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Preparation and Properties of Zinc Oxide Doped with Aluminum Nanostructured Thin Film

Ali Elkhidir Suliman and Yiwen Tang
Institute of Nano-Materials Science and Technology, Central China Normal University,
Wuhan 430079, China

Abstract: Al doped ZnO nanoparticles of about 40 nm in diameter were prepared by hydrothermal method. The phase and the morphology of the above nanoparticles were investigated by using SEM and XRD. The UV-VIS absorption and transmittance of the fabricated ZnO. Al thin films were studied; also the films electrical resistivity was measured. A low electrical resistivity of about 0.12 Ω cm and transmittance of about 85% were obtained.

Key words: Al doped ZnO nanoparticles, transmittance, thin films, solar energy materials, electrical resistivity

INTRODUCTION

Zinc oxide nano structures with excellent optoelectronic properties are used for light emitting diode (Saito *et al*., 2002; Liang *et al*., 2001). The preparation of different size and shapes often studied in previous reports (Wu and Liu, 2002). Dye-sensitized semi conducting single-crystal ZnO electrodes were studied early by Gerisscher and Tributsch (Saito *et al*., 2002; Lee *et al*., 2002). It had been found that as the effective surface area of ZnO electrode increased, the photo generated current could be considerably improved (Golego *et al*., 1998). Today the most promising dye-sensitized system is based on nano structured network of TiO_2, resulting in a very high internal area (Rensmo *et al*., 1997; Vayssiers *et al*., 2001). Photons-to-current conversion properties of a number of semi conducting nano structured materials have been reported, e.g., (TiO_2, SnO_2, Fe_2O_3, CDs and CdSC). Dye-sensitized nano structured electrodes, other than TiO_2 are much less studied. For ZnO dye-sensitized electrodes, over solar to electric energy conversion efficiencies of 0.4% (Redmond *et al*., 1994), 1.3% (Zhong *et al*., 2000), 1.5, 1.55 and 2%. Rensmo *et al*. (1997) were obtained. That thorough investigation of different materials should be worth while doing is especially true for nanostructured electrodes where, not only the inherent properties of the nanocrystallites, such as band gap position and surface structure are important; the whole system must be taken into account in optimizing a particular application. Particle size and shapes, porosity, necking structure, film thickness, distance between electrodes, electrolyte composition and illumination direction may also be factors of significant importance. It is also essential to compare different materials for a fundamental understanding of nanostructured system. ZnO thin films have attracted interest as transparent conductive coating material, because the materials consisted are cheap, readily produced for large-scale coating, allow tailoring of ultraviolet absorption, have a high stability in hydrogen plasma, have low growth temperature and also the electrical resistivity of ZnO thin films is readily modified by addition of impurity or reactive deposition. (Ghosh *et al*., 1991).

The optoelectric properties of ZnO thin films depend on the deposition and post deposition treatment conditions as these properties change significantly with the nature of chosen doing element, the adsorption of oxygen that takes place during film deposition, temperature and desorption during annealing process. (Pei *et al*., 2001). In this research ZnO doped with Al thin films were prepared, transmittance, absorption and electrical resistivity of Al doped ZnO thin film have been studied.

MATERIALS AND METHODS

Al doped ZnO powders of different Al concentrations were synthesized from $ZnCl_2$, $AlCl_3$ and $(H_2CH_2OH)_3N$ as follows, a solution of 68g ZnCl2 was added to equal amount of 1.36 g $AlCl_3$ solution, then a solution of 56.6 g $(H_2CH_2OH)_3N$ was added drop wise while stirring was going on. A white precipitation was immediately obtained. The precipitation was filtered, washed with distilled water and dried at 100°C. The dried precipitations annealed at 350°C For 3 h to get a fine

