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Synthesis, Characterization of F doped ZnO Thin Films

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Abstract

The F-doped ZnO films were deposited onto amorphous glass substrates using spray pyrolysis method at 450 ^0C substrate temperature. XRD pattern of F-doped samples showed preferential orientation along (002) plane. The 3D surface morphology and roughness analysis of FZO thin film was studied. The cluster consisting grains of average size ~120 nm is clearly observed.

Keywords: Spray pyrolysis; F-doped ZnO films; structural analysis, .

Introduction

Doped ZnO films offer a promising alternative to indium tin oxide (ITO) as a transparent conducting front contact layer in CdTe/CdS solar cells. The substitutional doping of ZnO films with group III metals such as Al, B and Ga has been widely reported [1–3], however out-diffusion of the electrically active metal dopants during subsequent cell fabrication procedures can lead to detrimental effects on device performance. It has been shown, using reactive RF sputtering, that ZnO films can instead be doped with fluorine and maintain comparable electrical and optical properties to those of the group III doped films [4–6]. Such films should be better suited for maintaining stability in CdTe/CdS solar cells where the diffusion of F out of the layer during subsequent high temperature fabrication of CdS and CdTe layers is unlikely to cause a significant degradation in device performance [7].

A renewed interest in the study of zinc oxide thin films exists due to the simultaneous properties of low resistivity and high transmittance besides chemical stability under strong reducing environments. Despite the extensive investigations on this material, there are still some unknown points related with the effect of some dopants in the transport properties. The case of fluorine doped ZnO thin films is an example for this.

Experimental details

The F-doped ZnO films were deposited onto amorphous glass substrates, chemically cleaned, using spray pyrolysis method at 450 ^0C substrate temperature. 0.5M solution of zinc acetate dehydrate [$Zn(CH_3COO)_2.2H2O$] diluted in methanol and deionized water (3:1) was used for all the films, and ammonium fluoride (NH_4F) was added to starting solution for fluorine-doping. Zinc acetate dehydrated and ammonium fluoride solutions were mixed together in different volume proportions ranging from 1 at% to 5 at% in steps of 1%. Air was used as the carrier gas, pressure at 0.2 bar. The ultrasonic nozzle to substrate distance was 28 cm and during deposition, solution flow rate was held constant at 3 ml/min.

The structural properties were studied by X-ray diffraction measurements (Rigaku-MiniFlex-II) using the CuKa radiation with λ=1:5405 Å The average dimension of crystallites was determined by the Scherrer method from the broadening of the diffraction peaks taking into account the instrumental broadening.

Results and discussions

Structural Characterization

Fig. 1 depicts XRD pattern of F-doped samples. All samples showed preferential orientation along (002) plane. The intensity of the peak corresponding to the plane (002) reduced on fluorine incorporation. The (002) direction corresponds to the c-axis of the crystal lattice, normal to the substrate plane. A weak XRD peak corresponding to the plane (100) and (101) were also observed for 2 at%, 3 at% 4 at% and 5 at% samples. But this peak completely vanished for the sample ZnO:F 1 at%. One can assume the substitution process of O by F species and this process could only be partial leading to the formation of a specific configuration like ZnF_xO_{1-x} [10]. Probably this could be the reason for reduced intensity of XRD peak of F: ZnO [9].

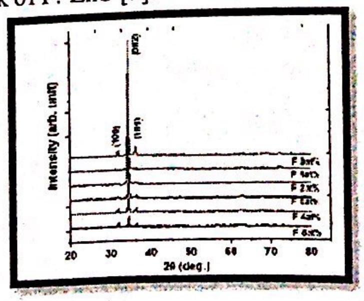
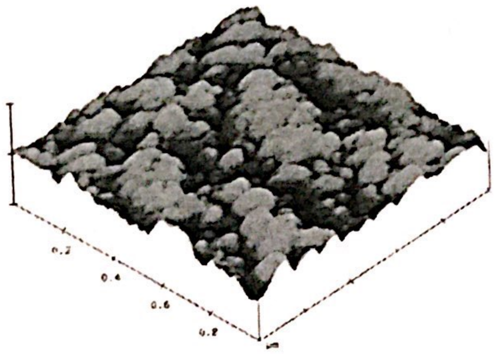


Figure 1 XRD pattern of F-doped ZnO thin films

Morphological properties of the FZO thin films



3D AFM image of FZO (1% F)

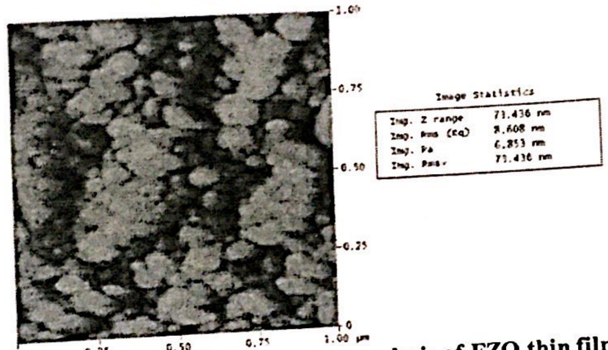


Figure 2 AFM Images 3D and 2D roughness analysis of FZO thin films (F 1at %)

The grain size of the FZO film was estimated from the 3D AFM image. The 3D surface morphology and roughness analysis of FZO thin film is shown in Fig. 2, where each cluster consisting grains of average size ~120 nm is clearly seen. The bright area shows the overgrown FZO crystallites of well developed grain morphology. The surface analysis showed the roughness of film surface increased as the F dopant increased up to 4 at % and further increase in F doping roughness decreased.

Conclusion

- Spray pyrolysis method at 450 ^{0}C substrate temperature used for deposition of F-doped ZnO films onto amorphous glass substrates.
- The (002) direction corresponds to the c-axis of the crystal lattice, normal to the substrate plane.
- The surface analysis showed the roughness of film surface increased as the F dopant increased up to 4 at % and further increase in F doping roughness decreased.

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