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Thermal studies of PADC Homalite detector and effect of gamma radiation on its thermal properties

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ABSTRACT

Thermal properties of PADC-Homalite Nuclear Track Detector is studied in the dose range of 10^1–10^6 Gy and compared with the pristine one. Thermal analysis of the pristine Homalite detector reveals that first step of weight loss of the detector takes place in the temperature range of 370^0C to 420^0C, which is endothermic in nature. Due to gamma exposure the thermal stability of the detector does not change very significantly till the dose of 10^4Gy. However, at the dose of 10^5 Gy and above, the detector loses its weight at lower temperature. Further, it is observed that at the dose of 10^6Gy, in addition to two endothermic transition, another minor endothermic transition is also seen in the temperature range 245^0C to 270^0C.

Keywords: TGA, DTA, DSC, Gamma Dose.

INTRODUCTION

PADC track detectors have become one of the most popular track detectors in recent years because of their wide applications in the fields of science and technology [1-4]. Owing to their excellent track detection properties, they find use in different radiation environments which in turn modify its physical and chemical properties to different extents depending on the type of radiations they are exposed to. Different authors have reported at different times about the modifications that occur in these PADC track detectors due to exposure to radiation. [5-16]. Since PADC track detectors are widely used as nuclear track detectors, most of the studies have focused on the effects of external radiation on track properties like bulk-etch rate, track-etch rate etc. It has been mostly reported that etch-rates of these detectors increase upon radiation exposure which 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 [8], the scissioning of polyallyl chains with diethyleneglycol takes place at a gamma dose of 10^6Gy.

Interaction of radiation with polymers leads to chain scission, chain aggregation, formation of double bonds and molecular emission etc. which leads to modifications in the physico-chemical properties of the polymers [17-26]. Since thermal properties of any polymer is strongly dependent on the internal structure of the polymer which is expected to be effected due to gamma exposure, it was considered to be worthwhile to study the modifications of their thermal properties due to gamma irradiation. Thus in this

paper an effort has been made to understand the effect of high gamma dose (upto the dose of 10^6 Gy) radiation on thermal properties of PADC-Homalite detector.

MATERIALS AND METHODS

Irradiation of the Detectors: Seven samples of the detector (thickness 1500 µm and density 1.32 g cm^{-3}, Manufacturer: Homalite Corporation) of sizes (2 x 2 cm^2) were exposed to ^{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.

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 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.

RESULTS AND DISCUSSION

The TGA (Thermo Gravimetric Analysis) and the DSC (Differential Scanning Calorimetry) thermogram of pristine (non-irradiated) PADC-Homalite is shown in Figure1. It is observed from the thermogram that the weight loss takes place in two steps. First step of weight loss is very distinct in nature starts at around 350^0C and continues till around 410^0C. Again a second step of weight loss starts around 415^0C and continues till around 445^0C-450^0C and this step of weight lost is very gradual in nature and continues with increasing temperature till around 480^0C, where complete weight loss takes place. Both the weight loss processes are observed to be endothermic in nature.

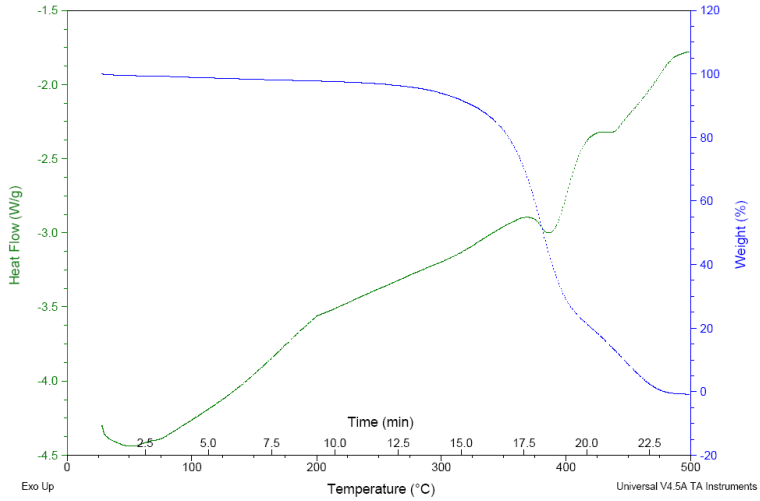

Fig.1. TGA and DSC thermogram of pristine PADC-Homalite Detector.

From DSC results it is understood that an amount of 21.67 J g^{-1} and 3.929 J g^{-1} heat is involved in the endothermic transition. Further, the first endothermic process takes place at around one minute, where as time required for second process is around 0.66 minutes. Figure 2 is the TGA & DSC thermogram, where time required and heat flow is reflected in the thermogram to understand the time required for endothermic weight loss process of the detector.

