

Examination of Energy Resolution of Track Detector LR-115 to Distinguish the Various Energies of Alpha Particles (1-4MeV) Using the Wblfit formula Fitting in Matlab Software

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ABSTRACT

This study aims to test energy resolution of the nuclear track detector LR-115 to distinguish the various energies of alpha particles (1-4MeV) that were obtained from radioactive isotope ^{241}Am . This method is based on the relationship between the energy deposited in the material by ionizing particles and the track developed after a well-established chemical process (NaOH, 2.5N, 60°C). Solid state nuclear track detectors (SSNTD's) have been used successfully as detecting devices and as a passive system to detect alpha contamination on different surfaces. The resulted tracks are performed with a digital image analysis system (image processing) associated with a PC mathematical processor and the track diameter distribution fitted by wblfit formula. The mean track diameter (D) for each used energy, its width ΔD at full width at half maximum (FWHM) and energy resolution power $(\Delta E/E)D$ were measured for each neighboring energies. The results of energy resolution of LR-115 were compared with results of another nuclear track detectors of similar studies at average energy (3.7 MeV).

Keywords: Isotope identification ; Nuclear tracks ; LR-115 ; Energy resolution.

(1-4MeV)

LR-115

LR-115
. ^{241}Am (1-4MeV)
.(NaOH, 60°C, 2.5N)
.(Wbl Track) ()
(D) .
.(FWHM) (ΔD)
.($\Delta E/E$)D

LR-115

.(3.7MeV)

LR-115

INTRODUCTION

As is well known, by making use of the relationship between the etching track parameters and the energy deposited in nuclear track detectors, different alpha particles can be identified (Espinosa and Moreno, 1979), (Ilic *et al.*, 1993).

The nuclear track detectors can be used successfully as detecting devices for radon, uranium, neutrons and heavy ionizing particle interaction with matter (Tawfiq *et al.*, 2013), (Babai *et al.*, 2012), (Noori and Ranjbar, 2012), (Najam *et al.*, 2011)

A possible use of plastics such as LR-115 has been explored to monitor low-level alpha particle contamination of solid surfaces. These detectors can be placed in contact with the surfaces to be tested for contamination. The fundamental physical phenomenon is the deposition of alpha particle energy in a cellulose nitrate and the formation of a cone along the particle trajectory in the material after a specific chemical process. The cone thus formed is determined by the relationship between its geometrical size and the energy deposited (Dorschel *et al.*, 2003).

The theoretical and experimental investigations of the penetration of charged particles in matter played a very important role in the development of modern physics. Solid state nuclear track detectors have become one of the most important tools for many branches of science and technology, for example, in neutron dosimetry, gamma and cosmic rays detection, heavy ion and nuclear physics and corpuscular diagnostics in high-temperature plasma experiments. The passage of heavy charged particles through most insulators leads to the formation (at the micro-structural level) of narrow regions of radiation-damaged matter; referred to as latent tracks (Durrani and Bull, 1987), (Fleischer *et al.*, 1975), (Tanner, 1980).

There is a method presents advances in a procedure for alpha particle analysis using the nuclear tracks formed in solid-state materials. This method is based on the relationship between the energy deposited in the material by ionizing particles and the track developed after a well-established chemical process. The experimental study included alpha particles in the energy range from 3.2 to 5.8 MeV emitted by Gd-148, U-238, Pu-239 and Cm-244 (Amero *et al.*, 2001).

Another study presents the response of CR-39 (for two types) to alpha particles from two sources, ^{238}Pu with energy 5 MeV and ^{241}Am with energy 5.4 MeV, the methods of etching and counting are investigated, along with the achievable linearity, efficiency and reproducibility. The sensitivity to low activity and energy resolution are studied (Zaki and El-Shaer, 2007).

This work is focused on the procedure for analysis of alpha particles using nuclear track detectors LR-115 which was supplied by Preshore Mouldings, Ltd., UK. The automatization of the data analysis was done to find the track diameter distribution of the radioisotope and corresponding energies in order to determine the energy resolution of LR-115.

