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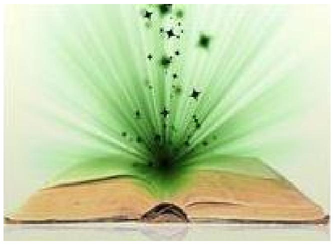

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A Comparison of Thermal Properties for Etched and Unetched PADC Detector Exposed to High Doses of Gamma Radiation

Dipak Sinha

Department of Chemistry, Nagaland University, Lumami-798627, Nagaland, India

E-mail: dipaksinha@gmail.com

ABSTRACT

Thermo gravimetric analysis of PADC (American Acrylics) detector exposed to gamma radiation indicates that due to gamma exposure, thermal stability of the detector decreases than the pristine one. Also, further due to chemical etching of the detector, the thermal stability decreases as comparison to the unetched one. The endothermomic behavior of the detector due to loss of weight normally changes in the temperature range of around 375^0C. Due to gamma exposure, this endothermic transition takes place at a lower temperature of around 350^0C. Chemical etching of the detector further lowers the temperature of this endothermic transition. The amount of heat involved for the endothermic transition is around 5.66 J g^{-1} for the pristine sample, whereas for irradiated samples, it is found to be 20.95 J g^{-1}.

Keywords: TGA, DTA, DSC, Gamma Dose, Etching.

INTRODUCTION

Solid State Nuclear Track Detectors (SSNTDs) are becoming very popular in recent years because of their wide applications in the fields of science and technology [1-4]. Track properties of these detectors are known to be modified to different extents depending on the type of radiations they are exposed to and in this regard a lot of works on PADC track detectors have been reported by several authors [5-16]. It has been mostly observed that etch-rates of these detectors increase upon gamma exposure. This increase in etch rates is attributed to scissioning of the molecular chains of the track detectors, which reduces their average molecular weight. For example, in the case of PADC American-Acrylics detector, it has been observed that [7] , the scissioning of polyallyl chains with diethyleneglycol takes place at a gamma dose of 10^6 Gy.

It is now an established fact that interaction of radiation with polymers leads to chain scission, chain aggregation, formation of double bonds and molecular emission etc. As a consequence of this, the physico-chemical properties like optical, electrical, mechanical, chemical and other properties of the polymer are greatly modified [17-21]. Among the different properties of a polymeric material, thermal studies are one of the most useful. Since thermal properties of a polymer are strongly dependent on the internal structure of the polymer, it is important to understand the effect of radiation on their thermal properties. A survey of related literature indicates that the thermal characterization of irradiated polymers have been studied by different authors [22-25]. However most of the author has either studied heavy ion effect or gamma effect of lower doses.

The present study deals with one type of PADC detector as these detectors are commonly used for the study of tracks. PADC polymers consist of ester functional group and it can be expected that during etching of the detector to study tracks, the etchant attacks the ester functionality which leads to partial dissociation of the polymeric chain, further leading to scissioning of the chain. Thus it might be possible that once the detector is exposed to radiation, followed by etching, the scissioning of the polymeric chain becomes more effective Thus it is expected that due etching of the detector, thermal properties of the detector will be further modified. This paper presents a brief report about modifications in thermal properties of both etched and unetched PADC-American Acrylics detector irradiated with gamma radiation.

MATERIALS AND METHODS

Irradiation of the Detectors : Seven samples of the detector (thickness 650 µm and density 1.32 g cm^{-3}, Manufacturer: American-Acrylics Corporation) of sizes (3 x 3 cm^2) were prepared and exposure was done from a ^{60}Co gamma source having a dose rate of 3.0 kGy h^{-1}. The exposure time varied from 12 s to nearly 14 days in order to deliver the required doses in the range of 10^1 to 10^6 Gy. One set was first exposed at normal incidence to fission fragments from a ^{252}Cf source, and then, together with the unexposed (second) set was subjected to various doses of gamma rays. The second set was then irradiated with fission products from a ^{252}Cf source. The first and second sets of detectors are generally termed as post-gamma and pre-gamma exposure respectively in this study. For this particular work, the sample exposed to 10^6 Gy (post-gamma) was chosen to make the comparative study.

Thermal Study: After the gamma exposure, the thermal study was performed using a using a TA Instrument, Model : Q600 SDT and Q20 DSC. Small pieces (0.25 × 0.25 cm^2) of the samples were made and thermal studies were done at a constant heating rate of 20^0C min^{-1}. This heating resulted in TG curves, in which the weight loss was recorded as a function of temperature. While losing weight the change of heat was recorded as a function of temperature which gave the DTA and DSC thermogram. Further to understand effect of etching on thermal properties, same studies were repeated for the etched detector exposed to 10^6 Gy. The post-gamma exposed detector (10^6Gy) was etched for 20 minutes and then cleaned thoroughly. The etched clean sample was then used for TGA, DTA and DSC studies.

