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RESEARCH ARTICLE

Characterization of ZnO Thin Films Prepared by Spin Coating Sol-gel Method for Solar cells

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Abstract

Nanostructures based on zinc oxide (ZnO) films have found an intensive attention of research community due to its significant applications in microelectronic and optoelectronic devices. Among various fabrication methods, sol-gel method is commonly preferred for the fabrication of ZnO films due to its simplicity and low process cost. In this work, we have characterized the various samples of ZnO films prepared on silicon and glass substrates by using sol-gel spin coating method. An intense absorption peak is observed at 370 nm by ZnO film of five coatings. The band gap and optical transmission of prepared film was found to be 3.35eV and 84% respectively. The transmittance in the visible and absorption in UV regions are corresponding to the ideal band gap of ZnO film. The surface topography of prepared samples were studied by atomic force microscopy which showed the spherical grains with uniform structure.

Introduction

One-dimensional nanostructures have attracted an extensive research attention due to their unique optical, chemical, thermal and electronic properties which is as a result of their low dimensionality. Zinc oxide nanostructures have got more attention among various semiconductors due to their potential applications in diversified areas. The potential for technological application of ZnO originates from its unique properties such as wide direct band gap (~3.37 eV) and large excitonic binding energy (60 meV at room temperature), high mechanical strength, excellent thermal and chemical stability at harsh operating conditions. In-spite of these, low-electron affinity and high aspect ratio of the ZnO nanostructures made its application as cold emitters in field emission based devices (Hou et al., 2009 and Sheini et al 2010). In dye-sensitized solar cells (DSSCs), the nanometersized semiconductor particles are sintered together to build 3-demensional network (Chu et al., 2009 and Lupana et al., 2010). In DSSCs, the typical material used for anode is made of a thick layer of ~10μm. A thick layer of TiO_2 nanoparticles are deposited as a paste and sintered to produce electrical continuity. So far the DSSCs based on TiO_2 nanoparticles have shown solar energy conversion efficiency upto 11.18%. Other semiconductor materials such as ZnO, CdSe, CdS, Fe_2O_3, SnO_2, Nb_2O_5 etc. have also been employed as an electrode material in DSSCs. Among all semiconductor nanostructures, wurtzite hexagonal phase ZnO has focused more and promising one in place of TiO_2 nanomaterials as a working electrode because of its higher electronic mobility, similar electron affinity and band gap.

ZnO-based nanostructures such as thin films, nanowires, nanotubes, nanorods etc. are the key components for a wide range of device applications. ZnO thin films are prepared using various methods such as spray pyrolysis, sputtering, sol-gel spin coating, chemical bath deposition (CBD), pulsed laser deposition (PLD), chemical vapor deposition (CVD) (Rao, 2000, Liu et al., 2005 and Mastubara et al., 2003). It is transparent semi-conducting film which has various applications including chemical & gas sensors, solar cells, light emitting diodes etc. Nowadays, the sol-gel method is extensively used to prepare various kinds of functional oxide films due to its simplicity and low cost. ZnO is II-VI semiconductor compound which is composed of hexagonal wurtzite crystal structure. For the fabrication of ZnO films, sol-gel method is preferred because of its easy control of chemical components with reduced fabrication cost. It has been noticed that the post-annealing plays an important role on the properties of ZnO films and the optical transmittance is very sensitive to the quality of crystal structure and to the presence of defects. With sol-gel method, the electrical and optical properties of ZnO films can be attained with a controlled size, morphology and desired doping profile.

In this paper, sol-gel based ZnO films were prepared and studied by using atomic force microscopy, Fourier transform infrared spectroscopy and UV-VIS measurements. In section two, the material and methods of sol-gel spin coating of ZnO films has been presented. In section third, the experimental results are discussed and finally, section fourth concludes the paper.

