Microstructure and cathodoluminescence of Y_2O_3:Eu i Gd_2O_3:Eu thin films

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Introduction

Among the large number of nanomaterials for optoelectronics, a special place is occupied by luminescent materials, which are used to create displays, scintillators, devices for recording and visualizing information. One of the most effective phosphors with a linear dependence of the luminescence brightness on the excitation current density is Y_2O_3:Eu [1, 2]. In particular, it is the most efficient phosphor that emits in the red region of the spectrum. The combination of small crystal particle sizes and the presence of a dopant, luminescent center, and Eu^{3+} ion provides uniform screen coverage when depositing thin Y_2O_3:Eu^{3+} films, which improves the efficiency and stability of luminescence and expands potential applications.

In this work, we investigate the surface structure and spectral properties of cathodoluminescence (CL) of isostructural Y_2O_3:Eu and Gd_2O_3:Eu thin films obtained by radio-frequency (RF) ion-plasma sputtering. This method is optimal for obtaining the most homogeneous semiconductor and dielectric films [3]. The used method of local cathodoluminescence is characterized by high sensitivity to changes in the electronic structure of the material (impurity and structural defects) and makes it possible to study changes in the luminescent properties of structures and materials at a depth of 10-20 nm to several microns.

Methods

Thin films Y_2O_3:Eu and Gd_2O_3:Eu 0.2 - 1.0 μm thick obtained by RF ion-plasma sputtering in an argon atmosphere on fused silica υ-SiO2 substrates. The initial raw material was Y_2O_3 of the ИтО-И brand, Gd_2O_3 and Eu_2O_3 of the “ос. ч.” brand. The activator concentration was 1.0 mol%. After the deposition of the films, they were heat treated in air at a temperature of 950-1050°C. X-ray diffraction studies have shown the presence of a similar polycrystalline structure of both types of films with a preferred orientation in the (222) plane.

Investigations of CL properties were carried out in the mode of pulsed electronic excitation.

Results

Typical AFM micrographs of the surface of Y_2O_3:Eu and Gd_2O_3:Eu films are shown in Fig. 1.

