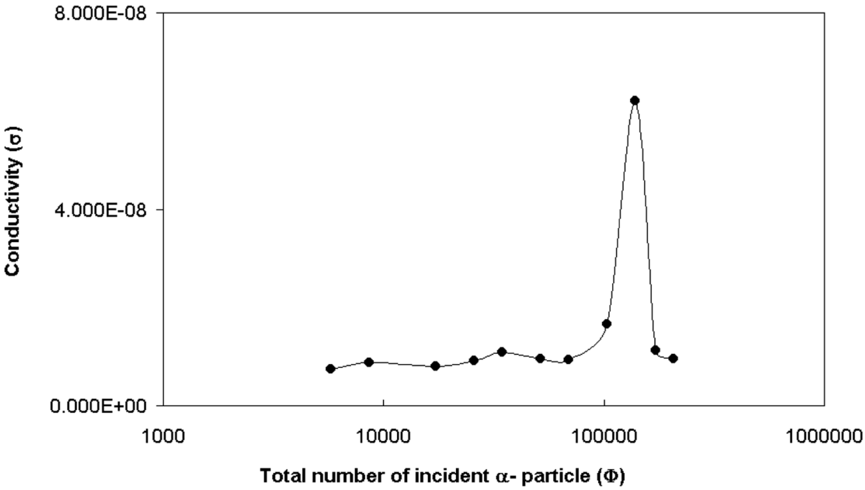

FIGURE 6 The variations of conductivity (σ) with the total number of α-particles (Φ) incident on CR-39 samples.

α-particles. This sensor does not need etching operation and scanning with an optical microscope as usual in dealing with CR-39 as a detector. Also, it is impossible to differentiate the tracks in CR-39 by the microscope at irradiation times 5.00 and 6.00 min.

The dependence on frequency of both dielectric loss and conductivity has the same behavior for dielectric constant as in Figures 5 and 6.

CONCLUSIONS

The dependences of the dielectric constant, dielectric loss, and conductivity on the total number of alpha particles (Φ) for unirradiated and irradiated CR-39 samples at 4.84 MeV α-particles and constant frequency (10 kHz) have been studied. This study shows that there is a possibility to use CR-39 as a good sensor (dosimeter) for counting α-particles at higher irradiation times (2.00–6.00 min).

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