RANGES OF ENERGETIC ^{40}Ar IONS IN ZnP-GLASS

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Abstract: Experimental ranges are determined for the passage of ^{40}Ar ions in ZnP-Glass for energies upto ~292 MeV using a versatile nuclear-track technique proposed by Saxena et al. ZnP-Glass which is a solid state nuclear track detector (SSNTD) used in the present study is a metaphosphate glass. The experimental data are compared with corresponding theoretical values obtained from SRIM program and from stopping power equations of Mukherji et. al. (DEDXT-program).

Keywords: Range; SSNTD; ZnP-Glass; SRIM; DEDXT

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1. Introduction:

Studies on physical and biological effects produced by the penetration of charged particles through matter invariably require large range of information. As experimental data are limited, people generally resort to values derived from different theoretical models. In addition, experimental data in the high energy region are scantier; hence, the accuracy of theoretical models in this region is speculative [1, 2]. The present work promotes a relatively simple method for the determination of ranges and stopping power, using nuclear track technique by Saxena et. al with little modifications [3,4]. Theoretical ranges of ^{40}Ar in ZnP-Glass up to ~292 MeV are presented and compared with the experimental results.

2. Experimental procedure:

a. Detector used: Metaphosphate Glass, (composition: $B_{2.67}$ $O_{68.86}$ $Al_{2.7}$ $Si_{0.35}$ $P_{23.12}$ $Zn_{2.30}$; molecular weight: 2079.7; density: 2.69 g/ml) commercially known as ZnP-Glass, is a very sensitive SSNTD and have been used for the present study.

b. Irradiation: The detector was irradiated at XO channel of UNILAC, GSI Darmstadt, Germany with a well collimated beam of 7.3 MeV/u ^{40}Ar ions at an incident angle of 45^{o} w.r.t detector surface. An optimum flux of ~10^4 cm^{-2} was used for irradiation.

c. Chemical etching: After irradiation the ZnP-Glass detectors were etched in 6N NaOH at 55^{o}C for a period of 2 - 4 hour till rounded track tips were observed. After complete etching and thorough washing the detectors were dried in a vacuum desiccator.

d. Observation and Measurement of Tracks: Diameters (D) and projected track lengths (l) were measured at random all over the detector surface using an optical microscope at a magnification of 1560 X (for l « 90 µm), whereas longer tracks were measured at a magnification of 650 X. From these track parameters, the maximum etchable true track lengths (L) were obtained using the formula given by Dwivedi and Mukherji [5].

3. Technique [6]:

With this technique, the range and stopping power can be obtained in a solid media that can form the ion tracks; here we use a well defined single nuclear track in a single detector instead of using 10 to 15 target detector assemblies. The detector (ZnP-glass) itself is considered as both the target as well as the detector by considering a division into two segments. For different values of target thickness (X_i), the true track lengths ($L - L_{Xi}$) are obtained and the corresponding energy is then obtained from the calibration curve [7] (which is a variation of true track length with incident ion energy as plotted in figure 1).

From these data, the energy loss curves are constructed by plotting ion energy as a function of target thickness.

The mean range $R(E)$ can easily be obtained by extrapolating the energy loss curve to energy $E_X = 0$. Range at energy E may be obtained from the equation

$$R(E) = R - X(E)$$

where, R is the total range of the ion, $X(E)$ is the target thickness which reduces the ion energy from E_i to E.

4. Experimental errors:

Track length are measured with an accuracy of ~ ±1.0 µm. Uncertainties in maximum etchable track length having their origin in etching temperature, time and etchant concentration fluctuations are mutually self-cancelling. The cumulative errors in range measurements are less than 5%.

5. Results and discussions:

Figure 2. shows the energy loss curve for ^{40}Ar in ZnP-Glass. The mean range obtained from energy loss curve for 7.3 MeV/u ^{40}Ar in ZnP-Glass is equal to 57.0 ± 2 µm and is reported in table 1. The range of ^{40}Ar in ZnP-Glass is also obtained at several lower energies using energy-loss curve and are given in table 1 along with corresponding theoretical values from DEDXT [8] and SRIM [9]. The plot of range energy variation for ^{40}Ar in ZnP-Glass is shown in figure 3 along with corresponding theoretical values from DEDXT [8] and SRIM [9]. Experimental range data follow much closer to the popular SRIM program as compared to that of the obscure DEDXT predictions.

Table1: Values of target thickness, transmitted ion energy, maximum etchable track length and the ranges of ^{40}Ar ions in ZnP-Glass detector along with the corresponding theoretical values.

Target Thickness (µm)	**Transmitted Ion Energy (MeV/u)**	**Track Length (µm)**	**^{40}Ar range in ZnP-Glass (µm)**		
			Experimental (Present Work)	**Theoretical**	
				(b)	**(c)**
No Target	7.3±0.3	63.8±1.1	57.0±2.0	72.4	114.8
3.6	6.9±0.3	60.2±1.1	53.4±2.2	67.0	106.3
8.1	6.5±0.3	55.7±1.0	48.9±2.1	61.7	98.1
12.6	6.0±0.3	51.2±1.1	44.4±2.3	55.9	90.1
19.8	5.1±0.3	44.0±0.8	37.2±2.4	45.6	74.9
23.9	4.6±0.3	39.9±1.0	33.1±2.6	40.4	67.7
28.3	4.2±0.3	35.5±0.7	28.7±2.6	37.4	60.8
33.3	3.7±0.3	30.5±0.7	23.7±2.7	32.9	54.1
40.1	3.0±0.3	23.7±0.6	16.9±2.7	26.0	47.6
44.2	2.5±0.3	19.6±0.8	12.8±2.8	21.7	41.3
50.5	1.8±0.3	13.3±0.9	6.5±2.8	15.6	35.0

