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Spectral characteristic of high-dose high-temperature emission from LiF:Mg,Cu,P (MCP-N) TL detectors

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HIGHLIGHTS

- MCP-N TL detectors were studied after exposures with doses up to hundreds of kGy.
- TL peaks emission spectra and TL glow curves were measured up to 550 °C.
- Activation of additional recombination centers was observed at doses higher than 4 kGy.
- It is speculated, that after irradiation with high doses (>1 kGy) some clustering processes will taken place.

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ABSTRACT

High-temperature emission spectra of LiF:Mg,Cu,P (MCP-N) TL detectors, irradiated above the nominal saturation level, up to the hundreds of kGy, have been measured. Emission spectra integrated over the whole temperature range, as well as the spectra recorded at the temperatures corresponding to the TL peaks maxima, were analyzed. With increasing dose of γ-radiation no significant changes were observed in the short wavelength emission range (220–450 nm) of the measured spectra. For doses of 4 kGy and higher the long wavelength emission (450–800 nm) started to be visible. All recorded spectra have been expressed in a form of the sum of several Gaussian-shape bands in the energy domain, which parameters remain in a general agreement with the measurements of Mandowska et al. (2010). Spectra of the low-temperature, main, high-temperature and "B" TL peaks were investigated. In the ranges of the low-temperature and the main dosimetric peaks, that is 100–125 and 210–230 °C, respectively, the short wavelength emission disappeared with increasing dose and for the highest doses the long wavelength emission became dominant. Both the high-temperature (290–320 °C) and the "B" (370–425 °C) peaks emission spectra exhibited somewhat different behavior with increasing dose. Initially, an even growth of the whole spectrum was observed and for doses higher than 16 kGy the intensity of the spectrum decreased, but the short wavelength emission band fell significantly faster, in case of the high-temperature TL peaks. In case of the "B" peak emission spectra the long wavelength emission did not play any role in the analyzed dose range. The spectra measured at the TL peaks maxima were also fitted with several Gaussian-shape bands. Dose-intensity dependences for all Gaussian-shape bands fitted to the measured spectra are also included in this paper.

1. Introduction

Dosimetric properties of LiF:Mg,Cu,P (MCP-N) thermoluminescent detectors (TLD) are of interest to many scientists. These detectors gained popularity thanks to their tissue-equivalence combined with high radio-sensitivity (about 25–50 times higher as compared to LiF:Mg,Ti detectors). Nowadays they are commonly used in a dosimetry of ionizing radiation from the level of μGy doses up to the level of the saturation of response at about 1 kGy. It is also worth mentioning that the dose–response dependence of these detectors does not exhibit supralinearity. Moreover, all available data indicate that the shape of its glow curve remains practically unchanged, and the spectrum of emission has a form of a narrow peak with a maximum at about 360 nm, in this dose range. These features make MCP-N suitable for a wide range of dosimetric applications.

From the previous works (Bilski, 2002; Bilski et al., 2008, 2010; Obryk et al., 2009, 2010, 2011; Obryk, 2010) it is known that the

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shape of the glow curve of LiF:Mg,Cu,P TL detectors, after irradiation above the nominal saturation level, undergoes a complete alteration. Decrease of the amplitude of the main dosimetric peak (at about 220 °C) is observed, with simultaneous growth of the peaks located between 250 and 400 °C, which are not visible below 1 kGy. This high-temperature structure undergoes further alterations after doses of 50 kGy and higher, when a new peak, at temperatures exceeding 400 °C, becomes visible. The high-temperature TL peak was denoted as the "B" peak (Obryk et al., 2009). The mechanism of its formation remains currently unknown. The goal of the present work was to study the evolution of the emission spectrum of MCP-N detectors after irradiation with doses up to hundreds of kGy. Similar studies were previously conducted, in cooperation with the Institute of Physics, Jan Długosz University, Czestochowa, Poland (Mandowska et al., 2010). However, due to the technical limitations, the spectra could be measured only up to temperature of 350 °C, therefore large part of emission spectra, including the "B" peak, was not recorded in case of the highest doses (see Fig. 1C, D). Because of that, the present paper aims at determining the TL emission spectra of LiF:Mg,Cu,P detectors in the high temperature range.

