Surface morphology and X-ray luminescent properties of β-Ga_2O_3 thin films

Bordun O. M. , Bordun B. O. , Medvid I. I

Ivan Franko National University of Lviv 50, Drahomanov Str., UA-79005 Lviv, Ukraine

E-mail: oleh.bordun@lnu.edu.ua

Recently, the metal oxide materials are attracting much attention through wide possibilities of their use in modern optoelectronics and instrument engineering. The Ga_2O_3 thin films can be dielectrics or semiconductors according to conditions of preparation. The films based on β–Ga_2O_3 are widely used as thin-film materials, which are promising for luminescent displays, field-effect transistors (FET), gas sensors and electrodes that are transparent in the UV region. Taking into account that the luminescence efficiency of thin β-Ga_2O_3 films are largely determined by the dimensional, morphological, and structural properties of the nanoparticles, which form these films, the effect of thermal treatment on the surface morphology of thin films is investigated here.

Thin films of β-Ga_2O_3 with a thickness of 0.2–0.8 µm were obtained by RF ion-plasma sputtering on substrates of υ-SiO2 fused quartz. RF sputtering was carried out in an atmosphere of argon in the system using the magnetic field of external solenoids for compression and additional ionization of the plasma column. After deposition of the films, the heat treatment in argon atmosphere at 1000–1100°C was held. X-ray diffraction studies showed the presence of a polycrystalline structure of films with a predominant orientation in the (400), (002), (111), and (512) planes. The surface morphology of films was investigated using atomic force microscope (AFM) 'Solver P47 PRO'.

