Characterization of ZnO by Means of C-V Measurement of Respective Schottky Diode by DLTS

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Abstract

Zinc Oxide (ZnO) has been characterized by means of capacitance spectroscopy. The capacitance voltage measurement of schottky diode is performed by standard method available in our DLTS setup. The capacitance voltage measurement of ZnO obtained at various temperatures under the same reverse biasing conditions for the material. From these measurements the following parameters were evaluated: The doping concentration of ZnO was calculated as 1.7979×10^{15} cm^{-3} at room temperature and the value decreased with decrease in temperature. The built in potential calculated for ZnO at room temperature was calculated as 0.64V. The value of built in potential of ZnO initially increased then decreased with the decrease of temperature. The depth profile of ZnO remained consistent and showed no change as the temperature varied from room temperature to lower values. Comparison of the data with the literature showed that all the samples were affected by native and/or intrinsic point defects developed during growth or metallization process.

Keywords: Semiconducting Zinc Oxide materials, C-V characteristics, Deep level transient spectroscopy of the material, schottky diode

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INTRODUCTION

There has been a great deal of interest in zinc oxide (ZnO) semiconductor material, which is a functional oxide material, has been studied over several decades due to its immense applications in variety of fields. They are used as coatings in thin film photovoltaic cells (Budianu et al., 2000), antireflective coatings in conventional silicon solar cells (Dimova-malinovska, 1999), light emitting diodes (Soki et al., 2000), thin film transistors (Elvira et al., 1989), etc. Due to its unique conduction mechanism based on oxygen vacancies, it is widely used in oxygen gas sensors ZnO has a unique combination of piezoelectric, conductive and optical properties (Zu et al., 1997). In recent years, it has been considered as an alternative to GaN due to its superior properties, namely: (i) a large exciton binding energy (~60 meV), (ii) low power thresholds for optical pumping at room temperature and (iii) tunable band gap energy from 2.8 to 3.3 eV and 3.3 to 4 eV by doping with CdO (Heo et al., 2005) and MgO (Muthukumar et al., 2004) respectively. The large exciton binding energy (~60 meV) of ZnO makes it well suited for developing UV light sources and transparent electronics. Due to considerable large band gap and relatively saturated drift velocity, III–V compound semiconductors are rapidly becoming critical materials for a variety of novel applications (Nakamura et al., 1996, Pearton et al., 1999).

Experimental Technique Sample preparation

The sample of p-type ZnO used for research was thin film of ZnO (400nm thick) were deposited on p-Si (111) maintained at 300

°C and 3 x 10^{-3} Torr by thermal evaporation using RF source operated at 200 W. Isochronal annealing in the temperature range 400 °C to 1000 °C for 30 minutes each under N_2 atmosphere was carried out to improve crystallinity and stoichiometry of the deposited film. Circular Schottky contacts having diameter of 2mm using Au and Ni separately were made by thermal evaporation.

Capacitance-Voltage C-V Measurements

The C-V measurements are necessary to determine the diode quality as well as to determine depth profile. At different temperatures capacitance voltage measurements were taken for various materials. From the C-V measurement we find the carrier concentration, built-in-potential and depth profile: Doping concentration 'N_d', Built-in potential 'V_{bi}' and Depth profile 'depth vs. N_d,

$$N_d = 2/[q\varepsilon_m * \text{slope}] \quad (1)$$

$$V_{bi} = [\text{intercept}*q\varepsilon_m N_d]/2 \quad (2)$$

$$Nd = [2(V_a + V_{bi})]/[q\varepsilon_m d/dv(A^2/C^2)] \quad (3)$$

And

$$D(C) = \varepsilon_m A/C$$

Where

V_a = Applied voltage, V_{bi} = Built-in potential, q = Electron charge,
ε_m = Relative permittivity of the material, D = Depth

RESULTS AND DISCUSSION

Capacitance-Voltage C-V Measurements of ZnO

The typical C-V characteristics of as grown p-type ZnO at different temperatures 295K to 400K are shown in Figures 1 to 12. In the graphs of Voltage (V) and $(A/C)^2$ the straight lines is taken as the theoretical linear fitting of the curves. The graphs of depth profiles have taken between depth and doping concentration shown in Figures 13 and 14. Using equations (1) and (2) and using equation (3) for depth profile. We have calculated the following parameters shown in table 1. From table 1 the value of doping concentration (N_d) was calculated in the range of of 1.7979 $\times 10^{15}$ to 1.3335×10^{15}cm^{-3}. The results show that the doping concentration almost remain constant with the change of temperature from R_T to 128K and other factors calculated from C-V was built in potential (V_{bi}) in the range of 0.58 to 0.66V. Our results approximately matched with Dhananjay et. al results. They described that from capacitance–voltage (C–V) measurements of p-type ZnO the carrier concentration of 2×10^{15}cm^{-3} and built-in voltage of 0.7eV was obtained for the heterojunction.

