Morphology of thin films Y_2O_3:Eu obtained by different methods

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Annotation

Thin films of Y_2O_3:Eu were obtained by the method of radio-frequency (RF) ion-plasma sputtering in an argon atmosphere and discrete evaporation in vacuum. Investigation of the surface morphology of thin films by atomic force microscopy (AFM) showed that when switching from RF sputtering to discrete evaporation, the mean square surface roughness increases at close diameters of nanocrystalline grains on the film surface. It has been established that the grain size distribution during RF sputtering corresponds to the normal logarithmic distribution with one distribution center, and for discrete evaporation with two distribution centers. The ratio of distribution centers indicates the coalescence of grains among themselves.

Introduction

Considerable interest in the study of nanostructures of various chemical composition, structure, and morphology is caused by interesting physicochemical, electrical, optical, and other properties of nanomaterials, which open up broad prospects for their practical application [1-3]. Among them, a special place is occupied by materials doped with rare-earth ions (REI), which are key elements of modern devices for generating, transmitting, and controlling optical signals. One of the most used REIs is europium Eu^{3+}, which is widely used in nuclear power, to generate laser radiation in the visible spectral region with a wavelength of 0.61 µm, and Y_2O_3:Eu^{3+} is the most efficient phosphor emitting in the red region of the spectrum.

Experimental technique

Thin Y_2O_3:Eu films 0.2 - 1.0 µm thick obtained by RF ion-plasma sputtering and discrete evaporation in vacuum on fused υ-SiO_2 quartz substrates. RF sputtering was carried out in an argon atmosphere in a system using the magnetic field of external solenoids for compression and additional ionization of the plasma column. The feedstock was Y_2O_3 of the ИтО-И brand and Eu_2O_3 of the "ос. ч." brand. The activator concentration was 1 mol. % After applying the films, they were heat treated at a temperature of 950-1050 °C in air.

Experimental technique

Using the X-ray diffraction analysis (Shimadzu XDR - 600), the structure and phase composition of the films were studied. X-ray diffraction studies showed the presence of a polycrystalline structure with a predominant orientation in the (222) plane

The surface morphology of the films was investigated using an atomic force microscope (AFM) «Solver P47 PRO». Processing of experimental data and calculation of surface morphology parameters was carried out using the «Image Analysis 2» software package.

Results and discussion

Based on the measurements, it was found that during RF ion-plasma sputtering and discrete evaporation, polycrystalline Y_2O_3:Eu films consisting of nanometer grains are formed. The topography of the samples was quantitatively characterized by standard parameters: root mean square roughness, maximum grain height with diameter and grain height, which were calculated according to AFM data for sections of the same size (1000×1000 nm). The characteristic parameters of thin Y_2O_3:Eu films obtained by various methods are listed in Table 1.

Table 1 - Parameters of crystalline grains of thin Y2O3:Eu films

Parameter	RF -sputtering	Discrete evaporation
Diameter of the grains, nm	15,7	15,7
Root mean square roughness, nm	0,7	1,2
Maximum grain height, nm	6,0	10,3
Grain volume, nm^3	1123,5	1469,5

Microphotographs of the surface of Y_2O_3:Eu films obtained by RF sputtering and discrete evaporation obtained using AFM are shown in Fig. 1.

