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A study of the response of solid state nuclear track detectors LR115-I, LR115-Π, CN85 and CR39 to alpha particles using track diameter measurement

H.Bakr
Department of Physics, College of Education, University of Basrah, Basrah, IRAQ.

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ABSTRACT

The accuracy of track diameter for (LR115-I, LR115-Π, CN85 and CR39) are measured in the present work. Comparison for the response curve is studied regarding the relation between the growth of the diameter (Vd) and the energy of alpha particles for different detectors with the given processing parameters. As a conclusion: alpha particles with energy 4 MeV give the better results.CR39 track detector is more effected by the energy of alpha particles and the response to register the charge particles than the other detectors used.

Keywords*:* Alpha sources; Americium 241; Dielectric track detectors; Etching; Particles tracks.

1. Introduction

Latent tracks are damage zones created by energetic charge particles in insulating solids termed as solid state nuclear track detectors (SSNTD's) . These damage trails show increased chemical reactivity. Chemical etching transforms these damaged trails into permanent structures called ion track.(SSNTD's) have found applications in different branches of science [1] . One of the challenging tasks in the application of (SSNTD's) is the accurate measurement of the depth and diameter of the tracks [2,3] .Indirect measurements of alpha-track depths are usually performed by optical methods. While measurements of track-opening diameters are relatively straightforward, some researchers might need or prefer direct measurements of track length. One approach involves the breaking of (SSNTD's) to reveal the lateral images of the tracks for direct measurements [4] and another involves the use of confocal microscopy [5] . Due to the numerous applications in cosmic-ray studies and many other areas of applied science , a number of researchers have studied track information mechansim and other related processes , e.g. annealing and etching of nuclear tracks [6-11] . Recent years have witnessed an increasing use of (SSNTD's) in a variety of fields such as cosmic rays experiments, nuclear reactions, space research and dosimetry applications. The wide spread use of (SSNTD's) is due to their unique features, e.g. low cost, less weight, threshold nature, no electronics requirement and integrated response [6,7,12] . Improvement in the understanding of track formation mechanism and related processes will further widen the application spectrum of these detectors.

This paper prsents results, of a set of systematic experiments carried out to study the response of (LR115-I, LR115-Π, CN85 and CR39) which exposed many sheets from each detector to different energy vertically incident alpha particles. And from the knowledge of accurate relations between energy of alpha particles and track diameters, response curves and verification of the good uniformity of the materials are obtained .

2. Experimental

The detectors used to study the response to alpha particles are (SSNTD's), LR115, CN85 (manufactured by Kodak, Path-France), and CR39 (manufactured by SGL Homalite copration, Wilminton, USA) [12]. (SSNTD's) used in the present study is cut to size (1.5 x 1) cm^2 pieces. These detector samples are irradiated with normal incident alpha particles from radioactive source . This source is supplied by the (Radioactive Ltd., Amersham. England) . After having been exposed to alpha particles with energies from (2 to 5.5)MeV step (0.5)MeV under normal incidence through a collimator . The alpha-source employed in the present study was ^{241}Am source with main energy (≈5.5)MeV under vacuum.

Normal air is used as the energy absorber to control the final alpha energies incident on detector . A relationship between the alpha energy and the air distance traveled by an alpha particles is therefore needed . After irradiation, the detectors are etched in a (2N) aqueous solution of NaOH maintained at $(60\pm0.5)^oC$ by a water bath for (70)min. . The detector were then taken out from the etchant, rinsed with distilled water and dried in air. The observation of induced tracks diameters is carried out using transmission optical Leitz microscope .

3. Results and Discussion

After having cut the solid state nuclear track detectors into small pieces and dividing it into four sets (LR115-I, LR115-Π, CN85 and CR39), then irradiated by alpha particles from the ^{241}Am source for different energies (2 - 5.5)MeV step (0.5) .

