Synthesis and Characterization of ZnO and Co doped ZnO

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Abstract

ZnO and Co doped ZnO was synthesized by simple precipitation method. In this study we used Zinc nitrate hexahydrate and Cobalt nitrate as the starting material. Ammonium hydroxide is used as the precipitating agent. The crystalline size of the doped and undoped ZnO were analysed by XRD. Optical properties of the samples were analysed by UV-Visible spectra. Morphology of the prepared samples were analysed by SEM analysis.

Key Words: ZnO, Co-Doping, Optical properties

1. Introduction

Zinc Oxide has become an important functional material. Catalysis, Photosensors, gas sensors, adsorption are the main applications of ZnO [1]. But it can absorb only UV region in the sunlight. This is the main drawback of ZnO for many of these applications [2]. There are lots of methods available to change the absorption edge from UV to Visible region. In this paper we are mainly focusing metal doping[3]. Metal doping is excellent method to tailor the optical properties of ZnO[4]. Optically active properties of transition metals especially Cobalt is very important due to the arrangement of electrons in the d orbitals[5]. It is reported that photocatalytic activity is doubled using Co doped ZnO. The new energy states are introduced due to doping. These states reduces the electron hole recombination and enchances average lifetime of the charge carriers[6,7]. The visible light absorption capacity of ZnO both before and after cobalt incorporation is the aim of this paper.

2. Experimental

Zinc nitrate hexahydrate was the starting material of ZnO. Cobalt nitrate hexahydrate was used as dopant. 0.1M solution of Zinc nitrate was dissolved in minimum amount of water and hydrolyzed by ammonia. pH of the resulting solution was maintained at 7.

The whole reaction was carried out at room temperature. The resulting Zn(OH)₂ was washed with distilled water and calcined at 500°C. Pure ZnO was also prepared at same conditions to compare the properties of doped sample. Crystalline nature and phase analysis of the products were studied by X-Ray diffraction studies using Cu Kα radiation (λ = 0.154 nm).

3. Result and Discussion

The crystalline nature of Co doped ZnO and pure ZnO was shown in the Figure.1. All the peaks correspond to the hexagonal wurtzite structure and diffraction data in agreement with JCPDS file(75-1526). There is no peak corresponding to cobalt or cobalt oxide.
But the diffraction peaks are shifted to lower angle. This create some changes in cell parameters. This shifting confirms the incorporation of Co$^{2+}$ on hexagonal structure of ZnO. Some Co$^{2+}$ ions may adsorb on the surface of the doped samples.

The average crystallite size was measured using Debye-Scherrer formula \[ D = \frac{\lambda}{\beta \cos \theta} \] where \( D \) is the crystallite size, \( \lambda \) is the wavelength of radiation (1.54 A° for Cu K$\alpha$ radiation), \( \beta \) the corrected peak width at half maximum intensity, and \( \theta \) is angle of diffraction. The crystallite size of the ZnO was found to be 36 nm where as Co doped ZnO show increased particle size. The increased particle size may be explained by the fact that the ionic radius of Co$^{2+}$ (0.74Å$^-$) is greater than that of Zn(0.70Å$^-$).

The morphology of the Co doped ZnO sample was studied by SEM and the image is shown in Figure 2. SEM image confirms the spherical structure. All the samples are uniform in nature.
Optical properties of the prepared samples were studied by UV-Visible spectra. From the UV-Visible spectra pure ZnO exhibits strong absorption at UV region. But in the Co doped ZnO there is a new absorption band present in between 400 and 800 nm region, which means that the band gap of ZnO was shifted to the visible region.
The absorption bands at UV-region are mainly due to the band gap (electronic excitation from valence band to conduction band) of ZnO. The electrons in the d orbitals of Cobalt cations will repel each other. Due to this repulsion the energies of d orbitals are split to different directions. This phenomenon was enhanced by the presence of electrons in oxygen anions in the crystal lattice. Which results the transition of electrons from lower to higher energy (d-d transition).

4. Conclusion

We have successfully synthesized the Co doped ZnO and pure ZnO through simple precipitation method at room temperature. The synthesized product were calcined at 500°C for getting the crystalline nature. All the samples were characterized by different technique like XRD, SEM and UV-Visible spectra. From the XRD pattern it is confirmed that the ZnO was exist in hexagonal structure with crystallite size 36 nm. The doped sample show increased crystallite size. Optical properties of ZnO and Co doped ZnO was analysed by UV-Visible spectroscopy. SEM image shows the spherical morphology of the product. The result shows that the absorption edge of ZnO was shifted from UV region to visible region due to doping.

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References