2. Materials and methods

2.1. Irradiations and readout conditions

Emission spectra measurements were performed using virgin LiF:Mg,Cu,P TL detectors manufactured at the Institute of Nuclear Physics Polish Academy of Sciences (IFJ PAN), Krakow, Poland. The detectors in the form of sintered pellets of 4.5 mm diameter and 0.9 mm thickness, were exerted. Before the irradiations standard annealing procedure of 10 min at 240 °C was applied. Irradiations have been implemented at the Delft University of Technology, Delft, The Netherlands. The dose was delivered using Co-60 γ-rays source (Gammacel 2200) at the dose rate of 2.251 kGy/h. The dose rate was determined with Fricke dosimetry. The applied doses were ranging from 1 to 284 kGy. Detectors were exposed inside a tissue equivalent plastic (A150) holder, under charged particle equilibrium. The wavelength resolved readouts were also performed at the Delft University of Technology, using Ocean Optics QE65000 spectrometer combined with the Riso TL/OSL-DA-15A/B reader, with a temperature resolution of 5 °C. Heating was realized in a temperature range from 50 °C to 550 °C, at a rate of 2 °C/s. TL emission spectra were recorded in a range of 220–800 nm. All measured spectra have been numerically corrected to the system response.

2.2. Data analysis

2.2.1. Temperature selection

MCP-N TL glow curve exhibits several TL peaks. In order to determine differences in emission spectra of particular peaks, the spectra recorded at the temperatures corresponding to positions of maxima of the following TL peaks were analyzed:

- Low-temperature peak (usually denoted as the peak number 2): 100–125 °C;
- Main dosimetric peak (number 4): 210–230 °C;
- High-temperature peaks area: 290–320 °C;
- "B" peak: 370–425 °C.

It should be mentioned here that the emission spectra were not integrated over the mentioned above temperature ranges, but always taken from a single spectrum, recorded at the specified temperature (corresponding to the peak maximum). These ranges represent just fluctuations of TL peaks maxima positions. When a peak maximum was not clearly visible, i.e. when there was no local maximum at the glow-curve (as e.g. for low-temperature TL peak at

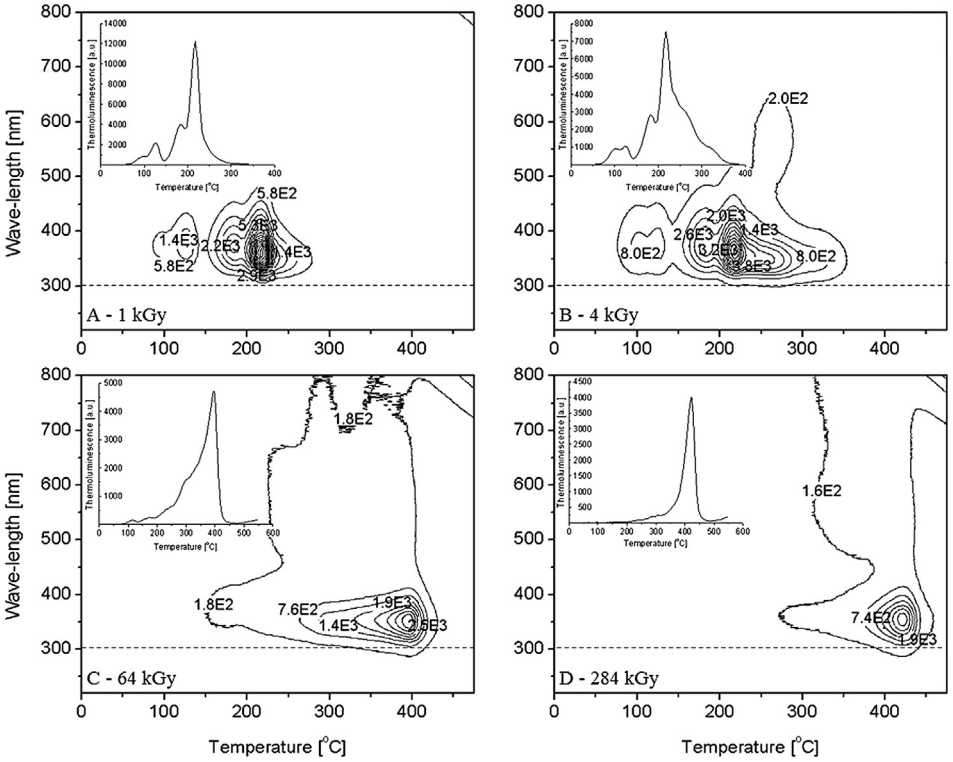

Fig. 1. Contour plots of LiF:Mg,Cu,P emission spectra after Co-60 γ-rays doses of 1 kGy, 4 kGy, 64 kGy and 284 kGy. In the insets the glow-curves integrated over the whole wavelength range are presented. Dotted lines indicate the level of 300 nm.