

Measurements of high fluences of neutrons and $^{10}\text{B}(\text{n},\alpha)^7\text{Li}$ reaction products that registered on CR-39 plastic detector using optical density technique.

Ammar A. Al-Sa'ad

Department of Physics, College of Science, Basrah University, Basrah, Iraq

ISSN -1817 -2695

((Received 22/10/2007, Accepted 2/6/2008))

Abstract

Optical densities have been measured for two groups of CR-39 nuclear track etch detector samples. The first group was irradiated with fast neutrons and the other one with a mixed radiation of fast neutrons and $^{10}\text{B}(\text{n}_{\text{th}},\alpha)^7\text{Li}$ reaction products.

A clear difference was observed in the behaviour of optical density versus etching time between the first and the second group samples. The optical density was observed to be increased as the incident neutron fluence dose increases.

Keywords: Solid State Nuclear Track Detectors (SSNTDs), CR-39, $^{10}\text{B}(\text{n}_{\text{th}},\alpha)^7\text{Li}$.

Introduction

Optical density, D , is one of many techniques that are used for studying and measuring the different properties of etched Solid State Nuclear Track Detectors (SSNTDs), and it correlated with transmission of light, T , through the samples by[1]

$$D = -\log(T) \quad \dots(1)$$

As the track density (the number of etched tracks per unit area of the SSNTD surface) is large, the process of counting them visually by the optical microscope is tedious and sometimes impossible and subjected

to a great errors because of the occurrence of track overlapping. For a fast process to measure the high fluence doses of ionizing particles that registered on SSNTDs, many studies[1-3] have used the optical density technique which was applied in this work to measure the doses of neutrons and study the behaviour of the optical density versus etching time for irradiated CR-39 detector with fast neutrons and $^{10}\text{B}(\text{n}_{\text{th}},\alpha)^7\text{Li}$ reaction products.

Experimental Procedures

Irradiations

Samples were irradiated by Am-Be neutron source of 5 Ci and $1.1 \times 10^7 \text{ n/s}$ for different times.

The source was supplied by Radio-Chemical, Ltd., Amersham, England.

The irradiation processes were done in two modes: fast neutrons and a mixed radiation of fast and α particles induced by thermal neutrons. The second mode of irradiation was done using a polyethylene (PE) cylinder of 3.7 cm diameter and 2 cm height to reflect neutrons thermally. A BN1 plate, ($\text{n}_{\text{th}},\alpha$) converter which contains natural boron compound supplied by Dosirad Company/France, was contacted with the CR-39 track detector to register the products of $^{10}\text{B}(\text{n}_{\text{th}},\alpha)^7\text{Li}$ reaction.

Samples Preparation

CR-39 Plastic Nuclear Track Detector was cut into pieces of $(1 \times 1) \text{ cm}^2$ dimensions. The samples were washed, dried and prepared for irradiation.

Etching Process

The irradiated samples of CR-39 detectors were etched chemically using 6.25 N NaOH solution of 70°C .

Optical density measurement

The optical density of each sample was measured using digital transmission densitometer DT 1505, which supplied by Parry Instruments, Ltd., England. The minimum reading of this instrument was 0.001.

The optical density readings have taken successively after every etching interval and for each sample.

Results and Discussion

Figures (1) and (2) show optical densities versus etching times of CR-39 detectors that register the tracks of fast neutrons, and that register both tracks of fast neutrons and $^{10}\text{B}(n_{\text{th}},\alpha)^7\text{Li}$ reaction products respectively. There is a clear difference in the behaviour among the curves of the two figures as etching time increase. In Fig. (2) there is an increase in the optical density with etching time followed by a decrease after reaching a maximum value. This behaviour may ascribed to the overlapping of etched tracks of short range (n_{th},α) reaction products in the plastic detector. This overlapping of tracks permits the light to transmit through the etched detector otherwise the reflection and refraction of light by the edges of isolated tracks will decrease the transmission[1,4]. So, as transmission increases via overlapping of tracks, the optical density will decrease and vice versa [see eq. (1)]. On the contrary of the behaviour of Fig. (2), the curves of Fig. (1) have a continuous increase in optical density as etching time increases which could be ascribed to the continuous increase of the indirect neutrons tracks that caused by neutron collisions with the nuclei of H, C and O that compose CR-39 plastic detector. These recoil nuclei cause a latent tracks in different depths within the CR-39 detector, so, as etching time increase, new tracks will be etched which cancel the overlapping effect, i.e. the optical density will increase continuously. On the other hand, the optical density increases as the incident neutron dose (time of irradiation) increases for both figures. One could observe, in Fig. (2), that the optical density peaks occur at shorter etching times as the incident neutron dose increases. This could be simply ascribed to the quick overlapping among the

large numbers of (n_{th},α) reaction products tracks, i. e. the overlapping of etched tracks will happen quickly as track density increases.

