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Research Article

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A Comparative Study of Radiation Damaged Nuclear Track Measurement using Allyl Diglycol Carbonate (ADC) and Acrylonitrile Butadiene Styrene (ABS) Polymer

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Abstract Exposure to energetic natural heavy nuclear particle activity in the home and workplace is one of the main risks of ionizing radiation causing millions of deaths from lung cancer each year globally. Other than lung cancer Renal effect (Nephrotoxicity), Neurological effects, Ocular effect, Body weight loss, Reproductive effect, Cardiovascular effects, Gastrointestinal effects, Hematological effects and various forms Cancer are observed for natural radiation exposure. For measuring these radioactivity in Pico Curie (10^{-12} Curie) range a polymer known as Acrylonitrile butadiene styrene (ABS) is studied under different etching condition using solid state nuclear track detector technique under various experimental and conventional etching process and the nuclear tracks so formed are compared with conventional Allyl diglycol carbonate (ADC) films. From present study of nuclear tracks, it is observed that for different polymer, different etching solution is suitable for better track formation and further more that depends upon other variables like etching time and temperature. The conventional etching process with 6N NaOH yielded tracks in both allyl diglycol carbonate and Acrylonitrile butadiene styrene (ABS).

Keywords Allyl Diglycol Carbonate (ADC), Acrylonitrile Butadiene Styrene (ABS), Radiation, Polymer

Introduction

EPA estimates that about 20,000 lung cancer deaths each year in the U.S.A. are radon-related. Exposure to radon is the second leading cause of lung cancer after smoking. Radon is an odorless, tasteless and invisible gas produced by the decay of naturally occurring uranium in soil and water. Radon is a form of ionizing radiation and a proven carcinogen. Lung cancer is the well-known effect on human health from exposure to radon in air [1,3]. Radon is one of a number of intermediate radioactive elements formed during the radioactive decay of uranium-238, uranium-235 or thorium-232 isotopes to form stable, non-radioactive isotopes of lead. Radon-222 is the radon isotope of most concern to public health because of its longer half-life (3.8 days). It is one of the decay products of uranium-238. It is formed by the radioactive decay of its immediate "parent isotope" radium-226 (1620 year half-life). Radon-222 decays to its "daughter isotope" polonium-218 (3.05 minute half-life). It forms from the radioactive decay of small amounts of uranium and thorium naturally present in rocks and soils. So some radon exists in all rocks and soils. Certain rock types, such as black shales and certain igneous rocks can have uranium and thorium in amounts higher than is typical for the earth's crust [1-3].

Solid state nuclear track detectors have unique capabilities for measuring the concentration and spatial distribution of certain radioactive elements. This area of research began with the measurement of uranium via the detection of fission fragments in samples irradiated with thermal neutrons [4]. Now a days energetic heavy particle emitting radioactivity can be easily determined by the formation of nuclear tracks which are easily

observed on a solid state nuclear track detector material such as organic polymer with suitable etching [5-6]. In this study, a solid state nuclear track detector material known as Acrylonitrile butadiene styrene (ABS) have been developed and compared the nuclear tracks with conventional Allyl diglycol carbonate (ADC) film under various experimental & conventional etching solutions and various etching variables.

Materials and Methods

Acrylonitrile butadiene styrene (ABS) is a common thermoplastic whose chemical formula is $(C_8H_8)_z \cdot (C_4H_6)_y \cdot (C_3H_3N)_x$. It is a copolymer made by polymerizing styrene and acrylonitrile in the presence of polybutadiene. The proportions can vary from 15 to 35% acrylonitrile, 5 to 30% butadiene and 40 to 60% styrene. The result is a long chain of polybutadiene criss-crossed with shorter chains of poly(styrene-co-acrylonitrile). The nitrile groups from neighboring chains, being polar, attract each other and bind the chains together, making ABS stronger than pure polystyrene. The styrene gives the plastic a shiny, impervious surface. The butadiene, a rubbery substance, provides resilience even at low temperatures. ABS is suitable from -25° C to 60° C. The properties are created by rubber toughening, where fine particles of elastomer are distributed throughout the rigid matrix. Production of 1 kg of ABS requires the equivalent of about 2 kg of oil for raw materials and energy. It can also be recycled [7].

