J. King Saud Univ., Vol. 14, *Science* (2), pp. 59-68, Riyadh (1422/2002)

The Response of Some SSNTD's to Alpha Energies in the Range (1 to 5) MeV

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(Received 21/12/1420H.; accepted for publication 22/6/1422H.)

Abstract. The optimum etching times of the SSNTD's used in this study and their response to alpha energies in the range 1- 5MeV are discussed. These etching times were found to be 8 hours for CR-39 in etching solution of 6.25N NaOH solution at 70°C, 1.5 hours for MK in a PEW solution at 70°C and 3 hours for both CN-85 and LR-115 when using 2.5N NaOH solution at 60°C. CR-39 detectors were found to have the highest response to alpha energies> 5MeV.

1. Introduction

The validity of various models of track formation may be judged by critical parameters such as charge, mass and energy of incident particles which are able to form etchable tracks. Various studies [1-3] suggested that the track formation may be related to a number of different parameters, such as total energy loss rate ,primary ionization ,restricted energy loss etc..These track formations can be tested by irradiating a given solid with a number of ions at various energies and recording the cases for which etchable tracks are formed . If the track has been etched successively until the end of the ion range, it performs a cone with a tip point. The shape of the developed tracks in the plastic detectors depends on the etching conditions. It goes through three phases namely conical, transition and spherical phases. Plastic track detectors are in use in diverse area of research such as radiation dosimetry, heavy ion physics, neutron physics, astrophysics, solar particles, geophysics and medicine [1-11]. These detectors consist of a long-chain organic molecules and have threshold for charged particle detection. Furthermore SSNTD's have some impressive features such as, they are cheap, simple in use, can be used in any space by any size and can be operated successfully in a wide range of fields [4-11].

The aim of the present work is to study the optimum etching time and the induced changes in the response for each detector's type and its dependence on the alpha energies.

2. Experimental Techniques

2.1 Sample preparation for etching time measurements

Different detectors of CR-39 (500m thickness) from Pershore Ltd, U.K, CN-85 (100m thickness) and LR-115 (12m thickness) from Kodak pathe and Makrofal (MK) (300m thickness) from Bayer, Germany were used in this work.The size of each detector is 2.5x2.5 cm.

To obtain the etching time at which we get the optimum response of SSNTD's, five groups from each type of detectors were used. The detectors were identified by numbering them on the upper right corners. LR-115 detectors were identified on the back support of the detectors.The SSNTD's were exposed to alpha-particles from a standard plutonium source ^{238}Pu (half-life 87.74 year) of activity 6.061×10^{3} Bq manufactured by National Bureau of Standards U.S. Department of Commerce. The plutonium source was used with five collimators of lengths 5.7, 15.9,24, 30.5 and 35.5 mm corresponding to alpha-particle energies 1,2,3,4,5 MeV respectively. These collimators were used also to obtain normally -incident alpha particles.

2.2 Counting technique

The resulting alpha-tracks on each detector were counted under an optical microscope at a total magnification of 400×. The number of alpha tracks per field was averaged over thirty fields counted for each detector and then the track density was obtained. The resulting data were used to study the relation between etching time and the response for each type of SSNTD's and at each energy of the alpha particles.

3. Results and Discussions

3.1 Characteristics of each SSNTD

3.1.1 *Etching time*

(a) CR-39

Figures 1(a to e) show the variation of the response of CR-39 detectors as a function of the etching time for different alpha energies (1-5MeV) respectively, at etching concentration of 6.25N NaOH solution at 70°C[11].

From these Figs. we can see that the latent tracks on the detectors can not be revealed before three hours of etching. It is also seen that the response of the detectors is increasing with etching time until it reaches a certain value, then a plateau like shape is observed i.e. the response is independent on the etching time. It is clear that CR-39 detectors reach their maximum response for all alpha energies at etching time of 6 hours.

