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The Use of Optical Properties of CR-39 in Alpha Particle Equivalent Dose Measurements

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ABSTRACT

In this work, optical properties of alpha irradiated CR-39 were measured as a function of optical photon wavelength from 200-1100 nm. Optical energy gap and optical absorption coefficient at finite wavelength were also calculated and correlated to alpha fluence and dose equivalent. Alpha doses were calculated from the corresponding irradiation fluence and specific energy loss using TRIM computer program.

It has been found that, the optical absorption of CR-39 was varied with alpha fluence and the corresponding equivalent doses. Also the optical energy gap was varied with fluence and dose equivalent of alpha particles. This work introduces a reasonably simple method for Rn dose equivalent calculation by CR-39 track detectors.

INTRODUCTION

Etch-track detectors have been extensively used in the registration of charged particles since several decades [1-8]. They also used in various dosimetric applications due to their excellent efficiency and negligible affect to environmental condition. In addition, they are used in Rn, neutrons dosimetry and fission track dating, …etc. through most of their applications, they need long etching duration and scanning under an optical microscope. In this work, registered alpha tracks in SSNTDs are carried out through a direct way by studying the physical properties of the irradiated detectors. One of this measurements is the optical properties which is believed to vary with the fluence of the charged particles. The optical absorption coefficient (α) as a function of the optical photon energy hν is given by Mott & Davis model [3] as

$$\alpha = \beta(h\nu - E_{opt})^n / h\nu \qquad \rightarrow \quad (1)$$

Where β is a constant and n is an index determined the nature of the electronic transition, whether it is direct or indirect during the absorption process. E_{opt} is the width of the optical energy gap which can be determined through the determination of α as a function of hυ.

The absorption coefficient α is calculated from the well known Urbach equation as [4].

$$\alpha = \alpha_o \exp(-h\nu / \Delta E) \qquad \rightarrow \quad (2)$$

Where ΔE is the width of the Urbach band tail of localized states in the normally forbidden gap that is associated with the amorphous nature of material.

The factor α can also be calculated from the optical absorption (A) and the material thickness (d) from the relation:

$$\alpha = 2.303 \frac{A}{d} \qquad \rightarrow \quad (3)$$

The aim of this paper is to calculate the alpha particles equivalent dose of using a reasonably simple method based on the calculation of the optical properties of CR-39 track detectors.

EXPERIMENTAL METHODS

Sheets of CR-39 (manufactured by TASTRAK) were irradiated by alpha particles using ^{241}Am sources and at different fluencies range from 10^6 up to 10^8 particle / cm^2 and of alpha energy of 3.5 MeV. CR-39 samples were etched in a recommended etching solution(8-11) (i.e. 6.25 N Na oH at 70 ^{o}C). The optical absorption of alpha irradiated samples were measured using photo-spectrometer Model Jasco V-530 at optical wave lengths from 200 to 1100 nm.

The equivalent doses of alpha particles were calculated using dE/dX function , obtained from the TRIM computer program at different alpha energies in CR-39.

RESULTS & DISCUSSION

Optical properties of CR-39

To study the optical properties of CR-39, a Jasco – V-530 spectrophotometer was used. Fig. 1 shows the variation of the optical absorption of CR-39 relative to air at wavelengths from 200 to 1200 nm of different fluencies alpha irradiated CR-39. This figure shows that, the optical absorption increases as the alpha fluence increases and the absorption edge is shifted towards the higher values of wavelength as the alpha fluence increases.

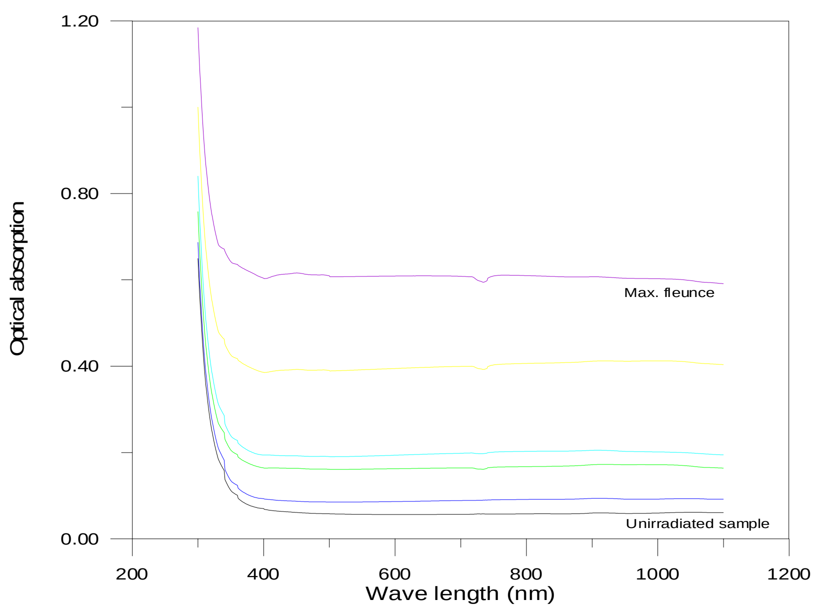

Fig. 1: The relation between optical absorption and wavelengths (nm) at different alpha fluencies for CR-39 samples.