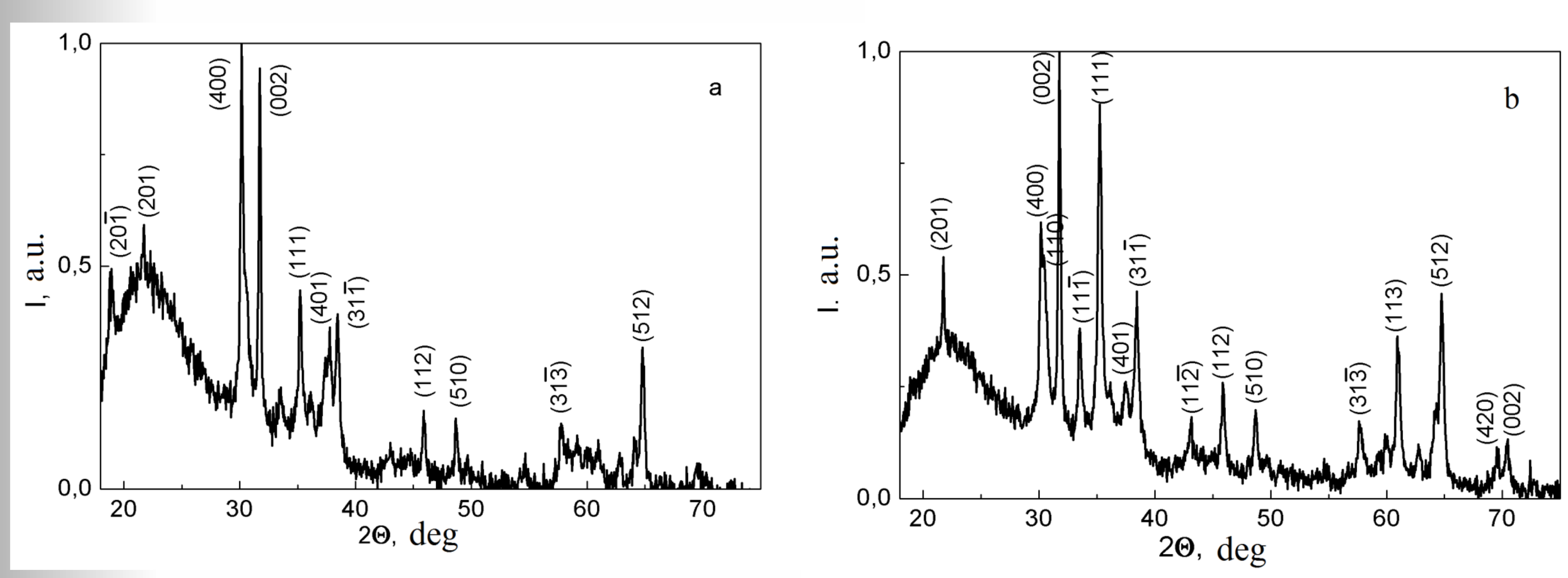

Fig. 1. The diffraction patterns (with CuKα-irradiation) of Ga_2O_3 thin films, *(a)* after heat treatment in the oxygen atmosphere and *(b)* in argon atmosphere at 1000°C

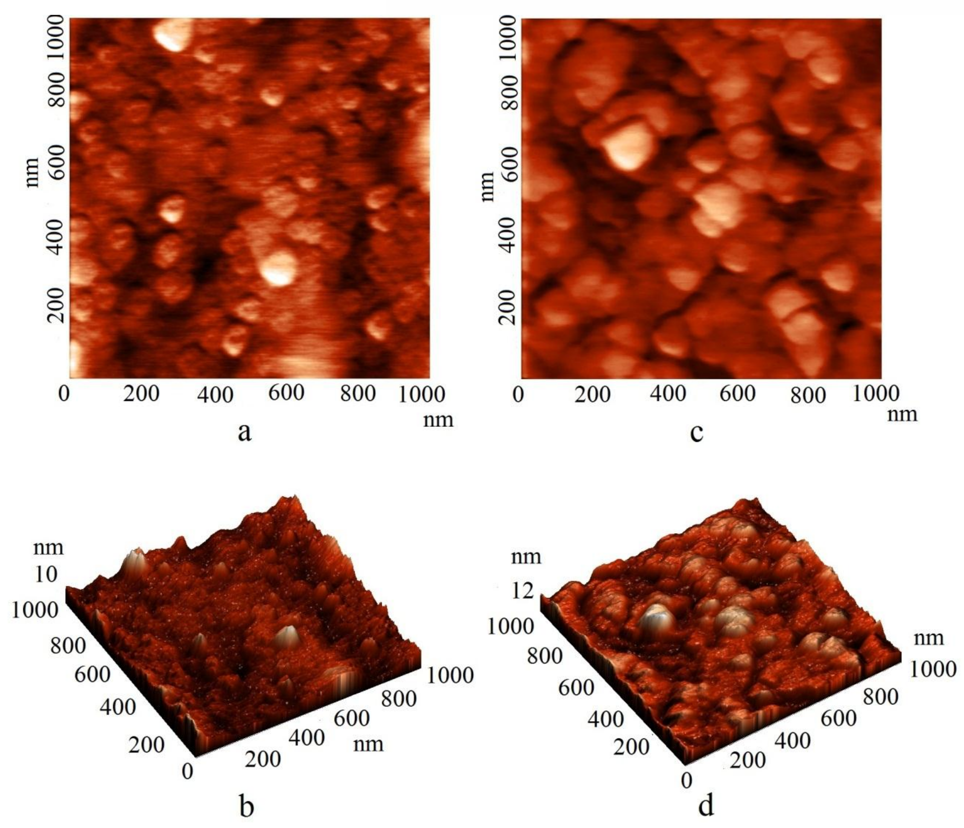

Fig. 2. Images of the surface morphology of β-Ga_2O_3 thin film obtained by RF sputtering: (*a*, *b*) without thermal treatment and (*c*, *d*) after thermal treatment in an argon atmosphere. Images *a* and *c* are two-dimensional; images *b* and *d* are three-dimensional.

Investigation of the surface morphology of thin films by atomic force microscopy (AFM) shows that, during thermal treatment, the mean size of nanocrystalline grains from which form films increases. According to AFM data, it is shown that, the presence of thermal treatment in an argon atmosphere leads to an increase in the mean diameters of nanocrystalline grains from 19.6 to 67.2 nm. Based on the analysis of grain size diameter distribution results, it was found that regardless of the presence of thermal treatment, the three modal distribution, which is formed during deposition of β-Ga_2O_3 thin films by RF sputtering is observed.

