Dosimetry Characteristic of Implanted Thermoluminescence Detector

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ABSTRACT

Thermoluminescence dosemeters (TLD300) were implanted with 20 keV boron-10 ions, in order to enhance their thermal neutron sensitivity. Photon emission spectra of the TLDs were studied before and after implantation. The gamma sensitivity of the TLDs were also analyzed. It was found that the implantation slightly reduces the gamma sensitivity. The emission spectra of TLDs, however, did not change due to the implantation. It was concluded that except some crystal damage the basic thermoluminescence dosimetric properties were not effected by ions implantation. The implanted TLD can be used as a more sensitivity radiation detector.

INTRODUCTION

Thermoluminescence Dosimeter (TLD)

Thermoluminescence dosemeters are widely used in gamma dosimetry because of their high sensitivity, small size, high dose range (10 μGy - 10^4 Gy), dose linearity, fast analysis and the possibility to use them in vivo. They have been continuously used in mixed field dosimetry to measure both gamma dose and neutron dose. For their small dimensions and their tissue equivalence for most radiation, TLDs give good support in the mapping of radiation fields. In fact, they allow three dimensional determination of absorbed dose with good spatial resolution.

TLD300 has a specific TL characteristic appropriate for mixed n-γ field dosimetry. It's glow curve has two well separable peaks which allow to determine dose and high LET dose simultaneously. Hoffmann and Songsiri-ritthigul (1992) used TLD300 to measure dose in a fast neutron field from a DT generator. They compared their measurement result with TE ionization chamber, GM counter measurement and Monte Carlo calculations (MORSE-CG code). They achieved ±5% accuracy for TLD300 measurement for both gamma and neutron dose which is similar to the accuracy of TE chamber and GM counter measurements. With special glow curve analysis techniques it is also possible to determine the radiation quality in high LET fields or mixed (n-γ) fields. In particular CaF_2:Tm (TLD300) exhibits two well separated glow peaks, their peak height ratio gives the information about the ratio of

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the fast neutron to the gamma dose. In addition the thermal neutron dose can be determined either with ^{6}LiF (TLD600) or possibly with a ^{10}B implanted TLD300 dosemeter. Therefore in principle it should be possible to measure all dose components of a mixed field such as BNCT with a few TLDs. We propose to implant the CaF_2:Tm. TLD with ^{10}B and measure its thermoluminescence dosimetry characteristics before and after the implantation.

Thermoluminescence emission spectrum

The TL effect can generally be described as a two step process: Ionization of electrons followed by trapping at defect sites and subsequent recombination during heating at TL centers causing photon emission. The study of glow curves and optical absorption measurement give some information on the nature of the trapping configuration, but in order to understand the configuration of the TL centers and the light emission process it is necessary to measure the spectral distribution of the emitted light.

Spectral measurements on CaF_2:Tm were performed by Prodhan and Bhatt at wavelengths between 300 and 500 nm. They found peaks at 345, 445 and 470 nm and observed a shifting ratio of the 445 to 470 nm peaks with temperature. Later Jacob found a strong infrared emission near 800 nm, which was 14 times higher than the visible light for the 140°C peak and 6 times higher for the 240°C peak. They proposed to use this emission for the recording of glow curves with IR showing broad IR peaks at 650 and 795 nm but did not show details of the line shape due to insufficient wavelength resolution.

Through recent developments in highly sensitive charge couple devices (CCD), optical spectrometers have become available, which allow, without using any expensive image intensifiers, spectra to be taken from TL, chips (3 mm x 3 mm x 0.9 mm) irradiated at moderate dose levels around 10 Gy with a wavelength resolution of 1nm. The sampling time can be as low as 0.1 s allowing temperature steps of 1°C even at high heating rates of $10°C.s^{-1}$. Now, very high resolution spectra can be taken at relatively simple instrument.

MATERIALS AND METHODS

CaF_2: Tm thermoluminescence dosemeter

CaF_2:Tm dosemeter obtained as single crystals, extruded rods and hot pressed chips. The conventional chips of size 3x 3x 0.9 mm^3 were used. The glow curve for CaF_2:Tm consists of several overlapping peaks, with a low temperature peak near 140°C (peak l) and a higher temperature complex of peaks near 240°C (peak 2). The glow curve for this material has been subject of several efforts to obtain kinetic parameters for the individual TL peaks and deconvolution program are now available.

Implantation

An ion implanter with a hot cathode Neilson ion source was used for ^{10}B implantation. BF_3 gas was feed into ion source chamber which electrons from a hot cathode oscillating under magnetic and electric field causing

discharge of BF_3 gas in low pressure chamber. The ion beam from Neilson ion source was extracted by a 20 kV extraction voltage. The BF ion current was measured by a Faraday cup. The implanting current was 2-4 μA at 20 keV kinetic energy.

The implanting dose varied from 10^{16} ions/TLD to 10^{17} ions/TLD. The implanted current and ions dose were shown in Table 1.

