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Effect of Annealing Temperature on Microstructure amd Surface Morphology (AFM) of ZnO thin films with Mg dopant

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ABSTRACT *The morphological properties of the thin films were studied with the help of atomic force microscopy (AFM) technique. The films were subsequently annealed in ambient air from 400°C to 500°C. The average grain size ranged from 15 to 27nm. Increasing annealing temperatures resulted in larger grain sizes and higher crystallinity, with the surface roughness of annealed films being more than twice if compared to unannealed film.*

KEYWORDS : AFM, Dopant, Surface Morphology, Spin Coating

Introduction

Currently, ZnO nanomaterials are being applied in electronics, photonics, catalysis, lighting, and chemical sensing. It is well known that ZnO exhibits many favorable properties, such as high chemical stability, wide bandgap of 3.37 eV, high exciton binding energy of 60 meV, and abundance in nature, and is also nontoxic [1] . High-quality ZnO films are mainly fabricated by using spin coating method. Additionally, it has low temperature deposition, is cost-effective, has good adhesion between films and substrate, and demonstrates uniform particle distribution, high purity. The formation of oxide due to the decomposition reaction is thermodynamically feasible and leaves no residue on other reactants[2]. The substrate temperature strongly affects film morphology. By increasing the temperature, the film's morphology can be changed from a cracked to a porous structure .The types and concentrations of precursor solution and additive elements are other vital variables that influence the properties and structure. The unannealed deposited film has high resistivity, low roughness, and less transparency due to its low crystallinity and the presence of organic residues[3]. The properties of the unannealed film can be enhanced due to the thermal annealing, plasma treatment, and laser treatment . Of these options, the thermal annealing is one of the simplest and effective method. The thermal annealing temperatures, time, and various gaseous environments influence films and structural defects in the materials. During the thermal annealing process, dislocations and other structural defects in the material, adsorption, or decomposition are retained on the surface; therefore, the structure and the stoichiometric ratio of the material are altered. Oxygen interstitials, zinc interstitials, oxygen vacancies, zinc vacancies, and excess oxygen are common defects found in deposited ZnO films.

The deposition of ZnO thin films using zinc acetate as a precursor. The synthesis of ZnO thin films using a zinc acetate dihydrate as a precursor. Synthesization ZnO thin films using zinc acetate precursor and described the effects of substrate temperature and the physical properties of ZnO thin films [4].

1.1 Experimental Details

The Mg-ZnO thin films were prepared by sol gel method. At first, Zn(CH3COO)2.2H2O and Mg(CH3COO)2.4H2O were dissolved together in methanol (CH3OH) at room temperature, and then the diethanolamine (HN(CH2CH2OH)2, DEA) was added to the solution as the stabilizer. The total concentration of the metal ions was controlled at 0.5 mol/L in the solution, and the molar ratio of the DEA to the total metal ions was 1:1. The Mg^{2}+ concentration were chosen as 0.00, 0.05, 0.10, 0.15 and 0.20 for different samples. The solution was stirred for 1 hour at 60°C by a magnetic stirrer until a clear and transparent solution was obtained.

1.2 Case-1 Deposition at 400°C
1.2.1 Spin Coating

The solution was dropped onto glass substrates which were rotated at 3000 rpm for 30 s. 7After depositing by spin coating, the films were dried at 120°C for 10 min. to evaporate the solvent and other organic components in the film. The procedures from coating to drying were repeated 6 times to get the final films. The films were then inserted into a furnace and annealed in air at 400°C for 4 hrs. Samples are named as 1.A1, 1.B1, 1.C1, 1.D1 and 1.E1 for 0, 5, 10, 15, 20 % Mg doped in ZnO respectively.

1.3 Case-2 Deposition at 500°C
1.3.1 Spin Coating

Same process is done for deposition of films but films were annealed in the air at 500°C for 5 hrs. Samples are named as 1.A2, 1.B2, 1.C2, 1.D2 and 1.E2 for 0, 5, 10, 15, 20 % Mg doped in ZnO respectively.

