The effect of the type of etchant

Solutions on nuclear tracks detector CR-39

AHMED ABD IBRAHIM

Kirkuk University / College of Science - Physics Dept.

Ahmedabd71@yahoo.com

Abstract

The aim of this paper is to find the effect of type of etchant solutions on nuclear track detector CR-39 . CR-39 detectors were irradiated with alpha particle from ^{241}Am. The irradiated detectors were etched in a number of some newly introduced etching solutions as well as in conventionally used 7 N NaOH and 7 N KOH at 70 °C. The newly prepared etching solutions included NaOH/1-propanol. Processing conditions were optimized for these etchants. From alpha track diameters, bulk etching velocity V_B , track etching velocity V_T , etching efficiency η , etching ratio V , sensitivity S and critical Angle $θ_C$ and their activation energies were determined and compared with that obtained for 7 N NaOH and 7 N KOH at 70 °C

تاثير نوع المحلول الناشط في كواشف الاثر النووي CR-39

احمد عبد ابراهيم

جامعة كركوك /كلية العلوم / قسم الفيزياء

Ahmedabd71@yahoo.com

الملخص

تم في هذا البحث ايجاد تاثير نوع المحلول القاشط في كاشف الاثر النووي CR-39 حيث شععت قطع كاشف الاثر النووي CR-39بسيل من بجسيمات الفا المنبعثة من المصدر الصناعي المشع الاميريشيوم 241Am تم معاملة قطع الكاشف المشععة بثلاث محاليل قشطية منها معروفة وهي هيدروكسيد البوتاسيوم KOH وهيدروكسيد الصوديوم NaOH وكذلك تم معاملة الكاشف بالمحلول القاشط بروبانول هيدروكسيد الصوديوم NaOH/1-propano حسبت المتغيرات القشطية لكل نوع من المحاليل القشطية والتي تشمل انصاف اقطار الاثار وسرعة القشط العام VB والأثر VT والزاوية الحرجة θc وكفائه القشط η وحساسية الكاشف S وكذلك تم ايجاد طاقتي تنشيط القشط العام EB والقشط على طول الاثر ET للمحاليل القشطية الثلاث المستخدمة .

الكلمات المفتاحية: كواشف الاثر النووي ،المحاليل القاشطة، الاثر النووي ،كاشف الاثر ، CR-39 ،طاقات التنشيط.

1. INTRODUCTION

The science of solid-state nuclear track detectors SSNTD was born in 1958 when D.A. Young discovered the first tracks in a crystal of Lif [1]. CR-39 was used as a nuclear track detector for the first time by Cartwright et al.[2]. CR-39 polymer detector is extensively used in various experiments in space science, nuclear science, cold fusion research , radiation effects on living cells [3] ,radiation detection and identification of the nature of nuclear particles .The principle of these detectors is based on their ability to detect and register charged particles as the

latent tracks. The required process to enlarge the primary latent tracks is called chemical etching CE [1] or alternatively electrochemical etching ECE [4] by which the latent tracks grow slowly and become visible. CR-39 polymeric nuclear track detector is the most popular member of the SSNTDs family and technology. The discovery that fission tracks in natural mica can be enlarged by chemical etching so that they can be observed under an optical microscope was the most important landmark in the history of SSNTDs [5]. There are many of factors that affect the response of nuclear track detectors including ultrasonic waves, electric field, light ions, temperature, high pressure, high dose of electromagnetic rays [6] time of radiation , angle of radiation incident , temperature of etching solution ,concentration of etching solution [7], type of detector and the energy of incident particle,[8] Besides, there are factors concerning the detector itself that affect the sensitivity of nuclear detectors i.e. the purity of the monomer and the molecular structure of the polymer,. in this paper we will investigate the effect of etching solutions type on registers proportion CR-39 detector , that are include ; diameter of tracks, numbers of tracks, bulk etching velocity VB , track diameter growth velocity VD , track etching velocity VT , etching ratio V , efficiency and sensitivity (S , η) and the critical Angle θC.