Fig. (3) shows the optical density, D, versus the neutrons fluence which drawn for two different etching times of CR-39 detector samples (1 and 3 hours). The data of this figure were extracted from the above two figures. The neutrons fluences were determined depending on a method described in prior work⁽⁵⁾ using a calibrated LR-115 (II) track etch detector.

The behaviour of data in this figure could be approximated to straight lines with two different slopes except for the irradiated samples with fast neutrons and etched for 1 hour, which may appear this behaviour at higher doses. The slope of each straight line represents the sensitivity of this technique to measure neutron fluence. The increase of the slope means directly an increase in the sensitivity and vice versa. So, the figure shows an increase in the sensitivity as etching time increase from 1 to 3 hours for both modes of irradiation.

Fig. (3) shows also that the addition of BN1 (in the second mode of irradiation configuration) will increase the sensitivity of the optical density technique to measure lower incident neutron fluence, which clearly ascribed to the increasing of track density via (n_{th},α) reaction products. The two slopes straight lines behaviour appears in Fig. (3) denotes to a change in the sensitivity as the incident neutrons fluence increase which is because of overlapping effect. That is, for a constant etching time, the overlapping among etched tracks happens and being more effective as the incident fluence increases.

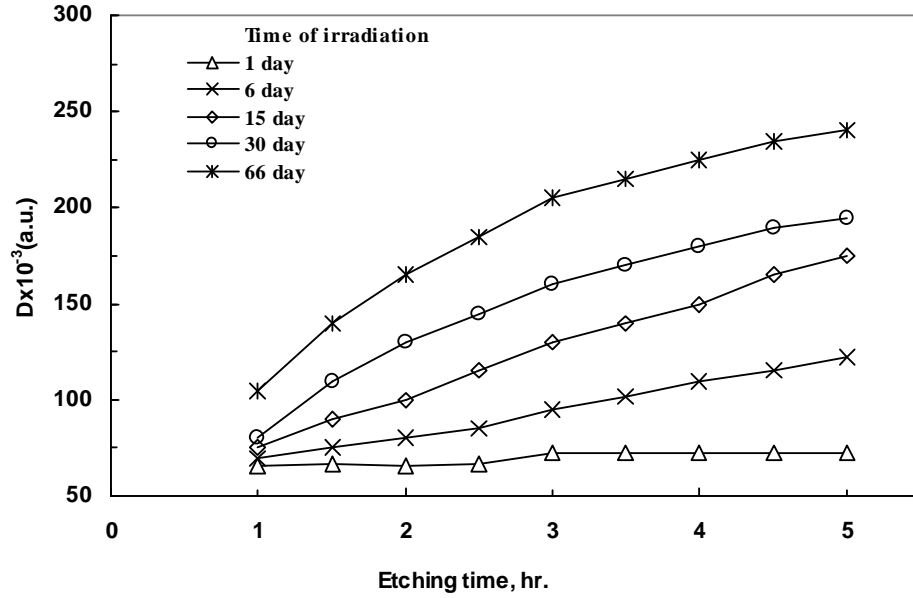


Fig.(1):- Optical density versus etching time of irradiated CR-39 detector with fast neutrons.

