

Parameters Affecting Bulk Etch Rate V_B for CR-39 Detector

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ABSTRACT

In this work, the dependence of the bulk etches rate V_B for CR-39 detector on the temperature T , etching time t and concentration N of the NaOH etchant solution has been studied for detectors material types PADC. The concentration, etching time, temperature and other conditions have been varied in the ranges (5.25-8.25) N, (1-5) hand (60-80) °C for PADC respectively. In this case, the thickness of material removed by etching ranges from 0.20 to 6.10 $\mu\text{m/hr}$ for CR-39 detector. The 6.25 N NaOH solution at 70°C with etching time 3 hours represents the optimum etching condition for nuclear detector CR-39.

1. INTRODUCTION

Nuclear track detectors CR-39 are vastly used for varied tasks in nuclear, cosmic ray, plasma physics, radiation protection, particle accelerator physics, environmental monitoring, medicine and biology because of their advantageous properties such as [1] insensitive to light, [2] expensive cost, [3] insensitivity against low-ionizing radiation, [4] without power supply, [5] insensitivity against environmental condition (heat, cold, vacuum, humidity), [6] low weight, [7] conveniently used and [8] small sizes [9]. CR-39 detector has been widely used, and its abundant propositions have been developed in various applications in different scientific and technical fields. These track detectors are used considerably to give data on different types of charged particles [9]. The charged particles track registration in CR-39 detectors are based on the main two parameters of the detector that govern the track development. These parameters are the bulk etches rate V_B and the track etches rate V_T . [10]. The CR-39 detector is extensively practiced in space radiation experiments [11].

The bulk etching rate V_B with CR-39 detector is the most leading factor to determine the applicability of these detectors in environmental dosimetry and technology research. It can be comprehended as a degeneracy of polymer material. The study of bulk etches rate gives product information on the composite chemical processes that happen within the matter included in the transportation of etching product radiation damage and the

diffusion of etching dissolvent [9]. For a chemist, the bulk etch rate is the interaction of the OH ions with bonds of the carbonate groups of the nuclear detectors poly allyl carbonate. It is evident, however, that the incipient interaction of fast ions with the detector material produces particular damage well-known as free radical production [10].

Energy, direction, and charge of an incident particle may be facily researched by measuring the trajectory profile at rightly chosen terms of temperature T of the etchant solution, etchant time and its concentration N . These parameters might affect the etching eliminating processes without irradiated detector material and detecting of the tracks [11]. The V_B can be measured by various methods like track diameter method of the fission fragment, weight difference before and after etching, and laser interferometer during the chemical etching [12]. Each of these techniques has its interest and noninterest and the choice of which technique to use depends upon the specimen volume or mass and the implementations under search as well [12].

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The main aim of this paper was to determine the effected Parameters such as the concentration and temperature for different etching times on the bulk etches rate VB of detectors CR- 39. The method used relies on the gauge of the mass of the detector before and after the etching process.

2. EXPERIMENTAL PART

The samples of the CR-39 detector used in this study were made by PershoreMoulding Ltd, UK, with composition: C12H18O7 and density: 1.32 g.cm⁻³[Z. A. Tayyeb]. Each detector plate is a square of (1cm×1cm) with athicknessof (500µm). For etching, we used varied concentrations solution of NaOH within the range (5.25-8.25 mol/l) at temperature range (60-80) °C for different etching times. Theetching time was varied from 1 to 5 hours. After that, these nuclear detector platelets were washed thoroughly with distilled water to remove surface contamination. The cleaned specimens were thendried inside a vacuum desiccator. Severalempirical procedures have been successfully used to determine the bulk etches rate. It is one of the crucial coefficients controlling the track development in nuclear track detectors. There are many methods to calculate the VB for the nuclear detector. The method used relies on the weight of the mass of the detector before and after the etching process.

Based on the known density and the mass difference of the detector, it is contingent to calculate the removed layer thickness and in turn, VB [13].

$$V_B(t) = \frac{1}{2} \rho A \frac{\Delta m}{\Delta t} \quad 1$$

Where Δm is the mass difference; A is the etched surface, Δt is an interval of time, ρ is the density of the detector. The integer number 2 in equation 1 takes account of the thickness removal from both sides of a detector.

