Available online at www.pelagiaresearchlibrary.com

Pelagia Research Library

Pelagia Research Library

Advances in Applied Science Research, 2012, 3 (4):2128-2133

Pelagia Research Library

ISSN: 0976-8610
CODEN (USA): AASRFC

Effect of gamma radiation on thermal stability of PADC-American Acrylics detector

Dipak Sinha[1*], Tokavi I.Chophi[1] and Toka Swu[2]

[1]Department of Chemistry, Nagaland University, Lumami-798627, Nagaland, India
[2]Department of Chemistry, Pondichery University, Puducherry-605014, India

---

ABSTRACT

A comparative study on thermal properties of gamma irradiated PADC-American Acrylics track detector is done in dose range of 10^1–10^6 Gy. TGA studies reveal that due to gamma exposure the thermal stability of the detector decreases at a dose higher than 10^4Gy. It is also observed that the post-gamma mode of exposure of the detector has got more significant effect on thermal stability then the pre-gamma mode of exposure. Due to etching of the detector, thermal stability of the detector decreases drastically at a dose of 10^6 Gy. The weight loss by the detector upon heating is found to be endothermic in nature and takes place in the temperature range of around 375^0C. However, due to gamma exposure, this endothermic transition takes place at a lower temperature of around 350^0C. Chemical etching of the detector leads to further lowering of this endothermic transition. The amount of heat involves for the endothermic process of weight loss is found to be around 5.66 J/g for the pristine sample, whereas for irradiated sample of 10^6 Gy, it is found to be 20.95 J/g.

Keywords : TGA,DTA, DSC, Gamma Dose

INTRODUCTION

Interaction of radiation with polymers lead to different structural modifications such as chain scission, chain aggregation, formation of double bonds and molecular emission, and consequently, many of their physico-chemical properties like optical, electrical, mechanical, chemical and track properties are modified [1-8]. In view of this, studies on application of radiation on polymeric materials are of great importance as they allow for desired improvements in polymer properties. Among the different studies on polymeric materials, thermal studies are one of the most useful as the different thermal properties of a polymer are strongly dependent on their internal structure of the polymer. Since exposure to radiation is known to be one of the major factors that change the structural properties of polymers, it was considered to be worthwhile to study the modifications of their thermal properties due to irradiation. A survey of the literature indicates that the thermal characterization of irradiated polymers have been studied by different authors [9-15]. However most of the authors have either studied polymers irradiated by heavy ions or by lower doses of gamma radiation. Keeping this in mind, the present paper presents details of thermal studies on gamma irradiated PADC-American detectors exposed to very high doses of gamma radiation (up to a dose of 10^6 Gy). In one of our earlier observations we have briefly reported [11] that due to gamma irradiation, the thermal stability of different polymers are significantly modified. Therefore, as a case study, in this present work a detailed study on modifications of thermal properties like its stability, exothermic and endothermic behaviour while loosing weight, ect. are presented for PADC-American Acrylics detector.

It had been observed in one of our earlier studies that the etch-rates of PADC detector are greatly altered by gamma exposure at the dose of 10^6 Gy [16-17]. Normally for track formation, the chemical etchant attacks the functional groups of the track detector, which subsequently leads to formation of tracks. Thus there is a possibility that due to etching, there might be a change in thermal stability of the detector. Through this piece of work a comparative assessment has been attempted to understand the difference in thermal properties of un-etched and etched detectors. However, since it has been observed by our earlier studies that etch rates are greatly altered only at a does 10^6 Gy, present study has been restricted to this dose only.

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. After cleaning and drying the samples, exposure was done from a ^{60}Co gamma source having a dose rate of 3.0 kGy/h. The time required for exposure 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. The errors in doses range from 8% for low dose (10 Gy) to about 1% for high doses. One set was first exposed at normal incidence to fission fragments from a ^{252}Cf source (having a half-life of 2.65 years and activities of 5.7×10^3 fission/min and 1.84×10^5 alpha particles/min) and then, together with the unexposed (second) set was subjected to various doses of gamma rays. The first and second sets of detectors are generally termed as post-gamma and pre-gamma exposure respectively in this study. Exposure to fission fragments from a ^{252}Cf source was done for track registration.

Thermal Studies

After the gamma exposure, thermal studies were conducted using a TA Instruments, Model : Q600 SDT and Q20 DSC. Small pieces (0.25×0.25 cm^2) of the samples were made from the gamma exposed samples (pre-gamma set), and thermal studies were done at a constant heating rate of 20^0C/min. All the detectors were heated up to a very high temperature (varied from one detector to another) so that in the process of heating they lost most of their weight. This heating resulted in TG curves, in which the weight loss was recorded as a function of temperature. The change of heat flow observed during weight loss was recorded as a function of temperature which gave the DTA and DSC thermogram. All the studies were done for both for both pre and post-gamma exposed detectors.