RESULTS AND DISCUSSION

Thermo gravimetric studies of gamma irradiated detector (post-gamma) at a dose of 10^6 Gy, and etched detector at the same dose is shown in Fig.1. It is observed that due to etching of the detector, thermal stability decreases drastically.

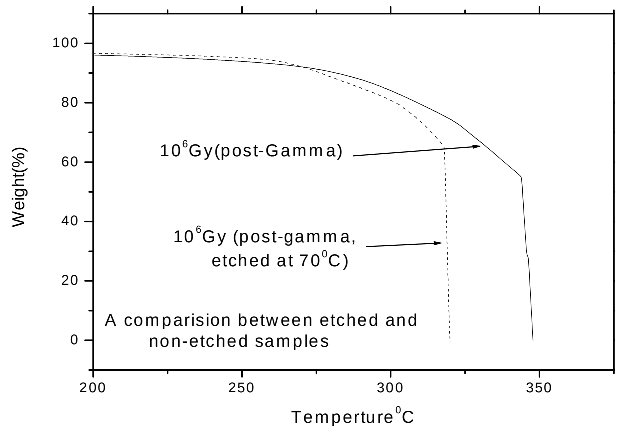

Fig.1. TGA Thermogram of gamma irradiated detector and etched detector

Unetched detector loses its complete weight at around 350^{0}C, but when etched, the complete weight loss takes place at around 320^{0}C. Also it is observed that even though for both the samples weight loss process starts at 275^{0}C, but the etched detector loses its weight completely at a much lower temperature. Thus it might be possible that due gamma exposure already there are scissioning of the polymer chain taken place. Due to etching, small smaller fragments of polymer chain are dissolved away thus reduces the molecular weight of the chain. Normally exposure to radiation leads to many broken segment in the polymer matrix. This scissioning is further enhanced due to chemical attack (shown in Fig.2) This chemical reaction leads to decrease in average molecular weight of the polymer and accordingly the stability of the sample decreases.

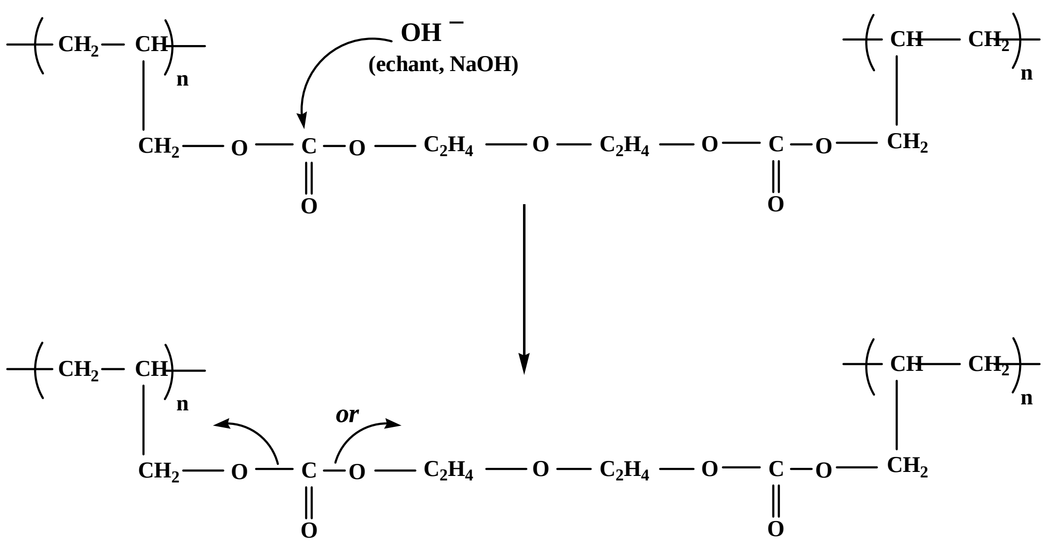

Fig.2 Attack of etchant NaOH to PADC polymer leads to scissioning of the polymer chain

Infact it has been reported earlier that due to gamma exposure scissioning of polyallyl chain joined by diethyleneglycol takes place due to gamma exposure at a dose of 10^6 Gy. Due to scissioning of the chain, the etch rates of the detector increases drastically at dose of 10^6 Gy.

