RADIATION RESPONSE OF SOME SOLID STATE DETECTORS

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AHMED MORSY AHMED

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بسم الله الرحمن الرحيم

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إن في خلق السموات والأرض واختلاف الليل والنهار
لآيات لأولي الألباب * الذين يذكرون الله قياما
وقعودا وعلى جنوبهم ويتفكرون في خلق السموات
والأرض ربنا ما خلقت هذا باطلا سبحانك
فقنا عذاب النار

صدق الله العظيم

A C K N O W L E D G E M E N T

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C O N T E N T S

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SUMMARY

The present study deals with radiation response of some solid state detectors, attention was paid to two main classes of solid state detectors, these are glasses and carbonate plastic detectors.

In the introductory chapter, the radiation units, interaction of radiation with matter, solid state detectors as well as the aim of work were discussed.

Chapter two deals with response of phosphate, borate and silicate glasses to gamma rays and its application in dosimetry.

The experimental arrangement and measuring techniques were explained.

The experimental results show that as a result of gamma ray interaction with glass, trap centres are formed and the radiation effect could be measured optically, spectrophotometrically or by thermoluminescence counting. Optical measurements showed that borate glass can yield information regarding the γ -ray absorbed dose up to 140 kGy, while phosphate glass up to 60 kGy. Spectrophotometric results showed that for unirradiated samples, phosphate glass has flat response, while borate glass has a peak at 4100 A° which highly resolved with increasing gamma rays dose

Due to irradiation of phosphate glass a peak at 5220 Å slightly appeared, and increases by increasing the exposure to gamma rays. while for silicate glass two bands at 4200 A° and 6400 A° were observed, its intensities increases as gamma absorbed dose increases.

TL measurements indicate that the TL yield of phosphate samples was higher than that for borate and silicate glasses.

For dosimetric application using phosphate, borate and silicate glasses in the field of gamma rays dosimetry the following factors should be taken into consideration:-

i- Fading results indicate the stability of the radiation affects over 40 days for borate glass, and 67 % drop in the optical density for phosphate and silicate samples within one week and a stable level may be reached after one month from the end of exposure.

ii- Attention should be paid to heating of the samples, experience with heating the samples at 200°C for ten minutes showed that it has major effect on phosphate glass (the removal of the radiation effect) and it has no response on the borate glass.

iii- Borate glass can be used as integral dosimeter up to 140 kGy for its good properties of no fading, while phosphate glass can not be used as integral dosimeter due to its fading properties, it can be resued for dosimetry up to 60 kGy after annealing.

As a mixed field dosimeter, the phosphate, borate as well as silicate glass showed measurable amount of radioactivity when the glass detectors were irradiated near the core of the reactor, the optical properties, spectrophotometric as well as TL properties of the samples exposed to mixed field are similar to that properties of samples exposed to high level of gamma ryas absorbed dose. The induced activity of the irradiated glass is identified to be ^{32}P in phosphate glass, ^{76}As in borate glass and ^{24}Na in silicate glass. Since these dosimetrs are recommended for use in mixed field of radiation and for radiation protection purposes, the resepective dose equivalent recived by the radiation worker should be as low as reasonably achievable.

Chapter three was devoted to carbonate plastic CR-39 as solid state nuclear track detector, while experimental results and discussions are reported in the next chapters.

In Chapter four, the American Acrylic CR-39 detector was used and it proved to offer excellent properties not only for track formation but also for detection of charged particles and neutrons.

The track kinitics were investigated and the results could be semmerized in the following:-

1- Chemical etching

Both NaOH and KOH solutions may be used for chemical etching of CR-39 detectors, the recommended etching conditions for fast neutrons detection is 3 hours. Furthermore KOH solutions are recommended for etching because of the formation of $NaCO_3$ during the preparation of NaOH solution.

Experimental results also show that the rate of track fromation is a linear function of etching time for about 160 minutes then saturation occurs.

Also, the studies of the effect of NaOH and KOH concentration showed linear increase of track density as concentration increase.

In an attempt to estimate the bulk etching rate of CR-39 by the gravimetric techinque showed that at $60^{o}C$ and using 30% KOH solution it was found to be (2.3 ± 0.1) microns per hour.