TLD300	BF current (μA)	Implant dose (ions)
#1	0.8	$4x10^{16}$
#2	0.8	$2x10^{17}$
#3	3.8	$2x10^{17}$

Table 1. *^{10}BF beam current and ion implant dose for each TLD300 chips.*

Gamma calibration

The ^{10}B implanted TLDs were exposed in Cobalt-60 gamma field with doses of about 40-60 Gy. The emission spectra were taken using the in house high resolution spectrometer which constructed by M.W.Rhodes [2000]. The high resolution spectrometer, using low cost CCD arrays, makes it possible to identify line of different width with a resolution of 1.3 nm.

RESULTS

Sensitivity of implanted TLDs

Before implantation the TLD300 chips were exposed with 39.3 cGy in a ^{60}CO field. Their glow curves were read out using a Harshaw TL reader. The height of peak1 and peak2 were recorded. Then the TLDs were implanted with 20 keV ^{10}BF ions dose range $4x10^{16}$ to $2x10^{17}$ ions/TLD. Recalibration with 39.3 cGy in ^{60}CO field, the height of peak1 and peak2 were recorded again. From peak height of the glow curve we found the sensitivity of implanted TLDs were reduced to about 91% of the pre-implant value (Table 2).

TLD300	Gamma	Before implantation.		After implantation.	
	dose (cGy)	Peak1(nA)	Peak2 (nA)	Peak1 (nA)	Peak2 (nA)
#1	39.3	1.744	567.6	1.545	544.60
#2	39.3	1.543	508.1	1.388	471.00
#3	39.3	1.535	514.5	1.303	478.00

Table 2. *Peak height signal of TLDs before and after implantation.*

TL emission Spectra

After the gamma calibration measurement, the implanted TLDs were exposed with doses of about 40-60 Gy in the ^{60}CO field. The emission spectra were read out using the high resolution spectrometer. The resulting spectra are shown in Fig.1 and Fig 2. The emission spectra clearly show that the material characteristics, spectral peak position and peak width, were not effected by the implantation procedure.

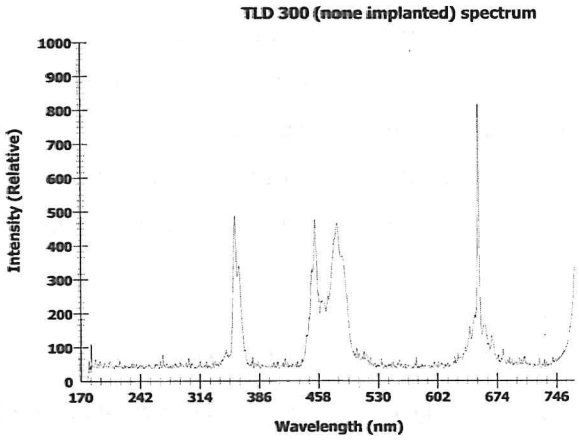


Fig 1. TLD300 (without ^{10}B ion implanted) wavelength spectrum at 140°C.

Figure 1 show spectra of the non implanted TLD taken at the temperatures corresponding to the first dosimetric peak (at 140 °C). The main spectral peaks show up at 356 nm, 455 nm, 482 nm, 650 nm and 795 nm.

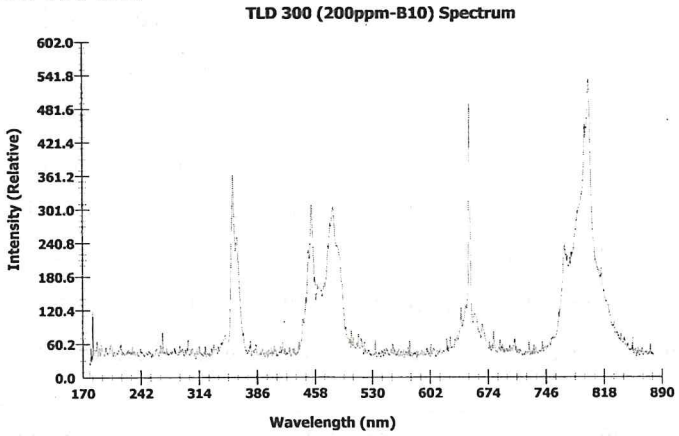


Fig 2. TLD300 (with $2x10^{17}$ ^{10}BF ions implanted) wavelength spectrum at 140°C.

Figure 2 show spectra of implanted TLD taken at the same temperatures as non implanted TLD (Fig 2). The luminescence spectral peaks of the implanted TLD show up at the same position as the non implanted TLD. The ^{10}BF implantation does not affect the luminescence characteristics of the dosemeters.

CONCLUSION

Ion implanting techniques can be used to modify solid state dosemeters. The implantation damages some luminescence structures and slightly reduces the radiation sensitivity of implanted TLDs. The emission spectra of the crystal dosemeter show that the light emitting process in the crystal is not affected. Therefore in principle it is possible to use the implanted TLD for fast and thermal neutron measurements.

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