By using Arrhenius-formula, it is possible to characterize the temperature dependence on the VB according to [E.M. Awad et al].

$$V_B(t) = A \cdot \exp(-\epsilon/KT) \quad 2$$

Where k Boltzmann's constant, ϵ the activation energy and A constant. The activation energy has to be idealistic of value for a chemical reaction. samples.

3. RESULTS AND DISCUSSION

The bulk etch rates of the solid state nuclear track detectors CR-39 with a thickness of 500µm etched in NaOH were found torange from 0.20 to 6.11µm/hr for different molarities at the different temperature as shown in Table 1.

Table 1: Experimental values of the Bulk etching rate VB(µm/hr) as a function of concentration N and temperature °C.

Concentration N				Temperature T °C
8.25	7.25	6.25	5.25	
Bulk etching rate VB (µm/hr)	1.20	0.88	0.50	0.20
	2.06	1.48	0.90	0.60
	2.90	1.76	1.38	1.00
	4.17	3.00	2.11	1.6
	6.10	3.85	2.80	2
				80

Fig.1show a substantial increase in the average removed thickness of the polymer with the increase of etching time at concentration (5.25 - 8.25) N for CR-39 detectors. The results indicated an increase in thickness removed from the polymer material with the increase of temperature, and the thickness removed shows a smaller slope at lower normality. This result is in agreement with result of [14]. The chemical etching behavior of CR-39 detectors surface was studied by measuring the cumulative thickness. Which results are used to calculate bulk etch rate using Eq (1) by performing a linear appropriate of Δm versus t.

The chemical etching behavior of CR-39 detectors surface was studied by measuring the cumulative thickness. The measured values of accumulative thickness removal CR-39 detector etched in the different conditions in terms of temperatures, etching times and etchant normality. To understand the effect of etchant normality on surface chemical etching demeanor of CR-39 as shown in Fig.2, the test slice was offered to etching in the same etchant, at different temperatures and different normality as in 5.25 N NaOH, 6.25 N NaOH, 7.25N NaOH, and 8.25 N NaOH. It is imposing noting that important footsteps of chemical bulk etching rate are permeation of the etchant into the polymer bulk, the reaction of the etchant with weaker bands in the polymer structure. The growth of bulk rate with the etchant concentration was not in a systematic pattern. Therefore, Bulk etch rate increases weakly with a concentration in these temperatures. In this regime, the slow reaction rate is predominant and the Arrhenius equation is applicable. The average bulk etching rate increases with the increase of chemical solution normality. It is due to the fact that once the etching process begins, more etchant concentration leads up to the growth in the etching of the detectors material, and hence higher mean of bulk etch rate.The great increase of concentration leads to an increase in chemical reaction processes with the detector material according to[15].

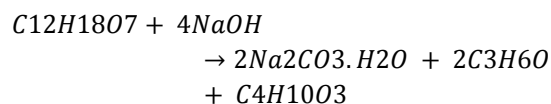


Fig.3 shows the increase in the means of bulk etches rate of the CR-39. detectors with an increase in temperature. This

result is in good agreement with [16]. From the comparison between Figures 2 and 3, we notice that the temperature change is more pronounced than the change in the concentration of the etchant solution on the values of the bulk rate.

Fig.4, shows a scheme of bulk etches rates against the inverse absolute temperature in a concentration from 5.25 to 8.25 N. Such logarithmical representations and their corresponding linear appropriate result in the activations of energy and temperature. The variance of activations energy is decided by the variations in concentration and temperature.