EXPERIMENTAL DETAILS

1- Sample Preparation

LR-115 detector was used in which it was covered with 1000 μm paper. This protection layer cover protects the detector material from interaction with radon during the transport and storage of the

LR-115. This protection layer is removed once the process is started . For this work, we have selected the polymer commercially named LR-115 (cellulose nitrate) with thickness 12 μm.

2- Alpha Particles Irradiation

Irradiation was performed in air using ²⁴¹Am alpha source with different energies 1 , 1.5 , 2 , 2.5 , 3.5, 4 MeV, with a 1 mm aluminum collimator placed between, the detector and the source. For reading we used only normal incidence alpha particles on the material detector. In this work we propose a single step chemical etching, this process is optimized, using a (2.5 N)NaOH solution at 60 ± 0.1°C. The chemical etching process for different time intervals was studied .

Energy resolution

In this experiment, we need to express the energy as a function of the diameter E(D). The displacement ΔE is carried out by means of the chain rule of the calculus (Thomas and Finney, 1992).

$$\Delta E = (\Delta E / \Delta D) \cdot \Delta D \dots\dots\dots(1)$$

Equation (1) can be written in a different form by using the approximation

$$\Delta E / \Delta D = (E_2 - E_1) / (D_2 - D_1) \dots\dots\dots(2)$$

As a consequence of this approach, eq. (1) takes the form

$$(\Delta E/E)D = [(E_2 - E_1) / 0.5(E_2+E_1)] * [\Delta D / (D_2 - D_1)] \dots\dots\dots(3)$$

This equation can be illustrated in Fig. (1).

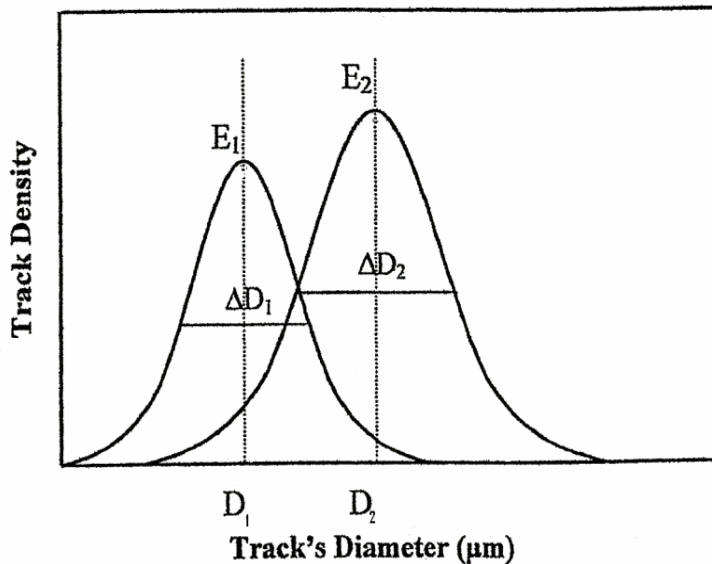


Fig. 1: Distribution spectrum of tracks density corresponding to tracks diameter

Where E1 and E2 are the energies of incident alpha particles, D1 and D2 are the mean track diameters corresponding to each energy and ΔD is the width of the diameter distribution(FWHM). D1, D2 and ΔD are determined by fitting the data for the track size distribution. This process was performed by a program which was written in matlab language for image processing of surface detector (digital system) that can be used to determine some of the nuclear parameters as mentioned

above .The diameter distribution was fitted by wblfit (for fitting many different parametric distributions using maximum likelihood). Weibull PDF takes the form (Devroye,1986).

