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Synthesis and Characterisation of Nanocrystalline ZnO - Core Shell Thin Films

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Abstract: Nanocrystalline zinc oxide (ZnO) core shell thin films comprising of zinc oxide/manganese oxide (ZnO/MnO), and zinc oxide/cadmium oxide (ZnO/CdO) thin films were successfully grown using the solution growth technique. The compositional, structural and optical properties of the films were investigated. Rutherford Back Scattering (RBS) techniques were employed to study the composition of the core-shell thin films. The structural characterisation was done using X-ray diffractometry (XRD). Optical spectroscopy was used to investigate the transmittance, absorbance and reflectance versus wavelength measurement and hence deduce some important optical constants. The results show that the refractive index was in the range 1.23 – 1.35. The energy band gap was found to be direct and ≤ 3.3 eV, with higher values obtained for the zinc oxide/cadmium oxide core shell thin films.

Keywords: Nanocrystalline, core-shell, refractive index, energy bandgap

INTRODUCTION

The development and applications of core-shell thin films in various optoelectronic, electronics, superconductors, and in nanotechnology has received considerable attention recently. Core-shell thin films of metals, transition metals, and semiconductors have been reported to exhibit excellent properties for application in various devices. In the literature, application of core-shell thin films in superconductors, permanent magnets, optoelectronics and in the electronic industry has been established[1-9]. In this communication, the potentials of ZnO-core shell thin films for applications in the optoelectronic, electronic, and solar thermal devices has been established.

EXPERIMENTAL

The initial step in the experimental set-up was to clean the soda-lime glasses used as substrate, using detergent and then degreased with acetone. The substrates were then further subjected to an ultrasonic cleaning to make the substrates completely dirt-free. A solution of ZnO was prepared by adding 60 ml of 0.l M Zinc nitrate hexahydrate $Zn[NO_3]_2.6H_2O$, and 28 ml of aqueous NH_3 together, with continuous heating and stirring. Four (4) clean glass slides, held with synthetic foam were immersed vertically into the solution. The deposition temperature and time were maintained at 333 K for 1 h in an oven after which the coated substrates were removed, rinsed with distilled water and dried in air. To obtain ZnO/MnO core/shell, the ZnO (core) film already deposited was inserted in a mixture containing 10 ml of 0.l M of $MnCl_2H_2O$, 4 ml of analytical grade of NH_3 (ammonia) and 46 ml of distilled water in 100 ml beaker respectively. The deposition was allowed for a temperature of 313 K for 2 h in an oven, after which the films were removed, rinsed with distilled water and dried in air. The structural characterisation of the films was carried out using X-ray diffractometry (XRD), compositional characterisation of the films was determined using Rutherford back scattering (RBS), while the optical properties of the films were measured at normal incident of light in the wavelength range of 200 nm to 900 nm using an Unico-UV2102PC spectrophotometer.

RESULTS AND DISCUSSION

Fig. 1 gives a typical RBS plots for the ZnO/MnO core shell thin films. The results indicate clearly that the composition of the films were relatively stoichiometric. The results of the variation of the transmittance with wavelength are shown on Fig. 2. The transmittance of the ZnO/CdO core shell films was higher while that of ZnO/MnO films was decreased. This behavior was attributed to closer lattice match in the latter compared to the former. The cut-off wavelengths of the core and ZnO/MnO films were relatively the same while that of the ZnO/CdO was about 300 nm. The values of the energy bandgap obtained in this study are in agreement with current reports in the literature[10-12].

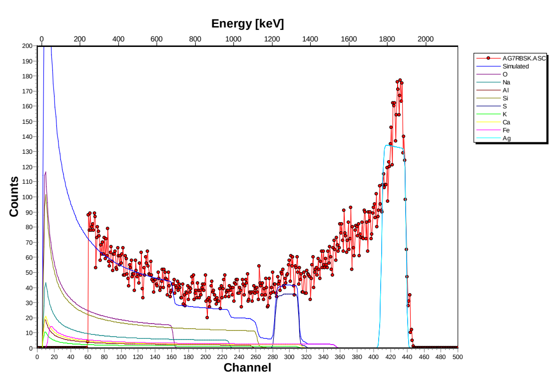

Fig. 1: Typical RBS plot of ZnO/MnO core shell thin film.

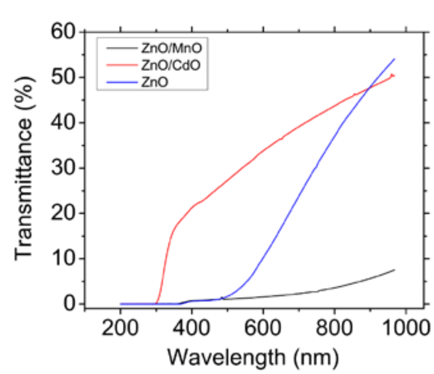

Fig. 2: Transmittance vs wavelength.

Fig. 3 gives the variation of the reflectance with wavelength range of 200 nm to 900 nm. The reflectance were higher at the onset for the core and ZnO/MnO films respectively, and then decreased with decreasing photon energies (longer wavelengths). Similar behavior has been observed by other authors [13-14]. It has been established that the refractive index, n, can be extracted from the reflectance data using the relation [15-16];

$$n = \frac{1+\sqrt{R}}{1-\sqrt{R}} \quad \text{… [1]}$$

Where n is the refractive index and R is the reflectance. The variation of the refractive index with wavelength is shown on Fig. 4. The refractive index was in the range 1.22 -1.35. These values are within the range reported by other authors in the literature[17-20].

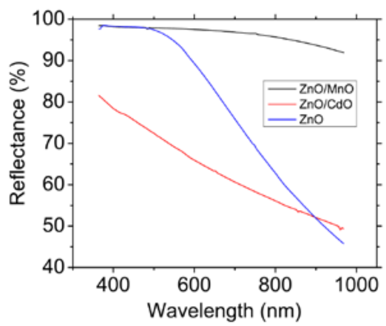

Fig. 3: Reflectance vs wavelength.

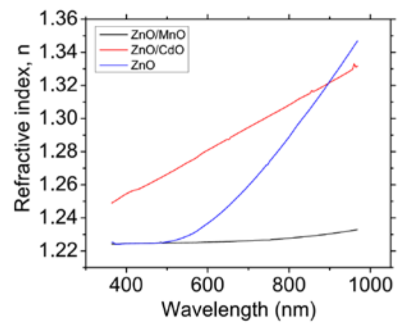

Fig. 4: Refractive index vs wavelength.

CONCLUSION

Nanocrystaline thin films of ZnO/MnO, and ZnO/CdO were successfully grown using the solution growth technique and the compositional and the optical properties are investigated and reported. The results show that the optical properties of the core (ZnO), can be tuned by the addition of the shells (MnO and CdO) to obtain more favourable properties for applications in different device designs. Results on core shell thin films (ZnO/MnO, and ZnO/CdO) are relatively very rare in the literature hence this communication will form a fundamental step for further research in core-shell thin films independent of the deposition technique.

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