Measurement of an effective mass attenuation coefficient for fission fragments in thorium targets

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Introduction

The response of a fission detector closely follows the fission cross-section modified by self scattering and self absorption of fission fragments in the fissile material and consequent registration efficiency variation (i.e. fraction of fission fragments detected). Solid state nuclear track detectors are now-a-days being used as a quantitative study of fission fragments. This type of work is mostly done by using special type of SSNTDs e.g. Lexan, as the medium for collecting tracks of fission fragments [1]. The present work is motivated to measure an effective mass attenuation coefficient for fission fragments in fast neutron induced fission of thorium.

Experimental Details:

Fissile material of different thicknesses are deposited on plastics and irradiated to known neutron fluences. The track density measured is then related to the mass of the material deposited on the Lexan detector through the following equation [2]

$$T = C\, m\, e^{-\mu m}. \qquad (1)$$

Where T is track density, m is mass per unit area of the material, C is required track density per unit mass for an infinitely thin target ($m \rightarrow 0$), and μ represents an "effective mass attenuation coefficients" for self absorption as well as self scattering process. Several pieces (1.0 cm × 1.0 cm) of Lexan plastic were cut from a sheet of uniform thickness (~ 200 μm). The fissile material solution of thorium nitrate $\{ThO_2(NO_3)_2\ 6H_2O\}$ was prepared by dissolving 1.0 gm of the material in 10.0 c.c. of distilled water. A known amount of the fissile material was deposited on each plastic detectors and then dried with the help of an infrared lamp. In this way, targets of different thicknesses were prepared. Then the Lexan pieces coated with fissile material were exposed to the fast neutrons from an AN-400 model Van-de-Graaff (14.2 MeV neutron) accelerator for different lengths of time (1.0hr, 3.0hr and 6.0hr) using same flux. The fast neutron fluence was 1×10^{10} to 6.7×10^{10} n cm^{-2} at that point where experiment was carried out. Lexan plastics coated with thorium of different thicknesses were irradiated together using same fluence.

Fast neutrons were produced by ${}_1H^2({}_1H^3,{}_2He^4)\,{}_0n^1$ reaction. The tritium (${}_1H^3$) target was right angle to deuteron beam. The distance of all Lexan detectors was the same (1.5 cm) from the place of tritium target. For independent determination of flux, an aluminum foil of same area as that of target was also irradiated sandwiched between thorium plastic targets. After irradiation the plastics along with an un-irradiated plastic were etched in 6.25 N NaOH solution at 60 ^{0}C for one hour to two hours, in a thermostatically controlled oven [3]. Etched fission tracks were counted to yield track density by viewing under an optical microscope using (Olympus, Model BH-2) 600X magnification. During scanning, proper care was taken not to count the same area of the detector more than once. In each plastic foil equal area (6.25×10^{-2} cm^2) was scanned.

Results and Discussion:

The track density measured is related to the mass of fissile material deposited on these detectors through Eq. 1. The exponential factor indicates a process of absorption or scattering of the fission fragments in the fissile material. The fission track densities for various mass of the fissile material and irradiation time is given in Table-I. Figure 1 shows the curve between fissile mass versus track densities for 1hr, 3hr & 6hrs. A least square fit of the experimental points was made using Eq.1 to find out the values of constants from the above figure. It may be observed that while the value of effective mass attenuation coefficient μ is nearly same for the three curves, the value of C increases in proportion to the time of irradiation, as it should, because by definition, C is track density per unit mass for an infinitely thin target ($m \rightarrow 0$). The values of μ and C obtained for different time of irradiation are given in Table-II. From the observation, an average value of 0.036 ± 0.001 is obtained for the effective mass attenuation coefficient for fission fragments in thorium nitrate.

Table-I: Mass of fissile material and track densities at different durations of time

S. No	Mass of Fissile Material, m (mg/cm^2)	Fission Track Density, T (10^4/cm^2) (1 hr)	Fission Track Density, T (10^4/cm^2 (3 hr)	Fission Track Density, T (10^4/cm^2) (6 hr)
1	12	0.50	2.61	3.40
2	16	0.55	2.65	3.75
3	18	0.65	2.8	3.84
4	20	0.50	2.9	3.76
5	22	0.60	2.55	3.65

Table-II: Effective mass attenuation coefficient (μ) and track density per unit mass for an infinitely thin target (C) at different duration of times.

S. No	Time of Irradiation	μ(cm^2/gm)	C(density per unit mass)
1	1 Hr.	0.03338	0.057
2	3 Hr.	0.03413	0.280
3	6 Hr.	0.03925	0.539

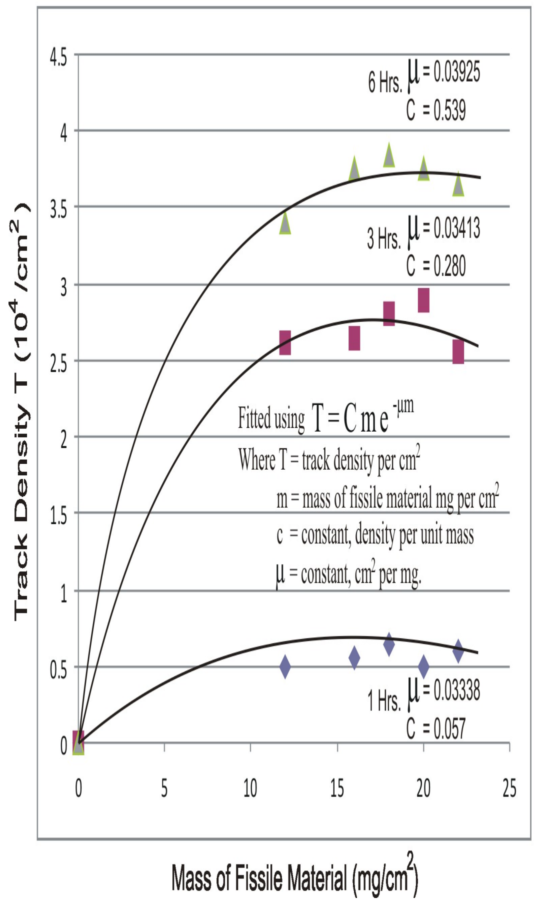

Fig 1

Fig.1: Plot between mass of fissile material and fission track densities at 14.2 MeV fast neutrons from an AN-400 model Van-de-Graff accelerator for different lengths of time (1hr, 3hr & 6hr).

References:

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