The variation of mean tracks diameter as a function of the energies of alpha particles for the four (SSNTD's) employed in the present studies are shown in Table(1) . And the variation of growth of diameter as a function of energies of alpha particles for the same four (SSNTD's) are shown in Table (2) .

The etch pit diameter spectra for normally incident (5.5) MeV alpha particles for (LR115-I, LR115-Π, CN85 and CR39) are shown in Figure (1) to Figure (4) respectively . It is noted that each spectra contains two parts of track diameters. The first part is due to the main alpha particles with peak position at (3.5)µm and contains diameters that are below (6)µm for (LR115-I, LR115-Π and CN85) detectors. While the peak position at (6.5)µm and contains diameters that are below (9)µm for CR39 detector ,the second part that contains the higher diameter is produced by the scattered alpha particles . Figure (5) shows the relation between track diameter and alpha particles energy for different detectors. Figure (6) shows the relation between growth of diameter (V_d = average of track diameter / etching time) and energy of alpha particles . The results show that (for all detectors used),track diameter increases with the increasing alpha particles energy and after attaining a maximum value, it starts slowly decreasing with the increase of the track diameter (as shown in Figure (5)) and a similar behavior of growth of diameter V_d as it first increases with the increasing track diameter and then start slowly decreasing after reaching a maximum value (as shown in Figur (6)) . The maxima occur in the interval (3.5-4.5) MeV.

Table(1): Variation of track diameter with alpha particles energy for different detectors by using etch condition (2N solution of NaOH at 60 °C for 70 min.) .

Energy of alpha articles (MeV)	*Track diameter (μm) for detector*			
	LR115-I	**LR115-II**	**CN85**	**CR39**
2	3.22±0.11	3.46±0.11	3.69±0.12	5.84±0.14
2.5	3.61±0.11	4.19±0.12	4.12±0.12	6.71±0.16
3	3.87±0.12	4.67±0.13	4.43±0.13	8.23±0.23
3.5	4.14±0.13	5.18±0.14	5.77±0.14	9.16±0.31
4	4.13±0.13	5.19±0.14	5.82±0.14	9.51±0.35
4.5	4.03±0.12	5.02±0.14	5.69±0.14	9.11±0.31
5	3.88±0.12	4.77±0.13	5.32±0.13	8.89±0.26
5.5	3.70±0.11	4.52±0.13	5.01±0.12	8.56±0.25

Table(2): Variation of growth of diameter with alpha particles energy for different detectors by using etch condition (2N solution of NaOH at 60 °C for 70 min.)

Energy of alpha articles (MeV)	*Growth of diameter V_d=D/t(μm/hr.) for detector*			
	LR115-I	**LR115-II**	**CN85**	**CR39**
2	2.76±0.09	3.00±0.09	3.16±0.10	5.01±0.12
2.5	3.09±0.09	3.59±0.10	3.53±0.10	5.75±0.14
3	3.32±0.10	4.00±0.11	3.80±0.11	7.05±0.20
3.5	3.55±0.11	4.44±0.12	4.95±0.12	7.85±0.27
4	3.54±0.11	4.45±.0.12	5.00±0.12	8.15±0.30
4.5	3.45±0.10	4.30±0.12	4.88±0.12	7.81±0.27
5	3.33±0.10	4.09±0.11	4.65±0.11	7.62±0.22
5.5	3.17±0.09	3.87±0.11	4.29±0.10	7.34±0.21

