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Measure the Bulk Etch Rate Using the Time-Diameter Method

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Abstract

The present work measured the bulk etch rate (V_B) of solid state nuclear track detector by taking the diameter time measurement of alpha particle in CR-39 detector. The values of the track diameter have been found by using TRACK-TEST program from Yu *et al*. function and Brun *et al*. function with different energies of alpha particles. The results showed that the time-diameter (*t-d*) method gave good results of the bulk etch rate (V_B) and these values were (1.705 and 1.72) μm·hr^{-1}. They showed good agreement with the values measured by using the other methods, and it was a simple method because it required getting diameters of the tracks in the detector with the etching time.

Keywords

Bulk Etch Rate, CR-39, Diameter-Time Measurements, Nuclear Track Detector (NTD)

1. Introduction

Solid State Nuclear Track Detectors (SSNTDs) are extensively used for registering nuclear tracks (Fleischer, Price and Walker, 1975) [1]. CR-39 is one of the most commonly used as SSNTDs. CR-39 is transparent in visible spectrum and combines an exceptional range of qualities which are not available in other SSNTDS [2].

A track is created in a SSNTD when an alpha particle hits the detector's surface. The formation of the track is characterized by the value of detector registration sensitivity ($V = Vt/Vb$), where (Vt) is the track etchrate, which is the removed layers of damaged surface of SSNTD (alpha-particle's hitting position) per unit time and (Vb) is the bulk etch rate. Vb is the rate of removing layers of the undamaged surface of SSNTD. Vb varies due to the SSNTD's chemical composition and manufacture process and to the chemical etching process. Vb can be calculated by using several methods, such as the decrease in the detector thickness method, the loss of the detector weight method or the fission-fragment diameter method [3]-[5].

It was theoretically established that change in the mass of the detector Δm and the density of the detector ma-

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terial is one of the main factors to measure the bulk etch rate [6].

$$V_B = \frac{\Delta m}{2A\rho t} \tag{1}$$

where Δm is mass difference; A is the etched surface area; ρ is the density of the detector and t is the etching time.

And a "peel-off" method has been proposed by Nikezic and Janicijevic to directly measure the bulk etch rate for the LR-115 detector based on surface profile measurements using an instrument called (Taylor Hobson, Leicester, England) [7].

Another method to measure V_B is the track of high gamma dose on the response of PADC detector (CR-39) [8].

$$V_B = \frac{D_f}{2t} \tag{2}$$

Also V_B could be measured by another method; and it is by measuring the track diameters D, and the track lengths Le (Le-D) method [9] [10].

$$V_B = \frac{D^2}{4tL_e}\left[1+\sqrt{1+\frac{4L_e^2}{D^2}}\right] \tag{3}$$

Another method has been proposed to determine the track etch rate by taking the relation between the etching time and the track diameters.

2. Experiment

The values of the tracks diameters of alpha particles in CR-39 detector and the etching time have been found by using TRACK_TEST program [11] from Yu *et al*. function [12] and from Brun *et al*. function [13] for the same energies of alpha particles (3.0, 3.6, 4.0 and 5.0) MeV for the two functions.

3. Results and Discussion

There are two methods to find the bulk etch rate for the used detector; it can be found either by irradiating it with charged particles or without irradiating it with those particles in the methods of measuring the V_B.

A simple method proposed to find the bulk etch rate in one hour for the used detector by using the following equation.

$$V_B = \frac{d}{t} \tag{4}$$

Figures 1-4 show the relationship between the etching time and the diameters of alpha particles in CR-39 detector for different energies of alpha particles (3.0, 3.6, 4.0 and 5.0 MeV) that have been obtained from Yu *et al.* function in TRACK_TEST program, from the figures a linear relationship has been shown between the etching times and the track diameters of alpha particles (linear increasing of the diameter with the etching process).

The bulk etch rate V_B can be found for one hour by applying Equation (4) on the linear relationship curve for each energy.

