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# Influence of defect luminescence and structural modification on the electrical properties of Magnesium Doped Zinc Oxide Nanorods

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Magnesium doped zinc oxide nanorod arrays on zinc oxide seed layers were grown by hydrothermal method. X-ray diffraction (XRD) patterns revealed the growth orientation along the preferential (002) direction. The hexagonal morphology was revealed from the field emission scanning electron microscope (FESEM) images. The elemental composition of the samples was confirmed by energy dispersive x-ray analysis spectra (EDS) and mapping dots. Carrier concentration, resistivity and mobility of the samples were obtained by Hall measurements. *I-V* characteristic curve confirmed the increase in resistivity upon doping. Photoluminescence (PL) spectra exposed the characteristic of UV emission along with defect mediated visible emission in the samples. Electrochemical impedance spectroscopy and cyclic voltammetry were undertaken to study the charge transport property. Owing to the change in the structural parameters and defect concentration the electrical properties of the doped samples were altered.



## 1. Introduction

One of the nifty materials in the family of semiconductors is the Zinc oxide (ZnO) which has a direct bandgap (3.37 *eV*) and large exciton binding energy (60 *meV*). Owing to its versatility, ZnO is finding its application in the fields of electronics [1], optoelectronics [2], sensing materials [3], and being used as gas sensors [4], photo diodes [5], light emitting diodes [6], photonic crystals [7], photo detectors [8] etc. As a result of its significant fundamental physical properties and applications to several nanostructured devices, ZnO has a multitude of interest in its low dimensional structures like thin film, nanorod, nano wire, nanoparticle, nanotube etc. [9–13]. To fabricate the above said structures various methods such as thermal evaporation, chemical vapour deposition, metal organic chemical vapour deposition, hydrothermal technique were used [14–17]. One

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dimensional ZnO are the reliable building blocks to manufacture nanoscale optoelectronic, photonic devices and circuits [18–20].

The structural, optical and electrical properties of ZnO can be tuned by doping with various elements in order to make use of ZnO in the above said device applications. Some of the doping elements investigated were Al, Ag, La, Na, Li, In, Ca, Y etc. [21–28]. One of the frequently doped materials in ZnO is Mg. Its structural, optical, magnetic, dielectric [29–34] properties were already undertaken. Sanghyun Ju et al. [35] discussed the application of MgZnO multiple nanorods as n-type FET. MgZnO nanorods were also used as deep UV photodetectors [36–39]. Mg doped ZnO grown by spray [40] and sol-gel [41] method reveal the decrease in electrical properties while increasing the Mg dopant concentration. But none of them gave a conclusive evidence of its electrical properties. It is important to uncover the cause for this variation so as to tailor them efficiently for a specific application.

In our present study, we emphasize on how the electrical properties are varying upon changes in structure and defect concentration in MgZnO nanorods grown by the mild mean hydrothermal technique.

## 2. Materials and methods

Soda lime glasses were used as substrates. At first ZnO seed layers were grown on the glass substrates by sol-gel spin coating method. The fabrication of ZnO seed layers was given elsewhere [42,43]. ZnO nanorods were grown on these seed layers by hydrothermal method. The precursors for preparing nanorod were zinc nitrate hexahydrate ($Zn(NO_3)_2 \cdot 6H_2O$), hexamethylene tetramine (HMT, $C_6H_{12}N_4$) and Magnesium nitrate hexahdrate ($Mg(NO_3)_2 \cdot 6H_2O$). All precursors were bought from Sigma Aldrich and used without further purification. Magnesium was doped at different percentages such as 0 mol%, 5 mol%, 10 mol% and 15 mol% in the milieu of ZnO. The procedure to prepare the nanorod was elaborately given in our previous work [44]. The samples were characterized by PANalytical X'Pert-PRO x-ray diffractometer with $CuK\alpha_1$ (1.5406 Å) monochromatic radiation to get the structural insights. Using field emission scanning electron microscope (Zeiss Auriga 39-16) the surface morphology and the elemental analyses from the Energy Dispersive X-ray Spectra and mapping dots were obtained. Hall measurements were done using Ecopia HMS −5000 instrument. *I-V* characteristics were studied at room temperature using Keithley 2450 sourcemeter. The photoluminescence measurements were performed at room temperature using Jobin–Yvon LabRAM HR 800UV micro-Raman system with 325 nm line of a He–Cd laser as excitation source. Impedance spectroscopy and cyclic voltammetry have been performed using CHI660C electrochemical workstation.

## 3. Results and discussion

The XRD patterns of undoped, 5 mol%, 10 mol% and 15 mol% Mg doped ZnO nanorods were shown in Fig. 1. The three major peaks appeared in the XRD patterns which belong to the (100), (002) and (101) directions of ZnO hexagonal wurtzite structure

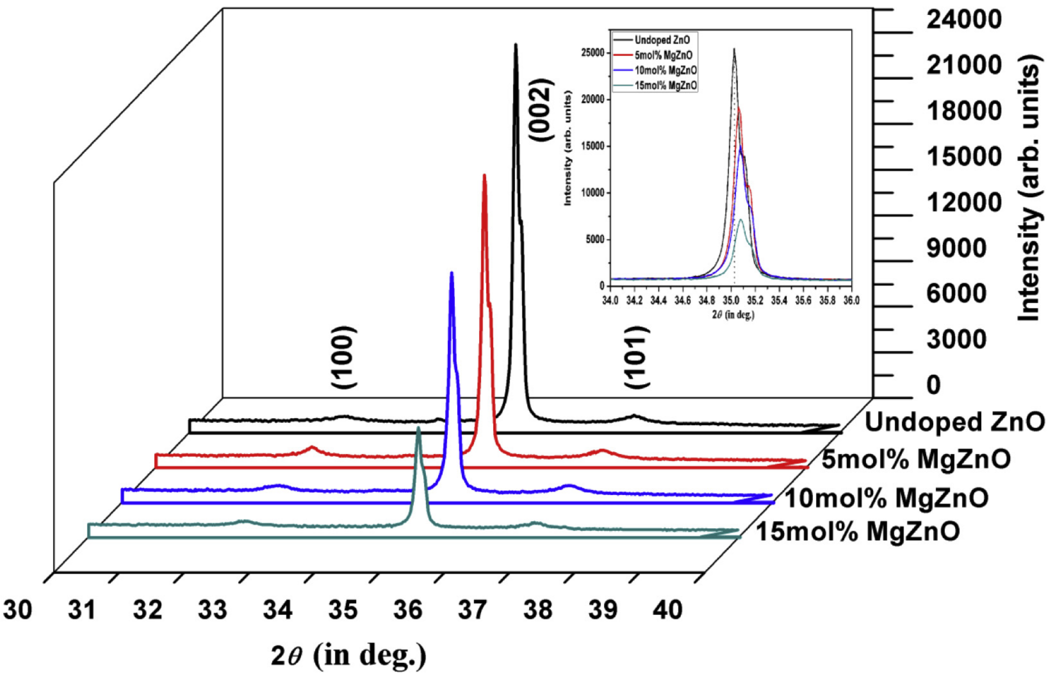


**Fig. 1.** XRD patterns with (100), (002) and (101) peaks taken within the range 30°–40° Inset indicates the (002) peak shift.