Thallium-doped sulphate potassium crystals as materials for radiation detectors

M.Myrzakhmet, M.Nikl*, V.Jary*, B.Dalelkhan, A.Zhanabergenov

Eurasian National University,
5 Munaytпасов St., 010008 Astana, Kazakhstan
*Institute of Physics, Academy of Sciences of Czech Republic,
10 Cukrovarnicka, 16253 Prague, Czech Republic

Received April 2, 2013

Luminescence characteristics of potassium sulphate (K₂SO₄) crystals doped with thallium were studied. Crystals were grown from water solution at slightly elevated temperature. The nature and properties of the luminescence centres in these crystals have been determined. The main monovalent thallium luminescence centres show the absorption peak at 216 nm and emission one peaking at 285 nm at room temperature. Thallium is substituting potassium which has two different positions in K₂SO₄ structure. Consequently, two different Tl⁺ centers were found for thallium centers in these crystals and the third center includes an unspecified perturbation agent nearby. Tl⁺ centers differ in radiative lifetime at low temperatures and in temperature dependence of decay times measured within 8–300 K.

Исследованы люминесцентные характеристики кристаллов сульфат калия (K₂SO₄), активированных таллием. Кристаллы выращены из водного раствора при комнатной температуре. Определены природу и свойства центров люминесценции в этих кристаллах. Основной одновалентный таллиевый центр люминесценции имеет при комнатной температуре поглощение при 216 нм и излучение при 285 нм. Таллий замещает калий, который имеет две различные позиции в структуре K₂SO₄. Определены два различных Tl⁺-центра для таллиевых центров в этих кристаллах, а также третий центр, который включает в себя как независимый, так и зависимый агент ампулирования. Tl⁺-центры отличаются радиационным временем жизни при низких температурах и по температурной зависимости времени затухания, измеренных в диапазоне 8–300 К.

Особенности кристаллов сульфат калия как материалов для детекторов выпр

1. Introduction

One of the most widely used recent methods of synthesis of nanostructures are the so-called method of "soft chemistry" that allows to create a wide range of nanomaterials in solutions using controlled phase formation and crystallization processes colloi-
null
two bands: intensive 4.0 eV band and a weak band around 2.02–2.05 eV. The excitation spectra corresponding to these emission bands are similar. They have maximum at 5.4 eV and a shoulder at higher energy within 5.8–5.9 eV. Gamma irradiation of crystals does not give rise to any new excitation/emission bands.

For low irradiation doses the thermally stimulated luminescence shows three glow curve peaks with maxima at 340, 395 and 445 K. The low-temperature peak with an increase in a dose of radiation is overlapped by the second peak. There is a considerable afterglow after the usual doses of radiation. Spectral structures of afterglow, as well as thermoluminescence under various peaks, consist of two bands 2.04 eV and 4.0 eV. The low-energy band is quite weak at the room temperature and lower temperatures, but its intensity increases significantly at higher temperatures [17].

In the optical absorption spectra the C absorption band of Ti$^{4+}$-ions is shown. The fluorescence shows emission of Ti$^{4+}$ due to transitions from the $3P_1$ and $3P_0$ levels on $1S_0$ level. Gamma irradiation causes a change in the valence of some of the Ti$^{4+}$-ions. Ti$^{4+}$ behaves during irradiation as an electronic trap. Formed Ti$^{0}$, evolving into Ti$^{4+}$ at the time of recombination with the hole in the center of the heating time, and this causes the observed recombination thermoluminescence. The emission spectra of thermoluminescence contain the same band of Ti$^{4+}$, as observed in the fluorescence [17].

In [18] it is shown that radiation X-ray beams of crystals at a temperature of liquid nitrogen leads to the formation of the Ti$^{4+}$ and Ti$^{2+}$ centers. When heating crystals to room temperature the intensive thermoluminescence is observed associated with the decay of these centers.

For crystals of potassium sulphate, activated by thallium, a number of questions was not solved:
- uncertainty of a shape and position A-, B-, C-bands absorption of Ti$^{4+}$-ions,
- difference in the optical properties of Ti$^{4+}$-ions for two various positions of potassium which they replace,
- optical properties of Ti$^{2+}$ pair centers in these crystals.

2. Experimental

Pure and thallium doped potassium sulphate crystals are grown in our laboratory from water solution by a method of slow evaporation at the room temperature. Measuring the optical properties of these crystals are carried out on the equipment of the Department of Optical Materials Institute of Physics of the Academy of Sciences of the Czech Republic in Prague [19]. Absorption of crystals was measured at the room temperature on the Shimadzu 3101PC spectrometer, luminescence spectra and decay kinetics were measured on HJY 5000M spectrofluorometer within 77–500 K.
3. Results and discussion

In X-ray excited luminescence spectra the samples doped by thallium always showed a more intensive band of emission with various intensity (depending on a shape of a sample, the concentration of thallium, the quality of a material).

The absorption spectra of the samples with impurity of thallium A-band of Ti⁺-ions with a maximum about 216 nm. Some of the undoped samples showed contamination by thallium and the same emission band, as in the Ti⁺-doped samples.

Upon excitation in the A-band near 216 nm the emission band is observed with a maximum at 285 nm, which belongs to the Ti⁺.

The excitation spectrum of the 285 nm band approximately copies the absorption A-band, some distortions arise likely due to high absorbance and resulting geometrical effects.

Thus, the luminescence centers in the crystals of potassium sulphate doped by thallium show absorption with a maximum at 216 nm and emission with a maximum at 285 nm at the room temperature. These centers belong to monovalent of thallium. Two different substitution sites show small effect in the luminescent characteristics.

Decay kinetic measurements complete further the description of the Ti⁺ centers (Fig. 1). Measurement of KSO·Ti down to 8 K showed a plateau in the decay time of a dominating band at 285 nm (lower than 30 K), but for the decay time of a band at 330 nm we have growth up to 8 K, so in this case division of metastable and radiating levels of this center less authentically, then at a 285 nm band.

The temperature dependence of the decay time of the emission band at 330 nm is given in Fig. 2. In Fig. 3 and 4 the excitation and emission spectra are shown, respectively, demonstration of one more emission center is proved in a matrix of potassium sulphate with an emission about 296 nm and excitation near to 243 nm peaks.

Value of a radiative lifetime of the 296 nm band several times exceeds those of the other two bands described above. Furthermore, the temperature dependence of the decay time of the emission is different: the plateau extends to higher temperatures, and then drops sharply (Fig. 5).
Detailed measurements of temperature dependences of the decay times and carefully distinguished luminescence spectra clearly proved three emission centers associated with monovalent thallium. Two of them arise due to two positions of potassium ions in the structure of potassium sulphate, the third can be associated with the \( \text{Tl}^+ \) with a defect nearby.

References