Table 1: Parameters calculated from CV measurements of ZnO

Temperature (T) K	Doping Concentration (N_d) cm^{-3}	Built in potential (V_{bi}) V
300	1.7979×10^{15}	0.58
240	1.4495×10^{15}	0.64
200	1.4255×10^{15}	0.66
180	1.4001×10^{15}	0.65
140	1.3335×10^{15}	0.64
128	1.3335×10^{15}	0.65

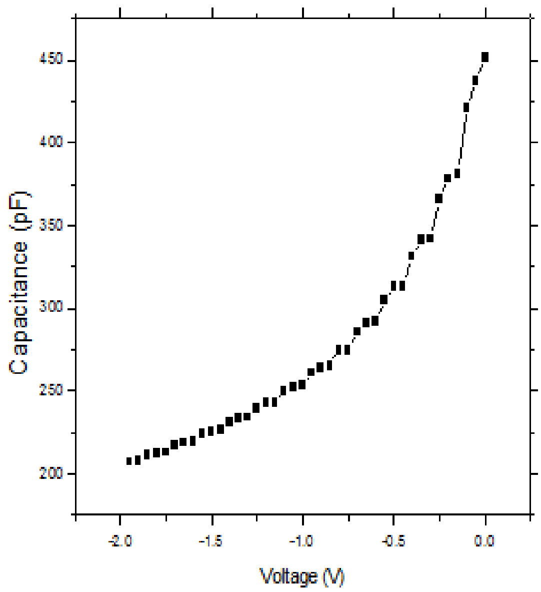

Figure 1: The graph between C-V of Zn O at T=300K

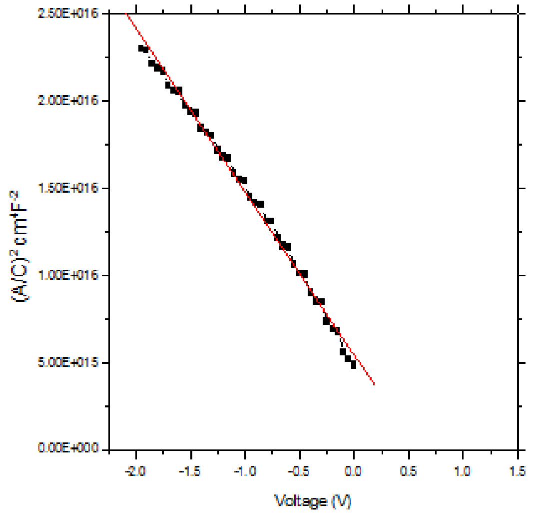

Figure 2: The graph between V and (A/Cof ZnO at T=300K.

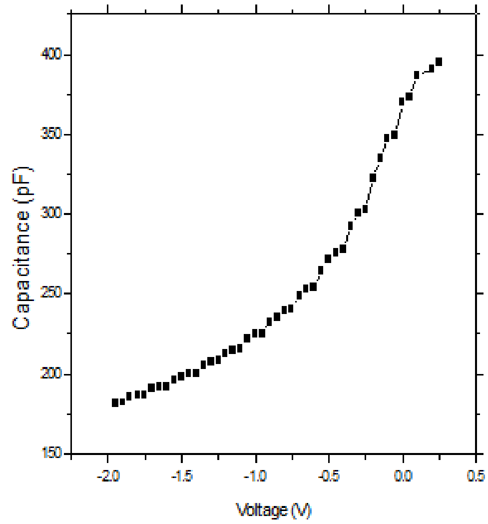

Figure 5: The graph between C-V of ZnO at T=200K.

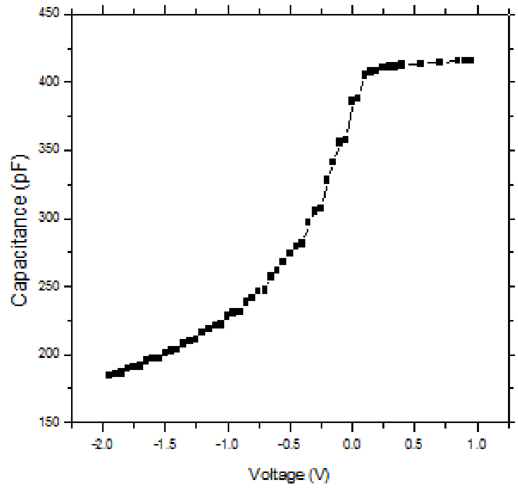

Figure 3: The graph between C-Vof ZnO at T=240K.

