# Structure and Thermally Stimulated Luminescence of β-$Ga_2O_3$ Thin Films

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Recently, the thin films of β-modification of gallium oxide (β-$Ga_2O_3$) are widely used in various optoelectronic devices. Particularly, the pure and doped thin films are used as a phosphors, cathode phosphors, electroluminescent phosphors, UV-detectors and gas sensors. The luminescent properties of β-$Ga_2O_3$ thin films are strongly dependent from the method as well as from the conditions of preparation. The efficiency of the transfer excitation energy from the basic material to the luminescent centers is largely determined by the presence trapping centers (TC), which manifest themselves in thermally stimulated luminescence (TSL). This led to investigation the TC of charge carriers and the determining of their parameters by the thermal activation methods.

β-$Ga_2O_3$ thin films with thickness from 0.2 to 1.0 μm were obtained by radio-frequency ion-plasmous sputtering. The deposition of thin films was occurred in the spraying argon atmosphere. The heat treatment of thin films was performed after deposition in oxygen atmosphere. X-ray diffraction studies showed the presence of the polycrystalline structure of thin films that preferentially oriented in the planes (400), (002), (111) and (512). The investigation of surface morphology of thin films by the atomic-force microscopy showed that the diameter of the grains on the surface of thin films without heat treatment is average equal to 30 nm and the average roughness of thin films is about 7 nm. The treatment of thin films in oxygen atmosphere leads to the increase size of grains through the processes of growth and sintering, thus, the average diameter of grains is increased to 45 nm. The surface roughness of thin films after annealing increases more than twice, the average to 15 nm.

The investigation of thermally stimulated luminescence (TSL) of β-$Ga_2O_3$ thin films after annealing in oxygen atmosphere and X-ray excitation showed 4 different of the TC in the temperature range 50-300 K. Meanwhile, the property the storage of light appears in the bands of the TSL with maxima at 77, 135, 178 and 235 K.

The analysis of the luminescence spectra of the TSL of β-$Ga_2O_3$ thin films shows that the radiative recombination at the termination TC passes through the same centers as in stationary regime luminescence. As in the spectra of stationary luminescence [1], the spectra of TSL of the films are well simulated by two independent Gaussians (the model linear electron-phonon coupling) with maxima at 2.95 and 3.14 eV. Thus, for the band with the maximum at 77 K in the spectrum of luminescence the dominant is the band with maximum at 3.14 eV and for more high-temperature bands are predominant the bands with maximum at 2.95 eV.

On the basis of several methods was defined the thermal activation energy of TC $E_T$ and frequency factor of trapping centers $p_0$ that characterizes the frequency of effective collisions which capable of vacate the localized charges.

Based on the deviations the dependence of $E_T(T)$ was done the hypothesis about the presence of remote diffuse-controlled tunnel mechanism of luminescence. The diffuse nature of migration of the electron excitations with the possible intermediate localization is confirmed also low values the defined factor of frequency $p_0$ of the processes of relaxation.

[1] O.M. Bordun, B.O. Bordun, I.Yo. Kukharskyy, I.I Medvid, *Zh. Prikl. Spektr.* **84** (1) (2017) 56-62.