Studies of Optical Properties of RF Magnetron Sputtered Deposited Zinc Oxide Films

S. K. Nandi

1 Introduction

Zinc oxide (ZnO) is of great interest as a suitable material for high temperature, high power electronic devices either as the active material or as a suitable substrate for epitaxial growth of group III-nitride compounds. With its large, direct band gap $\approx 3{\cdot}4$ eV, a low-power threshold (~160 μJ cm^{-2}) for optical pumping at room temperature and wurtzite crystal structure, ZnO is similar to GaN. Due to its relatively close match in lattice constants, it may be used as a substrate for GaN and AlN epitaxy. As a consequence, there is renewed interest in the properties of ZnO relevant for microelectronic device applications. ZnO thin films have been prepared by a wide variety of techniques, including sputtering, spray-pyrolysis, and electro deposition [1] etc. In particular, the r.f. sputter method has advantages over other processes because of its simplicity [2]. We investigate the optical properties of r.f. magnetron Sputter ZnO/Si films by photoluminescence (PL) measurements, Structure and composition of the ZnO/Si films have been investigated by X-ray diffraction (XRD), atomic force microscopy (AFM), scanning electron microscopy (SEM) and X-ray photoelectron spectroscopy (XPS) for chemical composition.

2 Experiment and Results

The undoped ZnO (100 nm) thin film deposited on Si (100) at 450 °C using 13.56 MHz r.f. magnetron sputtering system with a base pressure of 1.0×10^{-6} Torr., working pressure of 1.0×10^{-2} Torr., used gas of Argon, substrate temperature of 450 °C

S. K. Nandi (✉)
Department of Physics, Rishi Bankim Chandra College, 24-Parganas (North),
Naihati 743165, West Bengal, India
e-mail: susantanandi@gmail.com

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with RF power of 100 W. In the XRD pattern (Fig. 1) a major peak of preferential orientation along (103) and minor one related to (002) of the undoped ZnO films were observed. It indicates that ZnO films are polycrystalline structures.

Figure 2 shows the atomic force micrograph of ZnO film. The scan was taken on a 5 µm × 5 µm area. The statistical information of the topography of the ZnO films as observed from the height histogram of the AFM image are: Rms surface roughness (Zrms) and average roughness (Zav) were found to be 50.9 and 30.4 Å, respectively.

A scanning electron microscopy (SEM) image of the cross-sectional view of ZnO/Si film (Fig. 3) shows columnar growth which indicates an orientation parallel c-axis (002) with thickness 100 nm.

Figure 4 shows core levels of Zn 2p of the ZnO films measured by X-ray photoelectron spectroscopy (PHI-5800). The as-grown ZnO thin film of the peaks of Zn 2p are found to be at 1044·8 eV and 1021·7 eV for Zn $2p_{1/2}$ and Zn $2p_{3/2}$, respectively, with a separation of 23·1 eV between the two peaks which is due to the Zn 2p state.

To investigate the optical properties of the films, photoluminescence (PL) measurements were performed Under the 325 nm excitation, the emission PL spectra of a ZnO film at different temperatures are shown in Fig. 5. From the emission spectra,

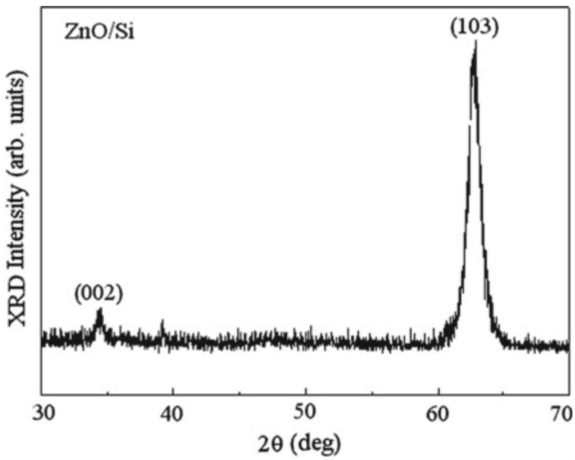

Fig. 1 X-ray diffraction pattern of the as-grown ZnO thin film at 450 °C and r.f. power 100 W