1.3.2 Atomic Force Microscopy

It is found that the Mg incorporation obviously affect the surface morphology which is indicated by the AFM photographs of the Zn1-xMgxO samples on glass substrate in Fig. (a). All samples exhibit very dense structure. With the increase of Mg content, the surface roughness reduces and the average grain size becomes smaller. The root-mean square of the surface roughness of these films ranged from 0.3 to 1 nm. For films annealed at higher temperature, crystalline surface features were present which indicates that higher temperatures resulted in polycrystalline films.

Conclusion

Magnesium substituted zinc oxide thin films have been prepared successfully by spin- coating technique. The grain size and the surface roughness were reduced due to the incorporation of Mg, while the band gap and the absolute intensity of the band-edge emission were increased.

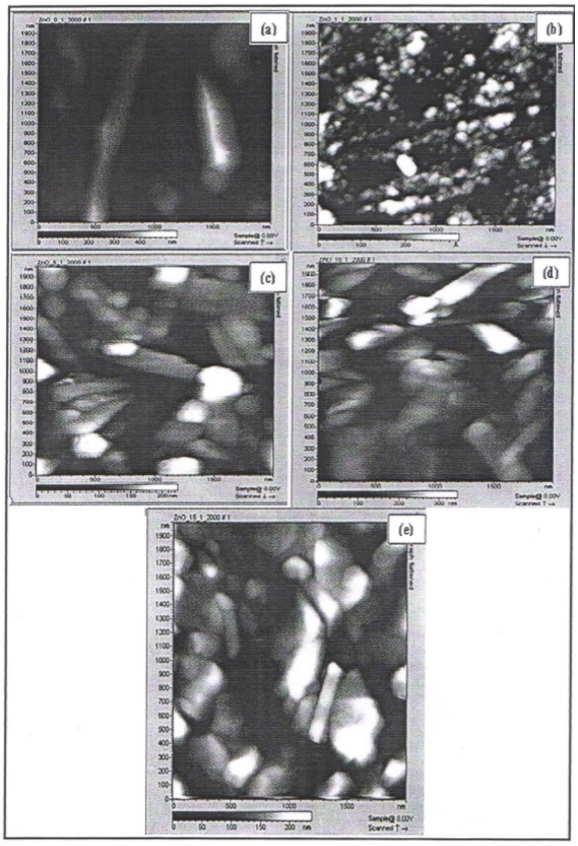

Fig. (a) AFM 2D images : Sample deposition by spin coating at 400°C

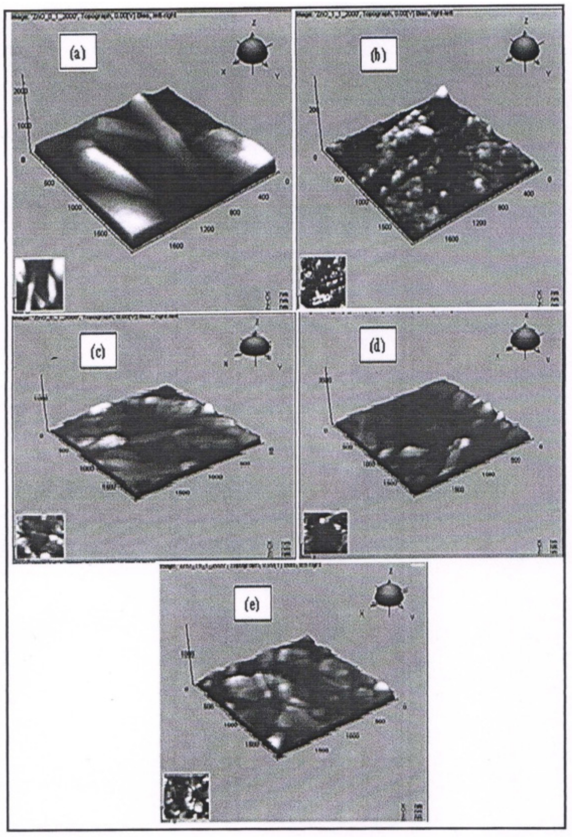

Fig. (b) AFM 3D images: Sample deposition by Spin coating at 500°C

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