

Electronic and optical character of cobalt doped zinc oxide

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ABSTRACT

Nanoclusters of Cobalt(Co) doped Zinc Oxide(ZnO) are chemically synthesized following natural self assembling in Sol-Gel process. The biopolymer is chosen as a base matrix due to a rigid perfect capping of nano-clusters. The resulting specimen was examined by Fourier Transformed Infra red (TIR) Spectroscopy and optical absorption using UV-VIS spectroscopy. The study also includes DC I-V characteristics and conductivity analysis of solid specimen at room temperature. Magnetism in the developed specimens was investigated at room temperature. In all the cases the developed specimens are amorphous in nature and exist with stable quantum confinement. The developed Co doped ZnO was found to behave as semiconductor with large indirect band gap.

Keywords: Nano-clusters, Electrical conduction, Magnetism, Optical band gap, Magnetic semi-conductor

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INTRODUCTION

In the recent time studies on metallic oxides gained a tremendous momentum. The ultimate goal of such studies is to develop spintronic materials. Many recent studies have come up with very broad analysis on the magnetic aspect of the oxide conductors.

The research in the field of dilute magnetic semiconductor (DMS) has recently been prompted by the discovery of room-temperature ferromagnetism in transition metal (TM) doped ZnO. General consideration of using doping with 3d transition-metal cations in conducting oxides like SnO, semiconducting oxide ZnO or insulating oxide like TiO have been undertaken, The motivation behind these study is to realize ferromagnetism at room temperature in the systems. The results thus obtained from the studies of different worker are found conflicting. The field of dilute magnetic semiconductors (DMS) is currently one of the field intense activities. These materials are of great interest because of the novelty of their fundamental properties and also due to their potential as the basis of future semiconductor spintronic technologies which promise integration of magnetic, semiconducting and optical properties and a combination of information processing and storage functionalities.

In earlier work authors undertaken studies on pure and doped Nickel Oxide (NiO) [1] and Nickel Sulphides [2]. The overall results obtained therein are found to good. Recently Zinc Oxide (ZnO) system in both pure and doped variety are studied extensively by different worker. Pure ZnO is an eco-friendly material moreover non toxic for human bodies. ZnO NC may be useful in bio-medical applications. ZnO nano clusters are large band gap semiconductor and they can be produced by various ways [3]. It has been found that ZnO is a semiconductor with direct wide band gap 3.27 eV [4]. Studies on doped ZnO are also reported. However, the ferromagnetic aspects of the doped ZnO are found to be incomplete and conflicting.

This present work is makes an attempt to investigate various electronic and optical aspects of doped ZnO. The details of the investigation, results and analysis are given in the following subsections.

MATERIALS AND METHODS

Cobalt doping in ZnO was carried out by chemical process following thermal dissociation of common acetate salt. The zinc acetate hydrate with proportionate amount of cobalt acetate, analytical grade (Alfa Aesar) were heated (about 320 C) for 8h to prepare Co doped ZnO powder. The developed Co doped ZnO powder was grinded and strongly heated (about 350 C) for 10h. Anhydrous Co doped ZnO were taken in form of pellets prepared by mechanical pressing at pressure 12 ton/cm² followed by sintering. Two specimens with respective cobalt doping 2% (specimen-a) and 5% (specimen-b) were developed

FTIR

The IR absorption of the Co doped ZnO powder specimen was carried out to extract information about energy difference due to vibrational [5,6] states originating from bond bending and signature of impurities in it. The analysis was carried out in KBr window using FTIR model, IR affinity 1, Shimadzu, Japan, at high resolution