2. MATERIAL AND METHOD

Fifty seven CR-39 detectors were exposed to alpha particles at normal incident from 241Am source of 330 kBq activity ,the detectors were 1cm x1cm area 1mm thickness , after irradiation , the detectors were divided into three groups. These detectors were exposed at incident angle 90 with normally incident alpha particles from 241Am source of activity 330 kBq with. After process irradiation , First group 16 pieces was etched in NaOH at different concentration (5, 7, 9 and 11 N) and different etching temperatures(50, 70, 80 and 90 ℃) .Second group 25 pieces etched in NaOH/1-propanol at different concentrations(0.6, 0.8, 1, 1.2 and 1.4N) and different etching temperatures(40,50,60,70, and,80 ℃) . Last group 16 pieces was etched in KOH at different concentration (5, 7, 9 and 11 N) and different etching temperatures(50, 70, 80 and 90 ℃) . After each etching step, detectors were washed with distilled water. Diameters of the alpha particle tracks were measured under optical microscope.

values of etching temperature and concentration were determined. bulk etching Velocity VB , track etching velocity VT , etching ratio V , efficiency and sensitivity S , η and the critical Angle θC were calculated.

3. RESULTS AND DISCUSSION

CR-39 detectors irradiated with alpha particles from 241Am source of activity 330 kBq was etched in NaOH/1-propanol solutions. Various concentrations and temperatures were used to achieve the optimum processing conditions. For comparison purposes, CR-39 detectors were also etched in aqueous solutions of NaOH and KOH Various concentrations and temperatures. After measuring track diameters, bulk Etching Velocity VB , track Diameter Growth Velocity VD , track etching velocity VT , etching ratio V ,   efficiency and sensitivity S , η and the critical Angle θC were determined .

Figure 1 shows average track diameter of alpha particles as a function of etching time for NaOH ,KOH and 1 N NaOH/1-propanol etching solution at the temperatures listed respectively on the graphs.   **Figure 2** show the   average track diameter increases gradually with an increase in concentration.
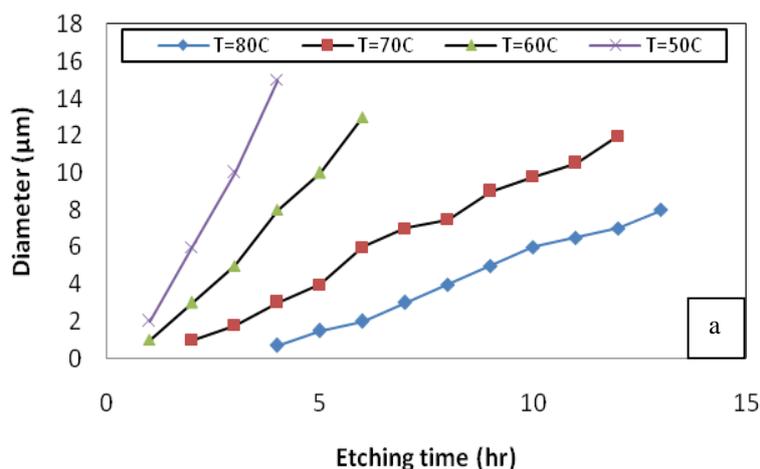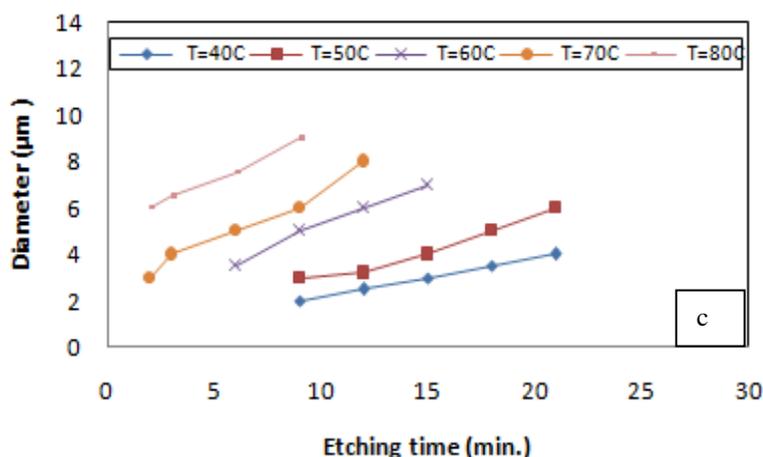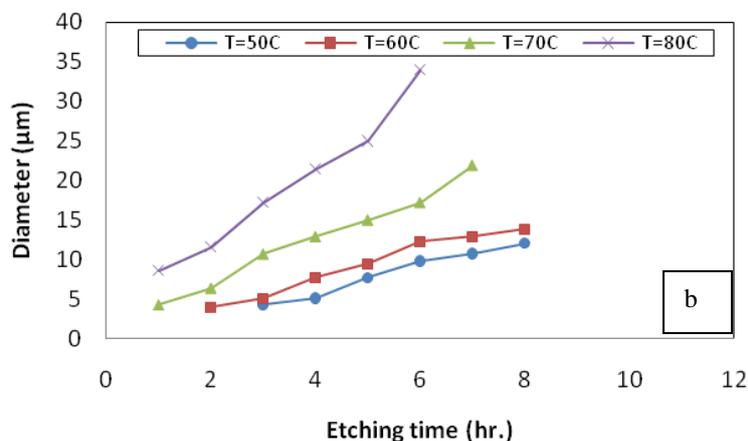
Figure 1: Average track diameter of alpha particles as a function of etching time (a) in 7 M NaOH ,(b) in 7 M KOH .(c) in 1 M NaOH/1-propanol at the listed temperatures .