Also **Figures 5-8** show the relationship between the etching time and the diameters of alpha particles in CR-39 detector for different energies of alpha particles (3.0, 3.6, 4.0 and 5.0 MeV) that have been obtained from Brun *et al*. function in TRACK_TEST program, from the figures a linear relationship has been shown between the etching times and the track diameters of alpha particles.

The bulk etch rate V_B can be found for one hour by applying Equation (4) on the linear relationship curve for each energy.

It could be seen from the **Table 1** that the bulk etch rate V_B is independent on energies of α-particles and the values of V_B are around 1.705 μm/hr for the time-diameter measurements that obtained by using Yu *et al.* function and 1.72 μm/hr for the time-diameter measurements that obtained by Brun *et al.* function.

These values are rather close to the value of V_B obtained by the method of Le-D and the method of measuring the thickness of the removed layer as which has been proved by (Al-Nia'emi and Kasim, 2013) [14] and the value of V_B is 1.7 μm/hr [15] and the value of V_B is 1.95 μm/hr [16].

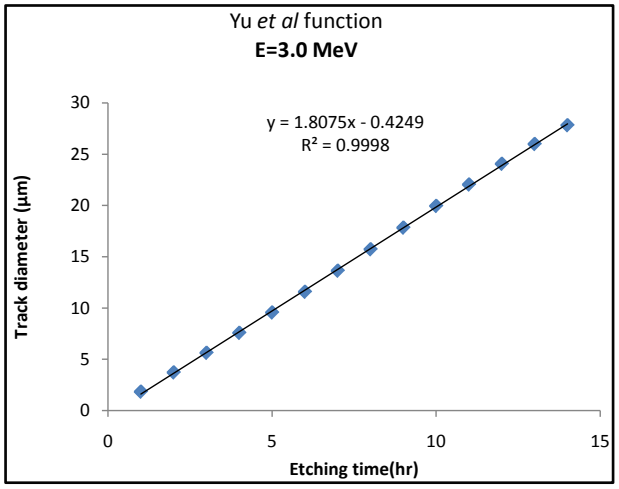

Figure 1. Track diameter (d) as a function of etching time (t) for alpha energy Eα = 3.0 MeV by using Yu *et al.* function.

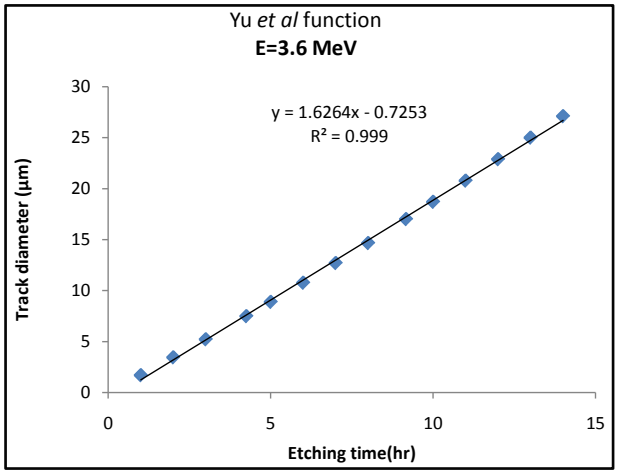

Figure 2. Track diameter (d) as a function of etching time (t) for alpha energy Eα = 3.6 MeV by using Yu *et al.* function.

