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The Effect of Different Concentrations of Tellurium on the Structural and Optical Properties of ZnO Nanostructured Films Deposited by Sol-Gel Method

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Undoped and Te-doped ZnO nanostructured films were prepared on glass substrates by a sol-gel technique with different atomic concentrations of Te. The deposited films were characterized to investigate the structural, surface, and optical properties. The films are polycrystalline in nature and have a hexagonal structure. The crystal structure of $ZnO_{1-x}Te_x$ films was determined, and various crystal parameters such as 2θ value, FWHM, crystalline size, lattice strain, and dislocation density were calculated. The surface morphology of the films was tailored, and it was found that as the doping concentration of Te increases in ZnO, a decrease in the grain size is observed. The transmittance spectra of undoped ZnO and Te-doped ZnO films were highly transparent (~ 80 %) in the visible region. The average transparency was increased to increase the Te doping concentration. Transmittance edges were shifted to lower wavelengths when the atomic percentage of Te concentration increased. When the concentration of Te increased, an increase in the optical band gap of the deposited films was observed. Photoluminescence (PL) shows that all nanofilms have strong peaks in the ultraviolet region and small deep-level emission peaks in the visible region, depending on the Te concentration. The PL spectra of Te-doped ZnO shows a large blue shift from 396 to 381 nm in the UV emission peak position. It was also observed that as the Te doping concentration increased, the intensities of the PL bands in the visible range also increased.

Keywords: Sol-gel preparation, Crystal structure, Crystalline size, Lattice strain.

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1. INTRODUCTION

Zinc oxide (ZnO) semiconductor material has a wide band gap of 3.44 eV, exciton binding energy of 60 meV, good transparency in the visible wavelength range at room temperature. Therefore, it can be used in the fabrication of various optoelectronic devices such as photodetectors, light-emitting diodes and solar cells [1]. There are mainly two types of nanostructural properties extracted from XRD peak analysis: crystallite size and lattice strain. The change in crystallite size and lattice strain depends on the behavior and concentration of dopant materials [2]. XRD peak position line broadening is used to investigate the dislocation distribution. Normally, doping is used to improve the electrical, structural, and optical properties of pure ZnO thin films to make them suitable for optoelectronic applications [3].

One of the most suitable dopants is Tellurium (Te) in ZnO; Te is a chalcogen family element [4]. Te acts as an anionic dopant in the ZnO lattice and changes its optical properties in the visible spectral region by reducing oxygen vacancies, thus rendering them as a prospective material for next-generation optoelectronic devices [5]. In the present investigation, the synthesis of nanoscale undoped and doped with various concentrations of Te ZnO films with different structural, surface and optical controlled properties is carried out by the sol-gel method on microscopic glass substrates.

2. EXPERIMENTAL DETAILS

The starting precursor reagents, solvent and stabilizer used for this deposition method, were zinc acetate dehydrate [($C_4H_6O_4Zn.2H_2O$) Sigma Aldrich-CAS No. 5970-45-6], tellurium tetrachloride [($TeCl_4$) Sigma Aldrich-CAS No. 10026-07-0], 2-Methoxyethanol [($C_3H_8O_2$) Rankem-CAS No. 109-86-4] and Ethanolamine [($H_2NCH_2CH_2OH$) Rankem-CAS No. 141-43-5]. 0.45 M solutions were prepared using zinc acetate dehydrate and tellurium tetrachloride powder, which were mixed to formula $ZnO_{1-x}Te_x$ taken at different at. % concentrations $x = 0$, 1, 3, 5 and 7 in 25 ml in 2-methoxy ethanol simultaneously. The solutions were stirred on a magnetic hot plate at ~ 75 °C for 30 min; five drops of ethanolamine were added to each solution. The mixture of solutions was stirred on a magnetic hot plate at a temperature of ~ 75 °C for half an hour; the solutions became transparent and finally aged for 8 h at room temperature.

Before deposition, glass substrates were cleaned with chromic acid and acetone. The films were deposited on a glass substrate using a spin coater. The spin coater speed was maintained at 2000 rpm for 25 s. The coating procedure was repeated twelve times. After each coating, all the films were preheated at 225 °C for 10 min. Finally, samples were post-annealed at a temperature of 350 °C for 1 h in the furnace.

3. RESULTS AND DISCUSSION

3.1 XRD

XRD spectra of various Te doping concentrations of 0, 1, 3, 5, and 7 at. % of nanostructured films are shown in Fig. 1a. The XRD spectra show that all deposited films have a hexagonal structure with JCPDS card No. 36-1451. The samples have a high orientation peak (002), indicating that all samples are strongly oriented along the *c*-axis. Dominant peaks are oriented at 2θ values of 31.77°, 34.42°, 36.25°, 47.53°, 56.60°, 62.86° and 67.96° with related XRD peak position of (100),

