THE CONDUCTIVITY MECHANISMS OF ZnO THIN FILMS STRUCTURED USING POLYVINYL ALCOHOL

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Introduction

The electrical conductivity changes of zinc oxide thin films in an environment, with hydrogen and oxygen containing gases, together with their chemical resistance, non-toxicity and low cost fabrication make them a promising material for the active gas sensors elements [1-4]. The mechanisms of gas sensitivity of a material are usually associated with its electrical conductivity special feature. In this work, we studied The mechanisms of electrical conductivity in a dry air atmosphere of thin ZnO films obtained from a zinc acetate solution with the addition of polyvinyl alcohol were studied.

Methods

ZnO films were obtained by immersing glass samples in an aqueous solution of zinc acetate with the addition of a 1% of polyvinyl alcohol (C2H4O) solution in equal proportions. Subsequently, the prepared films were annealed in air at 400 °C for 40-50 min.

For electrical characterization and clarification of the electrical conductivity mechanism in air, before and after several heatings to 440 K, the resistance, current-voltage characteristics, and dark current temperature dependences were measured.

Results

The band gap of the obtained thin films was 3.15-3.2 eV, which slightly exceeds such value for bulk material and indicates the nanoscale of the film crystallites formed in the bounding volumes of the PVA polymer matrix.

The electrical conductivity of ZnO films and the type of their current–voltage characteristics turned out to be significantly dependent on external conditions. The I–V characteristic of the ZnO film at room temperature tends to an exponential dependency, specific for the potential barriers influence on conductivity.

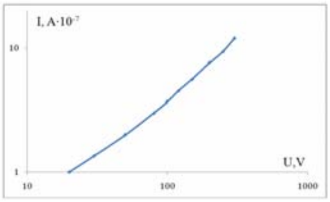

Fig.1 Volt-Current dependence of ZnO film in the open air (T=293K)

The cycles of heating-cooling of the films in the interval (440-293) K were fulfilled in vacuum and in air.

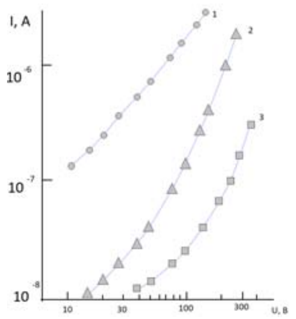

Fig.2 I - V characteristics of a ZnO film in dry air (T = 293 K): 1 - immediately after heating the film to 440 K and cooling in vacuum to 293 K, 2 - after several measurement cycles in air, 3 - after heating to 440 K and cooling to 293 K in air.

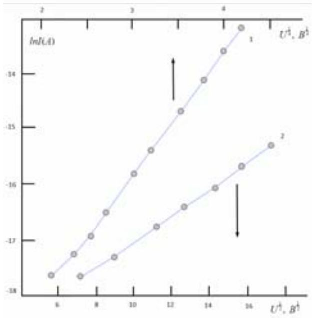

Fig. 3. I - V characteristics of the ZnO film in special coordinates (T = 293K): 1 - after several cycles of measurements in air (corresponds to curve 2 in Fig. 2), 2 - after heating to 440 K and cooling to 293 K in air (corresponds to curve 3 in Fig. 2).

The conductivity activation energy (0.43 eV) obtained from the CTD is consistent with the calculated height of intercrystalline potential barriers (0.45 eV) and is explained by the model of an inhomogeneous semiconductor with large-scale potential fluctuations.

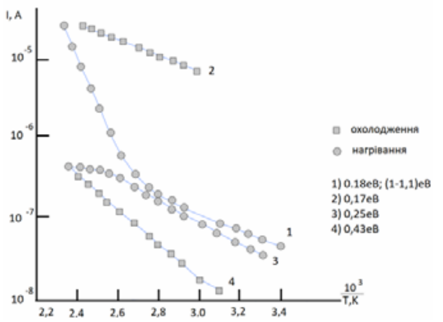

Fig. 4. Temperature dependences of the current in the ZnO film in vacuum (1.2) and in air (3.4). U = 50 V

Conclusions

The established character of current transport in vacuum is caused by the above-barrier Schottky emission over small intercrystalline potential barriers. Heating/cooling in the air atmosphere leads to the superlinearity of the current–voltage characteristic specific for the above-barrier Schottky emission over “thick” intercrystalline barriers.

The established barrier effects in the films’ conductivity are explained by the adsorption and subsequent diffusion of oxygen, which, capturing the conduction electrons, not only increases the surface locking curving of energy bands, but also increases the intercrystalline potential barriers height for electrons.

References

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