

Special Issue “1D, 2D, and 3D ZnO: Synthesis, Characterization, and Applications”

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1. Introduction

Zinc Oxide (ZnO) is a well-known II–VI semiconductor with a direct bandgap around 3.37 eV and large exciton binding energy (60 meV) at room temperature [1]. Nowadays, ZnO and ZnO-based materials are recognized in a wide spectrum of applications, which makes them unique materials because of the combination of multiple functional properties including electronics and human healthcare. Multiple research projects and the discovery of new applications for materials based on ZnO made this semiconductor the focus of important high-technology advances, such as optoelectronic devices, particularly those based on ZnO nanostructured for light emitters [2,3], ZnO thin-film transistors under ultraviolet irradiation [4], broadband photo-absorption architectures from UV–IR [5], gas sensors [6], acoustic wave devices, solar cells, transparent electronic and flat panel displays [7–9], photocatalytic applications [10], etc. However, the large range of industrial uses is strongly dependent on the experimental technique, parameters, preparation, post-treatment of the grown samples, etc. Optimizing these factors is the greatest challenge in obtaining these materials’ benefits. In this Special Issue, we focus our attention on this material and materials based particularly in its synthesis, properties, and applications as thin films, as well as on nanoscale zinc oxide systems, given their increasing importance in a great variety of fields.

2. The Special Issue “1D, 2D, and 3D ZnO: Synthesis, Characterization, and Applications”

The Special Issue “1D, 2D, and 3D ZnO: Synthesis, Characterization, and Applications” contains five research articles. The individual work is briefed below:

In “Low-Temperature Vapor-Solid Growth of ZnO Nanowhiskers for Electron Field Emission” by C. Hedrich et al., the authors present the effect of the process parameters, such as growth temperature, substrate position, and size, gas flow, used amount of zinc precursor, growth time, and substrate type on the morphology of ZnO nanowhiskers grown by low-temperature vapor–solid mechanism utilizing zinc acetylacetonate hydrate as a zinc precursor. The parameters were optimized to receive nanowhiskers with the nearest distribution in dimensions and aspect ratios as high as possible for using them for electron field emission applications [11].

C. Morales et al., in “Re-Oxidation of ZnO Clusters Grown on HOPG”, studies the chemical interaction between ZnO and highly oriented pyrolytic graphite for as-grown and thermally treated samples. In situ X-ray photoelectron spectroscopy and ex situ Raman spectroscopy confirm that graphite is affected by these processes, becoming oxidized and defective only in the presence of ZnO clusters that become recrystallized upon thermal re-oxidation processes performed at 400 °C. By comparing these results with other identical experiments performed with ZnO clusters grown on graphene and even with CoO clusters grown on graphite, the present results show how the interaction of the ZnO clusters with



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graphitic substrates depends on two factors—firstly, the model of growth and corresponding morphology, and secondly, the reactivity of the graphitic substrates, either graphene or graphite. The results presented here will help us understand the fundamental interactions in ZnO/graphitic heterostructures and to define their operating limits [12].

In “Self-Organized In-Depth Gradients in Highly Ti-Doped ZnO Films: Thermal Versus MW Plasma Annealing” by R. Ramadan et al., authors demonstrate that the surfaces of sol-gel processed Ti-rich ZnO thin films exhibit from their casting an enrichment in Ti. Spin casting from sols containing 6.22 wt.% Ti with respect to Zn led to overall Ti contents higher than 14 wt.%. This phenomenon can be attributed to the fastest condensation catalysis of the Ti precursor with respect to the Zn precursor. Not only were the films enriched, but also there was an in-depth gradient with an acute surface enrichment in Ti that decreased smoothly to reach a stable composition after a few tens of nm. The postprocessing techniques determined also different optical, electrical, and wetting properties. The MwPA films exhibited lower surface resistivity (and slightly higher capacitance) in spite of a remarkable optical bandgap (comparable to that of ZnO nanostructures) and behaved as highly hydrophilic surfaces. These results are extremely attractive for the implementation of the thin films in photovoltaic devices (in view of the promising low resistivity) and for photocatalytic processes (featuring wide optical bandgap and hydrophilic surfaces), ensuring high molecular affinity for the degradation of hydrophilic (polar) water pollutants. This novel approach proposed to exacerbate the interface stoichiometric gradients self-generated during sol-gel processing may be attractive for a wide range of ternary ceramic thin films (i.e., composed of transition metal oxides such as Ti, Zr, Va, Ta, Sn, etc.) where surface properties may be optimized with respect to interface properties [13].