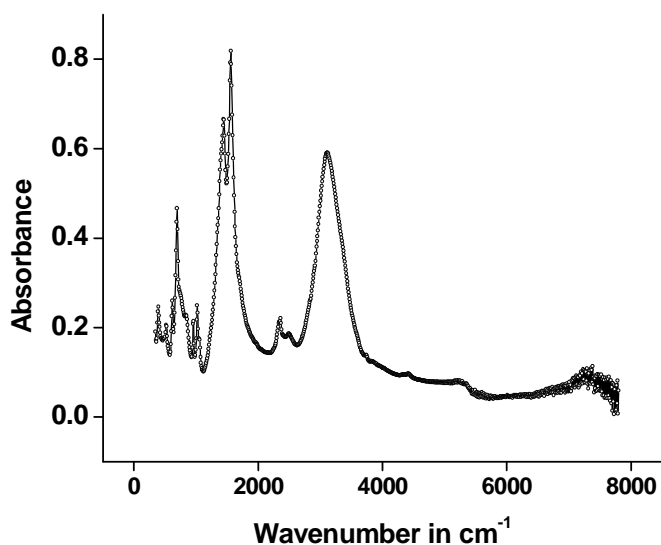


Figure 1. FTIR absorbance of Co-doped-ZnO (Co doping level 2%)

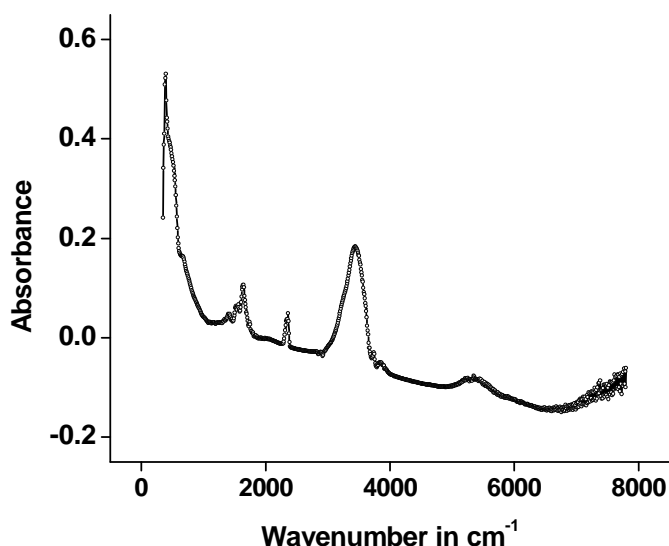


Figure 2. FTIR absorbance of Co-doped-ZnO (Co doping level 5%)

DC V-I Characteristics

DC current voltage characteristics (CVC) the developed Co doped ZnO specimens were studied. The developed pellet was sandwiched between two graphite electrodes for such electrical measurement. The applied field direction

is perpendicular to the 2-D plane of the specimen. The DC CVC was recorded at room temperature 22 C by Keithley 2400 (USA) Source meter unit and plotted by using characterization software.

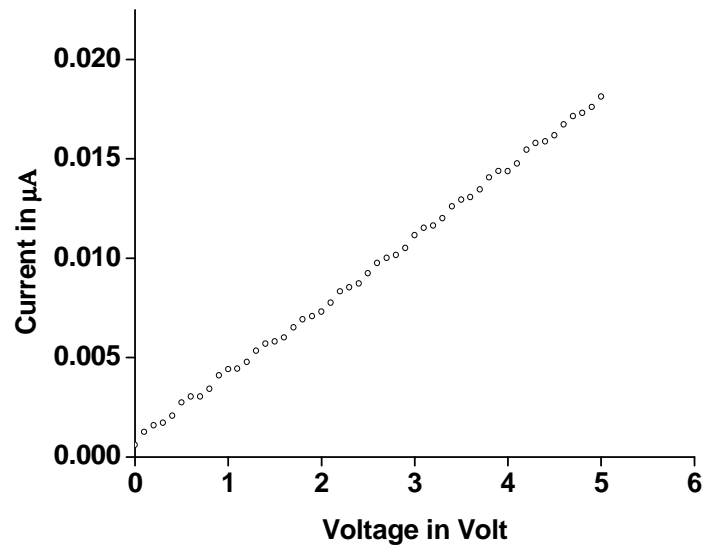


Figure 3. DC CVC of Co-doped-ZnO (Co doping level 5%)

