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Influence of substrate temperature on structural, optical properties and dielectric results of nano- ZnO thin films prepared by Radio Frequency technique

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ABSTRACT

A Radio Frequency (RF) technique was used to prepare ZnO thin films with different substrate temperature under ultra high vacuum. Structure results revealed that these films have crystalline structure. The structure of these films was carried out using X-ray Diffraction and Atomic Force Electron Microscope (AFM). The grain size for these films were determined using AFM photos. The optical parameters such as, optical energy gap, refractive index, extinction coefficient, dielectric loss and dielectric tangent loss for these films were determined. Another important parameters such as dispersion energy, oscillating energy and the ratio between the free carrier concentration/effective mass (N/m^*) were determined optically. It was found that, the substrate temperature for these investigated films plays an important rule for changing an optical and dielectric results of these films.

1. Introduction

Metal oxides have been attracted attentions for many scientists as a result of their importance for electronic applications especially opto-electrical and photovoltaic devices [1–3]. ZnO is an oxide semiconductor which has an important electronic applications such as photo-catalysts [4], thin film gas sensors [5], varistors [6], light emitting diodes [7], spintronic devices [8], nanolasers [9]. ZnO thin

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films have also been widely used as Surface Acoustic Wave (SAW) device and Film Bulk Acoustic Resonator (FBAR), as a result of their excellent piezoelectric properties [10,11].

ZnO is a wide band gap material (>3 eV), which had been studied because of its good optical properties, and its electronic applications such as solar cells [12,13], and many other electronic devices such as luminescent materials [14,15] and gas sensors [16–18].

Meierott et al. [19] had studied the effect of water percentage on the film structure and optical absorption for this ZnO nanoparticle.

Senthilkumaar et al. [20] had investigated the effect of doping with rare earth elements such as Mn on the physical properties of ZnO films, they had studied the structure, Fourier transform infrared (FTIR) spectroscopy and UV–VIS spectroscopy for these films. The effect of doping with transition metals on the optical and energy gap for ZnO nanoparticles were studied [21,22]. On the other hand the effect of doping on the transparent properties, energy gap and absorption edge of ZnO thin films at room temperature had been studied [23–26]. Musat et al. [27] had studied the effect of heat treatment on the optical and electrical properties of ZnO:Al thin films. Many authors had studied the effect of H_2 treatment on the electrical properties of ZnO:Al thin films [28–30].

Wang et al. [31] had studied the optical, thermal properties and the response as a gas sensor for ZnO thin films which were prepared by filter paper. They found that these films had highest gas-sensing ability. Gao et al. [32] had studied the effect of cooling on the optical properties of ZnO thin films which prepared by wet chemical method at low temperature. The optical properties of ZnO nanocrystalline powder were studied [33] in order to determine the optical energy gap dependence on the crystal size, they found that the energy gap decreases with decreasing crystal size. The photo electrical properties for ZnO thin films such as transmission, reflectivity, photoluminescence, direct and alternating photocurrents in order to use the ZnO thin films as active layers of optically pumped lasers [34]. The transparent properties such as optical transmission and reflection for undopped ZnO thin films were investigated at room temperature [35]. The optical anisotropy dependence on the structure of ZnO thin films had been investigated [36]. They found that the structure of ZnO thin films affect strongly on the anisotropic optical properties of these films. While the electrical properties and Hall mobility were studied for ZnO thin films in order to determine the conductivity and carrier concentration [37].

2. Experimental work

ZnO thin films were prepared using Radio Frequency (RF) technique. These films were prepared under vacuum less than 5.0×10^{-6} Torr, onto quartz substrates which were placed into RF sputtering, these films were prepared using ZnO ingot powder of purity (99.99%). The powder was placed in a disc target of four inches diameter. RF sputtering was adjusted with a power of 150 W for one hour with different substrate temperatures (room temperature, 100, 200, 300, 400 and 500 °C). The distance between the powder target and the substrate was maintained at 10 cm. Ar gas with a purity of 99.999% with a rate of flow 30 cm^3/min was injected during sputtering process.

The microstructures of the ZnO films were investigated using scanning electron microscopy (SEM; JEOL, JSM6335F) and X-ray diffraction (XRD; Rigaku, D/MAX-Rc) with Cu Kα radiation at a wavelength of 1.54 A°. The transmission spectra of the films were measured using UV/VIS double-beam spectrophotometer (Cary 5E) with a wavelength range from 300 nm to 1100 nm. The surface morphology and topography of these thin films were investigated by atomic force microscope (AFM, Seiko SPA400) in contact mode using Si_3N_4 cantilever (a force constant of ~0.08 N/m and a resonance frequency of ~34 kHz).

3. Results and discussion

3.1. Structure

The structure and surface topography of the investigated films with different substrate temperature (100, 200, 300, 400 and 500 °C) were studied using XRD and AFM respectively, as shown in Figs. 1, 3 and 4, from Fig. 1 it is clear that these films had polycrystalline structure hexagonal crystal structure as matched with JCPDS cards (No.74-1156) [38]. From this figure it was seen that the all peaks inten-