A STUDY ON NEUTRON AND GAMMA-RAY RESPONSES OF LABORATORY MADE LiF:Mg,Ti SINGLE CRYSTAL TLD

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ABSTRACT

The main objective of this study is to determine the neutron and gamma-ray sensitivities of laboratory made LiF:Mg,Ti thermoluminescence dosimeter (TLD) for practical application in neutron-gamma mixed field dosimetry.

INTRODUCTION

In recent years the application of TLD in neutron and gamma-ray mixed field has steadily increased to assess the dose burden of radiation workers. The dosimetry of neutrons in a mixed field is not as simple and precise as that of pure gamma-ray fields due to energy transfer processes and to variation in the reaction cross-sections with energy (1). In the presence of a mixed field (neutron+gamma), the separate evaluation of the neutron and gamma-ray contributions is essential. Thermoluminescence (TL) dosimeters are now extensively used in radiation dosimetry. Numerous investigations for the development of TL materials have been performed for mixed field radiation dosimetry (2-4). The most frequently used TLD in neutron and gamma-ray mixed field dosimetry is LiF:Mg,Ti. The isotopic constituents of the LiF:Mg,Ti family are: ^{6}Li 7.5% and ^{7}Li 92.5% for the TLD-100, ^{6}Li 0.01% and ^{7}Li 99.99% for the TLD-700 and ^{6}Li 95.62% and ^{7}Li 4.38% for the TLD-600. It is well known that TLD-700 is practically insensitive to neutrons and TLD-600 is sensitive to both neutrons (to a greater extent) and gamma-rays. TLD-100 is also sensitive to both neutrons (to some extent) and gamma-rays. The LiF:Mg,Ti (equivalent of commercially available TLD-100) single crystal of natural isotopic composition has been developed in the laboratory in order to use it for radiation dosimetry . The LiF:Mg, Ti dosimeters have been used for gamma-ray dosimetry (4-6). The objective of this study is to determine the neutron and gamma-ray sensitivities of laboratory made LiF:Mg,Ti single crystal for practical application in radiation monitoring in neutron and gamma-ray mixed field.

EXPERIMENTAL METHODS

The single crystal of LiF:Mg,Ti has been produced at the Atominstitut der Osterreichischen Universitaten,Vienna, Austria using the Czocharalaki technique (7). LiF:Mg,Ti single crystal, totally transparent, measures about 6mm x 6mm x 1mm in size. These TL dosimeters were submitted to the standard pre-annealing thermal treatments; heating at 400 ^{o}C for one hour followed by 2 hours heating at 100 ^{o}C. The photon irradiations were performed at the Secondary Standard Dosimetry Laboratory (SSDL), AERE, Savar with the standard radiation sources. Two gamma sources were used: ^{137}Cs and ^{60}Co, with gamma energies of 662 keV and 1250 keV$_{eff}$, respectively. The X-ray generator was used to produce normalized X-ray beams of 33, 48, 65, 83, 100 and 118 keV$_{eff}$. The collimated beams are horizontal, the dosimeters are positioned on the calibration bench at a distance of 1m by means of a laser beam. The

beams were calibrated with two secondary standard chambers NE2571 and NE2575. Thermal neutron irradiation was performed at the thermal column of the 250 kW TRIGA Mark-II research reactor at Vienna. The themal neutron flux was measured by using a gold foil activation technique. Fast neutron irradiation were performed in the ^{252}Cf (2.1 MeV), Am-Be (4.5 MeV) and neutron generator (14 MeV) neutron fields. The neutron doses were measured using a rem counter. After irradiation the TL responses were read by means of a laboratory made TLD DAT-II and a Harshaw TL reader Model 4000, using a linear heating rate of 10 °C/s from room temperature to 300 °C with a constant flow of nitrogen (about 3 l/min). No further treatment procedure was used in the period after irradiation and before evaluation, because all measurements of the irradiated TLDs were made at least 48 hrs after irradiation to allow decay of low temperature peaks. The responses to thermal neutrons were calculated after subtracting the gamma-ray contributions. A computer aided procedure was set up in order to store data and to display the glow curve. The LiF:Mg,Ti single crystal samples are totally transparent so that the emission of thermoluminescence light during readout is much larger compared to other similar lithium fluorides (TLD-100 and TLD-600) which are totally or partially opaque. The sensitivity was calculated by taking into account the integrated light from the most important peak only. The detailed procedures for calibration and messurement are described elsewhere (5).