$$y=(a/b) \cdot (x/a)^{(b-1)} \cdot \exp(-(x/a)^b) \dots\dots\dots(4)$$

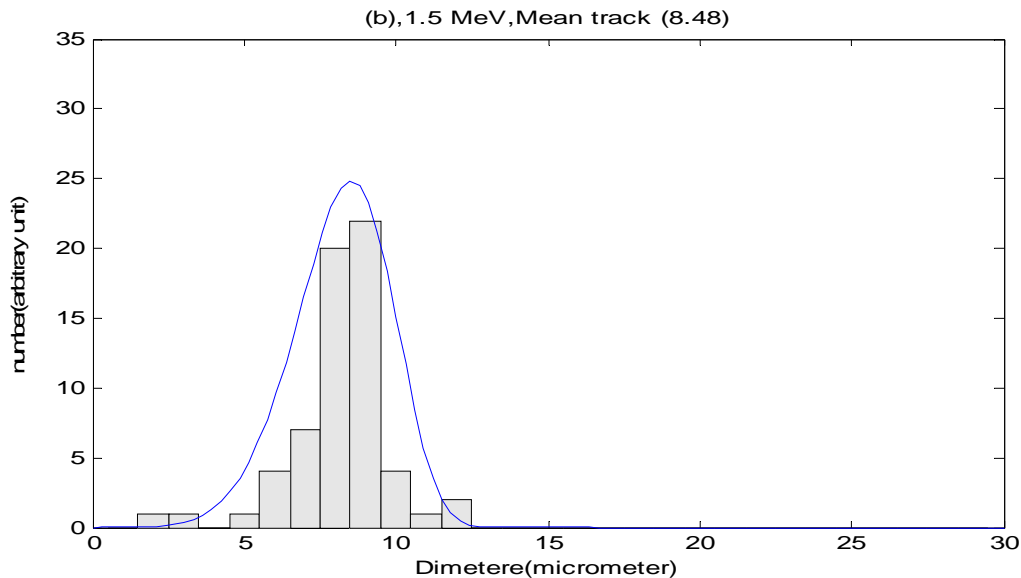
Where a and b are constant parameters.

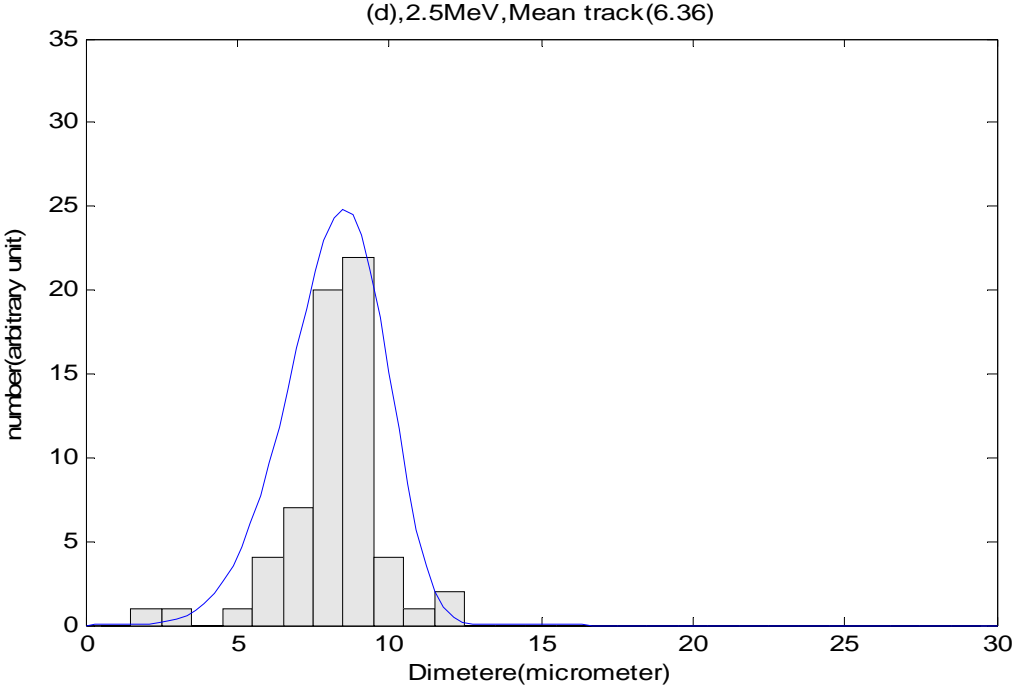
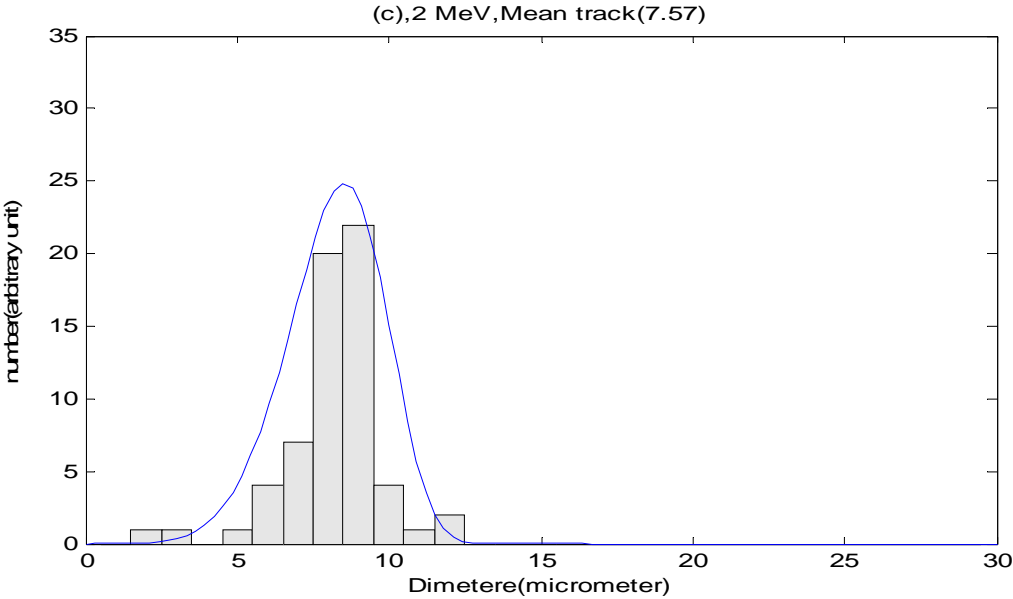
This is almost the same functional form as the Weibull curve used in the curve fitting. However, there is no separate parameter to independently scale the vertical height. Being a PDF, the function always integrates to 1. The Weibull curve we're using, just like other similar models such as Gaussian, gamma, or exponential curves (Devroye,1986).