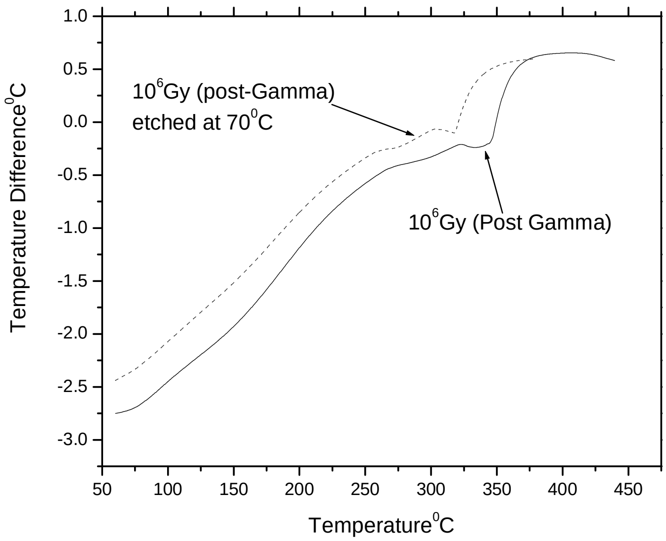

Fig. 3 DTA thermogram of gamma irradiated and etched detector

In order to understand about both qualitative and quantative changes in heat involved during the weight loss processes, DTA and DSC studies are performed for both pristine and samples irradiated with gamma doses and compared with the etched sample. Fig. 3 shows the DTA thermogram of the irradiated PADC detector (post-gamma) along with the etched detector. From the figure it can be understood that the endothermic behavior of the detector is found to be changed due to chemical etching. The etched detector shows the endothermic curve at much lower temperature i.e at 325^0C compared to the unetched one at 325^0C. Since endothermic change of the detector takes place at this temperature due to weight loss, it implies that the detector loses its weight at a much lower temperature as compared to the unetched one. This might be possible due to chemical attack of the etchant. Exposure to radiation leads to scissioning of the chain which further leads to formation of many small chains. Once the detector is subjected to etching, the chemical attack of the etchant dissolves away the damaged fragments of the polymer matrix. This probably leads to the reduction of molecular weight of the polymeric detector, and weight loss starts at much lower temperature for etched detector.

In order to understand the amount of heat involved during the endothermic process of the weight loss, DSC studies of the pristine, irradiated and etched detector have been carried out and Fig.4 shows the DSC thermogram of these detectors. The amount of heat involved in the endothermic process of weight loss is found to around 5.66 J g^{-1} for the pristine sample, whereas for irradiated samples, it is found to be 20.95 J g^{-1}.

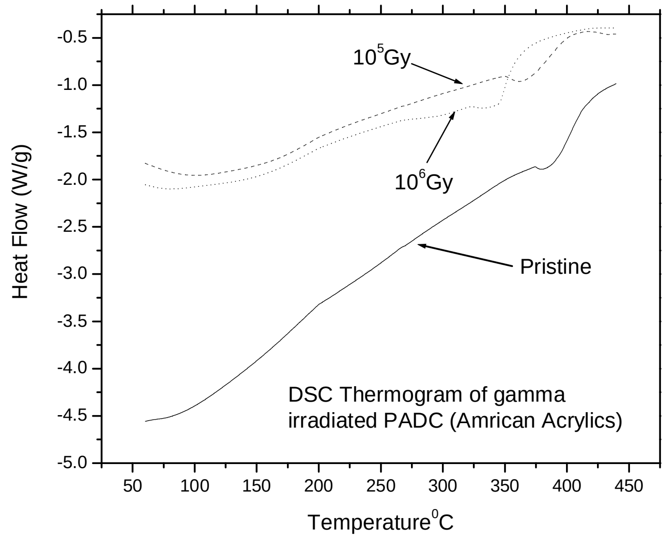

Fig. 3 DSC thermogram of gamma irradiated and pristine detector

APPLICATIONS

Thermal properties of PADC track detectors are greatly influenced due to gamma exposure, which however is found to be significant only at a dose of 10^6 Gy. Further it is observed that due to etching of the detector, thermal stability of the detector decreases. Thus these particular results will be very helpful in planning any experiment where gamma exposure of the PADC detectors is normally done. The detector can be safely used till the gamma dose of 10^5 or to be on the safer side, upto the dose of 10^4 Gy, as no apparent modifications takes place below the dose of 10^6 Gy.

CONCLUSION

On the basis of present study the conclusions has been made as follows

1. TGA studies reveal that due to gamma exposure the thermal stability of the detector decreases at a dose of 10^6 Gy and the effect is more significant for etched detector.
2. Due to etching of the detector, the thermal stability of the detector decreases as compare to the unetched detector.

Due to etching, the thermal stability of the detector decreases and accordingly endothermic transition is observed at lower temperature as compare to the unetched detector.

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