Material and Methods

We have prepared various samples of ZnO films on quartz silicon and glass substrates using spin coating sol-gel method. For the preparation of gel, zinc acetate dihydrate was dissolved in a solution of isopropanol and diethanolamine (DEA). The molar ratio of DEA to zinc acetate was maintained at 1.0 however, the concentration of zinc acetate was kept 0.8 mol/L. The solutions were stirred at 60 ℃ for 1 hr by a magnetic stirrer to yield a clear and homogeneous solution. Prepared solutions were then aged at room temperature for five days before coating. Before, the coatings, substrates were cleaned by acetone, alcohol and finally with de-ionized water. The spin coating is done with rotating speeds of 3000rpm for 30s. After one coating each sample was dried at 200 ℃ for 15 min. to evaporate the solvent and remove organic residuals. The prepared films were finally put into a furnace and annealed in air at selected temperatures for 40mins. After annealing, the fabricated ZnO films were studied by using Fourier transform infrared spectroscopy (Nicolet, USA), UV-VIS and atomic force microscopy (Nanoscope, contact mode).

Result and Discussion

Figure 1 and 2 shows the 3D atomic force microscopy images of ZnO films after three, four and five coatings respectively. As can be seen in figure 1, the prepared structure of four coatings (right side) is quite good than the ZnO film of three coatings (left side). In figure 2, it is observed that the ZnO film of five coatings showed more uniform and thick in comparison to films of three and four coating respectively. The AFM measurement has confirmed the formation of nanostructured films with spherical grains, low roughness and no cracks.

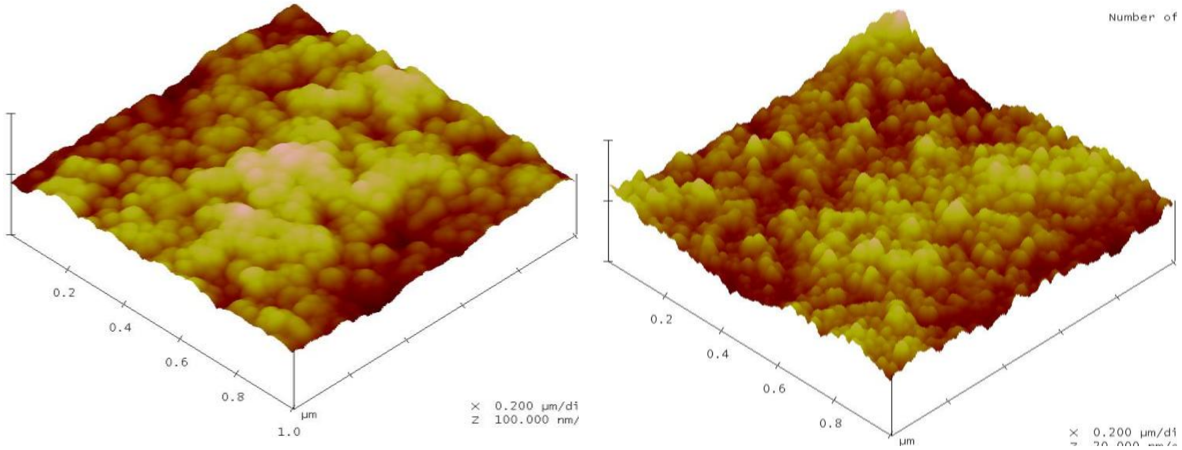

Figure 1. AFM images of ZnO films of three (left side) and four coatings (right side) respectively.

The refractive indices of prepared films were found to be 1.9, 2.2 and 2.4 corresponding to the three, four and five coatings respectively.

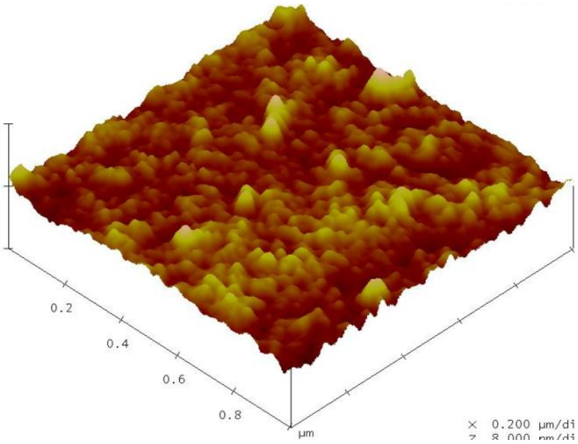

Figure 2. AFM image of ZnO film of five coatings**.**

Figure 3 reveals the FTIR spectra of ZnO film prepared on silicon substrate annealed at 400 ^{0}C. The intense absorbance peak can be seen in the IR spectra at 400cm^{-1} wave number which clearly indicates the presence of ZnO stretching bond and hence, the confirmation of crystalline formation of ZnO film**.**