2- Track diameter measurements

Typical photographs of charged particle tracks are presented and the frequency distribution of the recorded tracks is given for detectors chemically etched for 5 hours at $60^{o}C$ in 30% KOH solution.

As a result of the interaction $^{6}_{3}Li + ^{1}_{0}n \rightarrow ^{4}_{2}\alpha + ^{3}_{1}H$ two types of tracks were observed, a spherical with average track diameter 10.5 ± 1.9 microns and conical with average track diameter 4 ± 0.8 microns.

Pre-etching of the detectors gave rise to formation of small size tracks, those tracks are assumed to be due tritons, while for the ECE tracks are assumed to be due alpha particles. This assumption is based upon the energy of the particles and its range in CR-39 detector, noting that the charged particles are resulted from the interaction of incident thermal neutrons with ^{6}LiF external radiator placed in contact with the detector.

The average track diameter is found to be enlarged from 64 microns to 66 microns for ECE tracks and from 10 to 13.3 microns for non ECE tracks when the detectors is again chemically etched.

The seperation distance between the tracks is noticed to be 40 microns, it is also observed that as the charged particle fluense is increased the track density increased but the average track diameter is decrease. The latter observation and its theortical considerations was reported by AL-Najjar et al (1978).

3- Response to charged particles and neutrons

Three alpha particle sources were used these are ^{235}U (4.66 Mev), ^{241}Am (5.5 Mev) and ^{239}Pu (5.15 Mev). The frequency distribution of track diameter of alpha particle tracks recorded in CR-39 from ^{235}U source is shown as it was noticed that the average track diameter is 31.3 microns. The emission rate of the source per unit area is 820 alpha particle per second from ^{235}U. 2013 alpha particle for ^{241}Am source and 500 for ^{239}Pu source, the latter result is in the source certifcate supplied by the source manufacture.

Furthermore, variation of track density with the particle energy (variation of particle energy due to change the distance between the source and the detector) was measured experimentally using ^{241}Am and ^{239}Pu sources, results indicates considerable decrease in track density as the energy decrease. For fast neutrons , several sources were used namely ^{252}CF, ^{252}CF moderated neutrons, and Pu-Be neutrons.

The response to fast neutrons varies from 0.82×10^{-4} tracks/neutron for Pu-Be neutrons to 1.44×10^{-4} tracks/neutron for ^{252}CF neutron moderated by Al.

Therefore CR-39 is recommended as a fast neutron threshold detector and its threshold energy was reported by Griffith et al as 0.1 Mev.

For thermal neutrons the system of CR-39 in contact with ^{6}LiF foil as external radiator was used, the response of the system to thermal neutron is 9×10^{-4} tracks/neutron when ECE tracks are counted only, and it is 1.84×10^{-3} track/neutron when ECE tracks and CE tracks are counted.

In Chapter five the applicability of CR-39 for dosimetry is presented, for alpha particles, the absorbed dose rate is calculated for sources usually avaliable at nuclear physics and research Laboratories.

The sensitivity of CR-39 for fast neutron dosimetry is estimated to be 380 track/cm^2. mSv or 3.8 tracks /cm^2.m rem, as albedo-dosimeter (CR-39 ^{6}Lif), sensitivity is found to be maximum when the system is placed on phantom and for Cd uncovered system.

When the thickness of ^{6}Lif is greater than 2,5 mg/cm^2 the average response of the Cd covered albedo system to ^{252}CF neutrons, Pu-Be neutrons, ^{252}CF moderated neutrons wi ' AL and ^{252}CF moderated neutrons with D_2O was found to be in average 613 tracks/cm^2. mSv. Several (n, α) converters are tried such as introductory ^{6}Lif foil, $Li_2 B_4O_7$ in Hankins dosimeter,

Results show that Cd-covered (CR-39 ^{6}Lif) system could be recomended for neutron dosimetry and the relation ship between the track density at both faces of the CR-39 detector and the neutron dose equivalent could be represented by the relation

$$D = \frac{T_1 - T_{B.G}}{0.370} + \frac{T_2 - T_{B.G}}{610} \text{ in mSv.}$$

where:

T_1 is the track density in CR-39 face in contact with ^{6}Lif foil

T_2 is the track density in CR-39 second face.

$T_{B.G}$ is the back ground track density.