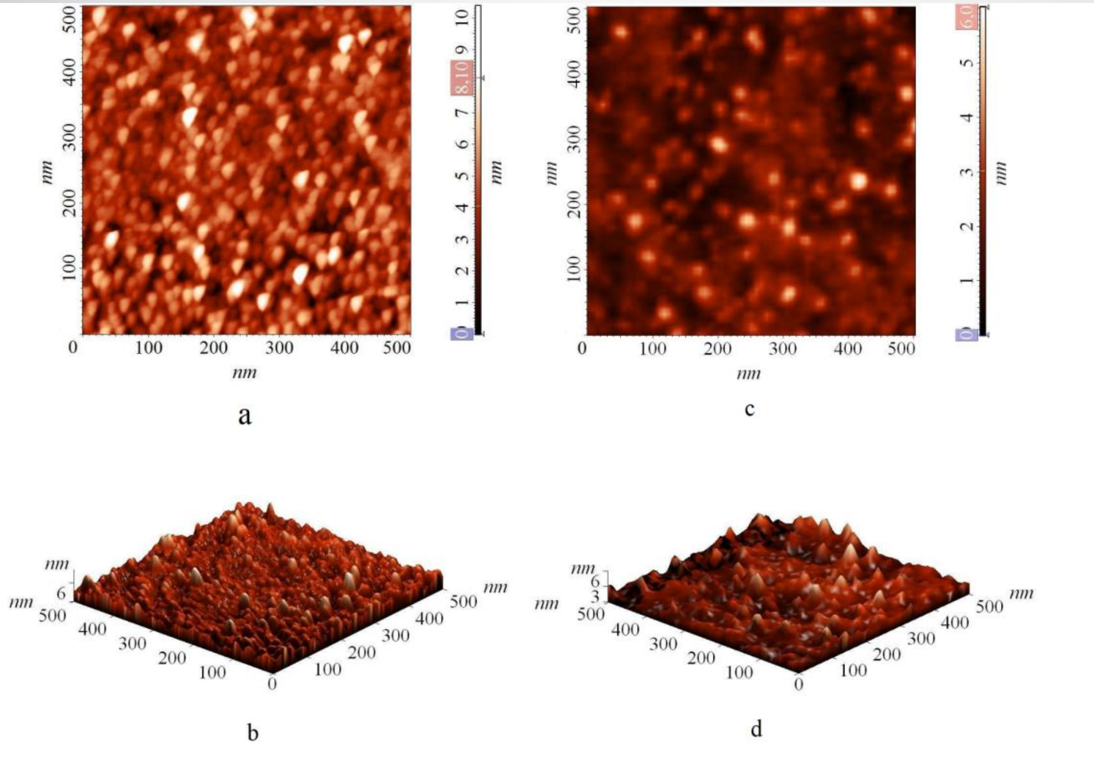

Fig. 1 Images of the surface morphology of a thin film Y_2O_3:Eu obtained by RF sputtering (a, b) and discrete evaporation (c, d). Image a and c are two-dimensional, b and d are three-dimensional.

An increase in the root mean square roughness parameter indicates a complication of the surface structure. A comparison of the histograms of the distribution of heights (Fig.2) shows that when switching from RF, sputtering into discrete evaporation leads to the formation of sharper peaks on the film surface.

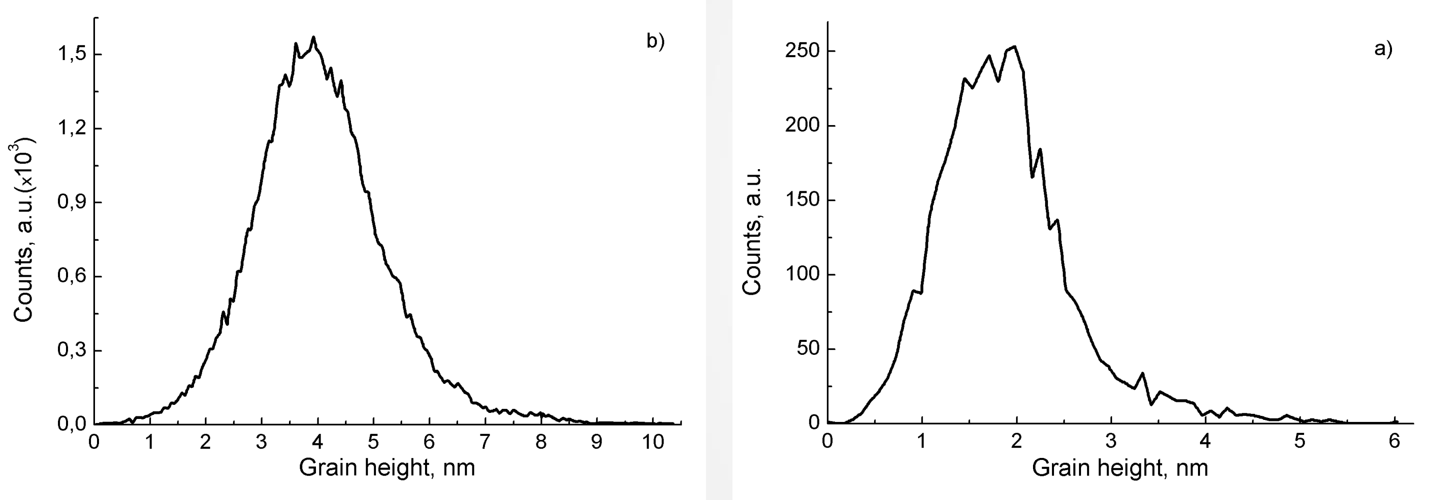

Fig. 2 Grain height distribution on an AFM image of thin films Y_2O_3:Eu obtained by RF sputtering (a) and discrete evaporation (b).

