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Effects of stabilizer ratio on the optical constants and optical dispersion parameters of ZnO nano-fiber thin films

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A B S T R A C T

The effects of the molar ratio of stabilizer on structural and optical properties of ZnO nanocrystalline films have been investigated. The AFM images indicate that the ZnO films are formed from the nanofibers. The optical transmittance spectrum indicates the average transmittance higher than 85% at higher wavelengths. In UV spectrum, the transmittance increases with followed by a slight decay within visible range. The results of the absorption coefficient were analyzed in order to determine the optical band gap of the films. The optical constants (refractive index and absorption index) of the thin films were determined. Moreover, the dispersion parameters such as dispersion energy, oscillator energy, dielectric constants and dissipation factor were determined. The most significant result of the present study is to indicate that the molar ratios of MEA to ZnAc in the prepared ZnO nanocrystalline films have a little effect on the optical band gap but can be used to modify the optical dispersion parameters of the prepared ZnO nanocrystalline thin films.

1. Introduction

Zinc oxide (ZnO) thin films have been extensively studied as an active area of research in different fields and applications because of their unique properties. ZnO is a II–VI oxide semiconductor with a

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wide band gap of about 3.3 eV. It is photoconducting, piezoelectric and optical waveguide material, is applied to various applications such as optical and magnetic memory devices, light emitting diodes, solar cells (transparent conducting electrodes), transducer, surface-acoustic-wave (SAW) device and chemical sensors [1,2].

The method of the sol–gel fabrication of metal oxide thin films gained much interest because of its simplicity, low processing temperature, stoichiometry control and its ability to produce uniform, chemically homogenous films over large areas that can provide integration with other circuit elements. The sol–gel method can be successfully used for preparation of pure oxides applied in electronics, optics, as ceramics for utilization of radioactive wastes as well as filters in chemical and food industries. During the last few years, this method has also been applied to the synthesis of high temperature superconductors (HTSC) [3].

The ZnO thin film is prepared using various methods such as spray pyrolysis, sputtering, sol–gel spin coating, pulsed laser deposition (PLD), chemical vapor deposition (CVD) [4–8]. In spite of few studies regarding to the sol gel method, the sol–gel method has some merits, such as the easy control of chemical components, and fabrication of thin film at a low cost to investigate structure and optical properties of ZnO thin films.

In present study, we have investigated the effects of molar ratios of MEA to ZnAc that maintained from 1:1 to 1:4 on morphological and optical properties of sol–gel derived ZnO film. We successfully synthesized uniform ZnO nanocrystalline films using a simple a non-vacuum sol–gel spin coating method with controlling the stabilizing solution. ZnO nano-structured films with various microstructures parameters can be controlled by changing the molar ratios of MEA to ZnAc. Moreover, the effect of molar ratios of MEA to ZnAc on the optical constants and parameters such as dispersion energy, oscillator energy, dielectric constants and dissipation factor and optical conductivity were determined.

2. Experimental

2.1. Materials and preparation

The zinc acetate dehydrate [$Zn(CH_3CO_2)_2{\cdot}2H_2O$;ZnAc], 2-methoxethanol and monoethanolamine (MEA) were used for preparation of the ZnO film. The molar ratios of MEA to ZnAc were maintained from 1:1 to 1:4. The solution was stirred at 60 °C for 2 h to yield a clear and homogeneous solution. The solution was kept in dark for ageing for 48 h to make gel. The microscopy glass substrates were cleaned in methanol and acetone for 10 min each by using an ultrasonic cleaner and then cleaned with deionized water and dried. The gel solution was deposited onto glass substrate at 2000 rpm for 30 s using a spin coater. After the deposition by spin coating, the films were preheated at 120 °C for 10 min in a furnace to evaporate the solvent and remove organic residuals. The last process was repeated for five times to increase the thickness of the studied films (i.e. successive layer by layer). The obtained solid films were annealed at 450 °C for 1 h.

2.2. Measurements

The surface morphology of the prepared films was observed by atomic force microscopy (AFM) type Park System XE-100E. The measurements of the absorption, transmittance $T(\lambda)$ and reflectance $R(\lambda)$ were carried out using a double beam spectrophotometer model Shimadzu UV–VIS–NIR 3600 spectrophotometer with an integrating sphere in the wavelength range 200–1100 nm with step of 0.5 nm. All the measurements were carried out at room temperature.

2.3. Method of optical constants calculations

In order to calculate the optical constants, the refractive index (n) and the absorption index (k) of thin films at different wavelengths, based on an absorbing thin film on a transparent substrate has several orders of magnitude larger than the thickness of the film, the spectrophotometric measurements of transmittance and reflectance measurements were used. ZnO thin films were deposited onto