The optical absorption coefficient α (cm^{-1}) was calculated from Eq.3 and is represented with the optical photon energy in Fig.2. This figure shows also that values of α shows increase with alpha fluence increase.

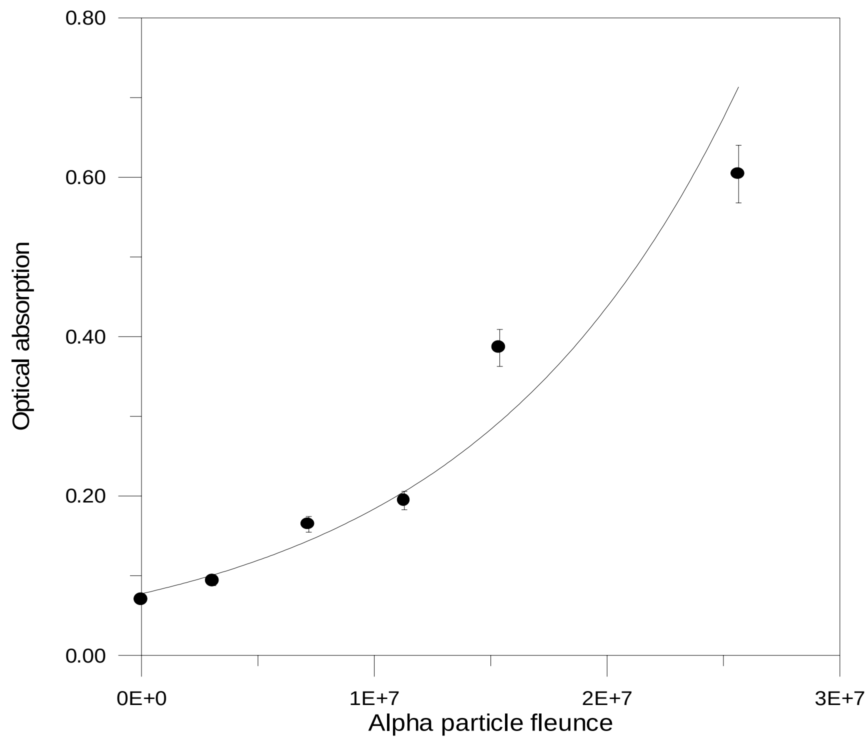

Fig. 2 : Variation of optical absorption and alpha particle fluence at wavelength 400 nm for CR-39 samples.

It is obvious increase with increasing the alpha fluence. The importance of Fig.2 is its use in calculating the alpha fluence from the measurement of an optical absorption coefficient. From the inspection of this figure one can notice that, the optical absorption increase with alpha fluence as the equation

Optical density = 0.077 exp(8.75E-8 * fluence) (4)

The optical energy gap of CR-39 can be obtained using Matt & Davis represented in equation (1). From the plotting $(\alpha h\nu)^2$ versus $h\nu$, E_p can be determined as represented in Fig.3 . The decrement of E_p may be attributed to the localization created as as a shadow under the conduction band.

The above conclusion is confirmed by the calculation of the localization or the band gap tail ΔE with alpha fluence as represented in Fig. 4 . This figure shows that the E_p localization is increase with alpha fluence nearly with the same rate of band gap decrement.