The chamber with detector configuration consisted of an open mouth insulating container of 8 cm in height and 7 cm in diameter. The middle portion of the chamber is covered with a semi permeable polyethylene membrane. The membrane slows down the normal diffusion of Nobel gases into the chamber and thus discriminates in favor of radon against thoron. This configuration is generally used in the exploration to eliminate the thoron interference and water condensation. Also it prevents the entrance of radon daughter. This detector configuration was calibrated in laboratory and used for radon measurement.

The Acrylonitrile butadiene styrene (ABS) and Allyl diglycol carbonate (ADC) polymer film of 1 cm x 1cm were hung from the bottom of the cap inside the chamber at 6 cm above the standard solution level. The containers were filled with 5 ml of standard solution. The detectors were exposed at 714.653 Bq/ M^3 standardize radon activity obtained by standard radium nitrate solution. The containers were closed and were made airtight. As a result, the detectors are exposed only to radon. One side of each detector was covered so that only one side of the detector was exposed to radon. All of these exposures were done in airtight environment for thirty days free from any disturbance. After exposure all the detectors are taken out and washed with distilled water for several times. Then the detectors were dried in room temperature and marked. After exposure for desired period of time the detectors were etched in various etching solution at constant temperature of 60^o C for two hours and constant temperature of 70°C for four hours. To achieve a fixed temperature of 60 ^{o} C and 70°C, a constant temperature water bath was used [6]. The etching solutions are: a) 10% acetone: 10% DMF : 6N NaOH, b) 10% isopropyl alcohol : 10% EtOH: 3N NaOH and c) 25% triethanolamine : 3N NaOH.

The detectors were dropped in cold water after etching of precise hours and were held under the flow from top with the help of a forceps for two or three minutes. Finally the detectors were washed in distilled water, soaked by tissue paper, dried in air and kept wrapped in tissue paper for subsequent study under a microscope. Similar procedures of etching and identical etching conditions were adopted for all the detectors. Especial care was taken to keep the concentration of the solution, the temperature and the period of time identical for each case. After etching the detectors were scanned under an optical microscope. Counting charts were prepared in which there were blocks recorded with number of counts. The count of each field of view was recorded and after completion of scanning of a detector the counts were added. The total count divided by the number of blocks gave the average number of alpha track etch pits per area of the field of view. Using the actual area of field of view the number of tracks per cm^2 was calculated [6,8,10].

The mathematical expression of track density could be given by [9]:

$$\rho_T = \frac{\sum_{L}^{n} N_i}{\sum n \times A} \qquad (1)$$

Where, ρ_T = Track density or tracks per cm^2, $\sum_L^n N_i$ = Total number of tracks, $\sum n$ = Total number of fields counted and A = Area of one field.

After the background correction, the corrected track density was recorded and analyzed. Growth of alpha tracks formed by 2 hours and 4 hours conventional 6N NaOH and experimental etching process for ABS and ADC polymers are shown in figure 1.