Corresponding Author: Ali Elkhidir Suliman, Institute of Nano-materials Science and Technology, Central China Normal University, Wuhan 430079, China

white-yellowish powder of ZnO doped with Al (ZnO: Al). During annealing, small amount of oxygen is lost from the lattice, resulting nonstoichiometric Zn1+xO phase (x≤70 ppm) that is slightly yellow. (Greenwood, 1984). Four other powders were prepared by similar way but with different Al_2Cl_3 quantities. Colloids were made by dissolving ZnO powders in ethanol alcohol. A Transparent Conducting Optically glass (TCO) glass: Fluorine doped SnO_2 coated glass was washed with distill water and ethanol. The two parallel edges of the glass were covered with adhesive tape to control the thickness of the ZnO film and to provide non-coated areas for electrical contact. A drop of the colloid was applied onto the TCO glass by the doctor blade technique at 30°C to make ZnO thin film layer. Finally, the ZnO film was dried with a hot air and then fired for 30 min at 450°C in air. X-ray Diffraction (XRD) of the powder and thin film were carried out in a Bruker D8 Advance diffractometer with Cu Kα radiation. Scanning electron microscope (SEM) was used to investigate the morphology of both ZnO powder and thin film. The UV-vis Diffuse Reflectance Spectrum (DRS) and transmittance was measured on a UV-vis spectrometer (UV-2550, Shimadzu. The resistivity of each film has been measured.

RESULTS AND DISCUSSION

Figure 1 and 2 show the SEM images of ZnO doped with Al thin film and Al doped ZnO nanoparticles morphologies subsequently, it is clear that the particles size is small (45 nm in diameter) compared with un doped ZnO, the particles have round shapes. Figure 3 shows XRD diffraction pattern we observed that Al doping caused no addition peaks, even Al_2O_3 content. All sharp peaks coincide with the peaks of ZnO (joint committee on powder diffraction standards file No. 36-1451) also from the pattern it shown that ZnO. Al films have hexagonal wurtzite and strongly oriented with the (101) and (100) faces, perpendicular to the substrate surface (c-axis orientation). Figure 4 shows the transmittance an average of transmittance of above 85°C in the visible light range was obtained, Fig. 5 shows the electrical resistivity

