Scattering of 10 Mev ^{238}U Heavy Ions with Silver Target Using Cr-39

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Abstract

A typical thickness of 1.2 mg cm^{-2} of the target layer silver was coated by vacuum deposition on the surface of detector CR-39. The target detector assemblies were irradiated at normal incidence to a fluence of 10^6 ions cm^{-2} sec^{-1} at GSI Darmstadt Germany. The target layers were then removed from the surface of the irradiated detectors, which were subsequently etched in NaOH solution for 3 hours at a temperature of 70 Co in order to reveal the nuclear tracks in the detector. The detectors were scanned for the observation of different events using an optical microscope and their track lengths and angular distributions with the beam were studied to investigate the characteristics of this interaction.

From the length frequency distributions of binary events, it is seen that particles having lengths in the range between 90-110 μ m are emitted with maximum probability of 50% as compared with shorter tracks of 20 % probality. It is also observed that the probabilities of emission of projectiles and target with respect to the beam direction are maximum in the intervals of 15 to 20 ^{0}.

Key Words: Scattering ,Heavy ions ,Enchant, Track length, Frequency distribution

Cr-39 Kullanılarak 10 MeV ^{238}U Ağır İyonların Gümüş Hedeften Saçılması

Özet

Tipik 1.2 mg/cm2 hedef kalınlığındaki gümüş CR-39 detektörünün yüzeyine vakum birikimi metoduyla kaplanmıştır. GSI Darmstadt Almanya' da 106 iyon/cm2-sec akışında dedektör asembleleri ışınlanmıştır. Detektörde Nükleer izlemeleri açıklamak için, daha sonra, hedef katmanları, ışınlanmış detektör yüzeylerinden söküp, NaOH çözeltisinde 70 Co de 3 saat birbiri arkasına "etching" yapılmıştır. Dedektörler başka olayları gözlemlemek için optikal bir mikroskopla ve açısal dağılım interaksiyonlarin karekterasyonlarını incelemek için izlenmiştir.

Uzunluk frekans dağılımları binary olaylarından görülmektedir ki, 90-110 µm uzunluk sıralarında parçacıklar, %20 kısa ihtimaline karşı %50 maksimum ihtimalinde yayınlanmaktadır. Yine hedef ve güllelerin akış yönüne göre yayınlama ihtimali 15^o – 20^o aralığında maksimumdur.

Anahtar Kelimeler: Saçınım, Ağır İyonlar, Çekici, Parça Uzunluğu, Frekans Dağılımı

1. Introduction

Heavy ion physics is the study of scattering and reactions of nuclei with large mass (A ≤ 12) and charge at high energies (E $\leq^5$ MeV). In heavy ion interactions large transfers of mass, charge and angular momentum take place. The track etch technique is a highly developed method for the detection of charged particles. Heavy ion research involving track detectors in several fields such as nuclear reactions [1,2] , fission-fusion and alpha evaporation [3] , particle identification [4],Cosmology[5] , and health physics [6], is well developed. The track etch technique is fairly accurate and does not require costly equipment such as time of flight (TOF) [7] , double time of flight (DTO) [8], or magnetic or recoil proton spectrometry [9] . High multiplicity events in heavy ion reactions have been observed and analyzed by [1,10 ,11,12] , and following the pioneering work of [13] , in which the quantitative kinematical analysis was first performed. The technique of Solid State Nuclear Track Detection (SSNTD) has various advantages such as (a) the permanent record of the track (b) high stopping power (c) continuous sensitivity (d) and ease of operation. In addition to these features, the detectors are inexpensive and insensitive to light. Comparison of SSNTD technique with other detection systems have been made by [14] .The exposed and etched detectors can be stored for longer periods of time under environmental conditions and could be analyzed anywhere. In this treatment, the parameters of the etched profile, track length and diameter, are related to the etching response V_T/V_B (with V_B = bulk etch rate, V_T = track etch rate) which in turn is related to the damage response S and finally to the particle parameters Charge (Z), mass (M), energy (E) and range. Thus, the measurement of the track parameters gives information on the particle parameters for identifying the particles. In the present work the interaction of 10 MeV, U-238 heavy ions with Silver target using CR-39 as solid state detector has been performed at UNILAC accelerator, GSI (Darmstadt, Germany).