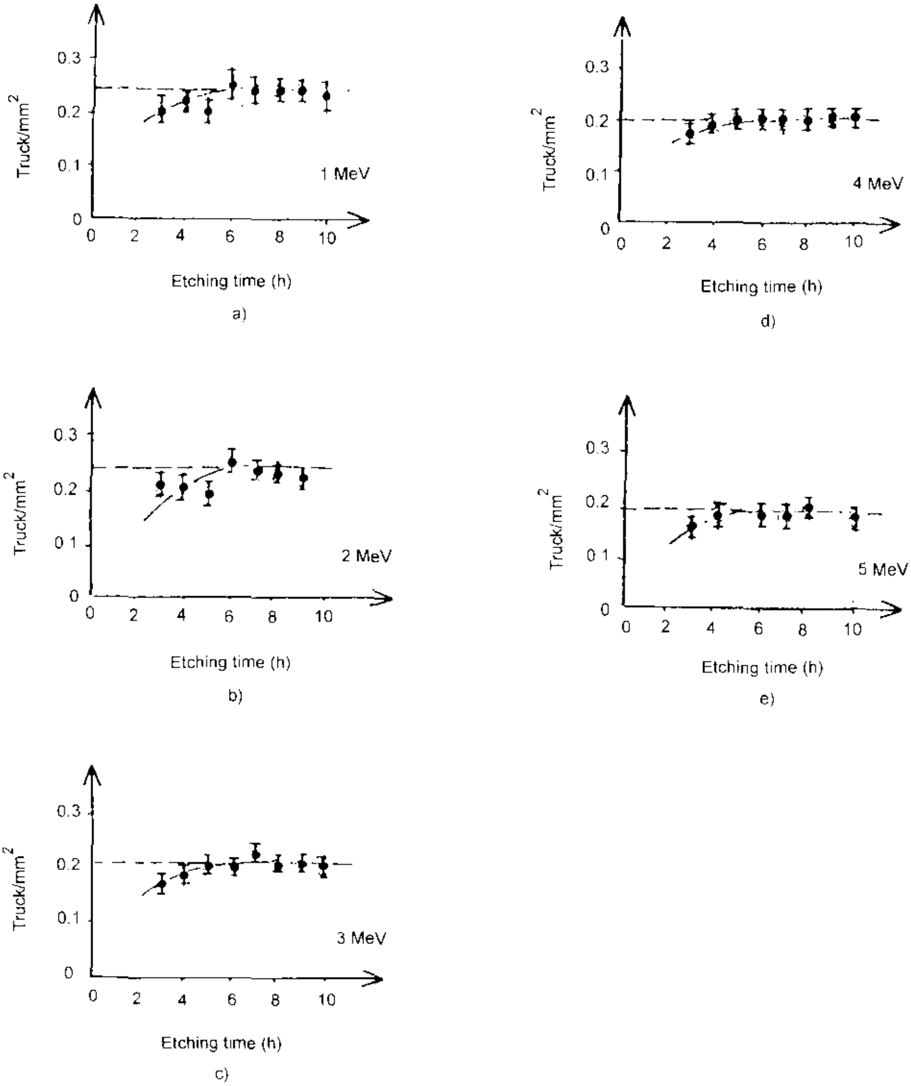

Fig. 1.(a-e). Variation of the response of CR-39 detectors for different alpha-energies. Etching condition: 6.25N NaOH solution at 70°C.

It can be concluded that 6 hours etching time in 6.25N NaOH solution at 70°C is enough for monitoring of alpha particles with energies in the range of 1-5MeV. To make the revealed tracks more clear especially for efficient monitoring of alpha particles of higher energies (alphas emitted by radon and its decay products), 8 hours etching time is suitable.

(b) Makrafal

Figures 2 (a to e) represent the variation of the response of MK detectors as a function of etching time for alpha energies (1-5MeV) in a solution of 45g H_2O + 40g C_2H_5OH + 15g KOH (PEW solution) at 70°C[11]. From these figures it is noticed that 0.25 hour is enough for the tracks at 1MeV and 2MeV just to appear (revealed), but for higher energies (3-4MeV) it takes 0.5 hour and 0.75 hour for 5MeV. The response of MK detectors reaches its maximum after 1.5 hours for alpha energies in the range 1-5MeV. At etching time higher than 1.5 hours, tracks of alpha energies 1MeV and 2MeV start to be overetched and the tracks became less clear. Therefore, the etching time for MK detectors should not exceed 1.5 hours at 70°C in the PEW solutions.