In order to understand effect of etching on thermal properties, same studies were repeated for the etched detector exposed to 10^6 Gy. The detector exposed to fission fragments and subsequently exposed to gamma dose of 10^6Gy (post-gamma) was etched for 20 minutes. After cleaning, the etched sample was then used for thermal studies.

RESULTS AND DISCUSSION

The results of thermogravimetric studies on gamma irradiated detector are presented in Fig.1. It is observed that due to gamma exposure, thermal stability of the detector changes significantly. However the most significant changes are observed at doses higher than 10^4 Gy. Even though the changes start at doses higher than 10^4 Gy, however, we observed that there is not much significant change in both pre or post -gamma exposure mode of the detector till the dose of 10^5 Gy. The drastic change in the thermal stability takes place at a dose of 10^6 Gy for post-gamma exposed detector.

It is interesting to observe that at a dose of 10^6Gy, the post-gamma mode of exposure had much greater effect than the pre-gamma one. As seen in Fig.1. the post-gamma exposed sample loses its weight completely at a much lower temperature than the pre-gamma one. This might be due to the fact that in the case of post-gamma, the detector is first exposed to fission fragments and alpha particles. Exposure to these charge particles leads to scissioning of the polymeric chain. This effect is further enhanced due to exposure to gamma radiation again.. It is also clear from the thermogram that the pristine sample loses its complete weight at around 425^0C, which is not the case for the exposed one. The detector loses its complete weight at around 348^0C for the exposed detector (10^6 Gy, Post-gamma) dose, which means thermal stability of the detector decreases drastically which is probably due to scissioning of the polymeric chain. Scissioning of the polymeric chain leads to decrease in the average molecular weight of the detector, which leads to decrease in thermal stability of the sample. Since there is no significant change observed at the lower doses of irradiation (both pre and post gamma exposure), the weight loss pattern is not shown in the thermogram.

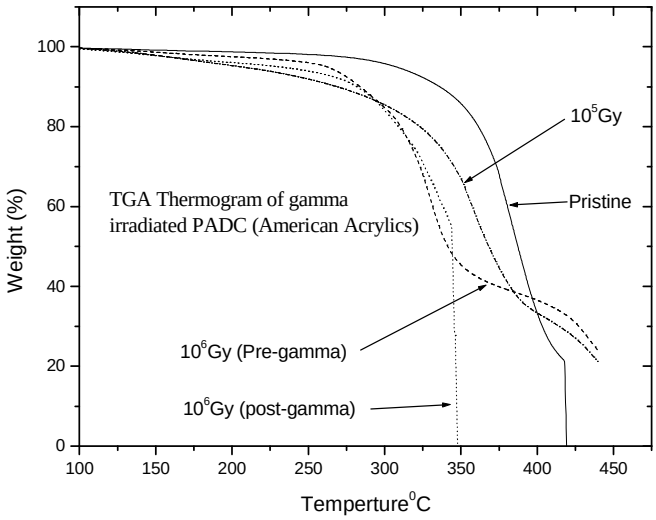

Fig.1. TGA Thermogram of gamma irradiated PADC-American Acrylics Detector

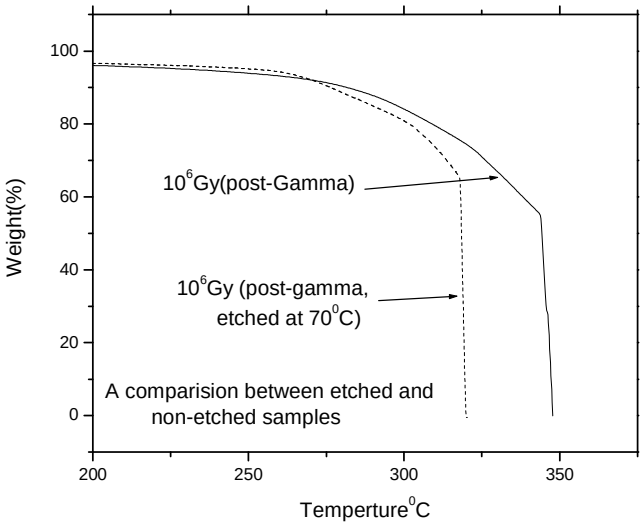

Fig.2. TGA Thermogram of gamma irradiated and etched Detector

Fig.2. is the TGA thermogram for the etched detector and unetched detector (post-gamma) exposed to 10^6 Gy. From these results, it is clear that the thermal stability of the detector decreases due to chemical etching. As shown in Fig.2, the detector looses its complete weight at around 320^0C for the etched sample as compared to 348^0C of the un-etched sample. This decrease might be due to further decrease in the molecular weight of the polymer chain due to chemical etching. Normally exposure to radiation leads to many broken segment in the polymer matrix. This scissioing is further enhanced due to chemical attack. Thus chemical etching leads to decrease in average molecular weight of the polymer and accordingly the stability of the polymer decreases.