2. Experimental Details and Results

The use of solid-state Nuclear Track detectors in 2π geometry in the study of heavy ion irradiation is now well established method. The technique has been fully explained elsewhere[13] , only some of the necessary experimental details is outlined here. A typical 1.2 mg cm-2 thickness of the target silver layer was vacuum deposited on the detector CR- 39. This detector has been used in heavy ions research, radiation dose due to exploration of extra heavy elements [15], This detector is one of the most sensitive materials for recording charged particles [16]

.The target track detector assemblies (target facing the beam first) were exposed perpendicularly to U-238 ions of 10 MeV/n, obtained from the UNILAC (GSI Darmstadt, Germany) with a fluence of the order of 106 ions cm-2 sec-1 . The CR-39 detectors were etched in 6M NaOH at 70 Co for three hours in order to reveal all the latent damage trails due to different reaction products. The etching conditions were optimized so as to etch the latent damages from all reaction products of an event up to their full length. During scanning of the sample, black dots were noted due to the projectiles, which penetrated the target without any reaction, and also events of two, three and four prongs were seen. Only four three prongs and one four prong event and mostly two prong events were observed in this reaction. Special attention was paid to the analysis of two prongs events. All binary events with angles having values between 170o-180o as seen in the plane perpendicular to the beam have been interpreted as genuine two pronged events.

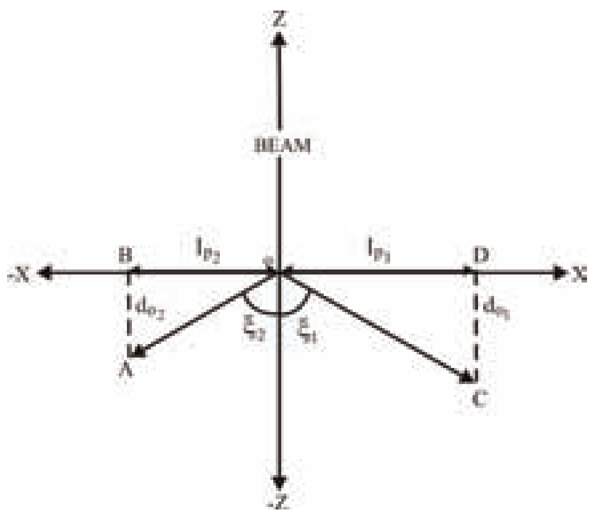

Fig.1: A schematic diagram showing track lengths and the angles with the beam.

The binary scattering reactions have only two fragments in their exit channel. An optical microscope coupled with a tracing tube and depth-measuring system was used for the analysis. The track lengths could be determined within $\pm 1.5 \mu$m (standard deviation) for the bulk data. The uncertainties in track angles are ±2o (standard deviation).

The track lengths and track angles of about 200 binary events were measured . A large number of tracks were scanned in order to achieve good statistics. It has been reported by [17] ,that the length of track is measured using two steps.

Firstly, the projected length (lp) of the track as OB or OD (Fig. 1) is measured by using an optical microscope. This is usually done either by a calibrated graticule placed in the eyepiece of the microscope or by tracing the etched track length using a tracing tube fitted to the microscope. Secondly, depth (d0) of the etched track (as AB or DC)(Figure 1) was measured using a Heidenhain depth measuring instrument, fixed to the microscope stage. The observed depth was measured and then corrected for the refraction of light i.e.; actual depth (d) = observed depth (d0) x n D / na/o ,where n D is the refractive index of the detector, and n a/o is the refractive index of air/oil, depending on whether a dry or an oil objective is used. Knowing the observed track parameters, the projected length (lp) and the actual depth (d), one can find the actual length (L) of the track due to a particular reaction product in this detector as follows:

L = (d2+ Lp 2) 1/2 and the angle ξ = arc tan (Lp/d).

In this work, about 170 binary events have been analyzed for their length and angular distributions with the beam. Fig 2 (a, b) shows the frequency distributions for the angles with the original direction of the beam; whereas Fig3 (a, b) shows the frequency distribution for the lengths. In order to clarify these features of the data and to estimate certain parameters statistical software “Minitab”[18] was used. The values along with remaining parameters for this distribution are given in Table1. The angular frequency distribution along with length frequency distributions are shown in Fig. 2 (a, b) and Fig. 3(a, b) respectively.

