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Structure, microstructure and determination of optical constants from transmittance data of co-doped $Zn_{0.90}Co_{0.05}M_{0.05}O$ (M=Al, Cu, Cd, Na) films

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ABSTRACT

ZnO, $Zn_{0.95}Co_{0.05}O$ and $Zn_{0.90}Co_{0.05}M_{0.05}O$ (M=Al, Cd, Na, Cu) single phase films have been successfully synthesized by ultrasonic spray pyrolysis technique. Structural analysis by X-ray diffraction show that all the films have hexagonal wurtzite structure with an average crystallite size in the range of 19–25 nm. SEM analysis revealed that Cd and Na preserve the shape of nanopetals observed with ZnO or Co—ZnO films, while the doping with Al or Cu promote the formation of dense films constituted of nanorods. By the application of Levenberg–Marquardt least square method, the experimental transmittance data were fitted perfectly with the transmittance data calculated via a combination of Wemple–DiDomenico model, absorption coefficient of an electronic transition and Tauc–Urbach model. The concentration of absorbing centres N_{Co} and oscillator strength f of d–d transition of Co^{2+} ions are calculated from Smakula's formula.

1. Introduction

Zinc oxide based semiconductors showed a great interest in recent years because of their wide range applications, in particular in the field of spintronics. ZnO is a semiconductor with a large band-gap (E_g = 3.31 eV), large exciton binding energy ~60 meV at room temperature [1] and a transmittance of approximately 0.9 in the visible region. ZnO crystallizes in a wurtzite structure which can be defined by a hexagonal lattice in which the Zn^{2+} ions occupy the tetrahedral sites formed by the O^{2-} ions.

Recently, transition metal-doped semiconductors have been the focus of numerous research investigations because of their unusual optical properties and promising potential for application in opto-electronic devices [2–5]. Among these semiconductors, ZnO that is doped with a small amount of transition metal ions, in particular Co-doped ZnO system has been highly investigated.

Dietl et al. [6] theoretically predicted room temperature ferromagnetism on transition metal (TM) doped ZnO known as diluted magnetic semiconductors (DMS). Since then, investigation of TM-doped ZnO, especially Co-doped ZnO, has attracted considerable attention due to their unique properties. Various deposition techniques have been used for the preparation of Co-doped ZnO thin films [7–10].

It is important to note that the defect environment can be altered when a dopant atom M (Co, Al, Cd, Cu and Na) substitutes a Zn atom. Therefore, it is worth investigating the doping effect on optical properties of ZnO: M system.

The refractive index dispersion plays an important role in optical communication and designing of the optical devices. The knowledge of accurate values of the wavelength dependent complex refractive index of thin films is very important, both from a fundamental and a technological viewpoint. It yields fundamental information on the optical energy band-gap, defect levels, phonon and plasma frequencies, etc.

Numerous theoretical methods have been developed for the determination of the refractive index of thin films. The combination of a normal incidence transmission measurement and a near-normal incidence reflectance measurement has been used for the determination of the refractive index (n) and the extinction coefficient (k) [11–13].

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