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 (both pre and post mode). Similar studies are carried out for the detector etched at 70^0C which was exposed to 10^6 Gy (post-gamma). Fig. 3 shows the DTA thermogram of pristine and irradiated PADC detector (post-gamma) detectors. The

thermogram clearly indicates that the pristine detector undergoes an endothermic transition at around 400^0C. This behavior remain same till the dose of 10^4 Gy. But at the dose of 10^5 Gy, the endothermic peak is observed at a much lower temperature of around 375^0C and at the highest dose of 10^6 Gy, this transition is observed 350^0C. This may explained as due to gamma exposure, scissoring of the chain takes in the polymer matrix which probably leads to weight smaller molecular chains/segments in the polymer matrix. Due to smaller fragments in the polymer matrix, weight loss process starts earlier for the exposed detector than from the pristine one. Higher is the dose, more is the scissioning of the polymer chain, which leads to weight loss at lower temperature.

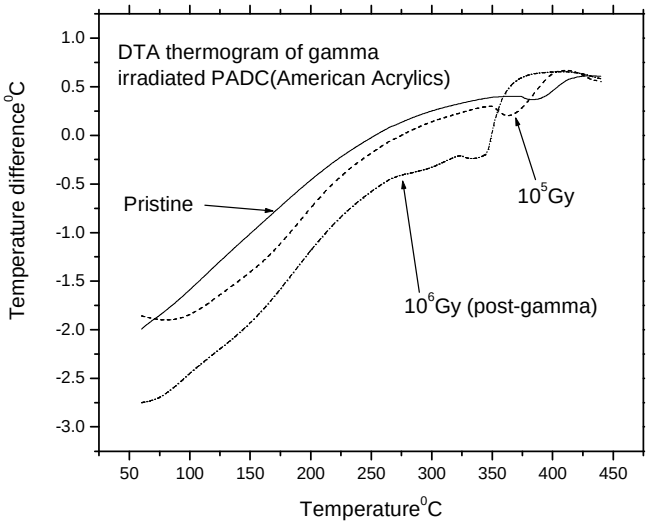

Fig.3. DTA thermogram of gamma irradiated PADC-American Acrylics Detector

DTA curve of the etched detector along with the unetched one is shown in Fig. 4. 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 than the unetched one at 325^0C. This means the detector looses its weight at lower temperature as compared to the unetched one. This might be possible due to chemical attack of the etchant. Exposure to radiation leads to scisssioning of the chain which further leads to formation of many small chains.

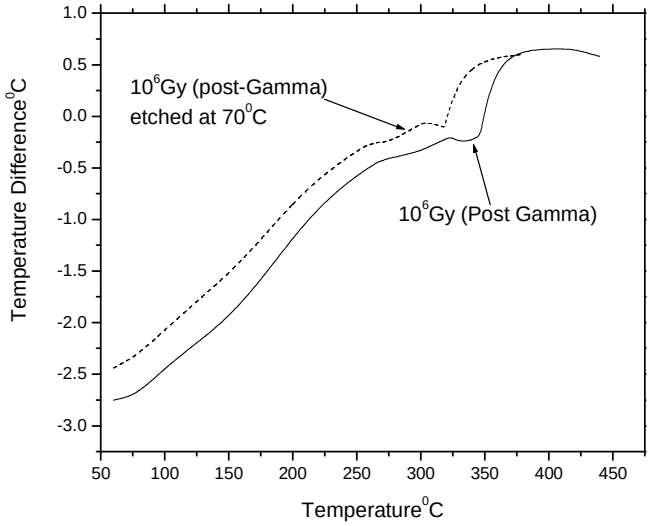

Fig. 4 DTA thermogram of gamma irradiated and etched detector

Once the detector is subjected to etching, the chemical attack of the etchant dissolved away the damage 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,

