

**5<sup>th</sup> Wide Bandgap Materials**  
– **progress in synthesis and applications**  
and  
**7<sup>th</sup> Diamond & Related Films**  
jointly with  
**2<sup>nd</sup> International Workshop on Science**  
**and Applications of Nanoscale Diamond Materials**

Integration and functionalisation of wide bandgap materials:  
fundamentals, device technology and applications for energy saving,  
environment friendly electronics and medical systems



**ABSTRACT PROCEEDINGS**



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## Optical Study of Al<sup>3+</sup> Ion-doped ZnO Nanofilms

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**Summary:** ZnO thin films deposited by nebulized spray pyrolysis have been simulated from transmittance spectra and their optical properties have been determined. Surface and structural properties have been studied by XRD, SEM and AFM measurements. The transmittance spectrum from UV-VIS-NIR spectrophotometer in 200 to 1100 nm wavelength range was used to retrieve the optical parameters and thickness for all films. XRD measurements confirmed mostly ZnO content of the thin films under consideration. The result of SEM analysis reveals that the deposits have a rather homogeneous nature with uniform ZnO nanocrystallites well below 100 nm. The SEM analysis has further been verified by AFM measurements.

**Keywords:** ZnO films, spray pyrolysis, characterization and simulation

### Introduction

Zinc oxide thin films continue to attract wide spread scientific attention because of its low toxicity as opposed to indium-coated tin oxide film. They can be used in fabricating a variety of devices including flat panel color displays [1] and electrode materials in LED and photovoltaic cells [2], gas sensors [3] and varistors [4]. Due to its high conductivity, suitable work function and transparency in the visible spectral range [5], tin-doped indium oxides (ITO) are the most widely used TCO films. The problem is that indium is a relatively scarce element in the earth's crust, which implies that ITO is a costly material. The other drawback of ITO films is its chemical instability in a reducing environment: the indium of ITO layer can simply diffuse into the organic materials, leading to the degradation of LED performance. Besides, the toxic nature of indium could be hazardous to both human health and environment. These factors entail that LED industry is in a need for a better electrode material with improved device performance and lower production cost. ZnO films are more stable in reducing atmosphere, more abundant and less expensive as opposed to ITO. In the past, Al and Ga ion-doped transparent conductive zinc oxide films have been extensively examined as an alternative to ITO films [6]. Due to a wide band gap (3.37 eV) and an exciton binding energy of 60 meV, ZnO has unique electrical and optical properties, such as low dielectric constant, high chemical stability, and good photoelectric and piezoelectric behaviors. ZnO has a number of other advantages comparing to those in other wide-band semiconductors such as GaN and SiC. These include higher quantum efficiency, greater resistance to high-energy radiation, and the possibility of wet chemical etching. However, despite much progress in ZnO technology in recent years, high-quality *p*-type ZnO and therefore, the manufacture of ZnO homojunctions, continues to be problematic. The properties of ZnO might be best exploited by constructing heterojunctions with ZnO active regions; in this way, the emission properties of an LED can still be determined by the advantageous properties of ZnO.

## Results

ZnO itself suffers from the lack of a reproducible, high-quality, *p*-type epitaxial growth technology. Although much progress has been made in this area, the fabrication of effective ZnO-based devices is still a challenging work. Currently, however, several groups have demonstrated good-quality *p*-type GaN (*p* GaN) and used these in fabricating LED thin film junction consisting of *n* ZnO with *p* GaN in combination [7]. The advantage of ZnO/GaN LEDs is that these heterostructure-based devices exhibit improved current confinement compared to homojunctions, which leads to higher recombination and improved device efficiency. The present work aims at casting Al<sup>3+</sup>-doped zinc oxide films of improved quality by a spray (water solutions of respected salts) coating method. The interest of using this technique in fabricating thin films springs from a number of practical considerations. These include its simplicity and room temperature-based solution chemistry, which helps homogenous mixing of chemicals, yielding homogeneous distribution of dopant ion within the host matrix. Secondly, since it does not require vacuum it is very economic as opposed to CVD method and rf sputtering techniques. Also, it can be adapted for making large-area films suitable for a display technology.

The transmittance spectra (UV-VIS-NIR spectrophotometer) in 200 to 1100 nm wavelength range were used to retrieve the basic optical parameters: optical band gap, refractive index, dielectric constant, packing density, dissipation factor, optical conductivity, relaxation time, carrier concentration to effective mass ratio, plasma frequency and thickness for all films. Instead of entire Swanepoel algorithm, the minimization approach, which is appropriate to achieve an absolute optical properties and thickness as well, was obtained from the transmittance spectra. The analysis of the optical data revealed that the percentage of transmittance decreases gradually and there is widening of optical band-gap accordingly on increasing the concentration of Al<sup>3+</sup> inside the ZnO. However, the other optical parameters showed that only limited concentration of Al<sup>3+</sup> ion could be adjusted inside the ZnO lattice.

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