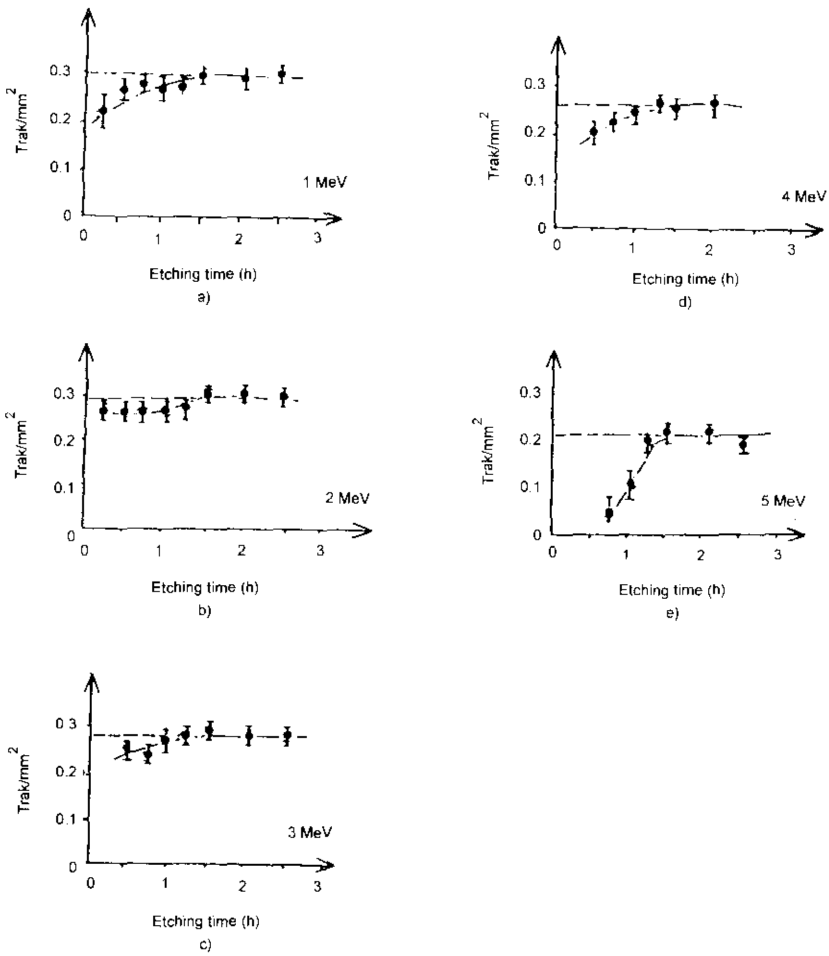

Fig. 2. (a-e). Variation of the response of MK detectors for different alpha-energies. Etching condition: PEW solution at 70°C.

(c) CN-85

Figures 3 (a to e) illustrate the variation of the response of CN-85 detectors as a function of etching time for the alpha energies 1-5MeV respectively in a 2.5N NaOH solution at 60°C [11].