As can be seen in the **Figure 1 a,b,c** and **Figure 2 a,b,c**   the average track diameters viruses etching time for three solutions, NaOH ,KOH and 1 N NaOH/1-propanol respectively .Different concentrations were investigated as shown in the **figure 2 a,b,c** .The NaOH and KOH solutions are held at a constant temperature of 70 °C   while the   1 N NaOH/1-propanol solution was held at a constant temperature of 50 °C .
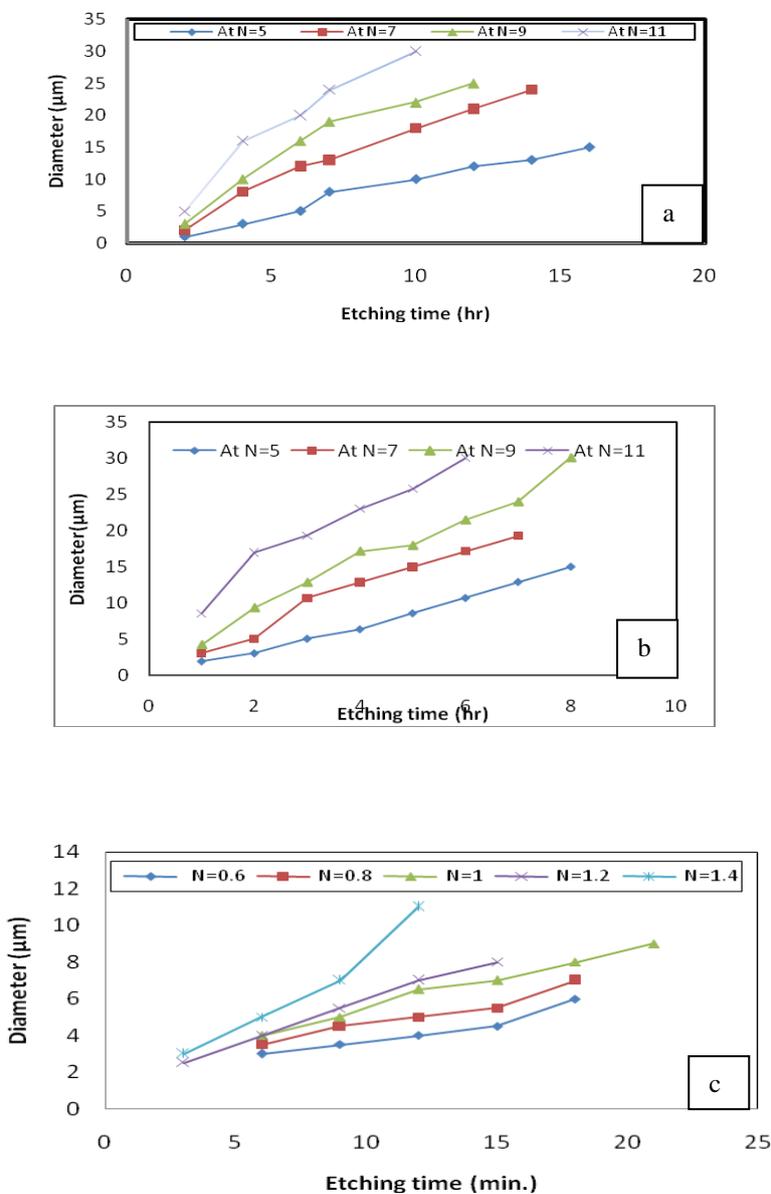
Figure 2: Average track diameter of alpha particles as a function of etching time.(a) 70 °C in NaOH, (b) 70 °C in KOH (c) 50 °C NaOH/1-propanol solution at the listed etchant concentrations respectively.