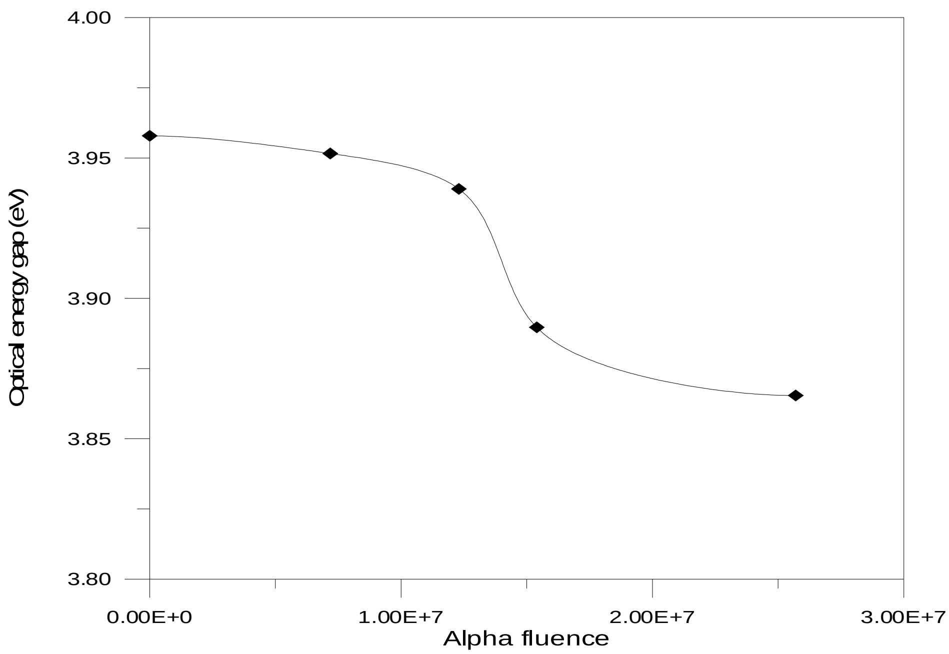

Fig. 3 Variation of optical energy gap (eV) with alpha fluence.

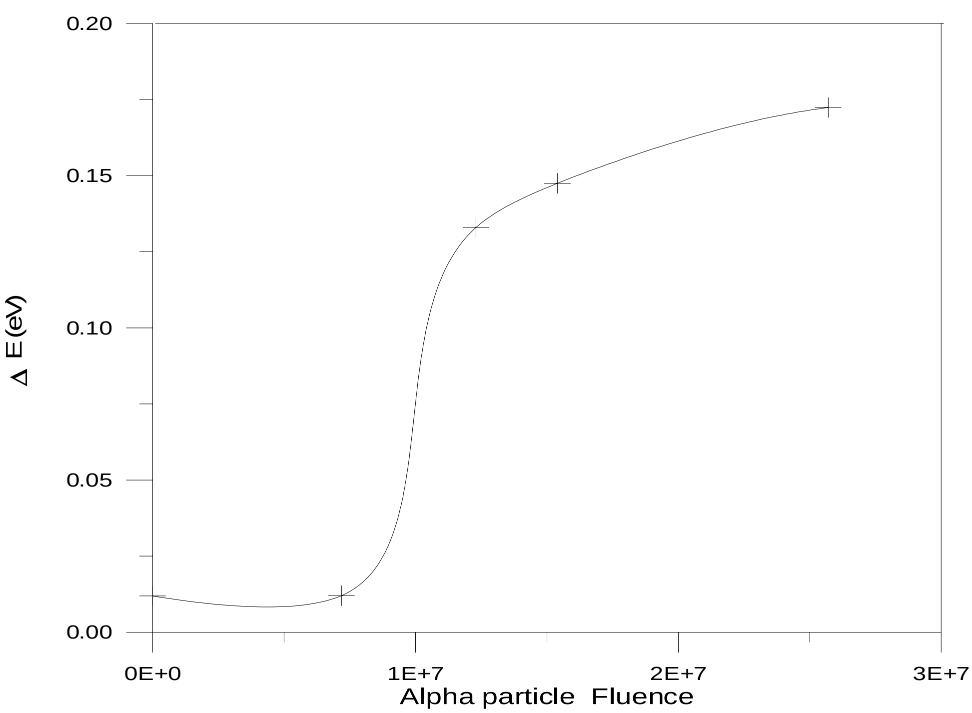

Fig. 4 Dependence of energy gap tail on alpha fluence.

Alpha Dose Determination

Alpha particle equivalent dose absorbed in any material as CR-38 with density ρ is given by

$$D\,(rad) = \frac{1.6ZX10^{-8}}{\rho}\int \frac{dE}{dX}\phi_E\,dE \qquad \rightarrow (5)$$

Where ρ is the CR-39 detector density, dE/dX is the energy loss, φ_E is the flux density of the charged particles i.e. fluence number per energy (MeV. cm^{-1}).

The above equation is calculated for different fluence and energies then represented in Figs. 5 and 6 respectively. These two figures represented that the dependence of dose on the fluence is much greater than its dependence on energy, that reflect the use of such method in the equivalent dose through the determination of alpha fluence from the corresponding optical properties using CR-39.