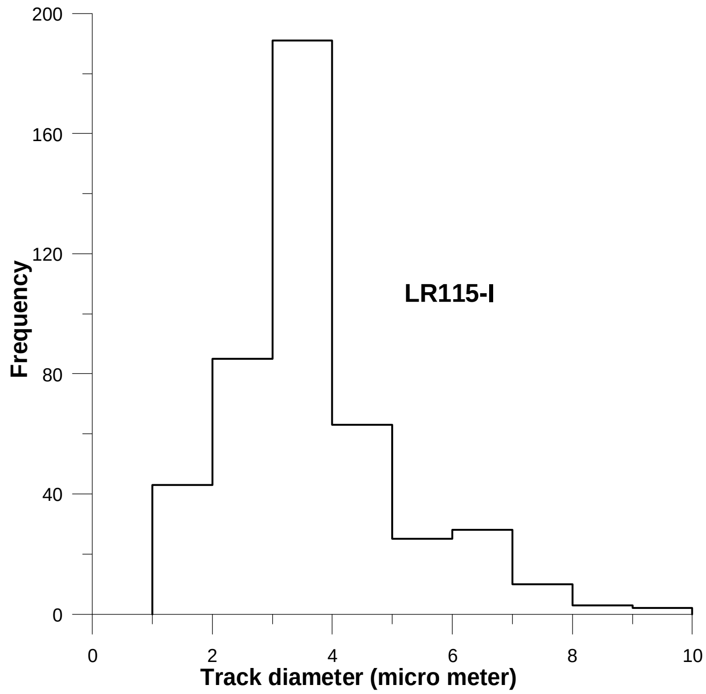

Fig. 1: Diameter distribution of 5.5 MeV alpha particle energy in LR115-I detector sample etch in 2N NaOH solution at $60^{o}C$ for 70 min..

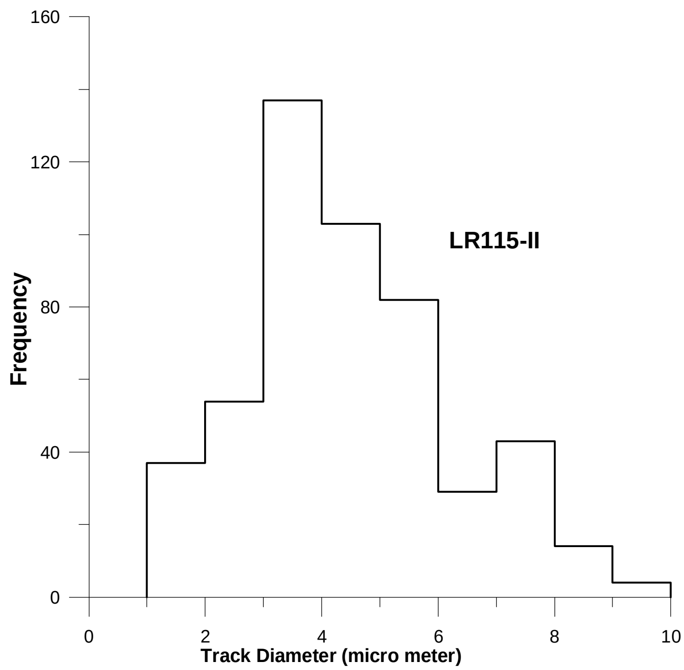

Fig. 2: Diameter distribution of 5.5 MeV alpha particle energy in LR115-II detector sample etch in 2N NaOH solution at $60^{o}C$ for 70 min..