Table 1,and 2   shows average track diameters, VB, VT ,V, Ө and η values of CR-39 detectors that were etched in the listed concentration of NaOH , KOH solution at 70 °C .The highest efficiency 68%, 70% for NaOH and KOH respectively were observable at a concentration of about 7N. This results agrees with those given in [9]. In table 3, η has maximum value 74% at 1M concentration of NaOH /1 propanol solution at 50 °C which is in agreement with results of published [10].

TABLE(1). Registration parameters of CR-39 in NaOH solution at different concentrations and 70 °C

| Concentration	VB(μmhr^{-1})	VT(μmhr^{-1})	V	S	Ө	H
5	1.2	2.2	1.83	0.83	33.1	0.45
7	2.1	6.8	3.2	2.2	18.1	0.68
9	3.81	6.9	1.81	0.81	33.5	0.44
11	4.5	7.2	1.6	0.60	38.6	0.37

TABLE (2). Registration parameters of CR-39 in KOH solution at different concentrations and 70 °C

Concentration	VB(μmm^{-1})	VT(μmm^{-1})	V	S	Ө	η
0.6	0.21	0.33	1.57	0.89	31.9	0.36
0.8	0.25	0.48	1.92	0.92	31.3	0.47
1	0.29	1.14	3.85	2.13	15.1	0.74
1.2	0.65	1.30	2.00	1.00	30.0	0.50
1.4	0.32	0.53	1.65	0.65	37.3	0.37

TABLE (3) Registration parameters of CR-39 in NaOH-1Propanol solution at different concentrations and 50 ℃

Concentration	VB(μmhr^{-1})	VT(μmhr^{-1})	V	S	θ	H
5	1.9	3.2	1.68	0.68	36.5	0.40
7	2.6	9.6	3.40	2.40	17.1	0.70
9	4.5	11.5	2.55	1.5	23.2	0.60
11	7.8	13.2	1.69	0.69	36.2	0.41

