Experimental Ranges Of Energetic ^{238}U Ions In Tantalum

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Abstract: Experimental ranges are determined for the passage of ^{238}U ion in Tantalum for energies up to ~3.8 GeV utilizing a versatile nuclear-track technique. The Solid State Nuclear Track Detector (SSNTD) utilized in the present examination is Polyallyl Diglycol Carbonate, industrially known as CR-39. The exploratory information are contrasted and comparing hypothetical qualities acquired from SRIM, conditions of Mukherji et al, the information tables of Hubert et al and of that of Northcliff and Schilling.

Keywords: Range, ^{238}U, Tantalum, CR-39, Solid State Nuclear Track Detector

1. Introduction

To study the biological effect of radiation/ charged particle we require the range of the particle in a matter, as experimental information are constrained, analysts by and large retreat to values got from various hypothetical/theoretical models. The present work advances a generally basic and modest strategy for the assurance of extents using a simple SSNTDs technique. [1-4] Experimental range values of Uranium in Tantalum up to ~3.8 GeV are also presented and compared with theoretical values obtained from SRIM [5], Mukherji et al [6, 7], Hubert et al [8] and Northcliff and Schilling [9].

2. Materials and Methods

2.1 Nuclear track technique

The Solid State Nuclear Track Detector (SSNTD) is calibrated for the given ion in terms of maximum etchable track length as a function of ion energy as discussed in our previous work.[10-13] The energy-loss of transmitted ions is obtained directly from the values of the measured track lengths in the SSNTD and calibration curve.[7,8] Extrapolation of the energy-loss curve down to ion energy zero, one may obtain the mean range (R_i) of the heavy ion at the given maximum ion energy (E_i) in the given target. Once R_i is known, the mean range $R(E)$ at any intermediate energy E may simply be obtained from the following relation:

$$R(E) = R_i - x(E) \quad (1)$$

where $x(E)$ is the target thickness which reduces ion energy fromthe maximum ion energy E_i to E and is obtained from the energy-loss curve.

2.2 Experimental Procedure

Polyallyl Diglycol Carbonate (composition: $C_{12}H_{18}O_7$; molecular weight: 274.0; density: 1.32 g/ml) commercially known as CR-39, is a very sensitive SSNTD which make it quite suitable for the present study. The calibration curve (Figure 1) is drawn between the track lengths of ^{238}U ions in CR-39 at various energies, data for which is reported elsewhere [1,13-15]. Tantalum targets of various thicknesses 7–52.5 µm with a uniformity of 1–5% are prepared and placed before CR-39 detectors of dimensions $2 \times 2 \times 0.15$ cm^3. These target-detector assemblies are then exposed to a beam of 16.34±0.1 MeV/u ^{238}U at XO port of UNILAC, GSI, Darmstadt. The true track lengths are then calculated from the projected track lengths which are obtained after etching the detector at 6N NaOH at 55^{o}C.

3. Results and Discussion

Using the calibration curve given in figure 1, the track lengths obtained from the experiment are converted to transmitted ion energy values; the plot of the transmitted ion energy versus the target thickness gives the energy-loss curve of ^{238}U ion in Tantalum shown in figure 2. Extrapolation using cubic spline fit of the energy-loss curve to ion energy zero suggests that 51.9±1.8µm of Tantalum is just sufficient to absorb ^{238}U ions of 16.34 MeV/u. Ranges are then calculated using equation (1); the experimental ranges so obtained are presented in table 1.The data viz. experimental mean ranges of ^{238}U in Tantalum as a function of ion energyhas also been plotted in figure 3 along with various theoretical/empiricalpredictions viz. Hubert et al and Northcliff and Schilling data tables, SRIM, the computed range values from stopping-power equations of Mukherji and coworkers [16, 17] for comparison. The experimental range data, agrees fairly well with the theoretical predictions.

4. Conclusions

The experimental range of ^{238}U in the elemental target of tantalum metal for energies upto 16.3 MeV/u has been reported. All considered theoretical ranges are broadly, within error limits, found to be in good agreement with our experimental results except for the Hubert et al. data at high energy values.For validation of any one of the theoretical/empirical model experimental setup with higher precision is required than used in the present study.