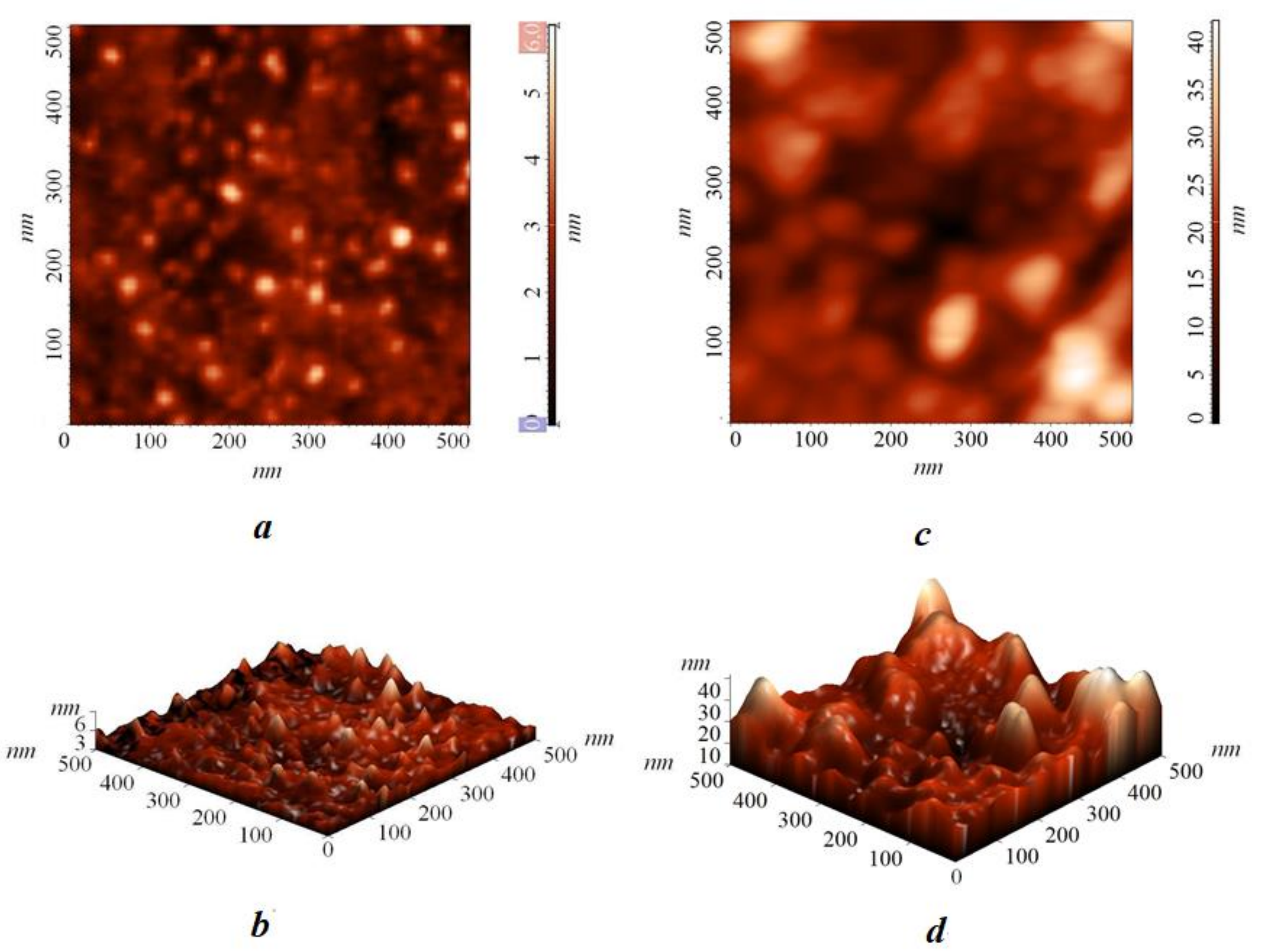

Fig. 1. Image of the surface morphology of Y_2O_3:Eu (***a, b***) and Gd_2O_3:Eu (***c, d***) thin films obtained by RF ion-plasma sputtering in an argon atmosphere at an activator concentration of 1 mol. %. Images ***a*** and ***c*** are two-dimensional, ***b*** and ***d*** are three-dimensional.

As can be seen from the results obtained, the Gd_2O_3:Eu films are formed from larger nanocrystalline grains than the Y_2O_3:Eu films and have a rougher surface. The characteristic structural parameters of the surface of the films under study are given in Table. 1.

Table 1

Average grain sizes, film surface roughness and "asymmetric ratio" I_{612}/I_{596} in Y_2O_3:Eu and Gd_2O_3:Eu thin films

Thin film	Average grain size, nm	Average surface roughness nm	"Asymmetric ratio" I_{612}/I_{596}
Y_2O_3:Eu	15.9	5.3	11.43
Gd_2O_3:Eu	31.3	12.7	6.66

They indicate that under the same preparation conditions, the surface structure of the Gd_2O_3:Eu films is formed from twice as large crystallites and has a twice as large roughness.

An investigation of the CL spectra of Y_2O_3:Eu and Gd_2O_3:Eu thin films shows that the shape of the luminescence spectra in both types of films is practically similar. Typical CL spectra in the films under study are shown in Fig. 2.

