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Electrical behaviour of ZnCdO nanocomposites

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ABSTRACT

ZnCdO nanocomposites have been synthesized by solvothermal process. X-ray diffraction spectra confirm that the sample is of hexagonal wurtzite structure, and a little Cd doping would not change the crystal structures of ZnO. The particle size is calculated using Debye Scherrer's formula from XRD patterns. The functional group is analyzed using FTIR studies. The ac and dc conductivity, resistivity and dielectric constant of ZncdO nano particles are measured by using Impedance analyzer with frequency range (400Hz- 4KHz) with temperatures 333K & 453K. Semiconducting behaviour of the sample is observed from the conductivity studies. The dielectric constant varied with temperature and frequency is also studied.

KEYWORDS

Nanocomposite;
Impedance;
Conductivity;
Resistivity;
Dielectric.

INTRODUCTION

Nanomaterials show properties distinct from bulk materials because of the nature of the atomic structure in the interfacial regions separating nanoparticles. The dielectric property of nanocrystalline materials exhibits unusual properties that play vital role in the development of new materials. A nanocomposite organic/inorganic materials is a fast growing area of research. Significant effort is focused on the ability to obtain control of the nanoscale structures via innovative synthetic approaches. The properties of nano-composite materials depend not only on the properties of their individual parents but also on their morphology and interfacial characteristics. Experimental work has generally shown that virtually all types and classes of nanocomposite materials lead to new and improved properties, when compared to their macrocomposite counterparts. Therefore nanocomposites promise new applications in many fields such as mechanically-reinforced lightweight components, non-linear optics, battery cathodes and ionics, nanowires, sensors and other systems[1]. ZnO has a relatively large direct band gap of 3.3 eV at room temperature. Advantages associated with a large band gap include higher breakdown voltages, ability to sustain large electric fields, lower electronic noise, and high-temperature and high-power operation. The band gap of ZnO can further be tuned to 3.0 – 4.0 eV by alloying it with magnesium oxide or cadmium oxide[2].

Cadmium oxide (CdO) is a well known II– VI semiconductor with a direct band gap of 2.2 eV (520 nm) and has developed various applications such as its use in solar cells, transparent electrodes, photodiodes, and sensors[3]. Cadmium oxide is an n-type semiconductor[4] with a band gap of 2.16 eV at room temperature[5]. CdO is used as a transparent conductive material[6], which was prepared as a transparent conducting film back in 1907[7]. Cadmium oxide in the form of thin films has been used in applications such as photodiodes, phototransistors, photovoltaic cells, transparent electrodes, liquid crystal displays, IR detectors, and anti reflection coatings[8]. CdO micro particles undergo band gap excitation when exposed to UV light and is also selective in phenol photo degradation[9]. W. Lehmann reported that about 10% of ZnO can be replaced by CdO with a corresponding shift, to lower energies, of the optical absorption edge, of the near-edge emission, and of the green emission[10].

Zhang[11] et al reported that with increasing Cd concentrations, the band gap of $Zn_{1"x}Cd_xO$ is decreased due to the increase of *s* states in the conduction band. The results of the imaginary part of the dielectric function $\varepsilon_2(\omega)$ indicate that the optical transition between O2*p* states in the highest valence band and Zn 4*s* states in the lowest conduction band has shifted to the low energy range as the Cd concentrations increase. Zinc Cadmium Oxide is a II-VI semiconductor compound. It is a single phase compound no secondary phase is seen in the XRD spectrum. It might be due to the low percentage of cadmium in the $Zinc_x$ $Cadmium_{1-x}$ where x is the stoichometric ratio and here its value is 0.8.

Sang Yeo LEE et al has successfully synthesized Simulation and Fabrication of ZnCdO light emitting diodes simulated current voltage characteristics as a function of cd composition. They studied the optical and electrical properties of the thin films[12]. Xiao lei Liu et al have successfully synthesized synthesis and electronic transport studies of ZnCdO nanoneedles using a chemical vapor deposition method. The characterizations were done by using SEM, TEM, XRD, AFM and IR techniques[13].

EXPERIMENTAL DETAILS

The synthesis of ZnCdO was carried out using solvothermal method. Ethylene glycol is used as the solvent and acetone is used to remove any unwanted organic substances present in the resulting powder particles. The synthesized nano particles were regrinded and mixed with a binder (Polyvinyl Alcohol). The mixture was then heated at 300° C to burnout the binder. Further, a pellet of 12 mm diameter and 1.2 mm thickness were made by applying 250 MPa of pressure using hydraulic press for further analysis. The prepared pellet was then used for dielectric measurement by coated its opposite faces using high grade conducting layer of silver paste. X-ray diffraction analysis has been carried out. DC conductivity was studied over the range room temperature to 400K. The dielectric loss, capacitance, resisitivity are measured using impedance spectroscopy analysis. By using SAI DEMO the electrical parameters of the ZnCdO nano particles are calculated. AC conductivity and dielectric measurements were carried out in the frequency range (400Hz- 4KHz) with temperatures 240 K & 300 K.