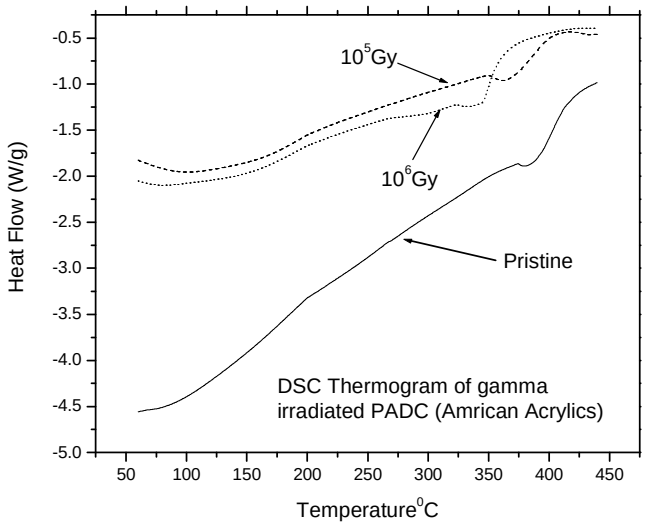

Fig. 5 DSC thermogram of gamma irradiated and pristine detector

DSC studies of the pristine and irradiated detector was carried out. Fig.5 shows the DSC thermogram of the detectors. The amount of heat involves for the endothermic process of weight loss is found to around 5.66 J/g for the pristine sample, whereas for irradiated samples, it is found to be 20.95 J/g.

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 higher then 10^4Gy and the effect is more significant for post gamma exposed detector only at the higher doses.
2. The pre-gamma and post-gamma exposure mode of exposure does not seems to have very significant effect at the lower doses.
3. The weight loss process of PADC-American Acrylics detector is endothermic in nature.
4. Due to exposure, the detector looses its weight at lower temperature and accordingly the endothermic transition is observed at a lower temperature.
5. Due to etching, the thermal stability of the detector decreases and accordingly endothermic transition is observed at lower temperature.

Acknowledgements
The authors are grateful to Central Instrumentation centre, Pondicherry University for the sample analysis. One of the author D.S. is grateful to Professor K.K. Dwivedi, Prof. V.G.Dedgaonkar, Prof. Alok Srivastava, Prof. Dietmar Fink for their help.

REFERENCES

[1] L. Calcagno, G. Compagnini, G. Foti ; *Nucl. Instrum. Methods* B, **1992**, 65, 413.
[2] D. Fink, W.H. Chung, R. Klett, A, Schmoldt, J. Cardoso, R. Montiel, M.H. Vazquez, L. Wang, F. Hosoi, H. Omichi, P. Goppelt-Langer ; *Radiat. Eff. Def. Solid* , **1995**, 133, 193.
[3] T. Phukan, D. Kanjilal, T.D. Goswami, H.L. Das, *Nucl. Instrum. Methods* B, **1999**, 155, 116.

[4] R. Mishra, S.P. Tripathy, D. Sinha, K.K Dwivedi, S. Ghosh, D.T. Khathing, M. Muller, D. Fink, W.H. Chung ; *Nucl. Instrum. Methods* B **2000**, 168, 59.
[5] R. Mishra, S.P.Tripathy, K.K. Dwivedi, D.T. Khathing, S. Ghosh, M. Muller, D. Fink ; *Radiat. Eff. Def. Solids* , **2000,** 127, 1.
[6] M. S. Babu1, P .V .S. Narayana, T. S. Reddy,D. U. Reddy ; *Adv. Appl. Sci. Res*., **2011**, 2, 226.
[7] I. Kaur , V. Kumari, B. Singh ; *Der Chemica Sinica*, **2012**, 3, 343.
[8] D. Sinha; *Adv. Appl. Sci. Res*, **2012**, 3 , 1365.
[9] U.S. Sias, G. Sanchez, J.R. Kaschny, L. Amaral, M. Behar, D. Fink ; *Nucl. Instrum. Methods* B **1998**, 134, 35.
[10] U.S. Sias, G. Sanchez, J.R. Kaschny, L. Amaral, M. Behar, D. Fink ; *Nucl. Instrum. Methods* B **1998**, 141, 187.
[11] D.Sinha, K.K. Dwivedi ; *Radiat. Meas.* **2003**, 36, 713.
[12] S.A. Nouh, M.H. Abde-Salem, Y.E. Radwan, S.S. Fouad ; *Radiat. Eff. Def. Solids* **2011**, 166, 178.
[13] P.C. Kalsi, A. Ramaswami ; *Indian J. Phys*., **2009**, 83, 1123.
[14] Y.H.A. Fawzy, A.E.H. Ali, E. Maghraby, R.M. Radwan ; *World Journal of Condensed Matter Physics* **2011**, 1, 12.
[15] R. Gupta, V. Kumar, P.K. Goyal, S. Kumar, P.C. Kalsi, S.L. Goyal ; *Adv. Appl. Sci. Res*. **2011**, 2, 248.
[16] D. Sinha ; *e-journal of Chemistry*, **2012**, 9, 2226.
[17] D. Sinha; *Radiation Effects and Defects in Solids* , **2009**, 164, 604.