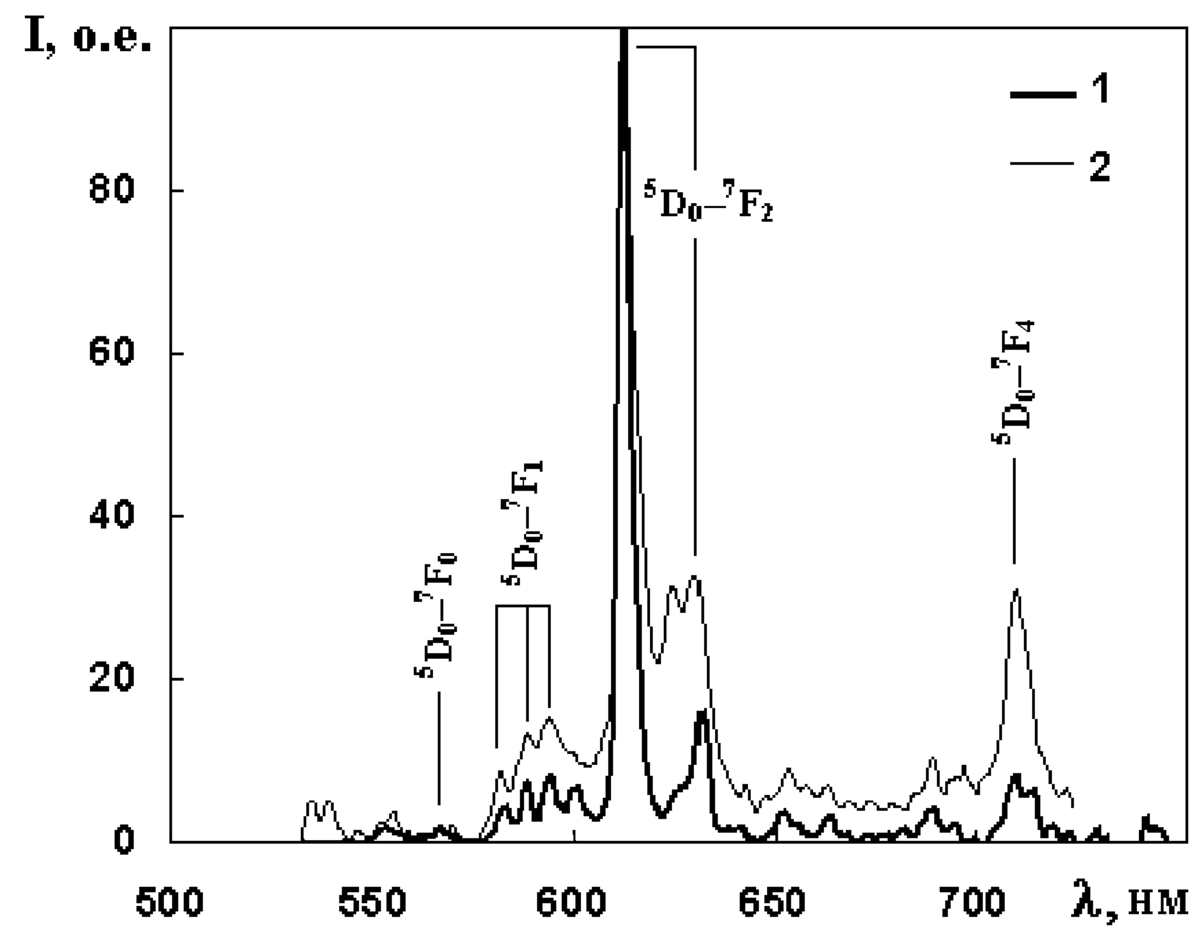

Fig. 2. CL spectra of (**1**) Y_2O_3:Eu and (**2**) Gd_2O_3:Eu thin films at an activator concentration of 1 mol.%. Parameters of electron irradiation pulses: electron beam current density j=5×10^{-2} А/м^2; pulse duration 5×10^{-4} s; pause between pulses 0.1 s; the energy of exciting electrons is 3 keV.

As can be seen from the figure, the CL spectra of both films exhibit narrow luminescence bands caused by intracenter transitions between the electron shells of the Eu^{3+} activator. These bands are associated with allowed $^5D_0$–$^7F_1$ magnetic dipole transitions (for Eu^{3+} ions in both C_2 and C_{3i} sites of the Y_2O_3:Eu or Gd_2O_3:Eu crystal lattice) and allowed electric dipole transitions $^5D_0$–$^7F_2$ (for Eu^{3+} ions only at C_2 sites). In this case, it is characteristic that in the Gd_2O_3:Eu films the relative intensity of the luminescence due to the electronic transitions $^5D_0$–$^7F_1$ is almost two times higher than the relative intensity of this luminescence in the Y_2O_3:Eu films.

Conclusion

The studies carried out show that with RF ion-plasma sputtering at a concentration of the activator Eu^{3+} 1 mol. % thin Gd_2O_3:Eu films are formed from larger grains with an average diameter of 31.3 nm compared to Y_2O_3:Eu films, the average grain diameter of which is 15.9 nm. The CL luminescence of Y_2O_3:Eu and Gd_2O_3:Eu thin films has a similar character and is caused by intracenter transitions between the electron shells of the Eu^{3+} activator. Based on the analysis of the CL spectra, it has been established that, in the glow of thin Gd_2O_3:Eu films, the relative contribution of the glow of Eu^{3+} ions at the sites of the crystal lattice with the point symmetry C_{3i} increases and the contribution of the glow of Eu^{3+} ions at the sites of the crystal lattice with the point symmetry of C_2 relative to the glow of thin films of Y_2O_3:Eu increases.

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