

Luminescent and electrophysical properties of nanostructured thin ZnO films

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Abstract. In article are presented the results investigation of the luminescent properties of thin ZnO films. Present the results of the investigation of the I-V characteristic in a zinc oxide film obtained by a reactive ion-plasma method. Presented the parameters of electrically active traps and quantity the mobility of charge carriers in ZnO.

1. Introduction

Thin ZnO films created by the reactive ion-plasma method are related to direct-gap semiconductors having a large band gap (more than 3.3 eV). This determines a lot of interesting properties of this semiconductors material, which are widely used in solid-state devices of optoelectronics and electronics. Also, because of low optical losses in the visible spectral range, high mobility of charge carriers and the possibility of doping, thin ZnO films are widely used as an active material for the creation of scintillation detectors, UV-photonics and transparent electronics [1].

In optoelectronics and transparent electronics are used various methods for created thin zinc oxide films: the CVD process, pulsed laser ablation of a ceramic target made from highly purified ZnO, or electron beam deposition in a pulsed mode [2]. In comparison with these methods, the method of reactive ion-plasma sputtering of a metal target makes it possible to create ZnO films with the smallest structural defects in the thin film, besides; this method allows doping of the film composition during its growth [3, 4]. The purpose of this work was investigation the luminescent properties of thin ZnO films and investigation the processes of charge carrier transport in ZnO films obtained by reactive ion-plasma sputtering.

2. Method preparation of thin films samples

The process of ion-plasma sputtering of the metallic target was carried out using a magnetron operating in a constant current mode. Process the synthesis of a zinc oxide film occurred in a gas atmosphere consisting of 30 % oxygen and 70 % argon. The pressure of the gas mixture under the cap of the sputtering installation did not exceed 101 Pa, and the substrate temperature did not exceed 423 K. The metal target was made from zinc grade extra clear. The substrate was making of quartz particularly transparent in the UV-range. Plates of quartz were polished in grade 12 cleanliness classes and were thickness of 2 mm.



The spraying of Al electrodes occurred on the magnetron installation. According to the data of microscopic studies, the thickness of the film ZnO was 1 μm . The thickness of film Al contact was 0.5 μm . X-ray diffraction investigation of synthesized zinc oxide films showed the presence of the hexagonal structure of ZnO films and its preferential orientation in the (001) direction. The dimensions of ZnO crystallites did not exceed 13 nm. The drawing of the investigated ZnO samples with the scheme by Al electrodes is shown in figure 1.

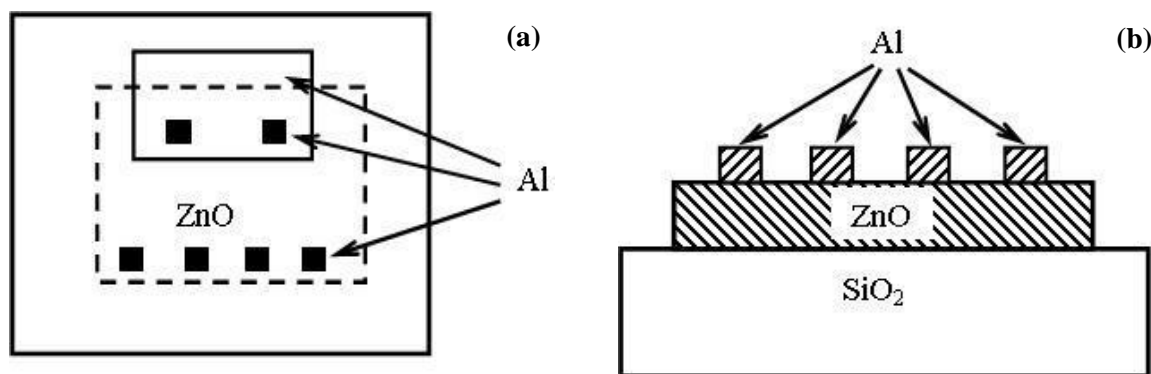


Figure 1. Appearance of the samples under study, top view (a) and side view (b).

3. Investigation of photoluminescence properties and current transport in ZnO films

Investigation of the photoluminescence spectra of ZnO films was carried out on a Perkin Elmer LM 50 fluorimeter at spectral range from 200 to 700 nm. The length of the exciting radiation was 337 nm. The measurements were carried out at a temperature of 300 K. Figure 2 shows the spectral dependence of the photoluminescence of a thin ZnO film.

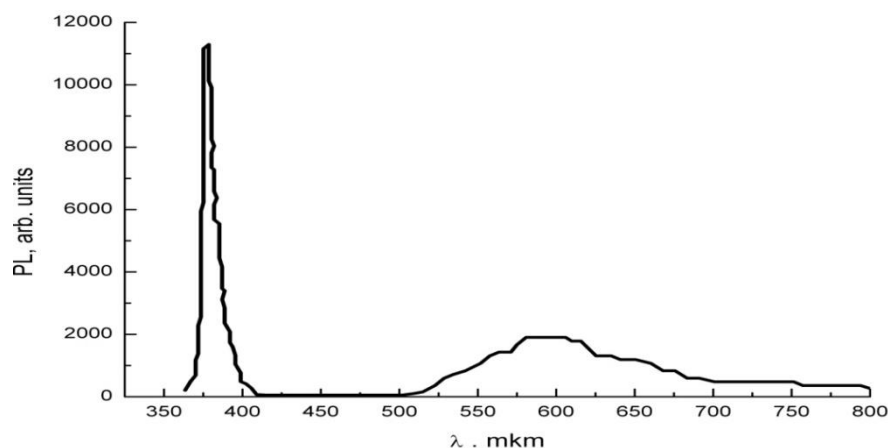


Figure 2. The photoluminescence spectrum in a ZnO film.