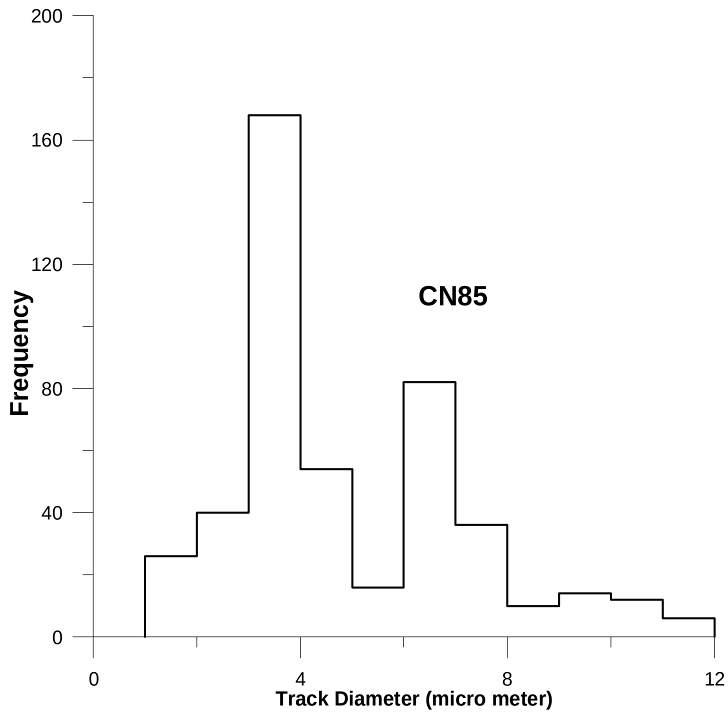

Fig. 3: Diameter distribution of 5.5 MeV alpha particle energy in CN85 detector sample etch in 2N NaOH solution at 60°C for 70 min..

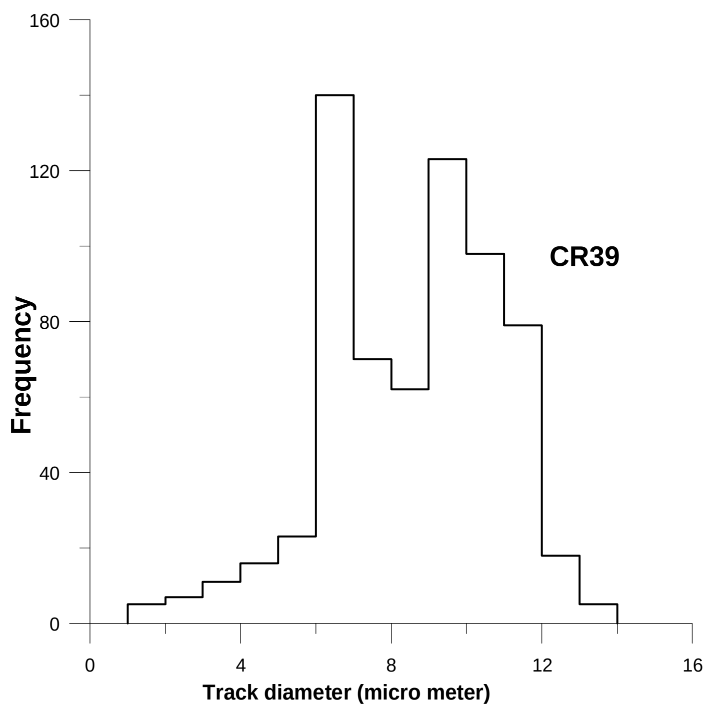

Fig. 4: Diameter distribution of 5.5 MeV alpha particle energy in CR39 detector sample etch in 2N NaOH solution at 60°C for 70 min..

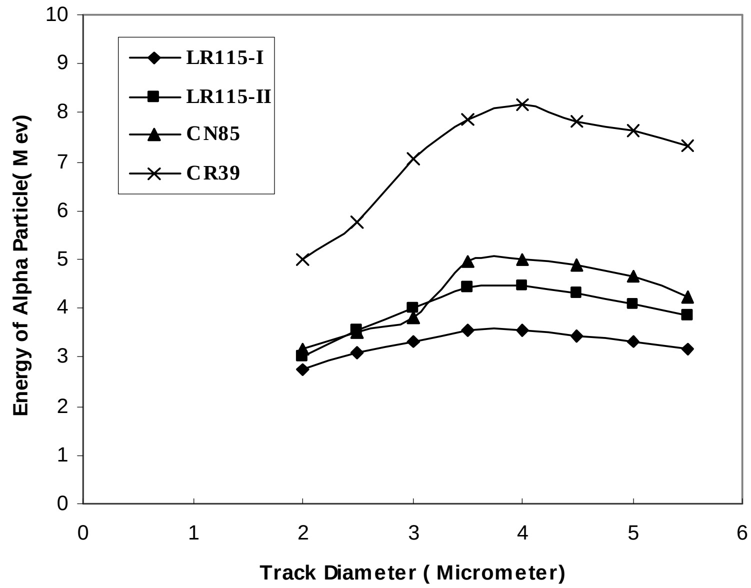

Fig.5:Track Diameter as a Function of Alpha Particle Energy for Different Detectors