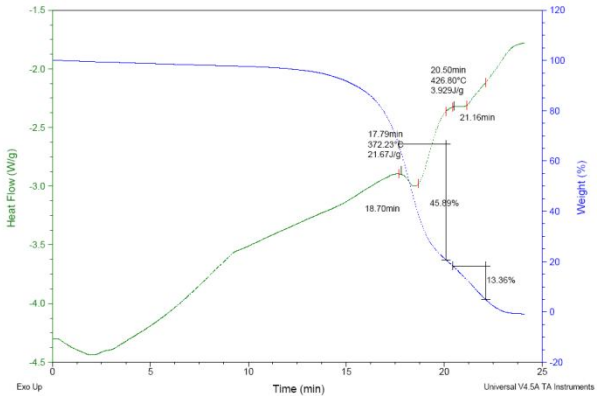

Fig.2. TGA and DSC thermogram of pristine detector where heat flow and time are reflected in the thermogram

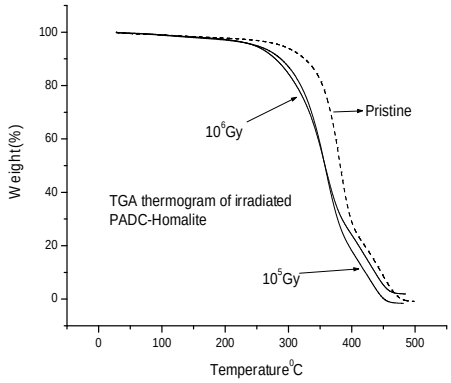

Fig. 3. TGA thermogram of gamma irradiated PADC-Homalite Detector

Figure 3 shows the TGA thermogram of gamma irradiated detector at higher doses along with the pristine one. It is clear from the result that, due to gamma exposure, the detector starts losing its weight at much lower temperature of around 230^0C for both 10^5 Gy and 10^6 Gy. However it was observed that till the dose of 10^4 Gy, there was no change in the decomposition pattern. It need to be mentioned that even though the weight loss starts at lower temperature, the pattern of the weight loss remains same. Thus it may be possible that at these doses, scissioning of the chain takes place to an significant extent even though, there may not be complete destruction of the polymer bond. In fact this results corroborates the earlier results [8,15] where enhanced etch-rate was observed due to scissioning of the polymeric chain.

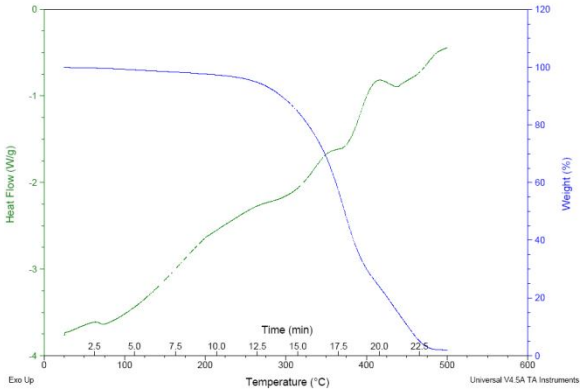

Fig.4. TGA-DSC thermogram of the PADC-Homalite detector, irradiated at a dose of 10^6 Gy.

Figure 4 shows the both TGA, DSC thermograms of the detector irradiated at a dose of 10^6 Gy. As reflected in the figure, the endothermic behavior of the detector due to weight loss occurs at much lower temperature for the irradiated detector. Further, it addition to two endothermic transition, another minor transition is also seen in the temperature range 245^0C to 270^0C.Thus it might be possible that at this dose of radiation, due to scissoring of the chain some amount of weight is lost which leads to the endothermic behavior of the sample. Figure 5 clearly indicates the three endothermic process of weight loss of the irradiated sample (10^6 Gy)

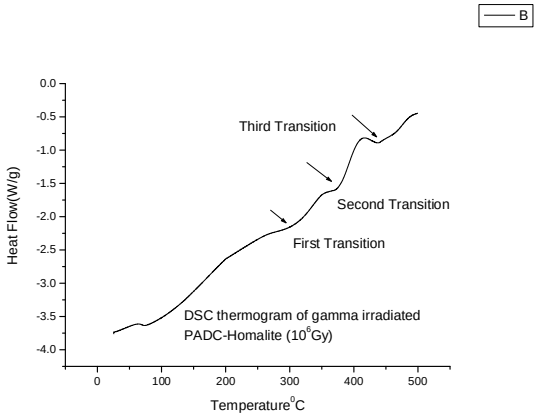

Fig.5 DSC thermogram of the detector, irradiated at a dose of 10^6 Gy shows three endothermic process of weight loss.

The comparative DSC thermogram of the pristine detector along with the irradiated at higher doses of radiation is shown in Figure 6. There seems to be not so much difference in the thermograms other than the fact that at the highest dose, one more endothermic transition takes place at lower temperature.

