Original Research Paper

Volume - 12 | Issue - 08 | August - 2022 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Physics

DIELECTRIC AND ELECTRICAL BEHAVIOUR OF ZNO AND CDO SEMICONDUCTING MATERIALS WITH AND WITHOUT MN DOPING

Manoj Pathak	Research Scholar Career Point University, Kota-324005,
Dr. R. K. Mangal*	Professor of Physics Jaipur Engineering College and Research Centre, Jaipur-302022*Corresponding Author
Dr. Balram Tripathi	Associate Professor S. S Jain Subodh P.G. (Auto.) College, Jaipur-302004

ABSTRACT ZnO and CdO pellets with and without Mn doping were prepared by using Hydraulic pressure machine at room temperature. The effect of Mn content (1,3,5 wt %) on the electrical properties have been carried out by Keithley meter. The result shows that the resistivity decreases as increasing Mn content. Impedance analyzer are used for dielectric behavior and results shows that decrement of dielectric constant as well as dielectric loss with the increment of frequency.

KEYWORDS : Resistivity, Keithley meter, Dielectric constant, Dielectric loss, Impedance analyzer

1. Introduction

Semiconductors are necessary component for advance designing of various electrical and electronics instruments in different fields like communications, healthcare, military systems, computing green energy and many more applications. The synthesis and characterization of compound semiconductor is the major new frontier in solid state physics. There is an increasing interest in these compounds because of their several practical applications like optical materials in laser, solar cell etc. But the development of transistor and subsequent growth of its use in electronic applications had also inaugurated an area of intensive study of the properties of the semiconductors in general. Compound semiconductors may be made by combining more than one element of different groups, like II-VI, II-IV, III-V and IV-VI etc.

ZnO is a wide band gap semiconductor of the II-VI semiconductor group. Its properties wide large direct optical band gap (3.37 eV at room temperature)[1], large excitation energy (60 meV) and low threshold power[2] for optical pumping are considered to be important features of zinc oxide. Advantages associated with a large band gap include higher breakdown voltages, ability to sustain large electric fields[3], lower electronic noise[4], and high-temperature[5] and high-power operation[6]. Zinc oxide crystallizes in two main forms, hexagonal wurtzite, and cubiczincblende. The many remarkable medical properties of creams containing ZnO can be explained by its elastic softness, which is characteristic of tetrahedral coordinated binary compounds close to the transition to octahedral structures[7].

ZnO are highly attractive in the development of materials area, due to their interesting physical properties as high transparency in the visible and near- ultraviolet (UV–VIS) spectral regions, as well as their luminescence[8,9]. The applications of ZnO have attracted much attention in recent years. Several techniques have been used for deposition of Mn doped thin films namely Thermal evaporation[10,11], Pulse laser deposition[12], Radio frequency magnetron sputtering[13] etc.

Cadmium oxide have also been preferable consideration due to its various useful applications such as gas sensors, photovoltaic photo diodes and transparent electrodes, etc. due to its low resistivity, high carrier concentration and high optical transmittance in the visible region of solar spectrum[14,15]. Cadmium oxide has much higher capacity for absorption and emission of radiation[16]. It is n-type semiconductor. The conductivity of cadmium oxide is nearly conductivity of metals[15] and the band gap is about 2.2 eV, large excitation binding energy at room temperature[17]. It has very short luminescence and high optical gain of about 300 cm^{-1} which are required for various optoelectronics and magneto-optical devices[17]. CdO is cubic structure with each ion surrounded by six ions of opposite electric charge, octahedral arranged[18,19]. Optoelectronic properties of CdO with doping of different metallic ions have been studied by many researchers such as [14], Indium [20], Aluminum [21], Gallium [22] and Manganese [23]. Physical properties of Mn doped CdO thin films have already been reported by some researchers. Study of Microstructure and Electrical properties of Mn doped CdO thin film prepared by home built spray pyrolysis techniques carried out by [24].

2. Experimental Techniques

Crystalline powder of pure zinc oxide and Mn doped ZnO (purchased by Alfa Aesar with 99.99% purity), were calcined and then it was crushed for nearly 2 hrs by mortar pestle for obtaining fine powder. This fine powder pelletized using Hydraulic pressure machine using a pressure of about 5 tones. These pellets are kept for annealing in vacuum oven for 30 hours at 600 temperatures. The diameter and the thickness of the pellets are 12 mm and 1mm respectively. For electrical contents, the flat circular faces of pellets are coated with silver paste. These pellets are mounted on Keithley meter for I-V Characterization and mounted on impedance analyzer for dielectric behavior of the materials. All data are measured at room temperature.

3. Result and Discussion

3.1 Electrical Properties:-

I-V characteristics can be used as a tool to measure intermixing of dopent structure with different percentage and preparation of controlled semi-conducting devices. I-V measurements of undoped and Mn doped ZnO pellets and CdO pellets were taken by Keithley meter at room temperature[25].