Investigation of the X-ray luminescent properties of these films show that in the temperature range of 80 to 300 K in thin films of β-Ga_2O_3 there is X-ray luminescence, the maximum of the spectrum of which with increasing temperature from 80 to 300 K shifts from 395 nm to 425 nm. This spectrum in the investigated temperature range using the linear electron-phonon coupling model was simulated by the superposition of two independent Gaussians with maxima at 3.14 and 2.95 eV. The temperature dependence of the X-ray luminescence intensity of the selected bands indicates the associative nature of the centers responsible for these bands. These centers are associated with the associative acceptor complex $(V_O V_{Ga})'$. The complex consists of a doubly charged oxygen vacancy V_O^{**} and a triple-charged vacancy of V_{Ga}'''.

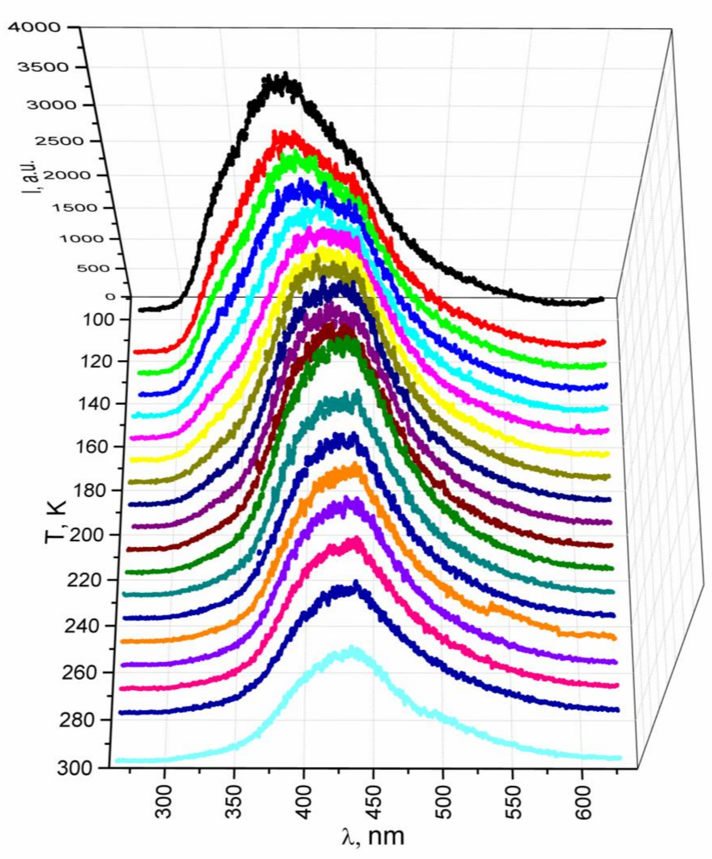

Fig.3. X-ray luminescence spectrum of β-Ga_2O_3 thin films at different temperatures

CONCLUSIONS

It has been established that, during RF ion-plasma sputtering, thin β-Ga_2O_3 films consisting of nanometer grains are formed. Investigation of the X-ray luminescent properties of these films show that in the temperature range of 80 to 300 K in thin films of β-Ga_2O_3 there is X-ray luminescence, the maximum of the spectrum of which with increasing temperature from 80 to 300 K shifts from 395 nm to 425 nm.

1. O.M. Bordun, B.O. Bordun, I.I. Medvid, I.Yo. Kukharskyy. Acta Phys. Pol. A, 133, №4 (2018) 910–913
2. T.Owen. Fundamentals of UV-visible spectroscopy. Hewlett-Packard GmbH, Waldronn, Germanny (1996)
3. O.M. Bordun, B.O. Bordun, , I.Yo. Kukharskyy I.I. Medvid Journal of Applied Spectroscopy., 84, №1 (2017) 46-51
4. W. L. Wanmaker, J. W. ter Vrugt. J. Electrochem. Soc. 116, №6 (1969) 871–872
5. C. V. Thompson, Sol. State Phys., 55: 270 (2001).