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Parameters Affecting Bulk Etch Rate $V_B$for CR-39 Detector

Khalid R. Flaih

Department of physics, College of science, University of Anbar, Iraq

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ABSTRACT

In this work, the dependence of the bulk etches rate VB for CR-39detector on thetemperature T, etching time t and concentration N of the NaOH etchant solution has been studied fordetectors material types PADC. The concentration, etching time, temperatureand other conditions havebeen 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 6.10μm/hr for CR-39detector.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 parametersof the detector that govern the track development. These parameters are the bulk etches rate VB and the track etches rate VT. [10]. The CR-39 detector is extensively practiced in space radiation experiments [11].

The bulk etching rate VB 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 facilely 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 VB 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].

*Corresponding author at: Department of Chemistry, College of Education for Pure Sciences University Of Anbar, Iraq. Tel.: +964 7703053530 ORCID:0000-0003-1778-6137
. E-Mail: khalidrokan478@gmail.com

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)=1/2ρA Δm/Δt 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.exp (-ε)/KT 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				
8.25	7.25	6.25	5.25	
Bulk etching rate VB (μm/hr)				Temperature T °C
1.20	0.88	0.50	0.20	60
2.06	1.48	0.90	0.60	65
2.90	1.76	1.38	1.00	70
4.17	3.00	2.11	1.6	75
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].

$$C12H18O7 + 4NaOH \rightarrow 2Na2CO3.H2O + 2C3H6O + C4H10O3$$

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

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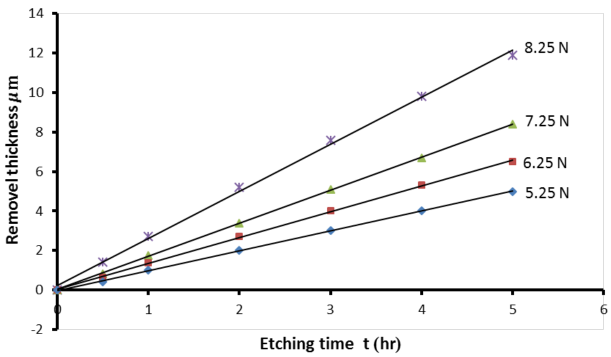
result is in good agreement with [16]. From the comparison between Figures 2 and 3, we notice that the temperature change is more pronounced than the change in the concentration of the etchant solution on the values of the bulk rate.

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.



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.

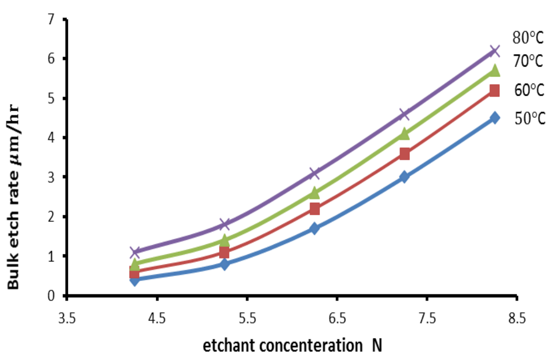


Fig:.2: Bulk etch rate VB as a function of etchant concentration within the detector for various temperatures.

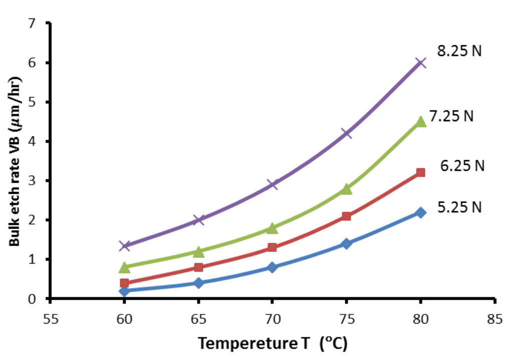


Fig:3: Bulk etch rate of CR-39 as a function NaOH concentration for different temperatures

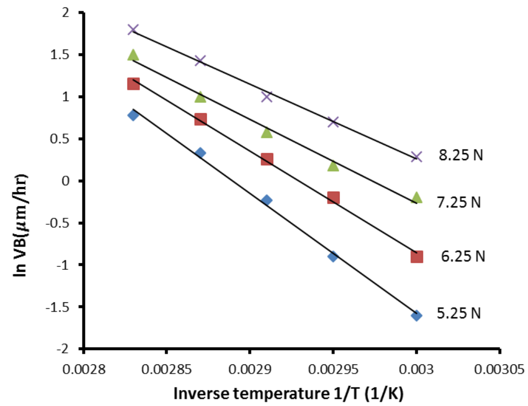


Fig:4: ln bulk etch rate VB as a function of the inverse temperature T-1(K-1) within the detector for various concentration.

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.

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المعلمات المؤثرة على معدل القشط الحجمي VB للكاشف النوويCR-39

خالد روكان فليح

قسم الفيزياء / كلية العلوم / جامعة الانبار / العراق

الخلاصة

في هذا العمل، تمت دراسة اعتماد معدل القشط الحجمي VBللكاشف CR-39 على درجة الحرارة T، وزمن القشطt وتركيزNالمحلول القاشط NaOH للكواشف من النوع PADC.تباين التركيز وزمن القشط ودرجة الحرارة في النطاقات (5.25-8.25) N و (1-5) ساعة و (60-80) درجة مئوية لـ PADC على التوالي. ولوحظ ان، سمك المادة التي تمت إزالتها عن طريق القشطي تراوح من 0.20 إلى6.10 / μmساعة للكاشف CR-39النووي. 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 الحجميVB؛ هيدروكسيد الصوديوم NaOH.