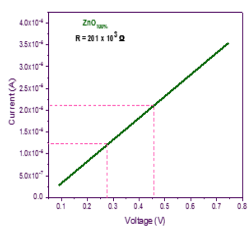
Figure 1 shows the I-V characteristics of pure and 1 %, 3%, and 5 % Mn doped ZnO pellets at room temperature. Figure 2 shows the resistivity of pure and 1%, 3% and 5% Mn doped ZnO pellets at room temperature.

All figures show linear behavior of the materials. The electrical resistance of the pellets was obtained from I-V curve by calculating the gradient of the curve,[24]. The electrical resistivity of the prepared pellets was determined using the relation-

$$\rho = \frac{RA}{l}$$

Figure 2 shows high resistivity at room temperature of pure ZnO pellets, but after mixing of Mn content, the resistivity decreases. This is due to mixing of both of materials. So it is clear that the resistivity of the material decreases then conductivity increases as increasing the dopant percentages. The decrement of resistance is very much in 5% Mn doped pellet. Decrement in resistance may be the suppression of intrinsic impurities in the host ZnO by Mn dopants,[26].

Changes in electrical properties of the materials depend on the different parameters such as preparing conditions, grain boundaries, grain size, defects and impurities. Moreover, increment in oxygen vacancies is considered as a significant parameter influencing the resistivity of ZnO pellets. Decreasing the resistivity with the increase in concentration can be probably due to the removal of defects from the structure,[27].



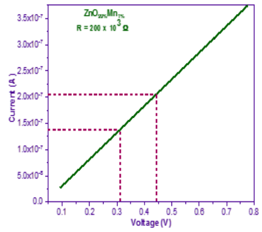
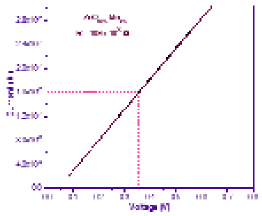


Figure 1-A :- V-I Characterstics curve of Pure ZnO pellet
Figure 1-B :- V-I Characteristics curve of 1% Mn doped ZnO pellet



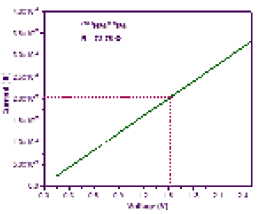


Figure 1-C :- V-I Characteristics curve of 3% Mn doped ZnO pellet
Figure.1-D :- V-I Characteristics curve of 5% Mn doped ZnO pellet

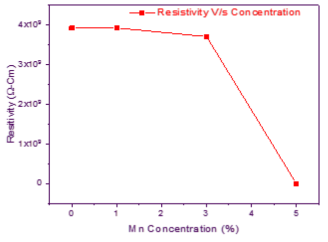
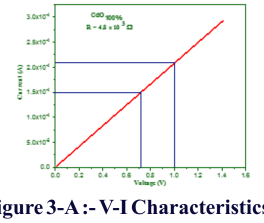


Figure 2 :- Resistivity v/s Mn Concentration (%)

The figure 3 shows the electrical behavior of pure and Mn doped CdO pellets. Figure 4 shows that resistivity of CdO pellets decreased as increased Mn concentration. Decrement of resistivity at room temperature indicates that the Mn ions are effectively placed into the CdO lattices[25] and may be act as donor by supplying free electrons and increased the carrier concentration of Mn ions into CdO lattices[28].



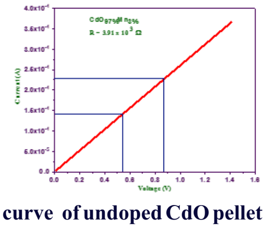
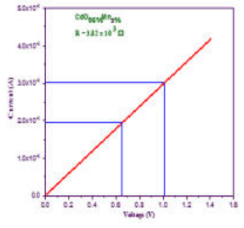


Figure 3-A :- V-I Characteristics curve of undoped CdO pellet
Figure 3-B :- V-I Characteristics curve of 3% Mn doped CdO pellet



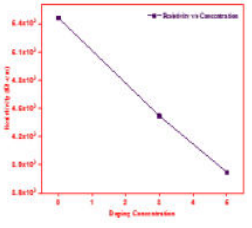


Figure 3-C :- V-I Characteristics curve of 5% Mn doped CdO pellet
Figure 4 :- Resistivity v/s Mn Concentration

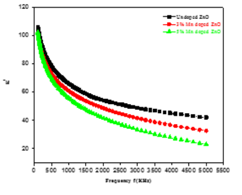
Dielectric Analysis:-
Dielectric constant is a important property of the materials which influences many optoelectronic and transport properties of material[29]. The dielectric constant ε" consists of real part ε_r' describes the stored energy and imaginary part ε_r'' (dielectric losses) which describes the dissipated energy[30].