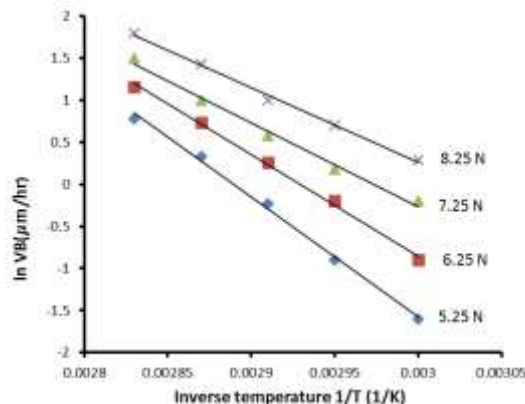
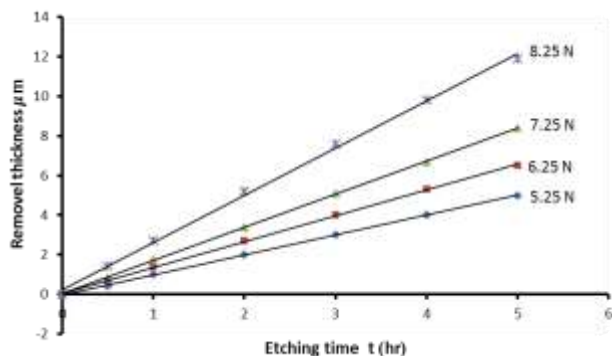


Fig:4: In bulk etch rate VB as a function of the inverse temperature T-1(K-1) within the detector for various concentration.



These results are in harmony with D. Hermsdorf [17].

Fig:1: Removal thickness as a function of the etchant time within the detector for various etchant concentration.

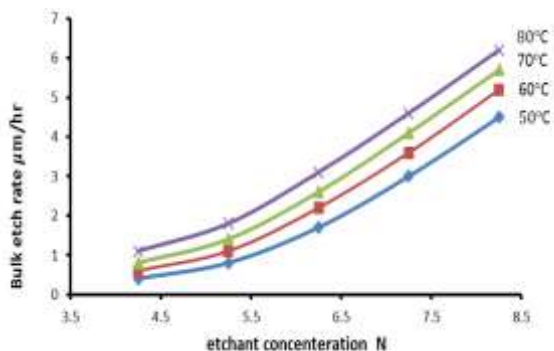


Fig:2: Bulk etch rate VB as a function of etchant concentration within the detector for various temperatures.

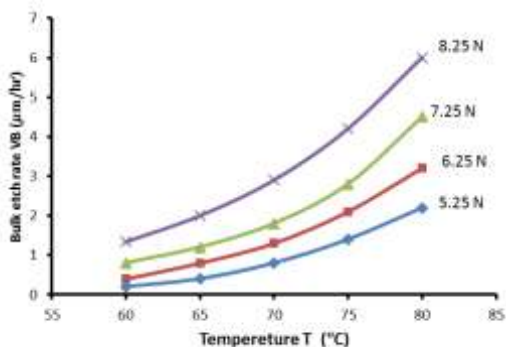


Fig:3: Bulk etch rate of CR-39 as a function NaOH concentration for different temperatures

4. CONCLUSIONS

The demeanor of the bulk etches rate VB of nuclear detector CR-39 in a broad range of NaOH etchant solution concentrations at different temperatures and different etching time has been investigated. From the comparison between Figures 2 and 3, we notice that the temperature change is more pronounced than the change in the concentration of the etchant solution on the values of the bulk rate. this study has shown that the 6.25 N NaOH solution at 70°C with etching time 3 hours represents the optimum etching condition for nuclear detector CR-39.

REFERENCES

- [1]Azooz A.A., Al-Jubbori M.A.,2013"Interrelated temperature dependence of bulk etch rate and track length saturation time in CR-39 detector" Nuclear Instruments and Methods in Physics Research B 316, pp.171–175.
- [2] Dorsche.B., Hermsdorf D.,and Kadner K. 2002"Studies of experimentally determined etch-rate ratios in CR-39 for ions of different kinds and energies" Radiation Measurements Vol. 35, pp.183–187.
- [3].Hermsdorf D.,2012 "Influence of external and internal conditions of detector sample treatment on the particle registration sensitivity of Solid State Nuclear Track Detectors of type CR-39" Radiation Measurements Vol. 47, pp.518-529,
- [4].Hermsdorf D.,2009 "Evaluation of the sensitivity function V for registration of a-particles in PADC CR-39 solid state nuclear track detector material"Radiation Measurements Vol. 44, pp.283–288.
- [5].Hermsdorf D,Arif Mahmood,2013 "Experimental and analytical determination of 4He-ion track development in etched PADC detectors of type CR-39 and its consequences for particle spectroscopy with SSNT detectors", Radiation Measurements, Vol.58, pp.101-106.