RESULTS AND DISCUSSIONS

The shape of glow curves for gamma-rays from ^{60}Co source and neutron+gamma-ray mixed radiations from reactor are shown in Figs.1a & 1b. Two main peaks at 200 °C and 250 °C are evident in case of gamma radiation from ^{60}Co source (Fig. 1a). The peak at 200 °C has to be considered as the main peak whereas peak at 120 °C appears as a shoulder of the main peak on

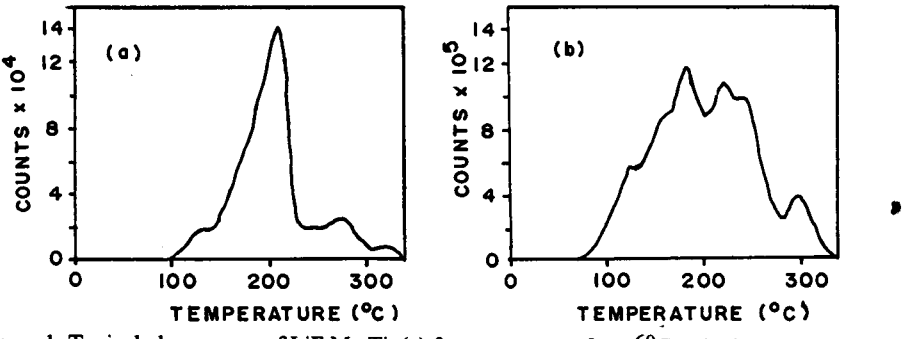

Figure 1. Typical glow curves of LiF:Mg,Ti: (a) for gamma-rays from ^{60}Co; (b) for neutron+ gamma-ray mixed fields from research reactor.

its low temperature side. From the Fig. 1b, it is found that the glow curve of laboratory made LiF:Mg,Ti TLD obtained from neutron+gamma-ray mixed radiations is quite different from those obtained from a gamma source (^{60}Co). In case of thermal neutron irradiation, a peak at 250 °C is produced more efficiently as compared to the 200 °C peak produced by the gamma-rays as well as the neutrons. Hence by following the difference between the two peak heights one can estimate the thermal neutron exposure from laboratory made single LiF:Mg, Ti dosimeter. Table 1 shows all the X and gamma-ray sources, the corresponding energies and the TLD sensitivities for each point of energy. The sensitivities were calculated by dividing their responses by the exact equivalent-dose delivered by each source. The relative gamma-ray sensitivity of LiF:Mg, Ti

compared to TLD-100 was found to be 0.97 which means that the dosimetric properties of laboratory made LiF:Mg,Ti TLD are comparable with those of TLD-100.

Table 2 shows all the neutron sources, the corresponding energies and the TLD sensitivities for each point of neutron energy. From Table 2, it is evident that the neutron sensitivities are highly dependent on neutron energies. The fast neutron sensitivity is less than that of thermal neutron sensitivity. The thermal neutron responses were reported interms of ^{60}Co equivalent roentgen (R) per 10^{10} $n.cm^{-2}$. The thermal neutron sensitivity varies from 325 to 389 R per 10^{10} $n.cm^{-2}$ with an average value of 368 R per 10^{10} $n.cm^{-2}$. This value agrees well with the values quoted in the literature for TLD-100 (2). The accuracy in neutron and gamma-ray responses in the present study was within $\pm$10%.

Table 1. TLD sensitivities at various photon energies.

Source	Energy (keV)	Sensitivity (nC/mSv)
X-ray	33	8.45
X-ray	48	6.35
X-ray	65	5.98
X-ray	100	5.12
X-ray	118	4.78
^{137}Cs	662	4.21
^{60}Co	1250	4.56

Table 2.TLD sensitivities at various neutron beams.

Neutron energy (MeV)	Source	Neutron fluence (cm^{-2})	Sensitivity (nC/mSv)
2.5E-08	Reactor	1.45E07	78.56
2.1	Cf-252	1.78E05	2.56
4.5	Am-Be	1.25E05	1.98
14.0	Neutron generator	2.35E05	1.24

CONCLUSIONS

From these results it can be concluded that the laboratory made LiF:Mg,Ti single crystal is suitable for practical application in thermal neutron-gamma mixed field dosimetry around the nuclear facilities. Further, this dosimeter can be used in fasst neutron dosimetry purposes if the dosimeters are embeded with fast neutron moderating materials.

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