Table 1: Experimental values obtained for different statistical parameters:

Parameter	**Length L_1 (μm)**	**length L_2 (μm)**	**Angle ξ_1 (deg)**	**Angle ξ_2 (deg)**
Maximum	153.02	147.65	88.71	90.84
Minimum	11.90	13.44	4.90	5.70
Mean	89.73	88.46	17.79	18.76
Median	95.16	94.75	16.54	17.77
Std. Deviation	24.23	24.45	7.39	7.1
Q_1	80.63	77.43	13.56	13.95
Q3	106.42	103.79	20.48	21.63

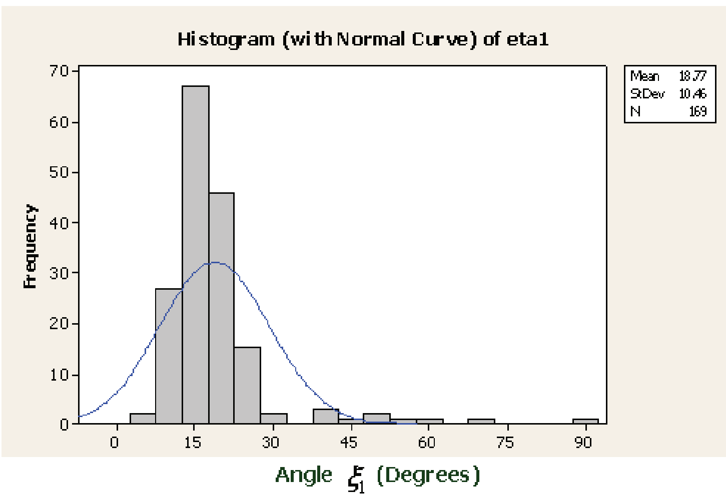

Fig. 2 (a). The frequency distribution of angle (ξ_1) with the beam.

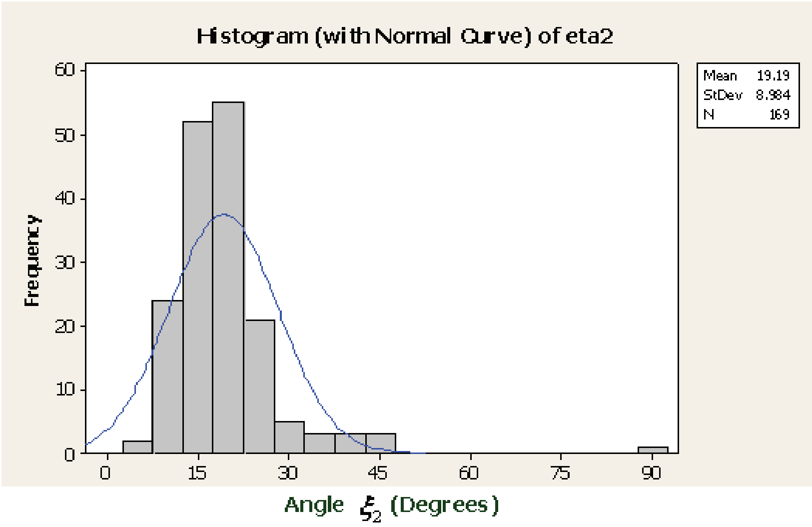

Fig. 2 (b). The frequency distribution of angle (ξ_2) with the beam.