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Table 1: Experimental data for the passage of ^{238}U in Tantalum

Target thickness (µm)	Track length (µm)	Transmitted ion energy (MeV/u)	Experimental Ranges (µm)
0	205 ± 2	16.34 ± 0.1	52± 2.0
7 ± 0.7	169 ± 2	13.76± 0.1	43.5± 2.1
13.2 ± 1.4	156 ± 3	12.52± 0.2	40.2± 2.5
20.2 ± 1.4	110 ± 3	8.28± 0.2	31± 2.5
26.5 ± 2.0	84 ± 4	5.75± 0.3	25.4± 2.8

26.5 ± 2.0	60 ± 4	3.36± 0.3	20± 2.8
38.1± 2.0	44 ± 4	1.84± 0.3	14.6± 2.8
48.8± 2.3	17 ± 4	0.45± 0.2	6.2± 3
52.5± 1.4	0	-	-

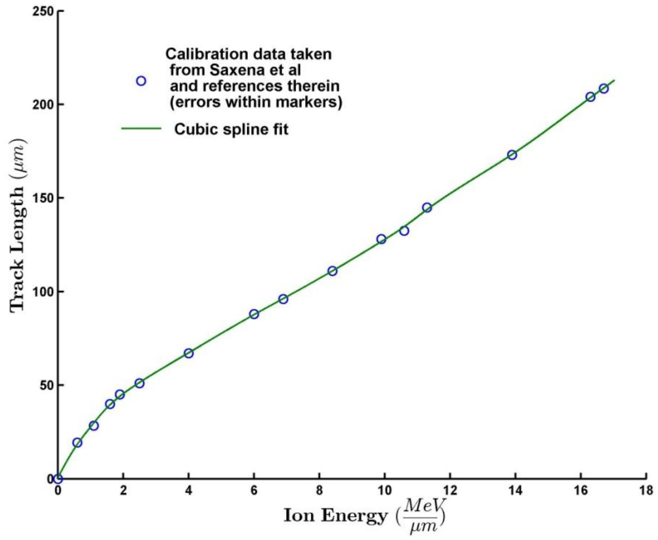

Figure 1: Calibration curve between the measured track length in CR-39 and corresponding energy of ^{238}U ion.

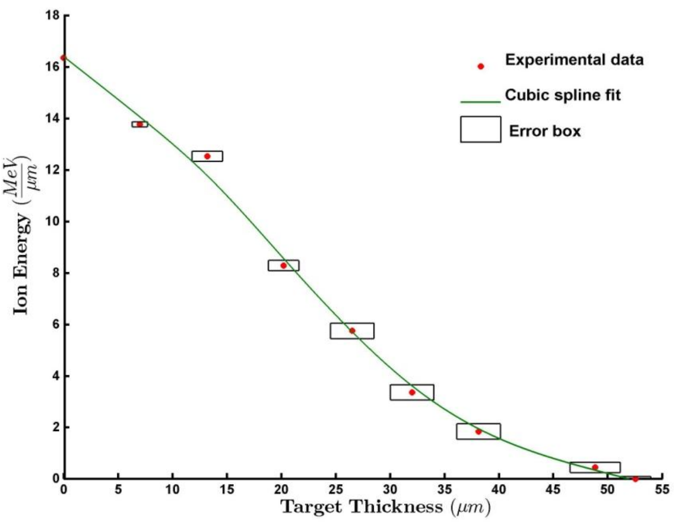

Figure 2 : The energy-loss curve for 16.3 MeV/u 238U ions in Tantalum. The error box incorporates uncertainties in the variables in both the axis.

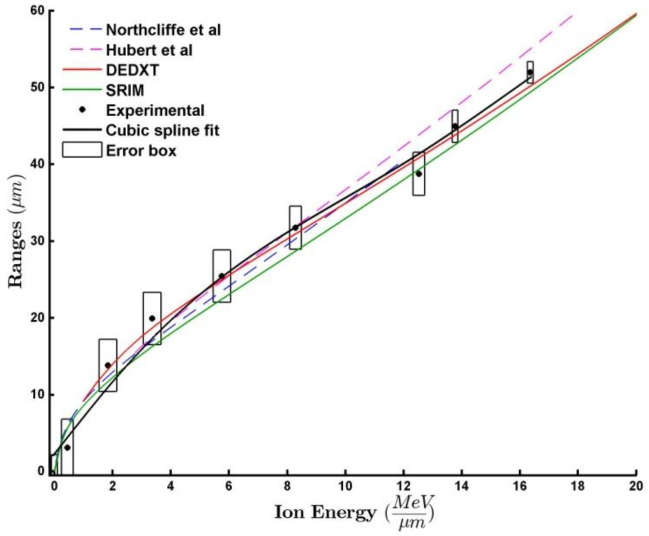

Figure 3 : Plot of the experimental range-energy data for 238U in Tantalum along with theoretical values.The error box incorporates uncertainties in the variables in both the axis.