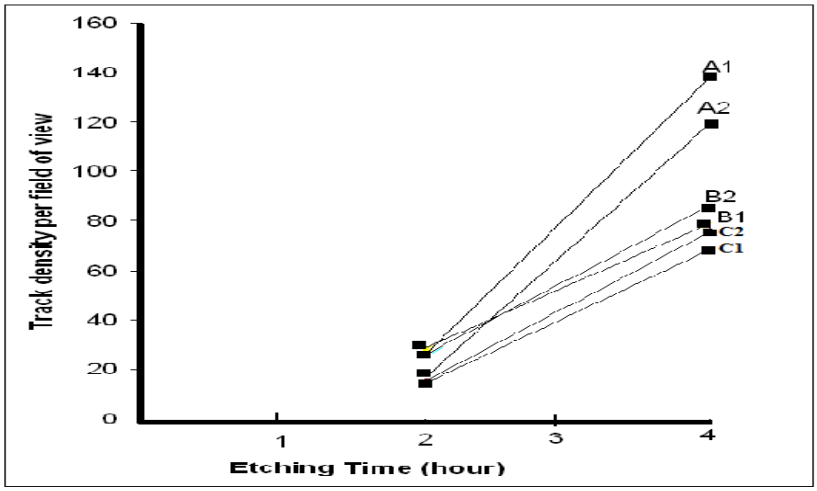

Figure 1: Track density field of view Vs Etching Time

Here, A1is the growth of nuclear tracks on ABS by 2 hours to 4 hours etching with 10% acetone : 10% DMF : 6N NaOH etching system, A2 is the growth of nuclear tracks on ADC by 2 hours to 4 hours etching with 10% acetone : 10% DMF : 6N NaOH etching system, B1 is the growth of nuclear tracks on ABS by 2 hours to 4 hours etching with 10% isopropyl alcohol : 10% EtOH: 3N NaOH etching system, B2 is the growth of nuclear tracks on ADC by 2 hours to 4 hours etching with 10% isopropyl alcohol : 10% EtOH: 3N NaOH etching system, C1 is the growth of nuclear tracks on ABS by 2 hours to 4 hours etching with 25% triethanolamine : 3N NaOH etching system and C2 is the growth of nuclear tracks on ADC by 2 hours to 4 hours etching with 25% triethanolamine : 3N NaOH etching system.

Result and Discussions

Tracks in each exposed detectors were counted for known areas. Using the number of tracks per field of view, track density was calculated for all the detectors. Then background correction was performed. For each etching condition separate blank test was performed. The corrected track density per field of view and track density per cm^2 (T/ cm^2) under various etching solutions and etching conditions are given in table 1 and table 2.

Table 1: Track density after two hours etching condition

Total number of detectors.	Etching solution.	Detector type.	Average tracks per field of view.	Track Density (T/ cm^2).
10	10% acetone : 10% DMF : 6N NaOH	ABS	23	18312±135
10	10% acetone : 10% DMF : 6N NaOH	ADC	14	11146±106
10	10% isopropyl alcohol : 10% EtOH: 3N NaOH	ABS	25	19904±141
10	10% isopropyl alcohol : 10% EtOH: 3N NaOH	ADC	22	17515±132
10	25% triethanolamine : 3N NaOH	ABS	12	9554±97
10	25% triethanolamine : 3N NaOH	ADC	24	19108±138

Table 2: Track density after four hours etching condition

Total number of detectors.	Etching solution	Detector type	Average tracks per field of view	Track Density. (T/ cm^2)
10	10% acetone : 10% DMF : 6N NaOH	ABS	135	107484±328
10	10% acetone : 10% DMF : 6N NaOH	ADC	116	92357±304
10	10% isopropyl alcohol : 10% EtOH: 3N KOH	ABS	75	59713±244
10	10% isopropyl alcohol : 10% EtOH: 3N KOH	ADC	82	65286±255
10	25% triethanolamine : 3N NaOH	ABS	65	52000±228
10	25% triethanolamine : 3N NaOH	ADC	73	58121±241

At two hours etching time with 60^o C constant temperature the highest track density recorded for allyl diglycol carbonate was 24 tracks per field of view and Track Density (T/ cm^2) 19108±138 by 25% triethanolamine : 3N NaOH and for Acrylonitrile butadiene styrene was 25 tracks per field of view and Track Density (T/ cm^2) 19904±141 by 10% isopropyl alcohol : 10% EtOH: 3N NaOH etching. At the same condition the lowest track density for allyl diglycol carbonate was recorded as 10 tracks per field of view and Track Density (T/ cm^2) 11146±106 by 10% acetone: 10% DMF: 6N NaOH etching and the lowest track density for Acrylonitrile butadiene styrene was found as 12 tracks per field of view and Track Density (T/ cm^2) 9554±97 by 25% triethanolamine : 3N NaOH etching. On the other hand at four hours etching time with 70^o C constant temperature the highest track density for both polymers were achieved by the same etching solution which was 10% acetone: 10% DMF : 6N NaOH solution and the highest track density was recorded for allyl diglycol carbonate was 122 tracks per field of view and Track Density (T/ cm^2) 92357±304. For Acrylonitrile butadiene styrene highest track density was found as 141 tracks per field of view and Track Density (T/ cm^2) 107484±328. Experimental etching system 10% acetone: 10% DMF: 6N NaOH yielded more clear and larger tracks even greater on diameter than the conventional 6N NaOH for Acrylonitrile butadiene styrene polymer. 10% acetone : 10% DM : 6N NaOH etching system yielded densely populated tracks in both polymers. This etching system yielded linear tracks on Acrylonitrile butadiene styrene polymer. Another etching solution 10% isopropyl alcohol: 10% EtOH: 3N NaOH yielded non linear but isolated clear tracks in both ADC and Acrylonitrile butadiene styrene polymer. From present study of alpha tracks it is observed that for different polymer, different etching solution is needed for better track formation and further more that depends upon other variables like etching time and temperature. The conventional etching process with 6N NaOH yielded tracks in both Acrylonitrile butadiene styrene and allyl diglycol carbonate polymer but the use of organic solvent with alkaline solution yielded more tracks with better visibility.

