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BRIEF COMMUNICATIONS

INFLUENCE OF THERMAL TREATMENT ON THE RECOMBINATION LUMINESCENCE OF POTASSIUM SULFATE ACTIVATED BY TRIVALENT GADOLINIUM IONS

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By the structure of the crystal lattice and chemical bond, potassium sulfate is an analog of a wide class of compounds. From this viewpoint, it can be considered as a model object for studying various processes, including radiation stimulated ones.

The present work studies the influence of thermal treatment of K_2SO_4 crystals activated by trivalent gadolinium ions on the recombination processes. The properties of ions of rare-earth elements in this matrix were studied only occasionally. For example, the data on the optical properties and thermally stimulated luminescence of potassium sulfate activated by bivalent europium ions were presented in [1].

Figure 1*a* shows the thermally stimulated luminescence of the K_2SO_4–Gd crystal after irradiation by x-ray quanta at the temperature of liquid nitrogen. The irradiation doze was 10 kGy. A single clearly pronounced peak of recombination luminescence with maximum at a temperature of 155 K can be seen from Fig. 1*a*. Its low-temperature wing has an arm caused by the presence of a peak of thermally stimulated luminescence with maximum at 100 K. We have already investigated the thermally stimulated luminescence of the K_2SO_4 single crystals activated by trivalent samarium ions in [2, 3]. It was established that the samarium ions transferred charge upon exposure to ionizing radiations. The curve of thermally stimulated luminescence for these samples had clearly expressed luminescence peaks with maxima at temperatures of 145, 190, 220, and 280–300 K. The recombination luminescence peak with maximum at 145 K is complex. It is bended in the region of the low-temperature wing, which testifies to the presence of one more luminescence peak with maximum at 100 K. The thermally stimulated luminescence peaks with maxima at 190 and 280–300 K are characteristic of the pure K_2SO_4 crystals [4]. The curve of thermally stimulated luminescence for the K_2SO_4–Gd single crystal is much simpler than the corresponding curve for the potassium sulfate single crystal activated by samarium. For both samples, the recombination luminescence peak with maximum at 100 K is observed. However, the dominant peak of the curve of thermally stimulated luminescence for potassium sulfate activated by gadolinium ions has anomalously large width along the temperature axis, which suggests that it is nonelementary. As already mentioned above, the pure potassium sulfate crystals have the thermally stimulated luminescence maxima at 190 and 280–300 K. For the sample activated by gadolinium ions, the recombination luminescence peaks with maxima at 190 K and 280–300 K are not recognized. The recombination luminescence has a small light sum. By the methods of absorption spectroscopy, it was established that after irradiation of the K_2SO_4–Gd crystals by x-rays at the temperature of liquid nitrogen, the optical density in the impurity absorption bands decreased. Hence, the gadolinium ions change their charge state upon exposure to ionized radiation.

The potassium sulfate single crystals grown from aqueous solutions with addition of gadolinium chloride were grinded into a powder and held for 1.5–2 h at a temperature of 600°C. The behavior of the thermally stimulated luminescence curve radically changed after thermal treatment. The result obtained is shown in Fig. 1. In the figure, four maxima at 100, 155, 190, and 300 K are clearly seen in the thermally stimulated luminescence curve. This result was obtained after sample irradiation with a doze of 10 kGy. Unlike the samples activated by samarium ions, some peaks of

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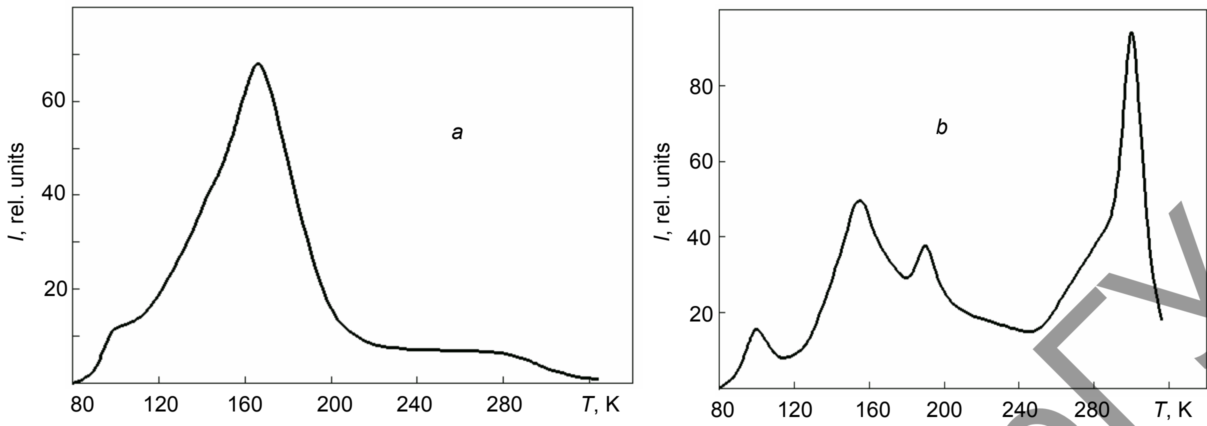

Fig. 1. Curves of thermally stimulated luminescence of the sulfate potassium crystal activated by gadolinium ions before (*a*) and after thermal treatment (*b*).

thermally stimulated luminescence did not disappear after thermal treatment. The light sum of the recombination luminescence peak with maximum at 155 K sharply decreased. As a result, the peaks of thermally stimulated luminescence with maxima at 100 and 190 K become clearly pronounced. In contrast with the result obtained for the single crystal, the luminescence peak with maximum at 300 K appeared after thermal treatment. For the K_2SO_4–Gd single crystals, this luminescence peak was suppressed.

We explain the radically different behavior of curves of thermally stimulated luminescence for K_2SO_4–Gd before and after thermal treatment by the presence of structural water. According to the literature data, potassium sulfate is not hydrogenated. Due to the complexity of the natural vibrational spectrum of the matrix, it is impossible to detect the presence of absorption bands of structural water by the methods of IR spectroscopy. However, it was established that long thermal treatment caused the light sum for the thermally stimulated luminescence peak with maximum at 100 K to decrease and for the thermally stimulated luminescence peaks at 280–300 K to increase significantly. The presence of the crystal lattice of trivalent gadolinium ions caused the occurrence of additional cation vacancies compensating the excessive charge. It is assumed that in the process of single crystal growth, the water molecules can be trapped from complex solutions into these vacancies. The thermally stimulated luminescence peaks at 280–300 K are due to the decay of hole defects such as SO_3^{2-} [5]. One of the products of water molecule radiolysis is atomic hydrogen. As is well known, it is energetically favorable for hydrogen to join the SO_3^{2-} defect [6]. This explains the suppression of light sum accumulation at 280–300 K for single crystals. After thermal treatment, a part of water is removed, thereby causing the observed changes in the curve of thermally stimulated luminescence. The similar influence of water molecules on the recombination processes was observed, for example, for crystals of monohydrate of lithium sulfate [7].

Thus, it has been experimentally established that thermal treatment of the K_2SO_4–Gd single crystals influences significantly the recombination processes. The assumption on the presence of structural water in the samples allowed the observed phenomena to be explained. It was established that the impurity ions transferred charge after irradiation. These centers led to the occurrence of the new peak of thermally stimulated luminescence with maximum at 155 K in the activated crystals.

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