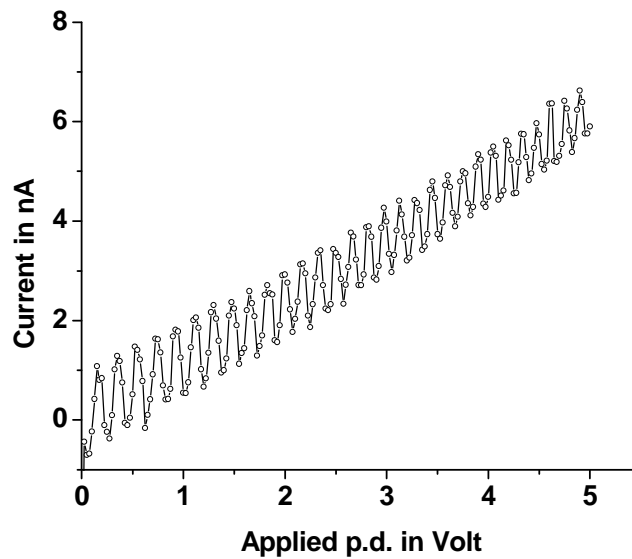


Figure4. DC CVC of Co-doped-ZnO (Co doping level 2%)

UV-VIS

UV-VIS absorption spectra of the specimens were studied with model UV-2450 UV-VIS spectrophotometer, Shimadzu, Japan in the range between 190nm to 900 nm at adequate accuracy using integrating sphere attachment.

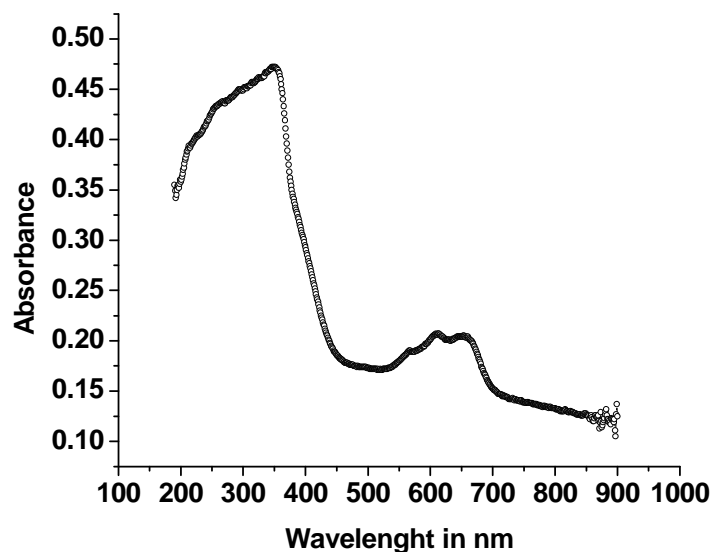


Figure5. Optical Absorbance Co doped ZnO (Co level 5%)

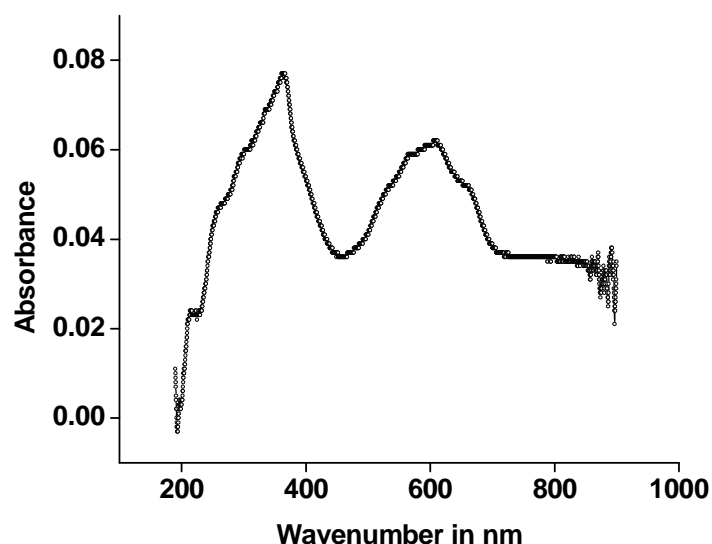


Figure6. Optical Absorbance Co doped ZnO (Co level 2%)

Magnetic measurement

Following Pal and Sarkar [7] type of magnetism in a specimen was estimated. The present technique of magnetic measurement makes use the principle of variation of self inductance of a coil. The experimental specimen is placed inside the core of the coil. The arrangement when subjected to external longitudinal d.c. magnetic field the self inductance of the coil changes in accordance to the magnetization of the specimen. The self inductance was measured by HIOKI (Japan) 3522 LCR Meter.