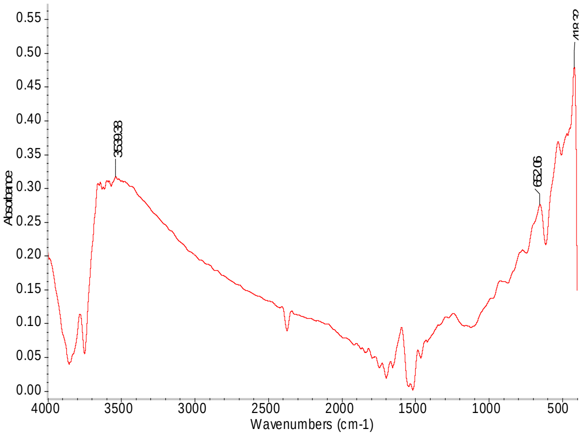

Figure 3. FTIR spectra of ZnO film grown on silicon substrate.

The optimum number of coatings plays an important role as anti-reflection layer of thin film solar cell as a fact that the absorption edges moves towards a higher wavelength with increased number of coatings. Figure 4 shows the absorption spectra of ZnO films of five coatings.

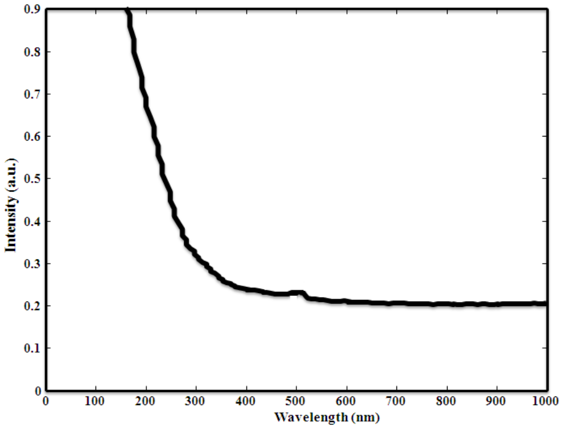

Figure 4. Absorption spectra of ZnO film of five coatings

In this figure, an absorption peak was observed at 370 nm from ZnO film of five coatings. The prepared thin film shows low absorbance in the visible and near infrared regions while absorbance is high in the ultraviolet region. The approximated band gap value of fabricated ZnO film of five coatings is 3.35eV.

Figure 5 shows the transmission spectra ZnO thin film of five coatings. It is found that the film was transparent in the visible region and it absorbed in the UV region. The transmission in the visible region was found to be about 84%. The good transmission in the visible region and good absorption in the UV region corresponds to the ideal band gap of the films.

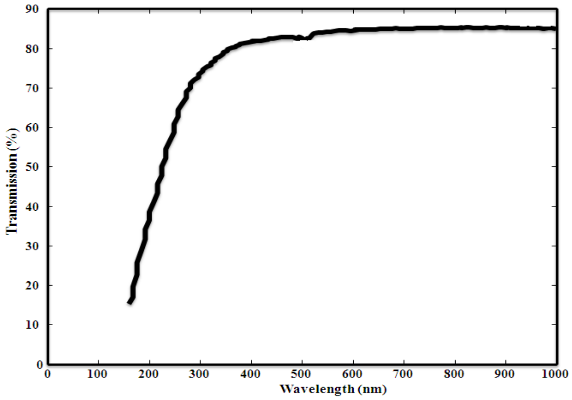

Figure 5. Optical Transmission of ZnO film of five coatings.

Conclusion

Zinc oxide films prepared on silicon and glass substrates have been characterized and studied. FTIR measurement has confirmed different types of chemical bonds onto the surface of the prepared film. The absorption edges were found to be moved towards a higher wavelength with increased number of coatings. From UV measurement, the absorption peak was found to be at 370 nm whereas the transmission in the visible region and absorption in the UV region indicates the ideal band gap of the ZnO films. AFM study showed the uniform structure of ZnO nanostructures with spherical shape grains without any cracks. Finally, this study is helpful to understand the optical properties of sol-gel spin coating ZnO films and suggests this material as a promising candidate to be useful as anti-reflection coating for thin film based solar cells.

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