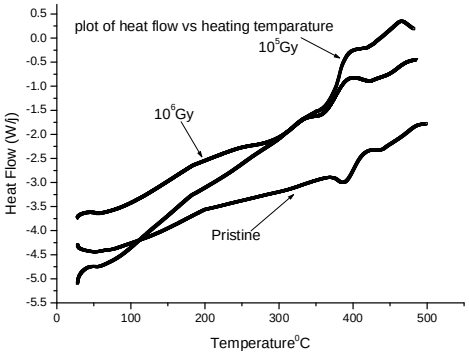

Fig.6. DSC thermogram of gamma irradiated PADC-Homalite Detector

APPLICATIONS

Thermal properties of PADC-Homalite track detectors are modified due to gamma exposure at a higher dose of 10^5Gy and above. Further it is observed that at the dose of 10^6Gy, three endothermic transition of the detector takes place while heating the sample in comparisons to two transitions to pristine one. Thus these particular results will be very helpful in planning any experiment where gamma exposure of the PADC-Homalite is done. The detector can be safely used till the gamma dose of 10^4 Gy, as no apparent modifications in thermal stability till the dose of 10^4 Gy.

CONCLUSIONS

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

1. Due to gamma exposure the thermal stability of the detector decreases at a dose of 10^5 Gy and 10^6 Gy.
2. The weight loss process of PADC detector is endothermic in nature.
3. Due to exposure, the detector loses its weight at lower temperature and accordingly the endothermic transition is observed at a lower temperature.

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REFERENCES

[1] R.L. Fleischer, P.B. Price, R.M. Walker, L.S.B. Leakley, *Science*, **1965**, 148, 72-74.
[2] B.E. Fischer R. Spohr, *Rev. Mod. Phys*., **1983**, 55, 907-948.
[3] D. Fink, Fundamentals of Ion-irradiated Polymers, 2004. (Springer Series in Materials Science
[4] D. Fink, P.S. Alegaonkar, A.V. Petrov, M. Wilhelm,P. Szimkowiak, M. Behar, D. Sinha,W.R. Fahrner , K. Hoppe, L.T. Chadderton, *Nucl. Instrum. Meth*.B, **2005**, 236**,** 11-20.
[5] R. Shweikani, S.A. Durrani, T. Tsuruta, *Nucl. Tracks Radiat. Meas*., 1993, 22, 153-156.
[6] Y. Komaki, N. Ishikawa, T. Sakurai, *Radiat. Meas.*, **1995**, 24, 193-196.
[7] T. Phukan, D. Kanjilal, T.D. Goswami, H.L. Das, *Nucl. Instrum. Methods* B, **1998**, 155, 116.
[8] D. Sinha, K.K. Dwivedi, *Radiat. Phys. Chem.*, **1998**, 53, 99-105.
[9] D. Sinha, R. Mishra, S.P. Tripathy, K.K Dwivedi, *Radiat. Meas.*, **2001**, 33, 139-143.
[10] D. Sinha, T. Swu, S.P. Tripathy, R. Mishra, K.K. Dwivedi, *Radiat. Meas*., 2003, 36, 229 –231.
[11] D. Sinha, K.K. Dwivedi, Radiat. *Meas***, 2003**, 36, 713–718.
[12] S. Singh, S. Prasher, *Nucl. Instrum. Meth*. B., **2004**, 222, 518-524.
[13] C. Agarwal, P.C. Kalsi, A. Ramaswami, *Radiat. Eff. Def. Solids*, **2006**, 161, 131 – 133.
[14] N.S. Prasher, S. Singh, *Radiat. Meas*., **2007**, 42**,** 135-137.
[15] D. Sinha, *Rad. Eff. Def. Sol.*, **2009**, 164, 604-610.
[16] D. Sinha ; *e-journal of Chemistry*, **2012**, 9, 2226- 2231.
[17] L. Calcagno, G. Compagnini, G. Foti, *Nucl. Instrum. Meth.* B, **1992**, 65, 413–422.
[18] 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. Solids*, **1995**, *133*, 193–208.
[19] U.S. Sias, G. Sanchez, J.R. Kaschny, L. Amaral, M. Behar, D. Fink, *Nucl. Instrum. Meth*. B, **1998**, 134, 35–45.
[20] R. Mishra, S.P. Tripathy, D. Sinha, K.K Dwivedi, S. Ghosh, D.T. Khathing, M. Muller, D. Fink, W.H. Chung; *Nucl. Instrum. Meth*. B **2000**, 168, 59-63.
[21] R. Mishra, S.P.Tripathy, K.K. Dwivedi, D.T. Khathing, S. Ghosh, M. Muller, D. Fink ; *Radiat. Eff. Def. Solids*., **2000,** 127, 1-8.
[22] P.C. Kalsi, A. Ramaswami, *Indian J.Phys*., **2009**, *83*, 1123-1128.
[23] M. S. Babu1, P .V .S. Narayana, T. S. Reddy, D. U. Reddy, *Adv. Appl. Sci. Res*., **2011**, 2, 226-232.
[24] S.A. Nouh, M.H. Abde-Salem, Y.E. Radwan, S.S. Fouad, *Radiat. Eff. Def. Solids*, **2011**, 166, 178-189.
[25] R. Gupta, V. Kumar, P.K. Goyal, S. Kumar, P.C. Kalsi, S.L. Goyal, *Adv. Appl. Sci. Res.* **2011**, *2*, 248-254.
[26] D. Sinha, *Adv. Appl. Sci. Res*, **2012**, 3, 1365 -1371.