Contribution ID: **167** Type: **not specified**

NEW SPECTRA OF HIGH-TEMPERATURE THERMALLY STIMULATED LUMINESCENCE IN LiF, Ti AND NaCl-Li DOSIMETRIC CRYSTALS

Materials based on ionic crystals (LiF:Mg,Ti and LiF:Mg,Cu,P) have been successfully employed as dosimeters (TLD-100 and TLD-700H) for detecting ionizing radiation up to 10 Gy. The primary dosimetric peaks are the high-temperature thermally stimulated luminescence (TSL) peaks with maxima at 473 K (TLD-100) and 490 K (TLD-700H).

Experimentally, the nature of the low-temperature (4.2 K ⟶ 300 K) TSL peaks in ionic crystals (ICs) has been extensively studied. These peaks are attributed to the recombination of migrating radiation defects with immobile defects possessing higher destruction temperatures. However, the mechanism underlying the high-temperature TSL peaks in ICs, which serve as primary probes in the registration of ionizing radiation by dosimetric thermoluminescent detectors, remains inadequately understood. It is primarily attributed to the absence of recorded spectra for high-temperature TSL peaks in ICs. Standard instruments, such as the Harshaw model 3500, only register the integral thermoluminescence that is used to estimate the absorbed dose of ionizing radiation by the dosimeter.

For the first time, spectra of high-temperature TSL peaks in LiF:Mg,Ti and NaCl-Li crystals have been recorded by us within 360÷400 K and 495÷620 K temperature ranges, provisionally designated as type I and type II TSL peaks, respectively.

Initially, for NaCl-Li crystals, we observed an effect of increased light output of the type II TSL peaks (535÷570 K), which intensifies with increasing lithium concentration. At concentrations of 400 ppm, the intensity growth reaches three orders of magnitude higher (105 ⟶ 108) than in pure NaCl crystals and one order higher than in TLD-100 thermoluminescent dosimeters.

The spectra of the high-temperature type II TSL peaks for NaCl-Li crystals exhibit maxima at 3.5 eV, coinciding with the spectra of X-ray luminescence (XL) and tunnel luminescence (TL). Similar spectral coincidences of XL, TL, and type II TSL peaks, with maxima at 2.8 eV and 3.1 eV, were also established for KCl-Na crystals.

The calculated temperature dependence of the vacancy defect jump frequency shows that in the temperature range corresponding to the main TSL maximum (535÷570 K), the values are $\nu_1 = 1025 \div 30\ s^{-1}$. The data suggest that halogen hole radiation defects are destroyed by mobile anionic and cationic vacancies.

Dissociation of halogen formations and electron color centers occurs due to the mobility of cationic and anionic vacancies with increasing sample temperature. Thermal dissociation of halogen formations (V_2, V_3-centers) in the crystal generates a flux of non-relaxed holes (h), while thermal dissociation of electron centers (F, F_2-centers) generates a flux of free electrons (e). Their recombination assembly occurs in the field of a light impurity ion (Li, Na, Ti), creating a potential well for their assembly —(e-h)SLi, (e-h)SNa, (e-h)STi —with maximum luminescence output [1, 2].

References:

[1] Shunkeyev K., Tilep A., Sagimbayeva Sh., Lushchik A., Ubaev Z. Crystals, Vol. 13(364), 2023, 1–13.
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Section

Energy and materials science (Section 2)

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Track Classification: The V International Scientific Forum “Nuclear Science and Technologies”: Energy and materials science (Section 2)