RESULTS AND DISCUSSION

Experimentally, it was observed that the track diameter distribution has a displacement along the x axis as a function of the etching time. For each etching time, from 90 to 150 min, a wblfit of the track distribution was made and the standard deviation calculated. The minimum value of the standard deviation was found for 105 min of chemical etching. Using this time as the optimum one, the wblfit to track diameter distribution for different energies is shown in Figs. (2,a,b,c,d,e,f).

The energies are identified as a function of the track diameter. To determine the response of the nuclear track detectors, the energies are plotted against the mean value of the respective track diameter . The response is linear corresponding to the fitting equation (Y= -1.1266 x +10.301) with R²=0.8945, in this case from 1 to 4 MeV, as seen in Fig. (3). Using the track diameter distribution and the mean value and standard deviation as obtained from the wblfit, the energy resolution for different alpha-energies are calculated using eq. (3). The results are shown in table 1. Fig. (4) illustrates the inverse proportion between energy resolution and energy of alpha particles. To obtain the track diameter distribution, for each one of the energies, the following considerations were taken: (a) The circular tracks where the relationship of minor d and major D diameters (d=D) is between 0.9and 1.0 are counted (Espinosa *et al.*,1996) ; (b) only the major diameter was considered for the analysis. With these two restrictions, the measurements were done for different etching times from 90 to 150min, for a period of 15 min of each. From this experiment it was observed that the diameter distribution histogram dose move along the x-axis as function of the etching time and energy of alpha particle. A wblfit analysis of the track distribution for each etching time of the detectors was made, obtaining that the lowest value of the standard deviation is for 105 min of etching.