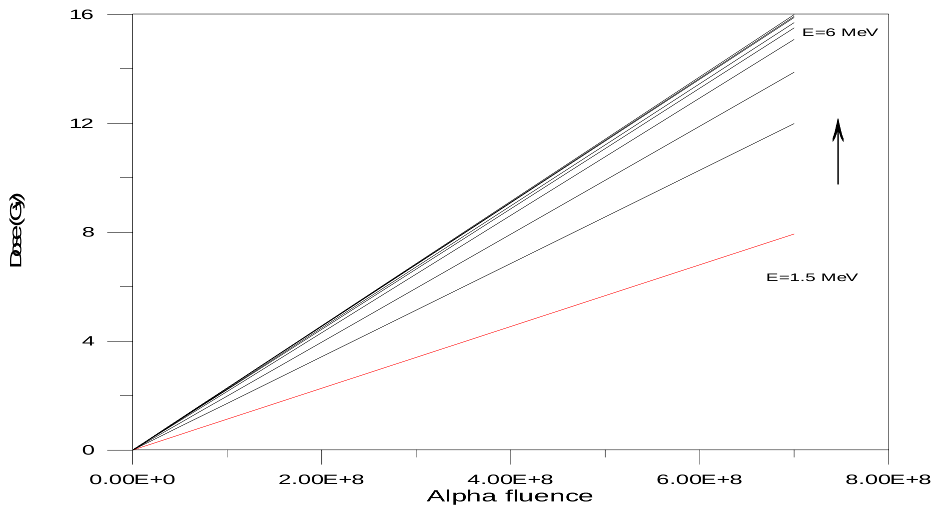

Fig. 5 Alpha doses (Gy) as a function of corresponding fluence.

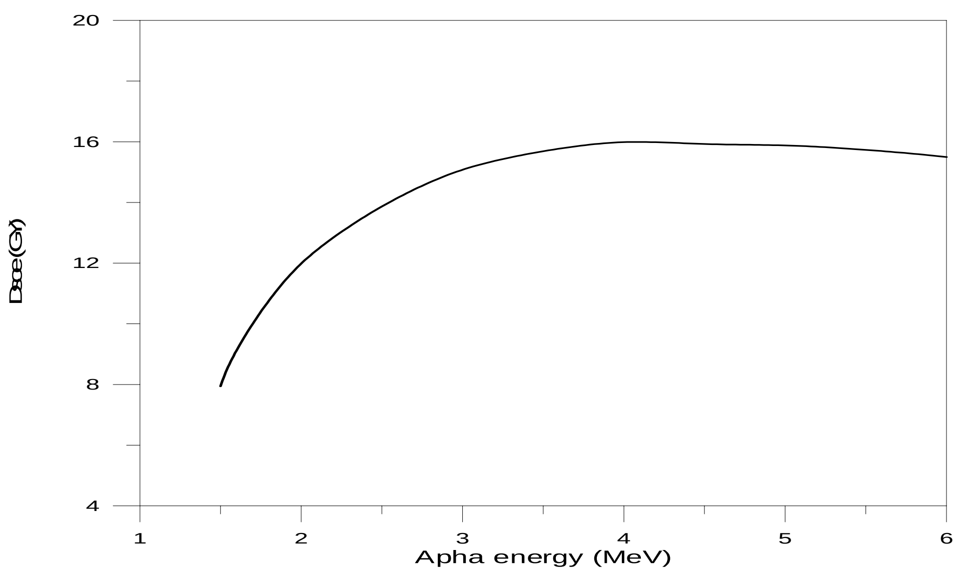

Fig. 6 Alpha doses (Gy) as a function of its energy

CONCLUSION

It was found that, the optical absorption and optical density of etched CR-39 was varied with alpha fluence. The optical energy gap tail was varied with fluence and dose equivalent of alpha particles. The dependence of the calculated alpha dose is dependent up on their fluence than its dependence on the energy. So this work introduces a reasonably simple method for the Rn dose equivalent estimation by CR-39 track through the measurement of its optical density.

REFERENCES

(1) Hesham Afifi, Ahmed El-Sersy and Noha Khaled, Radiation effects & defects in solids, Vol. 159 (2003)439–44.
(2) Magda A. El-Shahawy, Jour. Of Polymer Degradation and stability, 57 (1997)157.
(3) N. F. Mott and E. A. Davis., "Electronic processes in noncrystalline material" 2nd edn. Clarendon, Oxford, 1979.
(4) Mamdouh H. Abu Taleb., Egyptian Jour, of Biophysics, Vol.9. No 1 (2003)65.
(5) Hussein, Kh. A. Shnishin and A. A. Abu El Kheir, Journal of Material Science, J. Mater. Sci. 28,(1993) 6026.
(6) A. R. El-Sersy, N.E. Khaled and S. E. Eman., Nuclear Instruments and Methods in Physics Research B. 215, (2004)443- 448.
(7) A. R. El-Sersy, N.E. Khaled and S. E. Eman., Egyp. Jour. Of Biophys Vol. 12 No. 2(2006) 131-142.
(8) B. Dorschel, R. Bretschneider, D. Hermsdorf, K. Kadner, H. Kouhne, Radiat. Meas. 31 (1999) 103.
(9) J. Charvat, Radiat. Prot. Dosim. 23 (1/4) (1988) 171.
(10) E. Pitt, A. Scharmann, R. Simmer, Nucl. Tracks Radiat. Meas. 19 (1991) 517.
(11) S. Durrani, R. Bull, Solid State Nuclear Track Detection, Pergamon Press, Oxford, UK, 1987.