Dielectric behavior of pure and Mn doped ZnO pellets and CdO pellets have been carried out by impedance analyzer. The dielectric constant □' of the material is calculated using following formula,[31]:-

$$\varepsilon_r' = \frac{t \ X \ Cp}{A \ X \ \square \ o}$$

where t is the thickness of pellet, C_p is the equivalent parallel capacitance (obtaining experimentally), ε_o is the permittivity of vacuums and d is the diameter of electrodes. The dielectric losses ε_r'' is obtained from the measured value of dissipation factor D where $\varepsilon_r'' = D \ X \ \varepsilon_r'$. Here dissipation factor and equivalent parallel capacitance C_p are obtained from the measurements.

The dielectric constants as a function of frequency for all compositions of ZnO are shown in Figure 5. It can be seen from Figure that the dielectric constant decreases with the increase in frequency for all compositions. It has also been observed that the value of dielectric losses decreases with the increase in Mn dopant. It may be due to the small dielectric polarizability of manganese ions compared to Zinc ions[31]. Hence, as the increasing the concentration of Mn dopant Zn ions will be substituted by manganese ions and thereby decreasing the dielectric polarization[30]. Dielectric loss represents the energy dissipation in the dielectric system. Figure 3.12 shows the variation in dielectric loss factor with frequency at room temperature. It has been observed that dielectric losses decrease with the increase in frequency for all the compositions, which may be due to the space charge polarization[30]. H. Anwar[32] has been found similar results.



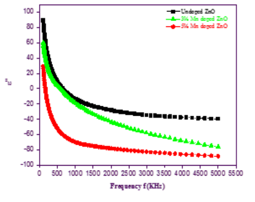
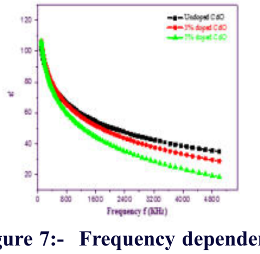


Figure 5:- Frequency dependence of dielectric constant of Pure, 3% and 5 % Mn doped ZnO pellets.
Figure 6 :- Frequency dependence of dielectric loss ε_r' of pure, 3% and 5%Mn doped ZnO pellets.

The dielectric constants as a function of frequency for all compositions of CdO are shown in Figure 5. It can be seen from Figure 5 that the dielectric constant decreases with the increase in frequency for all compositions. This behavior can be explained on the basis of Koop's theory which is based on Maxwell–Wagner model[34]. According to Maxwell Wagner interfacial model, a dielectric material is expected to be consisting of conducting grains, which are parted by non-conducting grain. When an external electric field is applied the charge carries float and get accumulated at the grain boundaries which can produce large polarization[33].

It has also been observed that the value of dielectric losses decreases with the increase in Mn dopant. It may be due to the small dielectric polarizability of manganese ions 2.64 Å3 compared to CdO ions[31]. Hence, the increasing concentration of Mn dopant Cd ions will be substituted by manganese ions and thereby decreasing the dielectric polarization30. Dielectric Loss represents the energy dissipation in the dielectric system. Figure 8 shows the variation in dielectric loss factor with frequency at room temperature. It has been observed that a dielectric loss decreases with the increase in frequency for all the compositions, which may be due to the space charge polarization33. Richa Bhargava[34] has been found similar results.



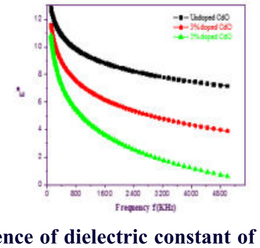


Figure 7:- Frequency dependence of dielectric constant of Pure and Mn doped CdO pellets.

Figure 8 :- Frequency dependence of Dielectric loss ε'' of Pure and Mn doped CdO pellets.

Conclusion:-

In the present work, hydraulic pressure machine is used to prepare pellets of pure ZnO, CdO and Mn doped ZnO, CdO semiconducting materials.

The dielectric constant (ε) as well dielectric losses (ε") of Mn doped ZnO semiconducting material decreases as compare to pure ZnO with increasing Mn content and keeping in view variation in frequency.

The conductivity increases and resistivity decreases in Mn doped ZnO semiconducting material as compare to pure ZnO with increasing Mn content semiconducting material at room temperature.

The dielectric constant (ε') as well dielectric losses (ε") of Mn doped CdO semiconducting material decreases as compare to pure CdO with increasing Mn content keeping in view variation in frequency.

The conductivity increases and resistivity decreases in Mn doped CdO semiconducting material as compare to pure CdO semiconducting material with increasing Mn content at room temperature

Acknowledgment

We are grateful to S. S. Jain Subodh PG College, Jaipur for providing experimental research facilities for the present research work.

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