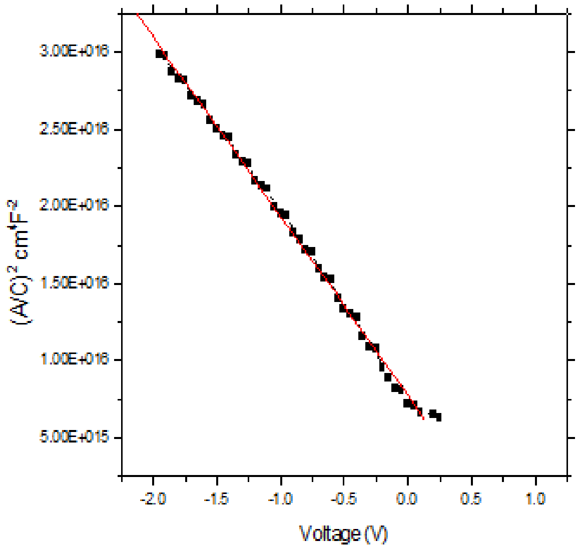

Figure 6: The graph between V and (A/Cof ZnO at T=200K.

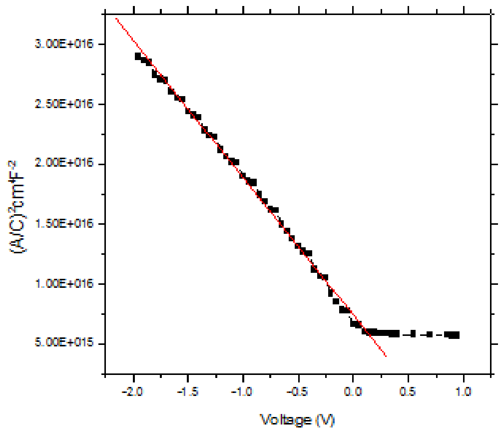

Figure 4: The graph between V and (A/C of ZnO at T=240K.

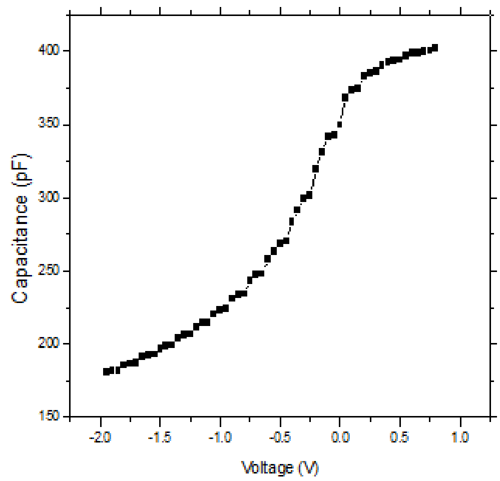

Figure 7: The graph between C-V of ZnO at T=180K.

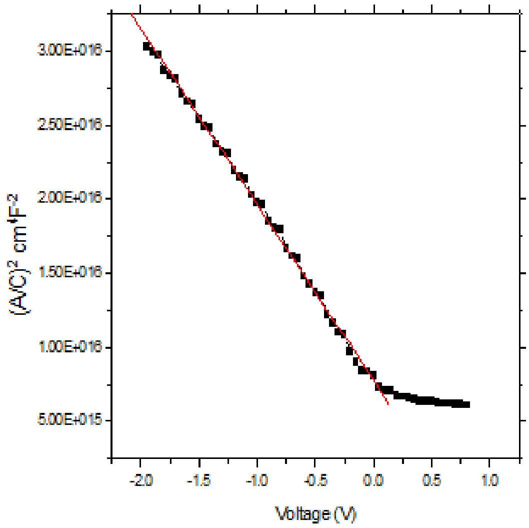

Figure 8: The graph between V and (A/C of ZnO at T=180K.