There are two peaks presents on the spectral dependence with maximums at 380 nm and at 600 nm. The narrow spectral peak, having a maximum at 380 nm, corresponds to the photoluminescence of excitons present in the volume of the thin ZnO film. The six fold decrease in the intensity of the broad peak relative to the narrow peak and the shift of the maximum of the spectrum from the green to the red region attest to the high structural quality of the synthesized ZnO film.

To study the current transport processes occurring in thin films ZnO, measurements of the current-voltage characteristics (CVC) at 300 K were carried out in the dark. The CVC characteristics are shown in figure 3. The CVC studies were carried out on an automated installation consisting of a programmable source voltage and a picoammeter 6485. Al contacts sputtered on a polished quartz substrate under a ZnO layer and on a zinc oxide layer are ohmic contacts, as evidenced by the symmetry of the CVC characteristic.

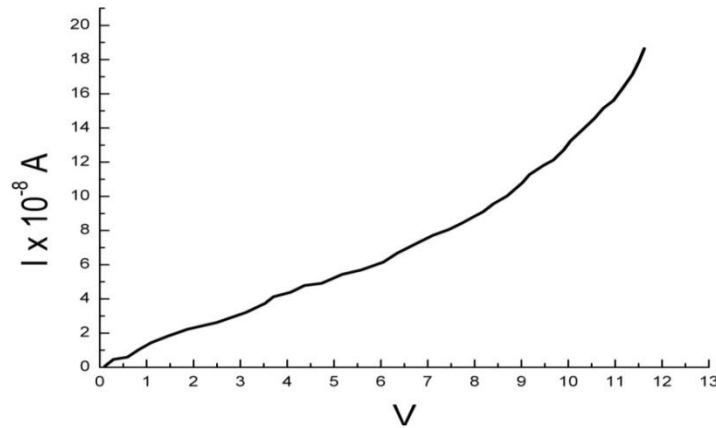


Figure 3. Volt-ampere characteristics (CVC) of the thin ZnO film.

4. Results and discussion

The processing of the CVC results with using the technique described in article [5] allows one to determine the mobility of charge carriers and the concentration of electrical activity defects.

A power-law dependence of the current is observed for the branches of the current-voltage characteristic: $I \sim U^b$. Reconstructing the CVC curve in double logarithmic coordinates, we can determine the value of the threshold voltage at which the transition to the quadratic dependence occurs current. Let us estimate the concentration n_i of small electrically active defects according to the calculated formula [5]:

$$n_i = 2.21 \times 10^{20} \times U_0, \quad (1)$$

where U_0 – the threshold voltage of the transition to the current rise of the CVC characteristic, reconstructed in double logarithmic coordinates.

The value of the effective mobility of charge carriers in the zinc oxide layer at a voltage U_0 can be estimated from the calculated formula [5]:

$$\mu_{\text{eff}} = \frac{8IL^3}{9\epsilon\epsilon_0 U_0^2}, \quad (2)$$

where U_0 – threshold voltage of the CVC characteristic; I – current value at the inflection point; L – zinc oxide film thickness.

Concentration electrically active defects n_i make up $0.24 \cdot 10^{19} \text{ cm}^{-3}$. Effective mobility of charge carriers in ZnO film make up $118 \text{ cm}^2/\text{V} \cdot \text{s}$.

5. Conclusions

Synthesis of films by a reactive ion-plasma method on pre-heated quartz substrates allows obtaining nanostructured ZnO films with the presence of a hexagonal phase of zinc oxide and structural properties equivalent to the properties of ZnO epitaxial films. The photoluminescence spectra of thin ZnO films contain two peaks: narrow with a maximum at 380 nm and a broad peak with a maximum at 600 nm. The narrow spectral peak corresponds to the photoluminescence of excitons present in the bulk of a thin ZnO film. A wide spectral peak can be caused to the photoluminescence of structural defects present in the zinc oxide film. The shortwave peak has six times large the intensity compared to the intensity of the broad spectral peak. The shift to the long-wave region of a broad photoluminescence peak can be explained by the structural perfection of the synthesized zinc oxide film. Investigation of the current-voltage characteristics of thin ZnO films made it possible to estimate the mobility of charge carriers and to estimate the concentration of electrically active defects present in the volume thin film zinc oxide.

Investigation of the spectral dependences of photoluminescence showed that the maximum of the spectral peak of excitons luminescence is near 380 nm. This makes it possible to create on the synthesized films luminescent media suitable for use in scintillation devices and for use in UV photonics structures.

Acknowledgment

The work was supported by the Russian Foundation for Basic Research: № 16-07-00237.

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