In “Fabrication of Zinc Oxide and Nanostructured Porous Silicon Composite Micropatterns on Silicon” by R. Ramadan et al., the luminescent properties and morphology of ZnO thin films and nanostructured porous silicon (PSi) layers were analyzed by a combination of photoluminescence (PL) spectroscopy, scanning electron microscopy (SEM), and energy-dispersive X-ray (EDX) analysis. The experimental PL spectra show blue broadband emissions for ZnO thin films centered at 2.63 eV and a red band centered at 1.71 eV for PSi layers. The origin of the blue light emissions from ZnO thin films is associated with the presence of oxygen vacancies in these films. Moreover, the broad shape of the band, as well as the shift in the bandgap value, might be related to several factors, including inhomogeneous thin layer thickness, composition, nanocrystal size and shape, and variation in the stoichiometry of the layers. The manifestation of quantum confinement effects and the presence of radiative defects in the PSi layers are, in general, the reason for the red emissions from those layers. Moreover, the emission peaks from the PSi layers can be tuned by changing their fabrication conditions. Furthermore, hexagonal ZnO+PSi micropatterns were fabricated on heavily doped crystalline silicon substrates. These structures are expected to reduce the electrical losses associated with the PSi areas since ZnO is in contact with the highly doped Si surface. Additionally, they enhance the PL emissions by combining blue emissions from the ZnO areas with red emissions from the PSi nanostructures. The authors show that the composite ZnO+PSi micropatterns could be of interest for photoemission applications and hence desirable for many solid-state lighting applications, such as light-emitting diodes [14].

Finally, in “ZnOTe Compounds Grown by DC-Magnetron Co-Sputtering” by O. Sánchez et al., ternary compound ZnOTe in thin films form were grown using DC magnetron co-sputtering technique starting from highly pure independent zinc and tellurium targets in a controlled oxygen/argon atmosphere at room temperature. The technique used in conjunction with the experimental configuration for obtaining this type of compound and the detailed analysis of its structure and optical properties are part of this work’s novelty. The use of constant power on the Zn cathode and two different powers on the Te cathode as well as the variation of the distance between the latter and the substrate allowed us to study the influence of these parameters on the structure, composition, and macroscopic properties of the samples. Under these conditions, the most important effect was the

variable amount of Te incorporated into each sample. In that sense, different chemical compositions for each, including a homogeneous distribution of Te along their thicknesses and a variable amount of excess oxygen, were determined by RBS experiments. On the other hand, the formation of the ZnO hexagonal phase in all samples was identified by mean XRD spectra. ZnO bandgap energy obtained from PL spectra was estimated at 3.26 eV, well in agreement with previously obtained values. Other highlighted results include the relative loss of ZnO crystalline quality for the largest Te content, and in general, a bandgap energy shift toward the lowest energies, which may account for the incorporation of Te into the ZnO crystalline network. Nevertheless, in the samples with the lowest Te content, the bandgap energy values were 3.32 and 3.3 eV, respectively, almost coincident with the standard value reported (3.36 eV) for the w-ZnO phase at room temperature. This suggests the possibility of certain improvements in ZnO crystallinity when moderate quantities of Te are incorporated in the ZnO network. The authors expect there exists a critical value of the Te concentration that helps to obtain optimal effects in the formation of interbands in the BG that are of great interest for solar cell efficiency [15].

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