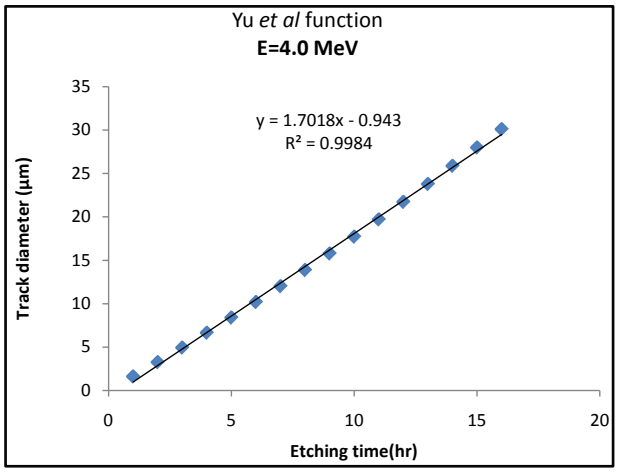

Figure 3. Track diameter (d) as a function of etching time (t) for alpha energy Eα = 4.0 MeV by using Yu *et al.* function.

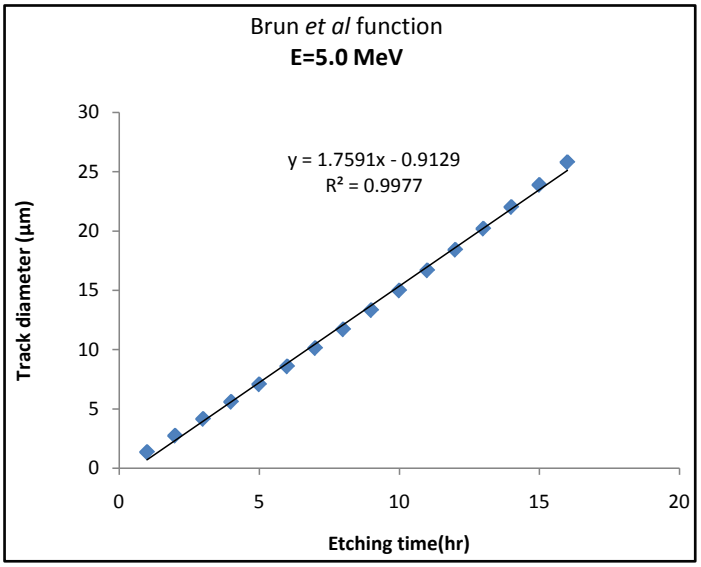

Figure 4. Track diameter (d) as a function of etching time (t) for alpha energy Eα = 5.0 MeV by using Yu *et al.* function.

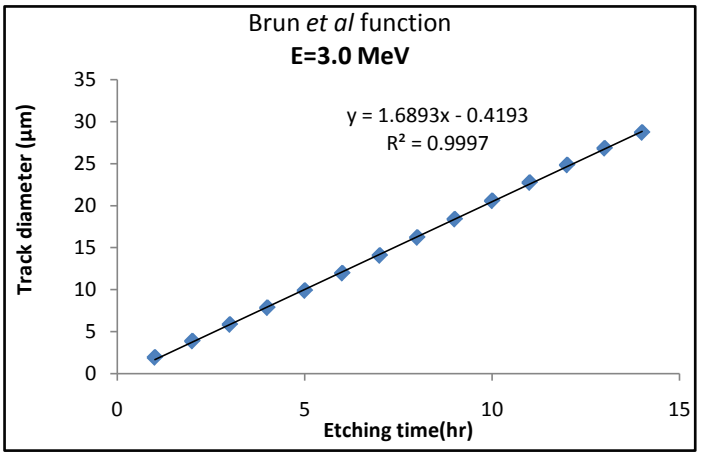

Figure 5. Track diameter (d) as a function of etching time (t) for alpha energy Eα = 3.0 MeV by using Brun *et al.* function.