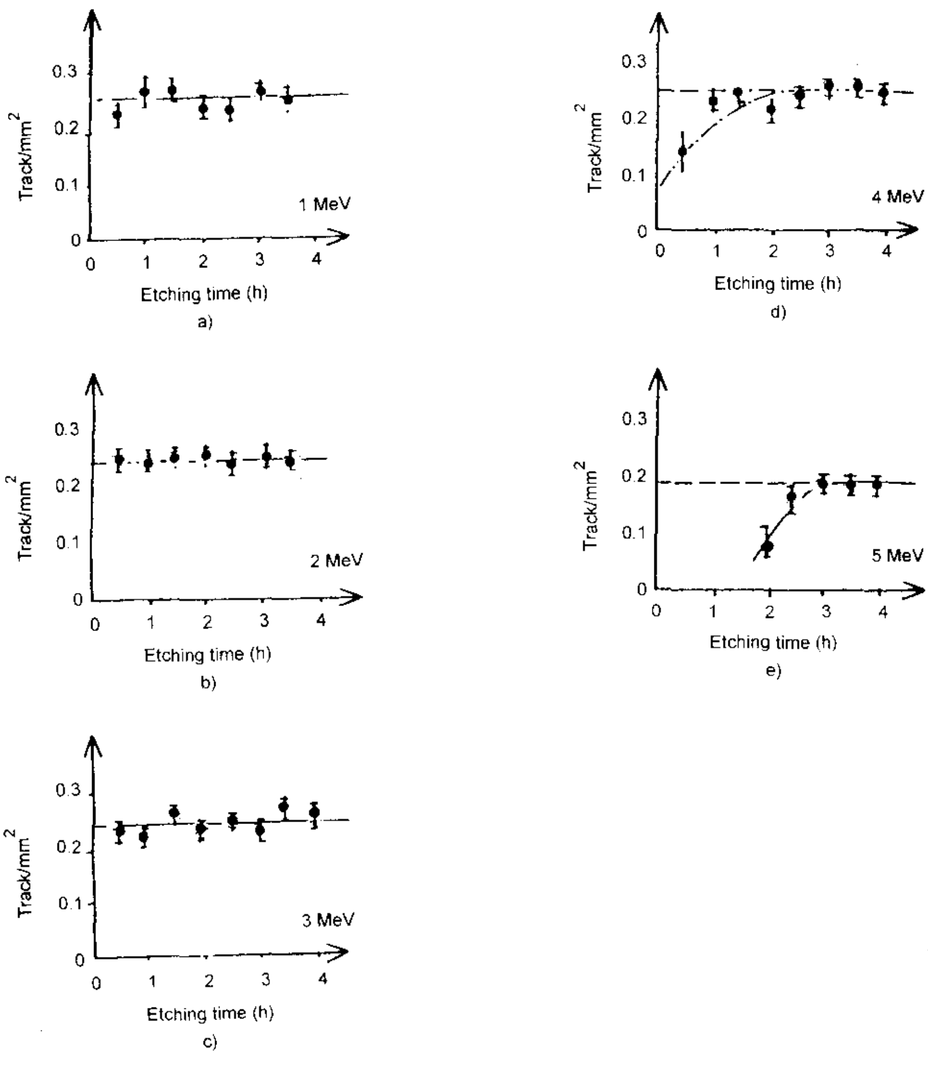

Fig. 3. (a-e). Variation of the response of CN-85 detectors for different alpha-energies. Etching condition: 2.5N of NaOH solution at 60°C.

Figures 3 (a to d) show that tracks of alpha energies 1,2,3 and 4MeV respectively started to appear after 0.5hour etching time while for 5MeV it started from 2hours etching time. The response of CN-85 detectors for alpha-energies, 1-3MeV is constant over the time interval 0.5-3.5hour. The response of CN-85 detectors at 4MeV and 5MeV alpha-energies reaches their maxima at 3hours and remain constant till 4hours. At etching time higher than 3hours, the tracks of the 1MeV and 2MeV alpha-energies were overetched and became less clear. It can be then concluded that 3hours etching time in a 2.5N NaOH solution is enough for efficient monitoring of alpha-particles with energies in the range 1-5MeV.

(d) LR-115

The variation of the response of LR-115 detectors as a function of etching time for the alpha energies 1-5MeV respectively is shown in Figures 4 (a to e). The detectors were etched in a 2.5N NaOH solution at 60°C [11].