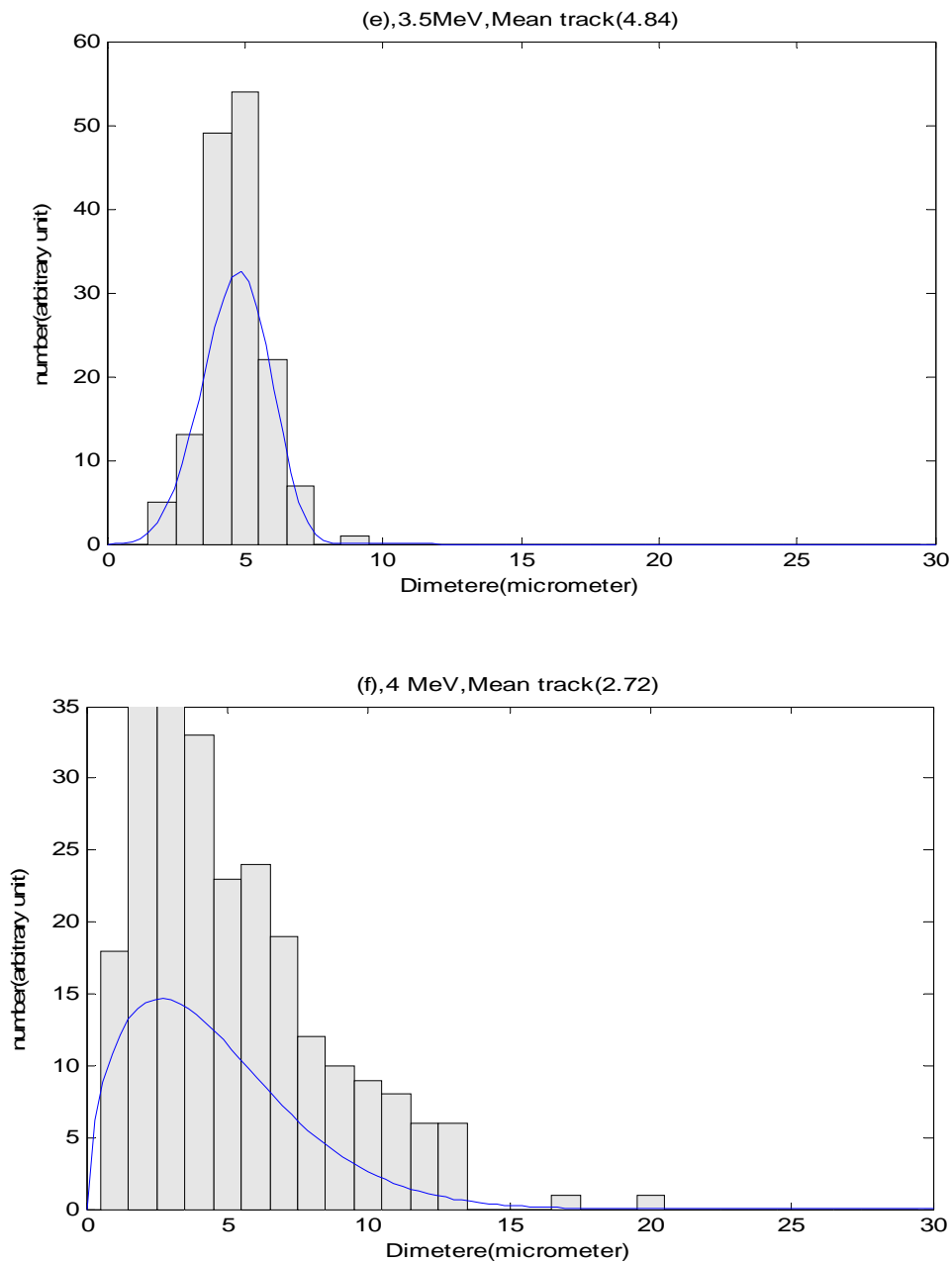


Fig. 2: Track diameter distribution and wblfit for each energy (a,b,c,d,e,f) of the ^{241}Am alpha source.

