

Structural and electrical properties of $(\text{ZnO})_k\text{Me}_2\text{O}_3$ (Me = Al, Ga, In) ceramics activated with halogens and zinc

G.V. Colibaba^{1*}, M.A. Koltsov², D. Rusnac¹, D. Untila², N. Spalatu²

¹Moldova State University, Institute of Applied Physics, Republic of Moldova;

²Tallinn University of Technology, Department of Materials and Environmental Technology, Estonia

***Email:** Gkolibaba@yandex.ru

Abstract: High-power magnetron sputtering is one of the most reproducible methods for the deposition of ZnO thin films with high structural perfection and low contamination level. The highest film quality requires homogeneous, highly thermally conductive ceramic targets, sintered at extremely high temperatures (1500 °C). Recently, a new low-temperature method for sintering ZnO based on chemical vapor transport (CVT) has been proposed [1, 2]. The sputtering of CVT ZnO targets makes it possible to double the conductivity and structural quality of films [3]. ZnO-based alloys are of considerable practical interest due to the variation of chemical, optical and electrical properties. The aim of the present work is to investigate the structural and electrical properties of $(\text{ZnO})_k\text{Me}_2\text{O}_3$ (Me = Al, Ga, In) ceramic alloys and to demonstrate the advantages of CVT based on various halides and Zn excess.

The properties of $(\text{ZnO})_k\text{Al}_2\text{O}_3$ alloys with Al concentrations of 2–67 at% have been investigated. The use of HCl-based CVT allows the solubility rate of Al_2O_3 in ZnO to be tripled at 1050 °C. The possibility of increasing ceramics conductivity by four orders of magnitude via Cl activation and Zn excess is demonstrated. Only two phases are observed: ZnO: Al and ZnAl_2O_4 . The solubility limit of Al is 2 at%. $(\text{ZnO})_k\text{Ga}_2\text{O}_3$ alloys with Ga concentrations from 2 to 67 at%, activated in HX, HX + H_2 , and HX + H_2 + C media (X = Cl, Br, I), have been obtained. The use of HCl-based CVT allows increasing the solubility rate of Ga_2O_3 in ZnO by 10 times at 1050 °C. The kinetics of HBr- and HI-based CVT are less intense. The conductivity of ceramics can be increased by a factor of 10^3 via stoichiometric deviation. Layered oxides of the $\text{Zn}_k\text{Ga}_2\text{O}_{k+3}$ type are not observed. The solubility limit of Ga is about 6 at%. The optimal range of stoichiometric deviation of ceramics has been determined; an excess of Zn beyond optimum promotes the formation of ZnGa_2O_4 spinel. Variation in the alloy composition k allows the band-gap and resistivity to be tuned over 3.3–4.4 eV and 10^{-3} – $10^4 \Omega\cdot\text{cm}$, respectively.

The structural and conducting properties of $(\text{ZnO})_k\text{In}_2\text{O}_3$ alloys with In concentrations from 2 to 22 at% have been investigated as well. The major part of In impurity forms layered oxides of the $\text{Zn}_k\text{In}_2\text{O}_{k+3}$ type, the most stable of which at 950 °C is $\text{Zn}_7\text{In}_2\text{O}_{10}$. The conductivity of ceramics can be increased by four orders of magnitude via halogen activation and stoichiometric deviation. The optimal range of stoichiometric deviation of ceramics has been determined; an excessive Zn content leads to large losses of In in the form of volatile InX halides.

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References:

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