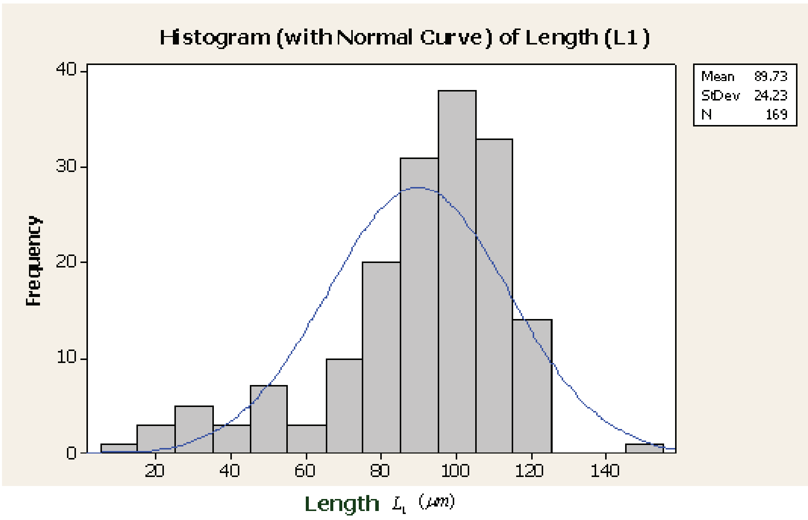

Fig. 3 (a). The frequency distribution of length (L_1).

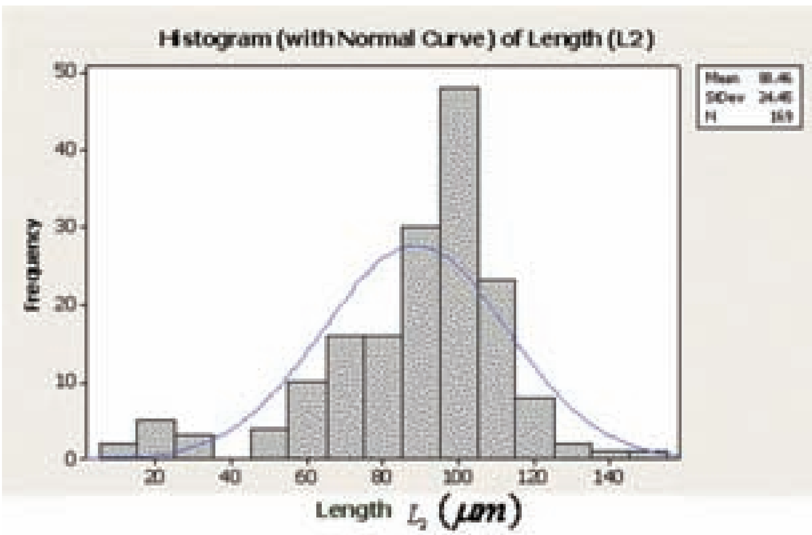

Fig. 3(b). The frequency distribution of length (L_2).

3. Discussion and Conclusion

The heavy ion scattering of 10 MeV/n U-238 has been investigated employing the 2^{π} geometry technique using solid state nuclear track detector(CR-39) . A statistical Minitab software program was used for the statistical analysis. The angular distributions with respect to the beam show a preferential direction (forward direction) of emission of particles (projectiles and target). Their probabilities of emission are maximum in the range of 15o and 20o as shown in Fig. 2 (a, b). The mean and standard deviations of angles ξ_1 and ξ_2 are 18.77±10.46 and 19.18 ± 8.98 respectively. If values of ξ_1 & ξ_2 higher than 60 are considered as outliers, then the values of mean and standard deviation appear to be having values 17.79±7.39 and 18.76±7.1 respectively. The data appears more normal after ignoring the outliers. The mean and standard deviation of the length L1 and L2 are 89.73±24.23 and 84.46 ±24.45 respectively. The means and the standard deviations are very close to each other. Similar behavior has been indicated through the histogram of Fig.3 (a, b), although the histogram of L1 shows a slight negative skewness, which could be ignored and obviously the data are normally fitted.

Khan et.al (1983) in the reaction of U-238 with Au (natural) has reported that the angular distributions of tracks are about 15o with respect to the beam direction. However, in their study, they have reported longer tracks (about 123 μ m). The longer track lengths in their study is not surprising, because of the higher energy (14MeV) used as compared to 10 MeV. In addition to binary scattering events, they have seen multiprong events; they believe that these are due to the sequential fission at this energy. As far as angular distribution of tracks is concered our results are in agreement with the results of Khan et. al. (1983). However, the difference in track lengths could be attributed to the difference in bombarding energy. The energy dependence phenomenon has been reported by Khan et. al (1987) in the interaction of U-238 with natural Uranium using CR-39 detectors.

4. Acknowledgments

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