The larger grain growth of the Y_2O_3:Eu film during discrete sputtering relative to RF sputtering leads to the appearance of additional maxima in the calculated diameter distribution of grains in AFM images (Fig. 3). The analysis shows that for the surface of the films during RF sputtering, one division is observed in diameter with a maximum of about 16 nm and a dispersion of 3 nm, and with discrete evaporation, at least two distributions with maxima of about 16 and 36 nm and a dispersion of 3,3 and 3,0 nm, respectively, and a certain increase in the number of grains in the region of small diameters.

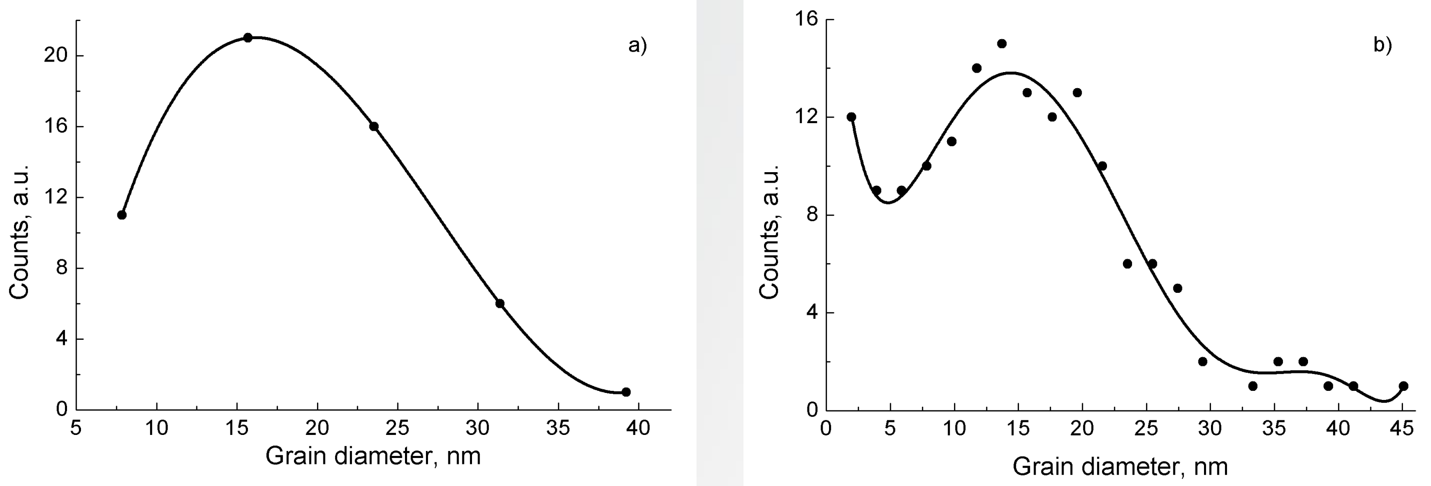

Fig. 3 Distribution of grain diameter sizes and calculated approximation of the diameter distribution on AFM images of Y_2O_3:Eu thin films obtained by RF sputtering (a) and discrete evaporation (b).

Conclusions

It has been established that during RF ion-plasma sputtering and discrete evaporation, polycrystalline Y2O3:Eu films consisting of nanometer grains are formed. According to AFM data, it is shown that upon transition from RF sputtering to discrete evaporation, the mean square surface roughness increases, although the average grain diameter on the film surface in both cases is 15.7 nm. In this case, the diameter distribution of grains during RF sputtering corresponds to the normal logarithmic distribution with one distribution center, and for discrete evaporation with two distribution centers, which approximately correlate as 1:2, which indicates grain coalescence.

References

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