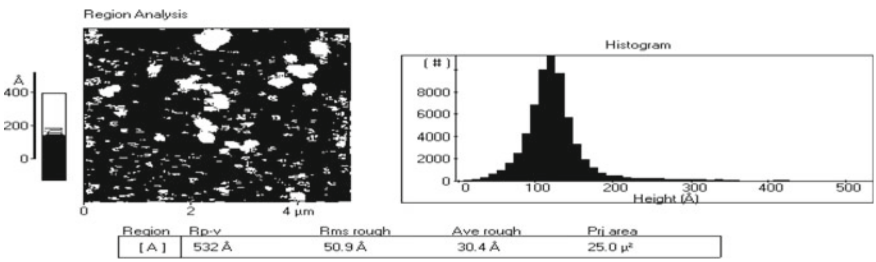

Fig. 2 Two-dimensional AFM image of ZnO Film with scan area of 5 µm × 5 µm

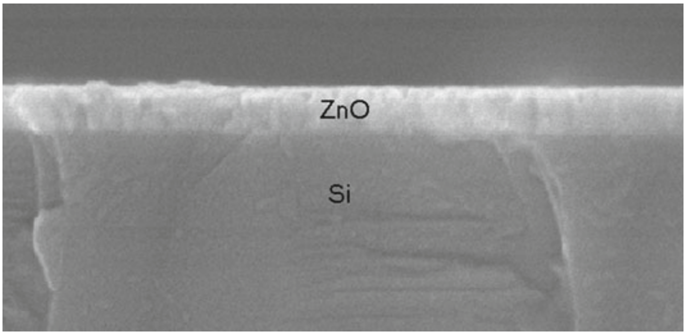

Fig. 3 SEM view of the rf sputtered ZnO film deposited on Si

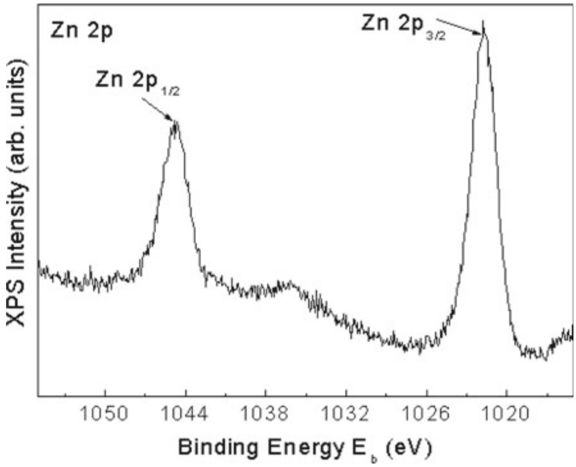

Fig. 4 XPS core-level of O 1 s and Zn 2p of the as-grown ZnO thin film

it is clearly found that there is two emission bands peaked at 380 nm (UV band) and 502 nm (green band) for all. The origin of the 380 and 502 nm bands has been ascribed to the band edge radiative recombination and intrinsic defects (mostly O vacancy) of ZnO, respectively in many reports [3]. From Fig. 6, it can be found that the intensity of 380 and 502 nm emission decreases when the sample temperature is increased. When the temperatures are higher than 100 K, the 502 nm emission disappears [4]. Meanwhile, the intensity of 380 nm increases as the sample temperature increases, until it reaches 200 K.

Afterwards, the intensity of 380 nm decreases when the sample temperature continues increasing. The integrated intensities of 380 and 502 nm emission peaks at different temperatures are shown in Fig. 6, which were calculated from the area under the curves of related emission peaks in Fig. 5.

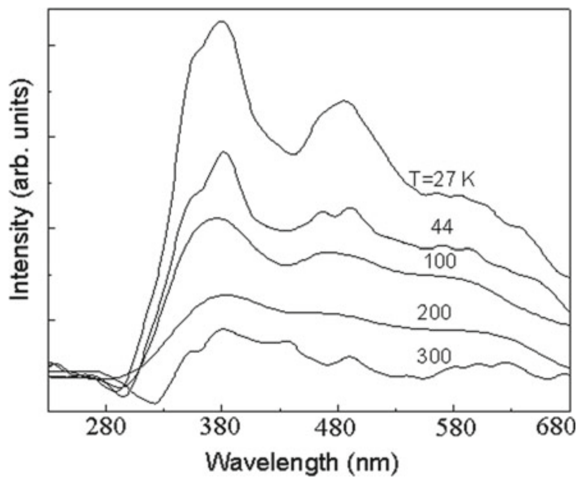

Fig. 5 Emission PL spectra of ZnO films at different temperatures

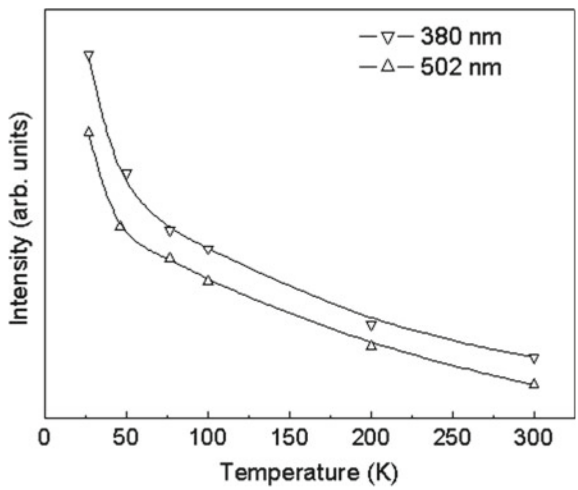

Fig. 6 Integrated intensities of 380 and 502 nm emission peaks at different temperatures

3 Conclusion

The r.f. magnetron sputter ZnO/Si films has been studied. Physical and chemical characterizations of the films were investigated using AFM, SEM, XRD and XPS. Due to its attractive properties ZnO films may have attracted much interest of potential commercial application in Photo voltaic Solar cell and optoelectronic devices, such as light-emitting diodes, laser diodes and UV photo detectors.

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