

Tailoring the surface topology, wettability, and optical bandgap of metal oxide films by means of tuning their compositions and technological conditions in spray pyrolysis

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Abstract: Oxide thin films with large band gaps offer a wealth of potential applications across various technological fields in energy, electronics, optoelectronics, and environmental technologies, due to their combination of unique optical and electronic properties [1,2]. Microfluidics is another application field of metal oxide films, when their wettability can be controlled [8].

Metal oxide thin films are prepared by a variety of technological methods, such as chemical vapor deposition (CVD), magnetron sputtering, atomic layer deposition (ALD), pulsed laser deposition (PLD), spray pyrolysis and many other techniques. Among these techniques, spray pyrolysis has a series of advantages, such as simplicity and cost-effectiveness, versatility, suitability for different substrates, low processing temperatures, ability to efficiently control the film properties.

A comprehensive analysis of relationships between topological features, wettability properties and optical bandgaps on a wide variety of metal oxide semiconductor films prepared by spray pyrolysis on various substrates is performed in this report, which is of especial importance for microfluidic and optoelectronic applications. Several classes of metal oxide materials are in the focus of research, such as $\text{Zn}_{1-x}\text{Mg}_x\text{O}$, $(\text{In}_{1-x}\text{Ga}_x)_2\text{O}_3$, $(\text{In}_{1-x}\text{Al}_x)_2\text{O}_3$, $(\text{Ga}_2\text{O}_3)_{1-x}(\text{SnO}_2)_x$, and $(\text{In}_2\text{O}_3)_{1-x}(\text{MgO})_x$.

X-ray diffraction (XRD) in combination of energy dispersive x-ray (EDX) analysis demonstrated that the films in these material systems can be produced in the form of solid solutions (alloys) in a certain range of x-value compositions, while they represent nanostructured composite films with a controlled ratio of composite phases, determined by the precursor solutions used. The 3D topography of the prepared films investigated by atomic force microscopy (AFM) image processing was explained in terms of formation of solid solutions and nanocomposite films, composed of nanocrystals with different crystal structure. Particularly, Mg ions are incorporated into the wurtzite $\text{Zn}_{1-x}\text{Mg}_x\text{O}$ structure only at low values of x, while a mixture of wurtzite type ZnMgO and cubic type MgO nanocrystallites is produced at high value of x, which resulted in increasing the roughness of films with increasing the x-value. $(\text{In}_{1-x}\text{Ga}_x)_2\text{O}_3$ films were found to be composed of In_2O_3 nanocrystallites with the *bixbyite* body-centered cubic structure and Ga_2O_3 nanocrystallites with the monoclinic crystal structure. In contrast to the $(\text{In}_{1-x}\text{Ga}_x)_2\text{O}_3$ system consisting of only two phases, a third *MgIn₂O₄ phase with spinel structures* was found in addition to the In_2O_3 and MgO phases in films of the $(\text{In}_2\text{O}_3)_{1-x}(\text{MgO})_x$ system.

The wetting properties and the optical bandgaps of the produced films have been explained in terms of a combined effect of the surface roughness, nature of chemical bonds, nature of the substrate, conditions of thermal treatment and other technological parameters, in the investigated material systems.

Keywords: Metal oxide films, Solid solutions, Composites, Roughness, Wettability, Optical bandgap.

References

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