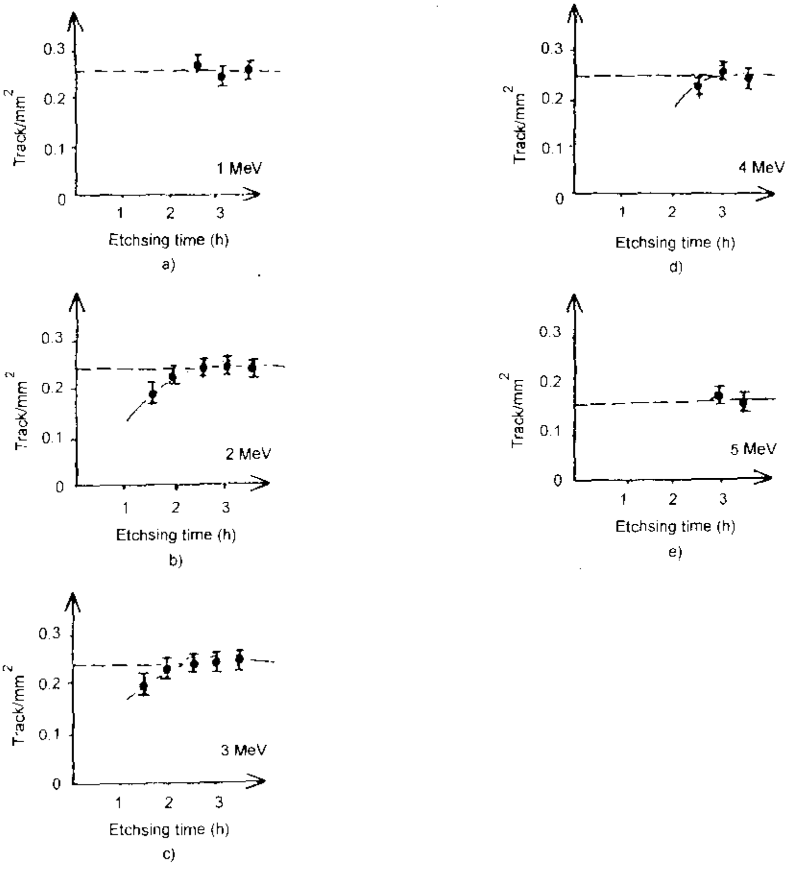

Fig. 4. (a-e). Variation of the response of LR-115 detectors for different alpha-energies. Etching condition: 2.5N of NaOH solution at 60°C.

For the 1MeV alpha energy , at etching time < 2.5hours reddish holes appeared in the red background of LR-115 because the range of 1MeV alpha-particle is small and more time of etching is needed (>2.5 h) to be white and can be counted. For alpha-particles with energies 2 and 3 MeV in (b) and (c), the tracks are revealed as white holes and can be counted after only 1.5hours etching time.

LR-115 detectors reach the maximum response for these energies at 2.5hours etching time and tends to be constant at etching time > 2.5hours. In Figure (4d) the tracks appear only after 2.5hours. This phenomenon is attributed to the fact that the range of alpha-particles with energies ≥ 4MeV is greater than the thickness of the thin layer of LR-115 since the linear energy transfer (LET) decreases with increasing energy of alpha particles. For 5MeV alpha particles the tracks are apparent after 3hours etching time. In general, the optimum etching time for the LR-115 detectors in 2.5N NaOH solution at 60°C is 3hours over the energy range 1-5 MeV of alpha particles to be detected. Table 1 represents the optimum conditions of etching for the four mentioned detectors CR-39 , MK , CN-85 and LR-115.

Table 1. Etching solutions and optimum etching conditions for the four types of SSNTD's ; CR-39, MK, CN-85 and LR-115

Detector type	Optimum conditions			
	Etching solution	Normality (N) [11]	Temperature C [11]	Etching time (h) this work
CR-39	NaOH	6.25	70	8
MK	45g H2O+40g C2H5OH+15g KOH		70	1.5
CN-85	NaOH	2.5	60	3
LR-115	NaOH	2.5	60	3

3.1.2 *Energy-response*

Figures 5 (a to d) illustrate the variation of the response of CR-39, MK, LR-115 and CN-85 respectively as a function of alpha energies at the optimum etching conditions of each detector. The response of MK detectors decreases slightly with a linear relationship over the energy range 1-4MeV. At higher energies, the response decreases sharply. The response of (CN-85and LR-115)detectors is constant over the energy range 1-4MeV but the response of these detectors decreases sharply with alpha energies higher than these values.

The response of CR-39 detectors decreases linearly of decrease with increasing alpha energies over the entire energy range 1-5MeV. This means that the response of CR-39 detectors at energies > 4MeV is higher than that of the other three detector types (MK, CN-85 and LR-115).In general, MK detectors are found to have the highest response in the energy range 1 to 5 MeV.