- [6].Hermsdorf D., Hunger M., Starke S., Weickert F. 2007"Measurement of bulk etch rates for poly-allyl-diglycol carbonate (PADC) and cellulose nitrate in a broad range of concentration and temperature of NaOH etching solution "Radiation Measurements Vol. 42, pp.1-7.
- [7] Nikezic D., Yu K.N.,2006 "Computer program TRACK_TEST for calculating parameters andplotting profiles for etch pits in nuclear track materials" Computer Physics Communications,Vol. 174,pp.160-165.
- [8] Awad.E.M., Ditlov V.A., Fromm M., Hermsdorf D.,2009"Description of the bulk etching rate of CR-39 by an extended Arrhenius-like law in increased intervals of temperature and etchant concentration" Radiation Measurements Vol. 44, pp.813-820.
- [9] Awad..E.M. 2017"Multi-hit model on CR-39, DAMADC and LR-115 SSNTDs: Statistical and comparative study", Radiation Measurements.
- [10] Spurny,F. Jadrničková,I., Bamblevski V.P., Molokanov A.G.,2005 "Upgrading of LET track-etch spectrometer calibration: Calibration and uncertainty analysis" Radiation Measurements, Vol. 40, pp.343-346.
- [11].Gavin Gillmore, David Wertheim, Simon Crust ,2017"Effects of etching time on alpha tracks in solid state nuclear track detectors" Science of the Total Environment, Vol. 575, , pp. 905-909.
- [12] Inozemtsev K.O., Kushin V.V. ,2016"Comparative analysis of CR-39 sensitivity for different sets of measurable track parameters" Radiation Measurements Vol. 91, pp.44-49.
- [13] Al-Jubbori MA,2016 "A parameterization of the chemistry-normality dependence of bulk etch rate in a CR-39 detector" Applied Radiation and Isotopes, Vol. 118, pp. 228-231.
- [14] AL-Najjar S. F., H. I. Hasan,2015 "Estimate the Optimum condition for CR-39 using two etchant solution" International Journal of Enhanced Research in Science, Technology & Engineering, Vol. 4, pp.2319-7463.
- [15] Tripathy S.P., 2015"Neutron Spectrometry and Dosimetry Using CR-39 Detectors", Solid State Phenomena, Vol. 238, pp. 1-15.
- [16] Ditlov V. ,2005"Formation model of bulk etching rate for polymer detectors" Radiation Measurements, Vol. 40, pp. 240-248.
- [17] Tayyeb Z. A.,2011 "Use of Cr-39 Polymer for Radiation Dosimetry", JKAU:Eng. Sci., Vol. 22, No.1,pp.79-96.

CR-39 للكاشف النووي VB المعلمات المؤثرة على معدل القشط الحجمي

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الخلاصة

في هذا العمل، تمت دراسة اعتماد معدل القشط الحجمي VB للكاشف CR-39 على درجة الحرارة T، وزمن القشط وتركيز N المحلول القاشط NaOH للكواشف من النوع PADC. تبين التركيز وزمن القشط ودرجة الحرارة في النطاقات (8.25-5.25) N و (5-1) ساعة و (80-60) درجة مئوية لـ PADC على التوالي. ولوحظ ان، سمك المادة التي تمت إزالتها عن طريق القشطي تراوح من 0.20 إلى 6.10 μm ساعة للكاشف CR-39 النووي. وكانت أفضل الشروط القشطية للكاشف النووي عند تركيز 6.25 N NaOH ودرجة حرارة 70°C وزمن قشط 3 ساعات.

الكلمات المفتاحية: الكاشف النووي؛ CR-39؛ معدل القشط الحجمي VB؛ هيدروكسيد الصوديوم NaOH.