(b) SRIM and (c) DEDXT program

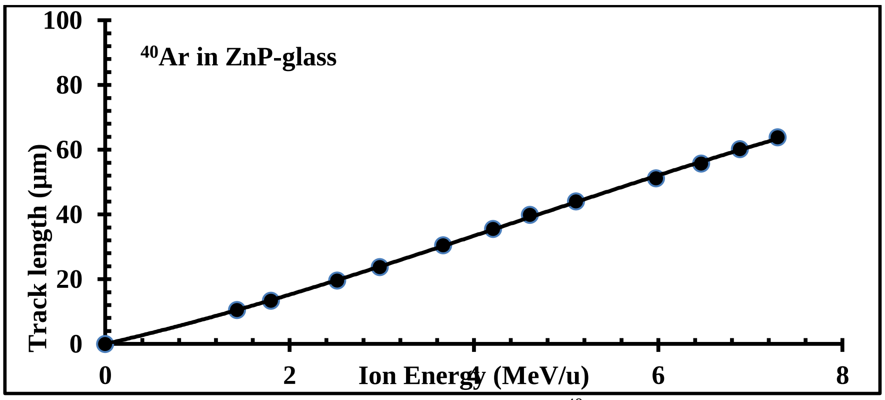

Figure 1: A Plot showing calibration curve between the energy of ^{40}Ar and measured track length in ZnP-glass [7].

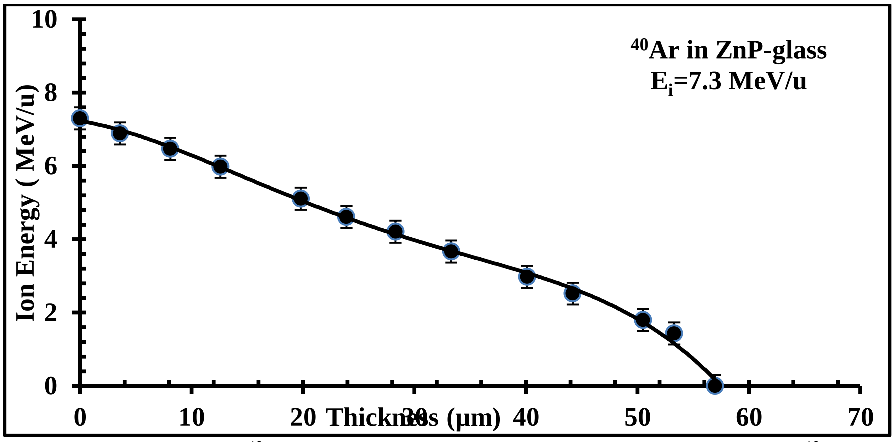

Figure 2: The energy loss curve for ^{40}Ar in ZnP-Glass. The mean range of 7.3 MeV/u ^{40}Ar in ZnP-glass is to 57.0 ± 2 µm.

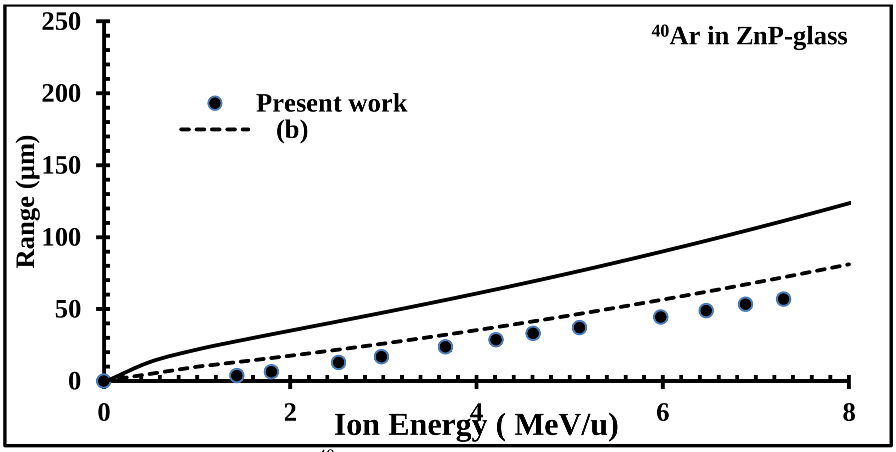

Figure 3: Measured range-energy data for ^{40}Ar in ZnP-glass along with the theoretical values from (b) SRIM and (c) DEDXT program.

6. Conclusions:

Experimental range values for the passage of ^{40}Ar in ZnP-Glass are obtained for energies up to 7.3 MeV/u, which were not available in earlier literatures. Our experimental values for range of ^{40}Ar in ZnP-Glass differ significantly with their theoretical values obtained using DEDXT and SRIM programs. The DEDXT values are higher by 30-60 µm while the SRIM values are higher by 8-15 µm with our experimental data for the entire energy region. The two theoretical values differ among themselves by ~ 20 - 40 µm. The experimental study thus allows us to conclude SRIM program is better equipped to study range of heavy ion in ZnP-glass than DEDXT program.

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