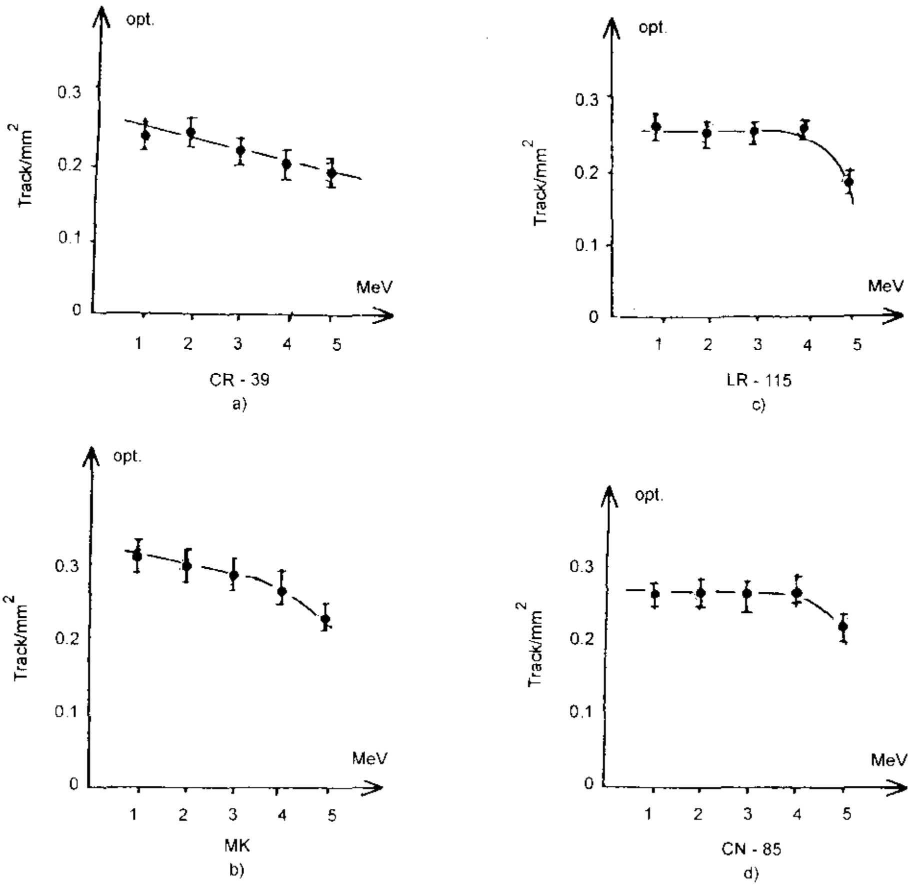

Fig. 5. (a-d). Variation of the response of a) CR-39, b) MK, c) LR-115 and d) CN-85 track detector for alpha-energies in the range 1-5 MeV at optimum etching condition of each detector.

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دراسة استجابة بعض كواشف الأثر النووي الصلبة لجسيمات ألفا ذات الطاقة (١-٥) م.ا.ف

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(قدّم للنشر في ١٢/٢١/١٤٢٠هـ ؛ وقبل للنشر في ١٤٢٢/٦/٢٢هـ)

ملخص البحث . تم في هذا البحث دراسة استجابة كواشف الأثر النووي لجسيمات ألفا ذات الطاقة من ١ إلى ٥ م.ا. ف. ووجد أن ظروف الحفر المثلى للكواشف المستخدمة في محلول هيدروكسيدالصوديوم ذو عيارية ٦,٢٥ عند ٧٠ °م هي ثماني ساعات لكواشف س ر-٣٩و في محلول PEWعند ٧٠°م لمدة ساعة ونصف لكواشف الماكروفول ، أما بالنسبة لكواشف س ن-٨٥ و كواشف ل ر-١١٥ فإن ظروف الحفر المثلى في محلول هيدروكسيد الصوديوم ذوالعيارية ٢,٥ عند ٦٠ °م هي ثلاث ساعات ، كما وجد أن كواشف س ر-٣٩ أعطت أعلى إستجابة لطاقات ألفا الأعلى من ٥ م.ا.ف.