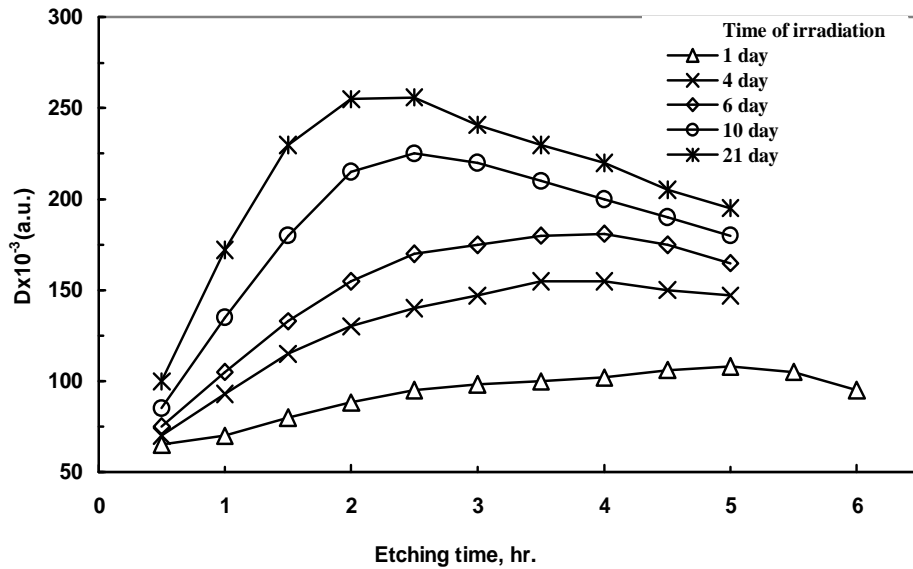


Fig.(2):- Optical density versus etching time of irradiated CR-39 detector with a mixed radiation of fast neutrons and $^{10}\text{B}(n,\alpha)^7\text{Li}$ reaction products.

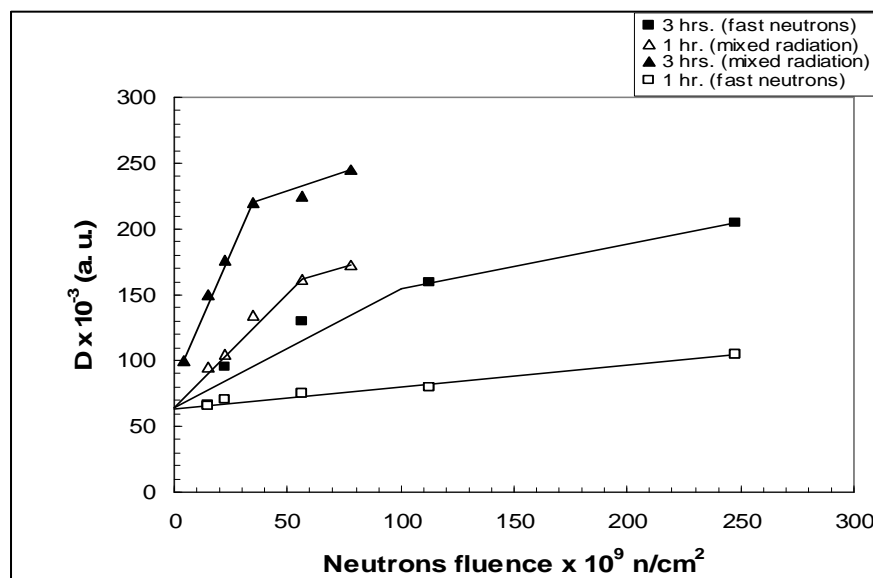


Fig.(3):-Optical density as a function of incident neutrons fluence that registered on CR-39 detector etched for 1 and 3 hrs.

Conclusion

Fig. (3) concludes the results of this work. According to this figure, each straight line could be used individually for determining the dose of neutrons of Am-Be source that registered on CR-39 nuclear track detector.

Three observations could be extracted from this figure:

1- For both modes of irradiation, the sensitivity of this technique to read lower incident neutrons

fluences will increase as etching time increases.

2- Sandwiching BN1 between PE reflector cylinder and CR-39 detector will increase the sensitivity of measurement.

3- The sensitivity decreases as incident neutron fluence increases.

References

- [1] R. Ilić, and M. Najžer, Nucl. Track Radiat. Meas., Vol. 17, No. 4, 453. 1990.
- [2] M. El Hofy, H. EL Samman and W. Arafa, Radiation Measurements, 31, 241. 1999.
- [3] G. M. Hassib, Nucl. Inst. Meth., 131, 125. 1975
- [4] J. Skvarč, Radiation Measurements, 131, 217. 1999.
- [5] A. A. Al- Sa'ad, and S. J. Abbas, accepted for publishing in the J. of Basic and Applied Sciences.

قياس الفيض التكاملي العالي للنيوترونات ونواتج التفاعل $^{10}\text{B}(\text{n},\alpha)^7\text{Li}$ المسجل على كاشف CR-39
البلاستيكي باستخدام تقنية الكثافة البصرية
عمار عبد الرحمن السعد
قسم الفيزياء - كلية العلوم - جامعة البصرة - العراق

المخلص

قيست الكثافات البصرية لمجموعتين من نماذج الكاشف الصلب للأثر النووي CR-39 ، إذ شععت المجموعة الأولى بالنيوترونات السريعة والثانية بكل من النيوترونات السريعة ونواتج التفاعل $^{10}\text{B}(\text{n}_{\text{th}},\alpha)^7\text{Li}$. ولوحظ حصول اختلاف واضح في سلوك الكثافة البصرية مقابل زمن الحفر بين نماذج المجموعتين. كما لوحظ أن الكثافة البصرية تزداد بازدياد الفيض التكاملي الساقط للنيوترونات.