Figures 3 a,b,c ,in these figures the highest efficiency verses in the three solutions are, respectively 74%,70% and 68% ,which occurs at concentration of 1 N,7 N and 7 M respectively .**Figures 4 a,b,c** shows , for the etching efficiency as a function of temperatures for 1M solution of NaOH /1 propanol , 7 M solution of NaOH and 7 N solution of KOH   . In these figures the highest efficiency viruses is again   74%,70% and 68% respectively which occurs at temperatures of 50 ^{o}C,70 ℃ and 70 ^{o}C respectively.
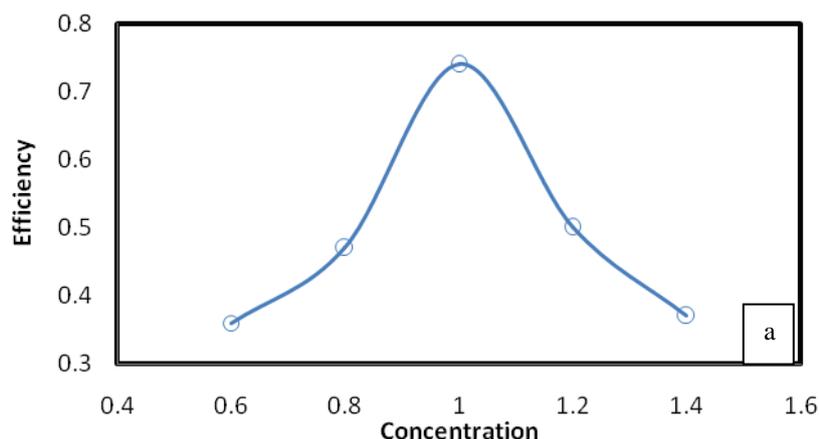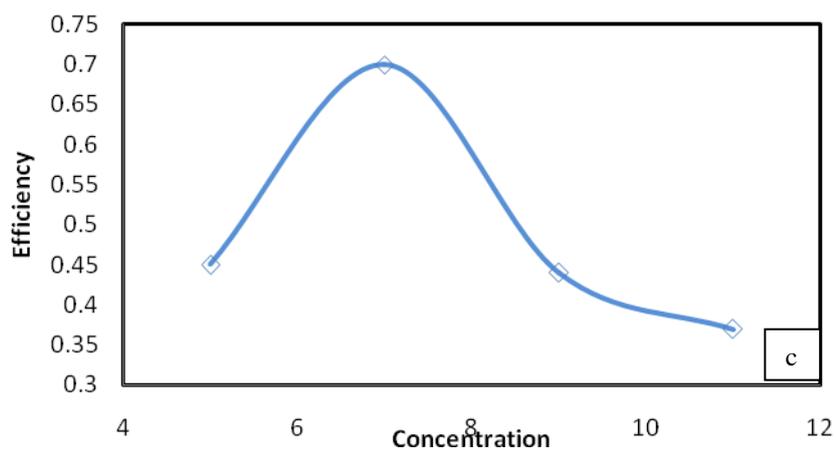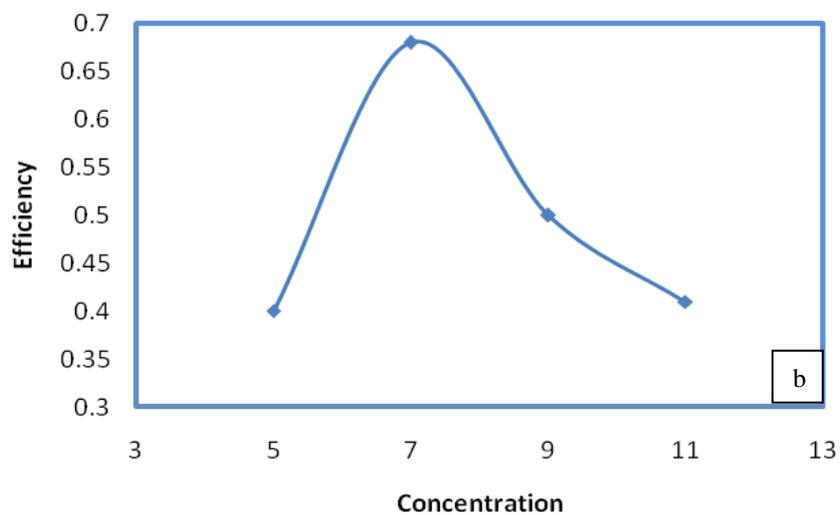
FIGURE 3: (a,b,c). Efficiency as a function of concentrations for NaOH/1-propanol , NaOH and KOH etchants respectively
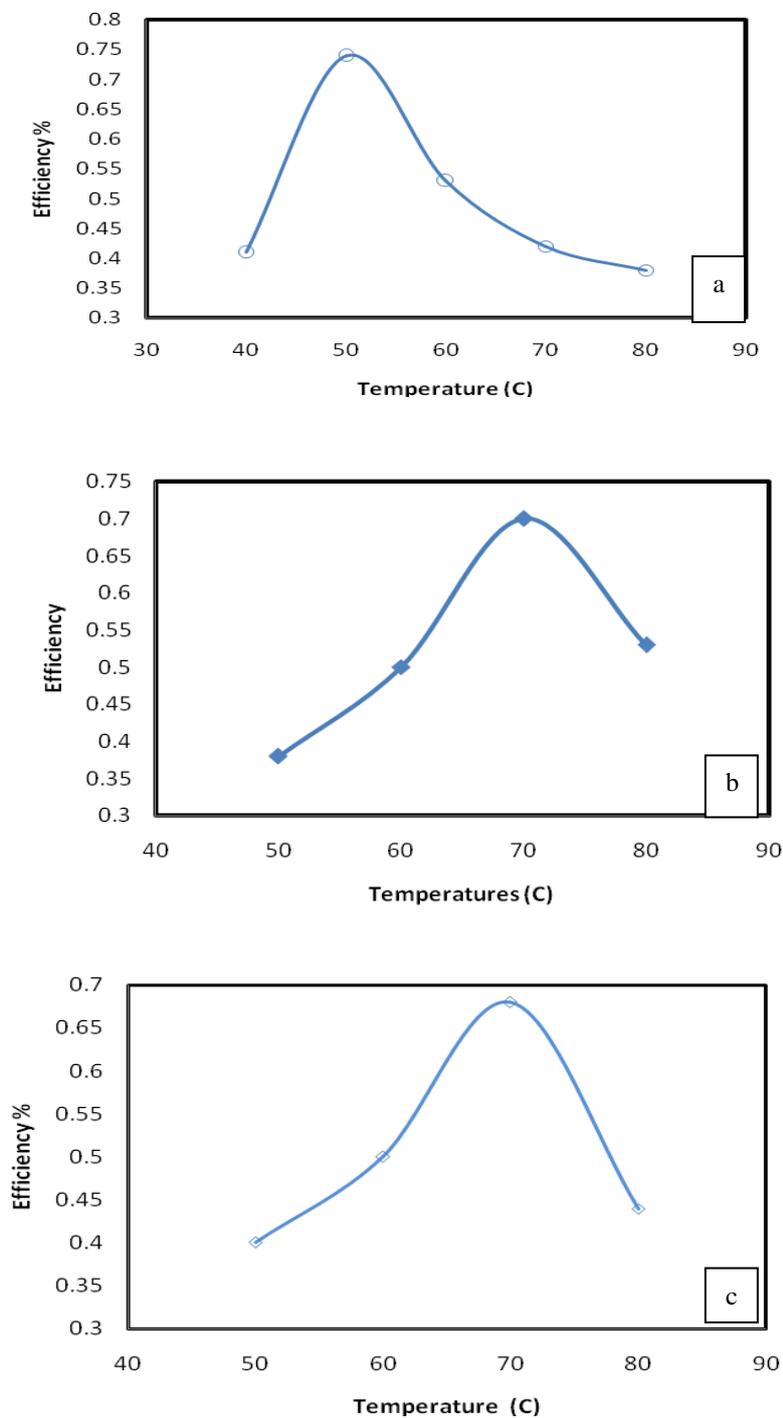
FIGURE 4: (a,b,c) Efficiency as a function of temperatures for NaOH /
1-propanol,NaOH and KOH etchants respectively