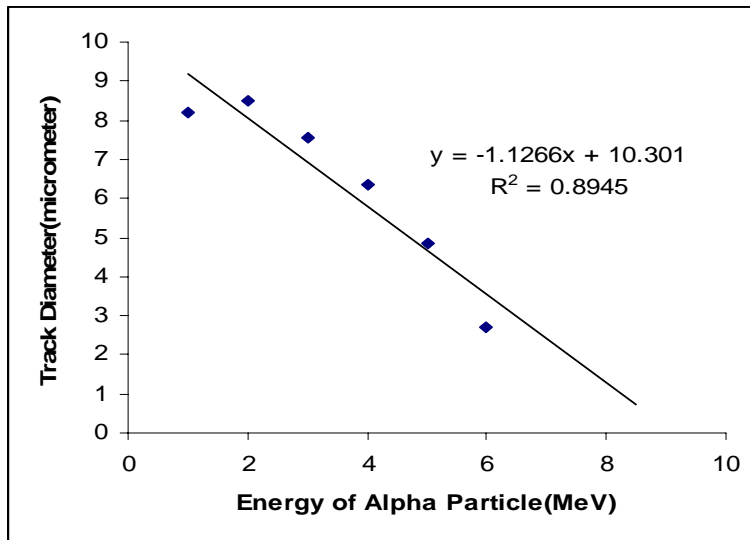


Fig. 3: Track diameter as a function of Alpha particle energy

Table 1 : Mean track diameter (D) for alpha particle energies after 105 min of etching time and the data for the energy resolution.

Energy (MeV)	Mean Track Diameter(D)	Standard Deviation	ΔD (FWHM)	Energy Resolution
1	8.18	1.41	3.33	
1.5	8.48	1.44	3.33	2.22
2	7.57	2.05	4.84	0.6413
2.5	6.36	1.54	3.63	0.3889
3.5	4.84	1.158	2.72	0.3505
4	2.72	2.574	6.06	0.1381

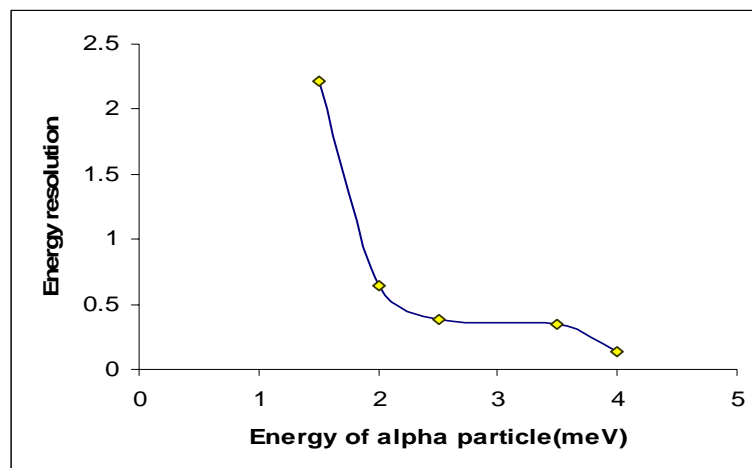


Fig. 4: Energy resolution versus Energy of alpha particles

Comparison the energy resolution of LR-115 at specific energy of alpha particle with other nuclear track detectors will be illustrated through the following Table(2) .

Table 2 : Comparison of energy resolution of different nuclear track detectors at specific energy of alpha particle.

References	Detector	Specific Energy of α - Particle	Energy Res.
Zaki and El- Shaer,2007	CR-39	3.7	0.1794
Amero <i>et al.</i> ,2001	CR-39	3.7	0.18
AL-jobouri ,2004	PM-355	3.87	0.54
Present Work	LR-115	3.7	0.13

This table reveals that the energy resolution of LR-115 better than the other nuclear track detectors at same energy of alpha particle.

CONCLUSION

- * The nuclear track detectors can be very useful for alpha energy analysis and as a particularization of alpha contamination.
- * Digital image analysis systems by using wblfit formula, are very helpful to measure automatically, the track diameter distribution and fast procedure for the alpha particle energy identification.
- * Being the nuclear track methodology, it is considered as another option for alpha spectroscopy with a reasonable resolution and cost.
- * The results showed an inverse proportion between energy resolution of LR-115 detector and energy of alpha particles.

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