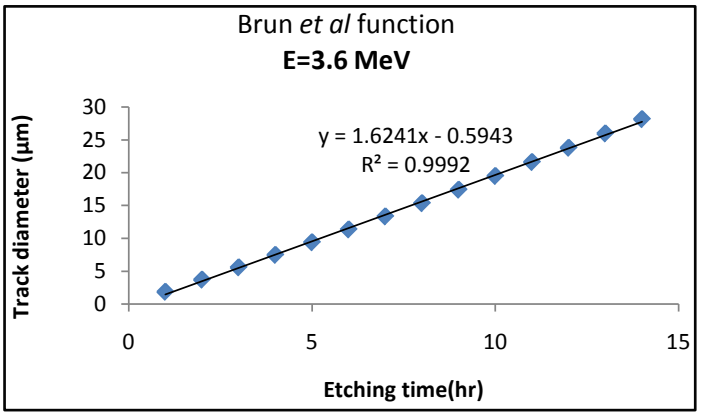

Figure 6. Track diameter (d) as a function of etching time (t) for alpha energy Eα = 3.6 MeV by using Brun *et al.* function.

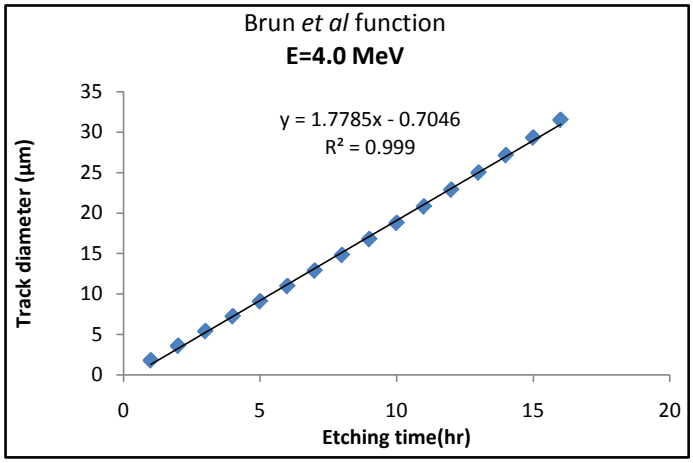

Figure 7. Track diameter (*d*) as a function of etching time (*t*) for alpha energy E*α* = 4.0 MeV by using Brun *et al.* function.

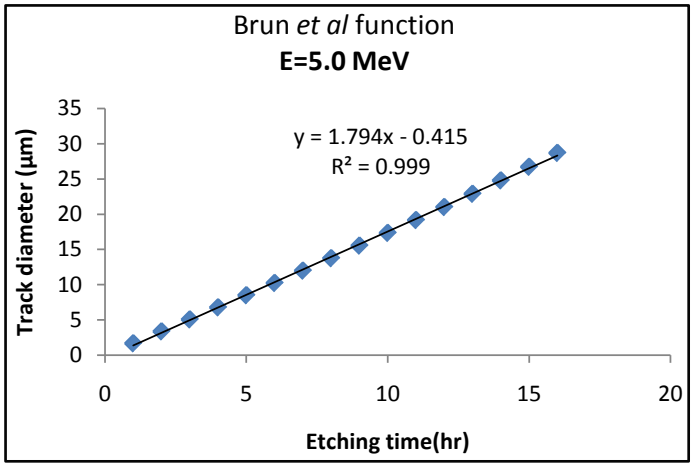

Figure 8. Track diameter (*d*) as a function of etching time (*t*) for alpha energy E*α* = 5.0 MeV by using Brun *et al.* function.

Table 1. The values of the bulk etch rate (μm/hr) of CR-39 detector for different values of *α*-particle energy by using time-diameter measurement.

E (MeV)	The bulk etch rate (μm/hr)	
	Yu *et al.*	Brun *et al.*
3.0	1.8075	1.6893
3.6	1.6264	1.6241
4.0	1.7018	1.7785
5.0	1.7591	1.7947

4. Conclusion

From the obtained results, we conclude that the time-diameter (*t*-*d*) method gives good results of the bulk etch rate (V_B), and it is a simple method because it requires getting diameters of the tracks in the detector. It was found that the results of V_B that were measured by using the time-diameter method close to the values were measured by using the other methods. Also the bulk etch rate does not depend on energy of the particles which used to irradiate the detector.

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