Journal of Thermal Analysis and Calorimetry, Vol. 78 (2004) 793–797

STUDY OF EFFECTS OF γ-IRRADIATION ON TUFFAK POLYCARBONATE TRACK DETECTOR BY TG

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Abstract

Effects induced by γ-irradiation in the dose range of 0–10 Mrad on Tuffak polycarbonate track detector films have been studied by thermogravimetry (TG). The samples were irradiated with ^{60}Co γ-rays for doses of 3, 5 and 10 Mrad. The TG studies indicate that unirradiated and the γ-irradiated samples degrade in two steps. The kinetics of the two steps of degradation was also evaluated from the TG curves. Irradiation enhances the degradation rate and the effect increases further with increasing radiation dose. The activation energy values calculated for all the steps decrease on irradiation. A linear relationship observed between the decrease in activation energy and the dose received by the sample suggests the possibility of the use of Tuffak polycarbonate detector as γ dosimeter.

Keywords: activation energy, degradation, γ-radiation, TG, Tuffak polycarbonate track detector

Introduction

Nuclear track detectors are insulating solids, both naturally occurring and man-made. A number of materials, both organic and inorganic, have been used as track detectors. Under the group of inorganic materials fall the various minerals, mica and glass. The organic detectors include the commercially available plastics such as cellulose nitrate, cellulose acetate, polycarbonates, etc.. A measure of the sensitivity of a track detector can be expressed in terms of the minimum value of Z/B, the ratio of the charge, Z, to the velocity relative to light, B for a charged particle to produce an etchable track in that material. The more sensitive the detector, the smaller is this value. A number of detector quality plastics have been fabricated to suit various requirements. One of the important applications of these detectors is in fission studies [1–3]. Generally, polycarbonate detectors are used in these studies. In studies connected with nuclear fission induced by neutrons, the detectors are exposed to large doses of radiations such as γ and β radiations, neutrons, etc. in a nuclear reactor. It was thought interesting to investigate the thermal behaviour of these track detectors and to see the influence of γ irradiation on these detectors. In the present work, these studies are carried out with Tuffak polycarbonate track detector because it has been recently introduced as a track detector for recording fission tracks [4]. Although

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1388–6150/2004/ $ 20.00

Akadémiai Kiadó, Budapest
Kluwer Academic Publishers, Dordrecht

the basic material of this plastic is also the same as for Lexan polycarbonate $(C_{16}H_{14}O_3)_n$ but it has been fabricated in such a manner that the Z/B value for this detector is 52 as compared to value of 60 for Lexan polycarbonate [5] a distinct improvement in track recording characteristics. Recently, we have reported a detailed study on the track registration and chemical etching properties of this detector [4]. In the present investigation, the effects induced by γ-radiation in the dose range of 0–10 Mrad on this detector have been studied by thermogravimetry (TG).

Experimental

Tuffak polycarbonate track detector used in the present studies was manufactured by Rohm and Hass in Philadelphia, Pennsylvania and distributed by Transiliorap Plastics, Doraville, Atlanta, Georgia [6]. The thermal studies of unirradiated and γ-irradiated films were carried out in static air using differential thermal analysis (DTA) and TG. The curves were recorded at the heating rate of 6°C min^{-1} upto 750°C in a ULVAC thermoanalyser using sintered Al_2O_3 as the reference material for DTA. The mass of the sample in each experiment was taken about 15 mg. For the γ-irradiation, the film pieces, 2 cm^2 in area were cut from a big sheet. These samples were irradiated with ^{60}Co γ-rays for doses of 3, 5 and 10 Mrad at the Radiochemistry Division, BARC.

Results and discussion

The TG results show that the unirradiated and the γ-irradiated samples degrade in two steps (Figs 1 and 2). The corresponding DTA curve also showed two endothermic peaks with respect to the two steps of degradation. Generally, the thermal degradation of polymers in air gives exothermic peaks in DTA indicating oxidation process. The DTA peaks obtained in the present study are endothermic. It may be possible that in the present case, the polymer degrades to two different volatile species which do not have much higher residence time in the crucible, so, oxidation process is not taking place in the vicinity of the DTA sensor. The TG curve also shows 100% mass loss confirming the formation of volatile product. The DTA data and TG temperatures for all these steps are given in Table 1. Only the TG curves were fully analysed in the present studies. Irradiation lowers the temperature of TG curves at which the decomposition begins (T_i) for each step. The complete degradation temperatures (T_f) were also lowered in the γ-irradiated samples. In order to compare quantitatively the effects of γ-irradiation on the Tuffak polycarbonate track detector, the kinetics of the two steps of thermal degradation were also investigated from the TG curves of the unirradiated and γ-irradiated samples according to the methods reported in [7, 8]. However our data for both unirradiated and irradiated Tuffak polycarbonate track detector were found to fit well to Horowitz–Metzger method [9] although we had tried Freeman and Carroll, and Coats and Redfern methods [7] also. In Horowitz–Metzger method $\log[\log(W_0/W)]$ is plotted *vs*. θ where W_0 and W are the masses of the film initially and at time t, and $\theta=T-T_s$, where T is the temperature at mass W of the film and T_s is the temperature at