RESULT AND DISCUSSION

XRD analysis

X – Ray Diffraction Analysis is carried out to confirm the crystalline nature of the as prepared sample. The XRD Spectrum was taken with the support of XRD instrument – SEIFERT – MODEL JSO – DEBYE FLEX 2002. Particle sizes were calculated using Debye- Sherrer's formula. X-ray diffractin pattern obtained from the as grown ZnCdO nanocomposite struc-

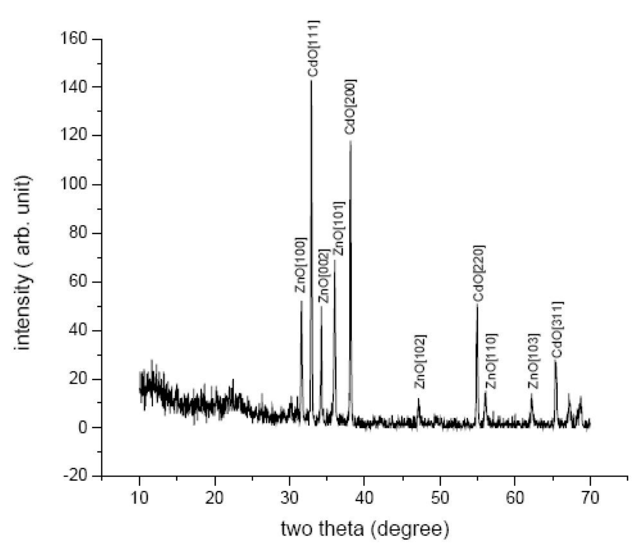

Figure 1 : XRD spectrum of ZnCdO nanocrystals

ture was shown in Figure 1. XRD pattern obtained from the ZnO –CdO composite structure showed additional peaks from (111), (200), (220) and (311) planes corresponding to cubic CdO (JCPDS no. {05-0640) beside hexagonal ZnO peaks. The ZnO-related XRD peaks observed for the ZnO –CdO composite structure were slightly deviated from the peaks observed for the ZnO sample. This suggests that there might be a very small ZnCdO phase at the interface.

Impedance spectroscopy analysis of ZnCdO nanocrystals

The SAI DEMO software is used to calculate the electrical parameters like resistance, capacitance, resistivity, dc conductivity, dielectric constant, etc. It is evident from the Figure 2, the Col-Col plot the resistance and hence the resistivity of semiconducting materials go on decreases as temperature increases. Almost for all the temperatures the Col-Col plot show the single semi circle behaviour. In the case of resistivity vs temperature, Figure 3 it is seen that when temperature increases the resistivity decreases. Particularly the resistivity decreases sharply for lower temperature regions and decreases very slightly as higher temperature regions. Figure 4 shows the relation between dc conductivity and temperature. It is evident from the figure that the conductivity increases exponentially as the temperature increases. Figure 5 show the relationship between log σ_{dc} and 1000/T. Figure 6 show the relationship between the dielectric constant and frequency for four different temperatures. In all the four graphs the dielectric

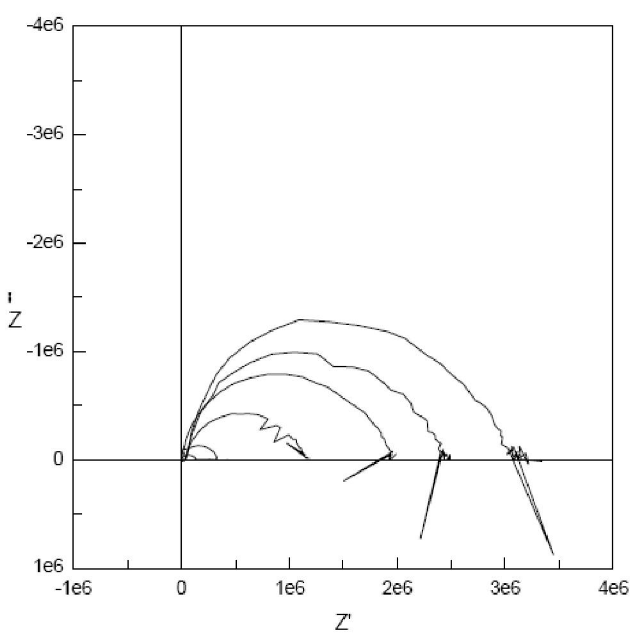

Figure 2 : Col-Col plot for ZnCdO for different temperatures (333 K to 453 K)