Conclusion

In order to study the nuclear tracks formed in organic polymer ABS solid state nuclear track detector technique has been used. The nuclear tracks formed in this polymer were compared with standard allyl diglycol carbonate film. The conventional etching solutions yielded tracks in ABS but experimental etching solution 10% acetone: 10% DMF: 6N NaOH and 10% isopropyl alcohol: 10% EtOH: 3N KOH yielded more tracks even than allyl diglycol carbonate film. From present study it is observed that at higher temperature with more etching time, more nuclear tracks are formed. But with a suitable etching solution for a particular polymer, temperature and time could be reduced. The conventional 6N NaOH solution yielded nuclear tracks in both ABS and ADC polymer but it seems that both of them developed more tracks with organic solvent and alkali mixture. 25% triethanolamine: 3N NaOH etching system contains organic base triethanolamine. This etching solution yielded clear tracks in both polymer, but fewer in number at lower temperature. Another etching solution 10% isopropyl

alcohol: 10% EtOH: 3N NaOH developed isolated tracks in both polymers with no overlapping. 6N NaOH solution on the other hand developed linear tracks in ABS film but non-linear yet clear tracks on ADC film. As we have studied the nuclear track forming property of ABS with various etching solution, we have found the results are satisfactory compared to the conventional SSNTD allyl diglycol carbonate film. With suitable etching solution ABS film seems to be more sensitive in developing tracks than the conventional ADC film. The calibration characteristics of ABS, shows that, these detectors are more convenient for diagnostic purposes and detailed experimental studies of primary ions, emitted from high temperature plasmas. Such calibrated ABS detector can be used for measurements of different nuclear reactions products, i.e. fast fusion protons, energetic tritons, He-ions, and fast neutrons. The calibrated ABS detectors can also be applied for energy and flux measurements of pulsed plasma-ion streams generated by different plasma facilities including those used for technological purposes like ion implantation, surface treatment, and metallic coating etc.

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References:

[1]. Depleted uranium: Source, exposure and Health effects, Department of protections of the Human environment, World Health organization Geneva, April 2001.
[2]. Brtish Geological Survey, Ground Water Studies of Arsenic Contentment of Bangladesh- final report, June 7, (2000).
[3]. Environmental Protection Agency, Office of Air and Radiation (6604J), EPA 402-R-92-004, July 1992 (revised). Page 2-38.
[4]. N. Segoria and J. Cejendo , Nuclear Tracks, Vol- 8, 407, (1984).
[5]. I. Gomboa, G. Eslimona, A. Morero, J. I. Golzarri and F cartillo, Nuclear tracks and Measurements 8, Nos. 1-4, 443-445 (1982)
[6]. R.L. Fleischer, P.B Price and R.M. Walker, Nuclear tracks in solids, principles and applications, university of California press, Berkley, 1975.
[7]. C.A. Harper., Handbook of plastic and Elastomers, McGraw-Hill, NY, 1975, pp. 1-3, 1-62, 2-42, 3-1.
[8]. B. G. Cart weight R. Shirk, PB Pric: Nacl. Inster and Meth. 153, 457 (1978).
[9]. P. B. Price, R. M. walker: Electron Microscope Observations of Etched Tracks from Sapalation Recoils in Mica. Phys. Rev. Lettery 8:217-219, 1962a.
[10]. P. B. Price R. M. waler: Chemical Etching of charged particle Tracks, Journal of Applied Physics. 33: 3407-3412, 1962b.