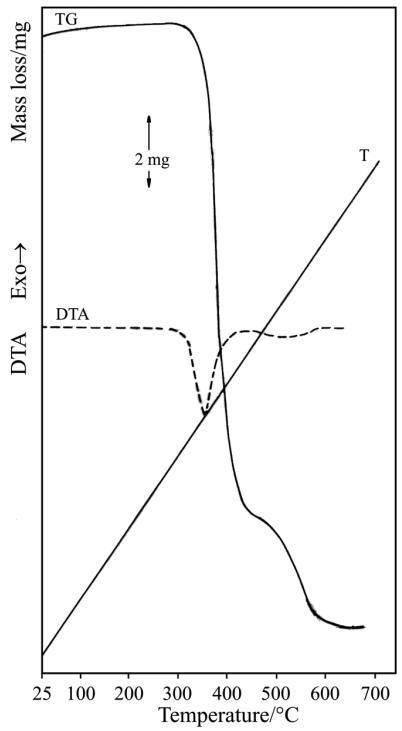

Fig. 1 TG and DTA curves of unirradiated Tuffak polycarbonate track detector

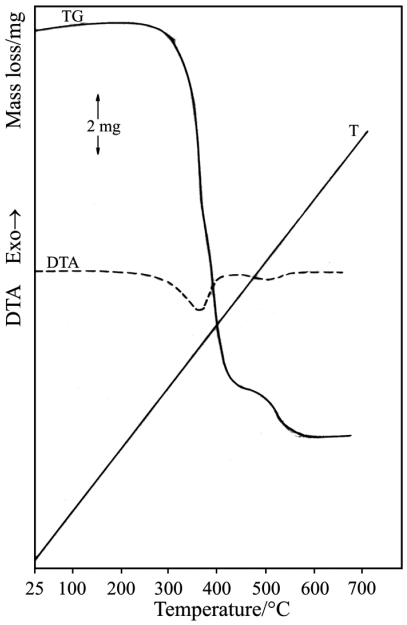

Fig. 2 TG and DTA curves of 5 Mrad γ-irradiated Tuffak polycarbonate track detector

Table 1 Thermal degradation data for unirradiated and γ-irradiated Tuffak polycarbonate track detector films

Sample	DTA peak inception temp./°C	TG temperatures		Mass loss/%	E/kJ mol^{-1}
		T_i/°C	T_f/°C		
Unirradiated detector					
Step 1	340 (endo)	350	500	80	146
Step 2	470 (endo)	500	645	100	183
3 Mrad γ-irradiated detector					
Step 1	330 (endo)	340	490	80	129
Step 2	465 (endo)	490	630	100	159
5 Mrad γ-irradiated detector					
Step 1	280 (endo)	290	480	83	117
Step 2	455 (endo)	480	620	100	124
10 Mrad γ-irradiated detector					
Step 1	260 (endo)	270	470	84	99
Step 2	450 (endo)	470	600	100	91

which W_0/W equals 1/e. The slope of the straight line thus obtained is given by $E/2.3RT_s^2$ where R is the gas constant and E is the energy of activation. The activation energy (E) values obtained by Horowitz–Metzger method from the kinetics studies for both the steps of degradation (unirradiated sample 146, 183 kJ mol^{-1}; 3 Mrad γ-irradiated sample 129, 159 kJ mol^{-1}; 5 Mrad γ-irradiated sample 117, 124 kJ mol^{-1} and 10 Mrad γ-irradiated sample 99, 91 kJ mol^{-1}) were found to decrease with increase in γ dose (Table 1). The RSD (relative standard deviation) obtained on E values by analysing few sets two times was found to be ±5%. It is obvious that γ-irradiation results in a substantial decrease in E in that values decrease with increasing dose. This decrease in activation energy values indicates that scission is predominant in γ-irradiation of Tuffak polycarbonate track detector. Thus Tuffak polycarbonate track detector undergoes scission upon γ-irradiation. A calibration curve drawn between T_f temperatures and the corresponding γ doses was found to be linear. It is observed from the data presented in Table 1 that the plots of E *vs*. dose in Mrad also yield straight lines. It is felt that this plot is more representative of the processes taking place in the material as compared to the linear plot obtained between the temperature of completion of degradation and the γ dose to which it is subjected. Further since the activation energy data is derived under fixed experimental conditions, the effect of γ dose in it is highlighted in true sense. Moreover, it is directly connected with the mechanism of the process involved and would truly represent the influence of γ dose on scission. The quantities T_f, T_i, etc. on the other hand are highly dependent on heating rate, sample size and other experimental parameters. This suggests the possibility of using the linearity between the E and γ dose for the estimation of γ dose.

The authors are thankful to Dr. V. K. Manchanda, Head, Radiochemistry Division, BARC for his encouragement and support during this work.

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