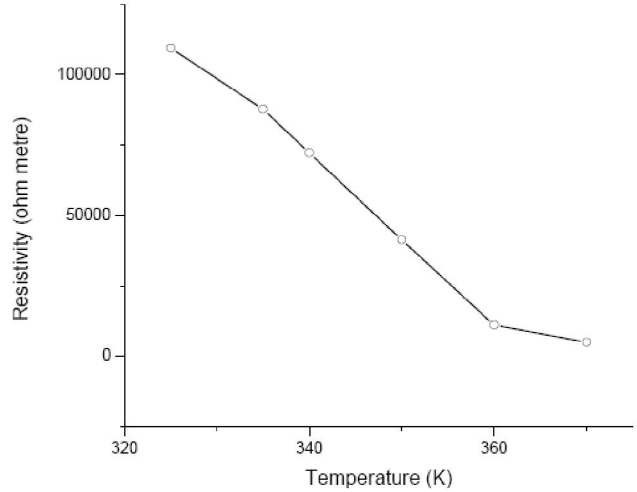

Figure 3 : Resistivity vs temperature of ZnCdO nanocrystals

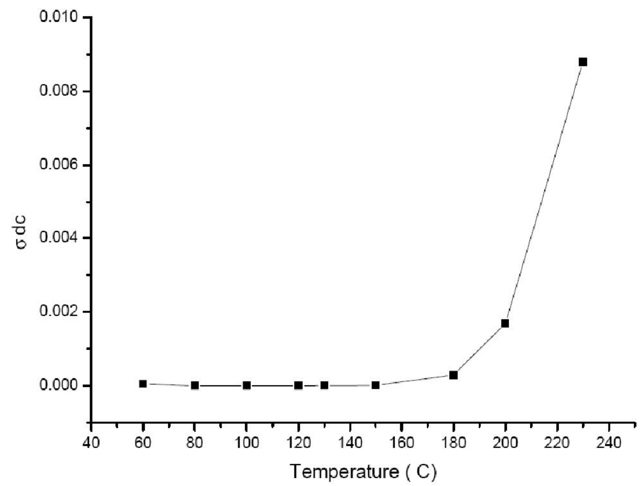

Figure 4 : DC conductivity Vs temperature (σ Vs T)

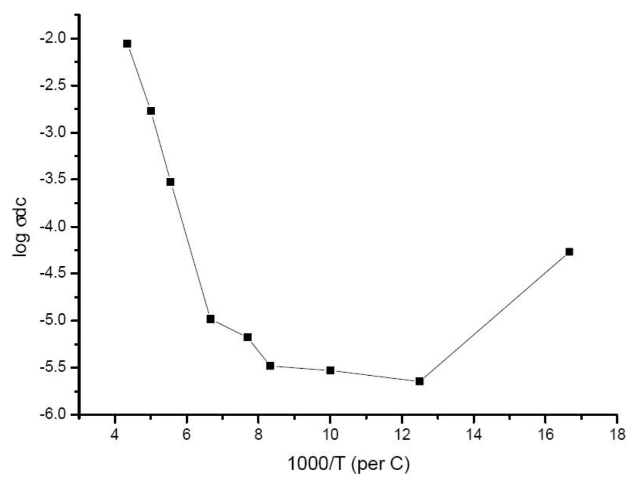

Figure 5 : Log DC conductivity Vs temperature(Log σ Vs T)

constant value is maximum at lower frequencies. It might be due to the reason that the dielectric constant is proportional to the polarization. The four polarizations will be present at lower frequencies. As frequency increases the four polarizations start to go off one by one in the following order, space charge polarization, dipolar polarization, ionic polarization and electronic polarization. Here in these four spectra also it is evident to see the dielectric constant decreases as the frequency increases. The values of the dielectric constant for any temperature at any desired frequency could be taken from the graph straight away.

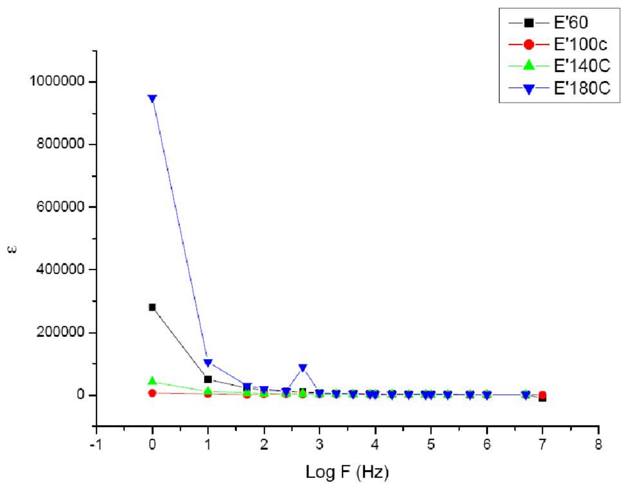

Figure 6 : Log frequency Vs dielectric constant for different temperatures (Log f Vs ε^1)

CONCLUSION

This research was aimed to prepare nanocrystals of ZnCdO by Solvothermal (microwave strategy) method. The following conclusions are drawn from the analysis of the results of the study. Nanoparticles of ZnCdO are prepared by a chemical route. The XRD analysis of ZnCdO gives a particle size of 60.2877nm. Complex impedance analysis study gives the electrical characteristics such as resistance, capacitance, resistivity, ac conductivity, dc conductivity and dielectric constant of the ZnCdO nano composites.

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