STUDY OF SOME PROPERTIES OF SOLID STATE NUCLEAR DETECTORS

THESIS

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BY

MOHAMED ASHRAF FAROUK MOHAMED

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TO MY MOTHER

AND

FATHER,

FOR ALL WHAT THEY DONE

FOR ME

بسم الله الرحمن الرحيم

STUDY OF SOME PROPERTIES OF

SOLID STATE NUCLEAR DETECTORS

Thesis Advisors

Name	Position	Signature
1- Prof. Dr. M.A. Kenawy	Chairman of Physics University College of Girls, Ein Shams University	M. A. Kenawy
2- Prof. Dr. M.A. El-Fiki	Head of the radiation Measurements Laboratory N I S, Cairo.	M. El Fiki
3- Dr. A.F. Abbas	Glass Research Lab., N R C, Cairo.	A. Kamal Abbas
4- Dr. M.A. El Kolaly	Atomic Energy Commission	M El Kolaly

Head of Physics Department

Prof. Dr. M. A. Kenawy

M. A. Kenawy

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CONTENTS

INTRODUCTION

It is almost three decades since the introduction of the first practical dosimetry method based on luminescence changes in solids, the radiophoto - luminescence method. Other luminescence - based methods were proposed shortly nearafter in rather quick succession

- thermoluminescence, infrared stimulated luminescence and luminescence degradation.

The lion's share of effort has been development of solid - state materials and devices to exploit radiophotoluminescence and thermoluminescence. The principle of TLD is based upon the phosphorecence phenomenon. When a phosphor is exposed to ionizing radiation at a sufficiently low temperature, many of the released electrons are trapped in the lattice defects, there byproducing long lived metastable state. The electrons remain trapped for a long period of time if the phosphor isstored as that at lower temperature. When the phosphor is heated, the electrons escape from the traps to their original position with the emission of light. If the heating rate is uniform, the intensity of the emitted light varies as a function of time, and the curve of (intensity) versus - (time) resulting from a uniform rate of heating is called the glow curve.

The earliest attempts to use thromluminescence for dosimetry created on lithium fluoride as the sensitive material[1].

The complexity of its behavior led to the abandoment of this salt in favor of Al_2O_3 [2] and $CaSo_4$: Mn[3]. The former suffered from insufficient sensitivity for most purpose, and the latter from a too shallow trap depth, so that the thermoluminescene method of dosimetry remained for years in a state of suspended animation, more or less as a laboratory curiosity. The situation was suddenly changed with the development of manganese-activated calcium fluoride phosphor, which had high radiation sensitivity and a relatively simple distribution of stable trapping centers[4]. With the employment of this phosphor in an appropriatly designed dosimeter confirmation[5] most of the tremendous potential of thermoluminescence dosimetry was achieved, and interest in this method was abruptly revived.

AIM OF STUDY

In this study the thermoluminescence - characteristics of lithium boro silicate glass of different activators and the usability of such types of glasses in radiation dosimetery were throughly investigated. The main problems to be investigated could be summarized in the following :

1. The characteristic glow curve of all glasses.
2. The response to gamma radiation covering the dose range $1 - 10^4$ for all glasses.
3. The fading characteristic of these glasses at three elevated temperatures 100°C, 150°C, 200°C.
4. Proper temperature and time required for regeneration of the previously irradiated glasses "Pre-irradiation annealing".
5. Study of the dose rate dependence.
6. The dependence of the TL - response on the energy of the radiation field.

CHAPTER I

GENERAL REVIEW

1.1. Radiation Units :

Exposure and absorbed dose :

The international comission on radiological units and measurments[6] (ICRU) develops the definition of radiation units to the following :

The absorbed dose :

The absorbed dose (D) is the quotient of ΔE_D by Δm, where ΔE_D is the energy imparted to the matter by ionizing radiation, in a volume element, and Δm is the mass of the matter in the volume element. The symbol Δ preceds the symbol for a quantity that can be averaged over a volume large enough to contain many interactions and be traversed by many particles, but so small that a further reduction in size would not appreciably change the mean value of the quotient of energy by mass accordingly $D = \dfrac{\Delta E_D}{\Delta m}$

The special unit of absorbed dose is the rad :

$$1 \text{ rad} = 100 \text{ erg g}^{-1}$$

a new unit is recently in use is called the Gray (Gy) and its equivalent to 1 J/kgm i.e. 1 GY = 100 rad

The Exposure dose :

The exposure dose (X) is the quotient of ΔQ by Δm, where ΔQ is the sum of the electrical charges on all the ions of one sign produced in air when all the electrons (negatrons and positrons) liberated by photons in a volume element of air whose mass is Δ m are completely stopped in air :

$$X = \frac{\Delta Q}{\Delta m}$$

The special unit of exposure is the Röntgen (R)

$$1 \text{ R} = 2.58 \times 10^{-4} \text{ coulomb.Kg}^{-1}$$

Also the röntgen is equivalent to the production of

$$\frac{2.58 \times 10^{-4}}{1.6 \times 10^{-9}} = 1.61 \times 10^{15} \text{ ion pairs.Kg}^{-1}$$

Thus the energy deposition associated with an exposure of 1 R will be :

$$1.61 \times 10^{15} \times 34.5 = 5.6 \times 10^{16} \text{ ev.Kg}^{-1}$$

A more commonly used value is :

$$1 \text{ R} = 5.6 \times 10^{16} \times 10^{-3} \times 1.6 \times 10^{-12}$$
$$= 89 \text{ erg.g}^{-1}$$

The Kerma :

The kerma (K) is the quotient of ΔE_K by Δ m, where ΔE_K is the sum of the initial Kinetic energies of all the charged particles liberated by indirectly ionizing radiation in a volume element of the specified material, and Δ m is the mass of the matter in the volume element;

$$K = \frac{\Delta E_K}{\Delta m}$$

1.2. Physical requirements for dosimetric Measurements

1. Response to radiation :

The detector response should not be affected by any environmental factors such as atmospheric temperature, humidity and pressure, dust vapours and trace chemical contaminates in the atmosphere, day light specially U.V electric and magnetic fields, mechanical disturbances such as shock, viberations, etc, but it should respond only to the types of radiations intended to be measured.

2. Range of dose measurement :

The sensitivity is defined as the magnitude of response per unit dose. The response of the detector should be independent on the dose rate. The dose response curve should perferably be linear over the entire range of dose measurement, for convenience of calibration and measurement.

3. Accuracy :

The uncertainity in dose assesmment includes errors due to variations in the dosimeter response with the energy and direction of the incidence of the radiation as well as interinsic errors in the dosimeter and its calibration[7,8].

4. MEANS OF IDENTIFICATION - EASE TO USE AND Readout:

It should be possible to provide means for easy identification of the dosimeter so as to facilitate the issue of dosimeters to users. The dosimeter should not require extensive processing to obtain the close information after its use.

In accident circumstances it would be desirable to obtain the dose information as quickly and accuratly as a first measurement.(9)

5. Energy and direction dependence of dosimeter:

In routine personnal monitoring it is necessary to determine the doses with detailed knowledge of type, energy and radiation geometry and several other factors(10)

Several types of detectors and dosimeters are in use for both area monitoring and personal dosimetry. The area monitoring detectors are gas filled detectors, Scintillation detector, etc. While the radiation dosimeters include those which are capable of recording accumulated dose.