4. ACTIVATION ENERGY

The activation energy of CR-39 polymer detector (bulk or track) is defined as the energy required to activate the reaction between the detector material and the etchant solution [11]. Many works [12,13] studied the activation energy of the CR-39 polymer detector.. It tells us about the kinetics of the reaction. Figure 5 a, b show ln VT as a function of T-1 (10 4 K−1 and ln VB as a function of T-1 (10 4 K−1) for NaOH ,KOH and NaOH/1-propanol .   At any particular temperature it can be seen that VB and VT are higher for NaOH/1-propanol etchant, than that for KOH, etchant and this one is higher than that for NaOH etchant . The values of activation energies were obtained from slopes of straight lines, shown in **Figure 5 a,b** they are tabulated in table 4. The values of EB and ET agree with results of [14] . Higher value of activation energy indicates a greater temperature dependence of the reaction rate [10]. This was clearly observed in our data obtained for all etchants. It was also observed that the track activation energy ET is lower than the bulk activation energy EB. It reveals that the chemical etchant attacks damaged regions faster than that for undamaged regions.
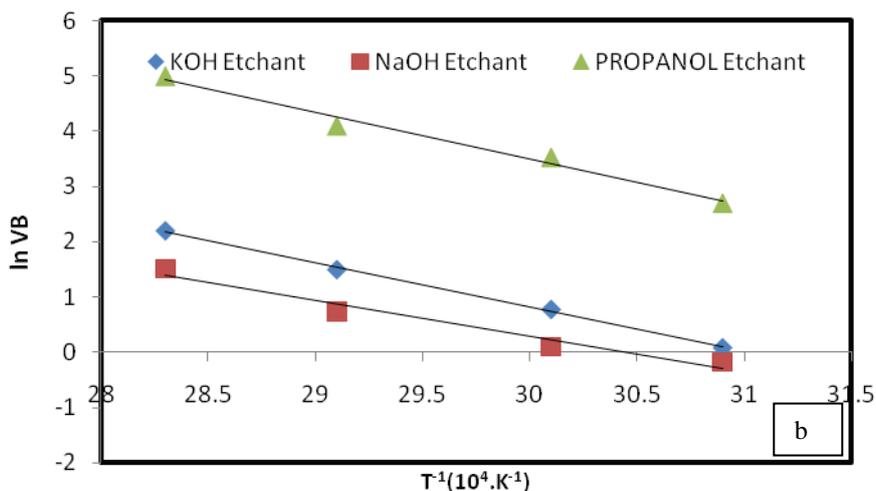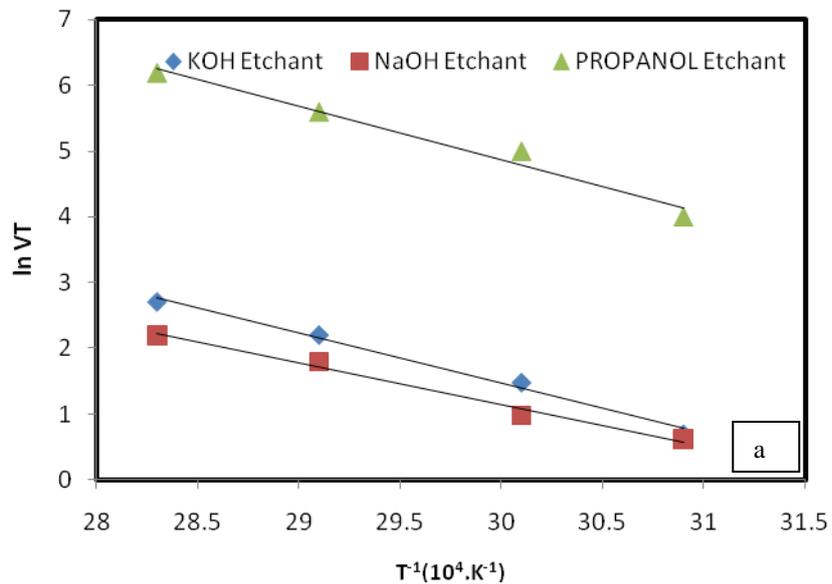
FIGUR. 5 :(a) ln track etch rate VT and (b) ln bulk etch VB , plotted against T-1 (104 K-1) for the listed etchants for CR-39 detector. The slope of the straight lines gives value of the bulk activation energy ET and, EB respectively