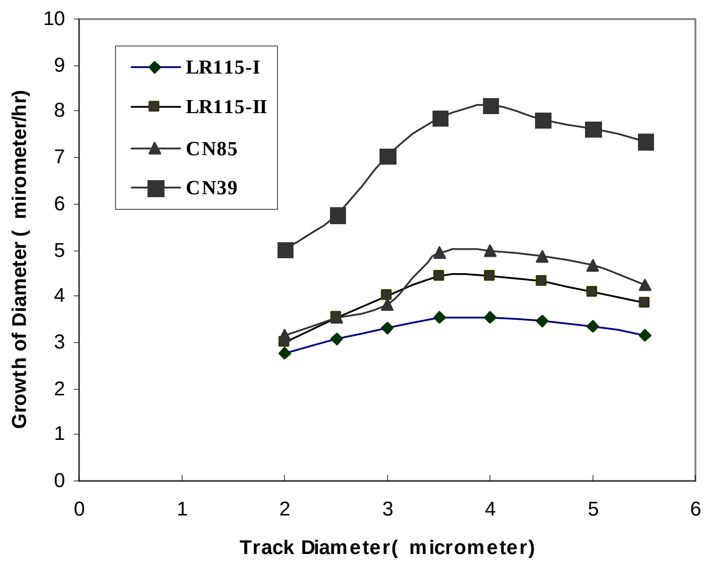

Fig.6:Growth Diameter(V_d) as a Function of Alpha Particle Energy for Different Detectors

4. Conclusions

The following conclusions have been drawn from the above results:

1) The (LR115-I, LR115-Π, CN85 and CR39) are sensitive detectors and

suitable for integral (n , α) reaction rate .

2) Alpha particles with energy (4) MeV gives better results (in terms of higher detection efficiency and / or more precise spectrometry) than other energies.

3) Diameter growth for the tracks is faster in CR39 than CN85, which is faster than LR115-Π and the last one faster than LR115-I as shown in Figure (6).

CR39 track detector is more effected by energy of alpha particles and response to register the charged particles than CN85 track detector which is more than LR115-Π and the last one more than LR115-I .

4)There is a relation between the energy of alpha particles and track diameter for (LR115-I, LR115-Π, CN85 and CR39) track detectors, as shown in Figure(5).

5) There is a relation between the energy of alpha particle and the growth of diameter for all track detectors used in the present work, as shown in Figure(6).

6) When alpha particles traverse the medium, their primary ionization follows the Bragg curve [13] . This can be seen in Figure(5) and Figure(6). The maximum point of Bragg curve depends on the type of the detectors.

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دراسة استجابة كواشف الآثار النووية الصلبة *LR115-I, LR115-Π , CN85* و *CR39* لجسيمات آلفا بأستخدام قياس قطر الأثر

حمـزة بكـر سلمـان

قسم الفيزياء/كلية التربية/جامعة البصرة/ البصـرة –العـراق.

الخلاصــة:

تم في البحث الحالي دراسة الدقة في قطر الأثر للكواشف (*LR115-I, LR115-Π , CN85* و *CR39*) . ودرس منحني الاستجابة من خلال العلاقة بين نمو أقطار الآثار ***(Vd)*** وطاقة جسيمات آلفا للكواشف المستخدمة وبشروط معينة.
استنتج من الدراسة الحالية بان طاقة (4 MeV) لجسيمات آلفا تعطي افضل نتائج . وأن كاشف الأثر الصلب CR39 هو أكثر الكواشف استجابة لجسيمات آلفا من الكواشف الأخرى المستخدمة في هذا البحث.