RESULTS AND DISCUSSION

FTIR analysis was carried out on 2% Co doped ZnO specimen (a) and on 5% Co doped ZnO specimen (b) was also carried out. Fig. 1 and 2 show the FTIR spectrum of specimen (a) and (b) respectively. There exists no substantial -COOH signature in shown by curve (b). This confirms that the chemical process is complete and developed specimen is the desired one. The results of FTIR analysis show a clear structural difference between specimen (a) and (b).

Figures 3 and 4 show the result of DC CVC measurement on Co doped ZnO specimens (a) and (b) respectively. The observed current exhibits oscillation like behaviour with applied voltage. It can be inferred that nano-composites do not follow Ohm's law of conduction. These functional characters of NC's are also observed in ZnO nano structures [3, 8,9]. The existence of step like discontinuities in I – V characteristics are almost Coulomb charging like steps [10]. The thermal fluctuation effects and quantum tunneling effect appears to be competitive for these specimens. Fig.3 shows large amplitudes of oscillations compared to that in Fig.4. The change in oscillation frequency is due to difference in nano-structures, in the specimen, which is the effect of Co doping in ZnO. The 5% Co doped ZnO specimen (b) apparently exhibit lower oscillation amplitude due difference in current scale. In fact specimen (b) has greater electrical bulk conductivity than that in specimen (a) The very clear nature of I – V characteristics may be attributed due to quantum effect. The magnitudes of discontinuities are thus detectable even at near room temperature.

Optical absorbance of the specimens (a and b) is shown Fig. 5 and Fig.6 Absorption spectrum in Fig.5 exhibits board and valley peaks around wavelength region 340nm to 380nm. This result is the direct consequence of that the average cluster size in Co-doped ZnO specimens have a small difference due variation Co doping level. The analysis is consistent with that DC CVC results. The band gap of Co doped ZnO was estimated from the measured optical absorbance and found to be 2.55eV and 2.85eV respectively for specimens (a) and (b). The results show that optical band decreases with increasing Co doping level.

The outcome of simple magnetic measurement shows that 5% Co doped ZnO specimen is paramagnetic (permeability $\mu \approx 1$) at room temperature. However, 2% Co doped ZnO specimen shows the signature of weak antiferromagnetic nature at RT. Both the mention systems are investigated by many workers [11-14] . Tietze *et al.* [15] investigated 5% Co-doped ZnO film developed by PLD which exhibited no ferromagnetism at RT. However, it has been reported [16] that Co doped ZnO exhibit ferromagnetism at RT. Moreover there exists conflicting conclusion on analysed magnetism of Co-doped ZnO. It may be emphasized that dilute magnetic oxides are perhaps not uniformly magnetized. The ambiguity of magnetic behavior of doped ZnO is related to structural defects, which depend on external parameters like temperature and oxygen concentration while sample preparation.

CONCLUSION

Formation of nano-clusters in sintered specimen is distinct and clear from I-V characteristic curve. From the study of optical absorption spectroscopy we can assume that as if three type of sized dependent nanocomposite formed and it is confirmed that Co doped ZnO nano-cluster is wide band gap semiconductor. The overall magnetic nature of the Co doped ZnO nano composite is amazing. Apart from the conflicting claim the present study finds a weak antiferromagnetism in 2% Co doped ZnO and paramagnetic nature in 5% Co doped ZnO specimen at RT. The scope of further studies on the system may provide many interesting aspect of material science.

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