TABLE (4). Values of bulk activation energy and track activation energy for different etchants

Type Etchant	EB (ev)	ET(ev)
NaOH/1-propanol	0.91	0.88
KOH	0.87	0.82
NaOH	0.80	0.76

5.CONCLUSION

In this paper we have experimentally verified the following conclusions regarding the effect of The Effect of type of etchant Solutions on nuclear tracks detector (CR-39). Average track diameters gradually increases with an increase in the etching temperature. Average track diameters gradually increases with an increase in the concentration of solutions. Both 1N NaOH/1-propanol solution and KOH are more efficient than that of aqueous NaOH. Track activation energy, ET, has found to be lower than the bulk activation energy, EB, for CR-39 detector in all solvents considered in this work.

REFERENCES

[1] Yaung, D. A. Nature.1958, 182, 375-377.

[2] Cartwright, B. G; Shirk, E.K.; Price P.B. Nucl. Instr. and Meth., 1976,153 ,457-460.

[3] Dorschela, B.; Hermsdorfa, D.; Pieckb S.; Starkea S.; Thielea, S. Nucl. Instr. and Meth. In Physics Research, 2002, B 187, 525–534.

[4] Yaung, D. A.; AL-Najjor , S. A .R. Nucl. Instr. and Meth.1980, 173, 97-102.

[5] Fleischer, R. L.; Price, P.B.; Walker, R. M., Nuclear Tracks in Solids Principles & Application , University of California press , England 1975

[6] Singh, S.; Neerja, A. Radiation measurement. 2007, 42, 1507-1509.

[7]   Hermsdort, D. Radiation Measurements, 2012, xxx, 1-12.

[8]   Khayrat, A. H.; Durrani, S.A. Radiation Measurements 1999, 30, 15-18.

[9]   Durrani, S. A.; Bull, R.K, Solid State Nuclear Track Detection, Principles, Methods and Applications, Pergamum Press, Oxford, 1987.

[10]   Matiullah, S.; Rehman, S.; Zaman, W. Radiation Measurements, 2005, 39, 337 – 343.

[11]   Saffarini, G.; Nidal, D.; El-Hassan, M.; Sato F; Kato ;Lida T. Nucl.Instr.and math in phy. Research A, 2012, 680,82-85.

[12]   Rana, M. A.; Qureshi, I .E.; Manzoor, U.; Shajhzad, E. M.; Khan H. A. Nucl.Instr.and Meth in phy. Research, 2000, B.170.149-155.

[13]   Rana, M. A. Nucl.Instr.and Math in phy. Research, 2012, B.672.57-36.

[14]   Awad, E. M; El-Samman, H. M. Radiat. Meas.1999, 31, 109–114.

AUTHOR

Dr. Ahmed A. Ibrahem:
Academic Qualifications:
1- B. Sc. Certificate in physics from University of Mosul in 1994-1995.
2- M. Sc. Certificate in physics (Nuclear physics) from University of Mosul in 2000 Title of Thesis:
  "The effect of the etching factors and heating treatment on the nuclear tracks detectors"
3- Ph. D. Certificate in physics (Health physics) from al-mustansry University in 2006 Title of Thesis:
  " The effect of gamma rays and beta particles on erythrocyte sedimentation rate).
Occupations:
    1996- 2000 teacher in al-ryde secondary school for boys-kirkjuk-iraq
    2001-2004: Assistant lecturer at teacher institution for girls- Kirkuk –iraq
    2004 to 2013: Assistant professor at Kirkuk university-College of Science-Physics Department.
Now Dean of College of Science Kirkuk University