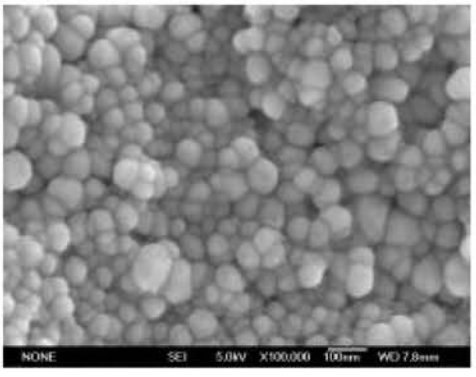

Fig. 1: The SEM image of Al doped ZnO thin film

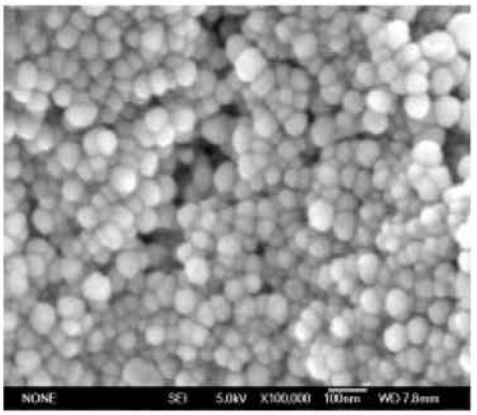

Fig. 2: The SEM image of Al doped ZnO nanoparticles

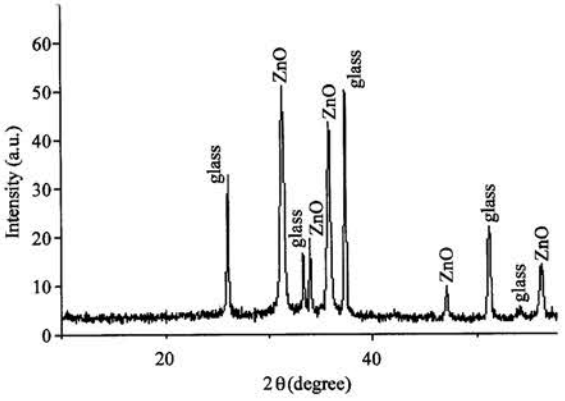

Fig. 3: The XRD diffraction pattern of Al doped ZnO thin films

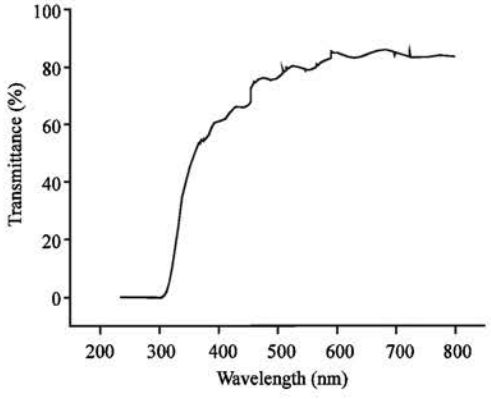

Fig. 4: The optical transmittance spectrum of Al doped ZnO thin film

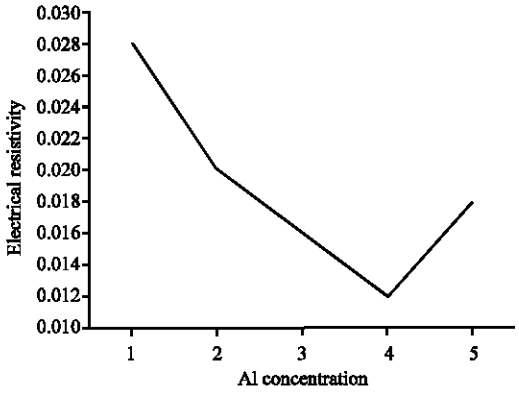

Fig. 5: The variation of electrical resistivity of Al doped ZnO thin film with Al concentration

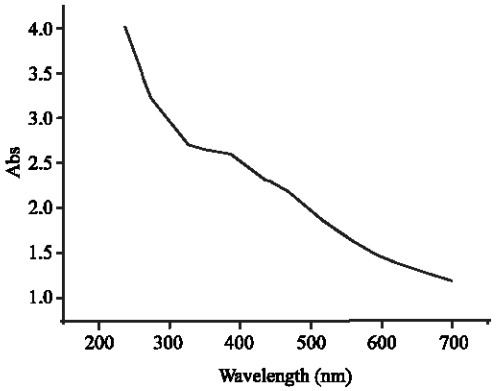

Fig. 6: The optical absorption spectrum of Al doped ZnO thin film

variation with Al content, we can see that the film resistivity decreases as the Al concentration increases this due to the decreasing of hall mobility of ZnO. Al thin films as the impurity content was increased, the impurity content dependence of Hall mobility is not related to the crystallinity, the crystallinity did not change with increasing impurity content. (Tadatsugu *et al*., 2000), in contrast the carriers concentration increased as impurity content was increased, this may be due to that the atom doped into ZnO lattice effectively acts as a donor by supplying a single free electron when it occupies the site of a Z_n^{++} ion. Also the absence of oxygen attributed carrier's resource. Figure 6 shows the Al doped ZnO thin film absorption it can be seen that photo current generated in the wave length range of 300-700 nm, by Al doped ZnO thin film electrodes was larger than that generated by ZnO nanostructure electrode, which was reported in previous studies this, ensured that Al doping displayed excellent properties of light conversion to electricity.

CONCLUSIONS

Zinc oxide doped with aluminum nanoparticles of about 40 nm in diameter were prepared by hydrothermal method. Al doped ZnO thin film electrodes appeared light transmittance of about 85°C and good absorption in visible light range. The electrical resistivity of Al doped ZnO thin films decreases as the concentration of Al increases. Low resistivity of about 0.012 Ω cm was obtained.

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