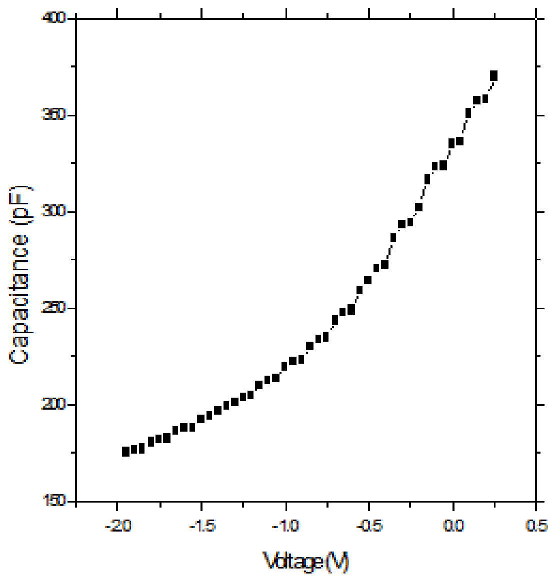

Figure 9: The graph between C-V of ZnO at T=140K.

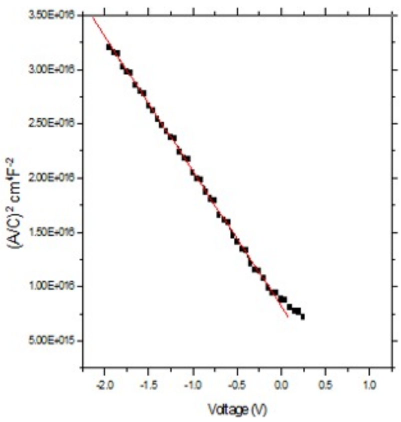

Figure 10: The graph between V and (A/C of ZnO at T=140K.

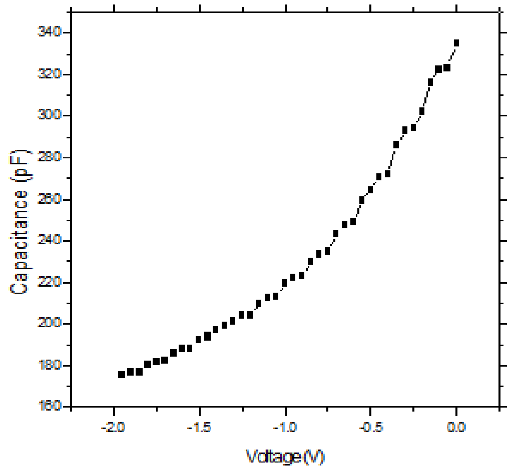

Figure 11: The graph between C-V of ZnO at T=128K

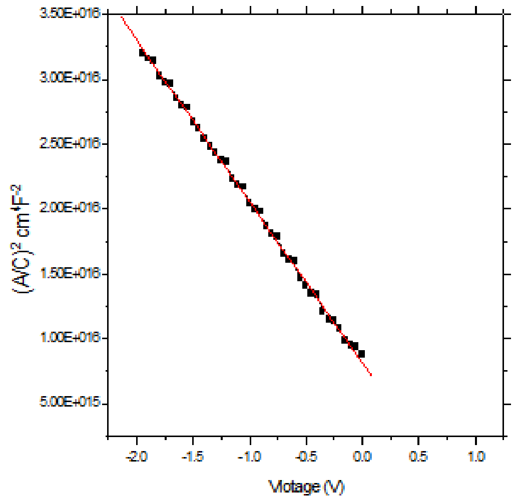

Figure 12: The graph between V and (A/C of ZnO at T=128K.

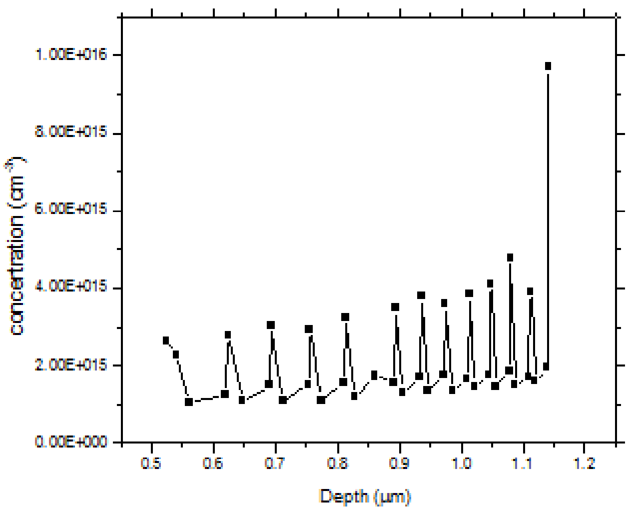

Figure 13: Depth profile of ZnO at temperature 300K

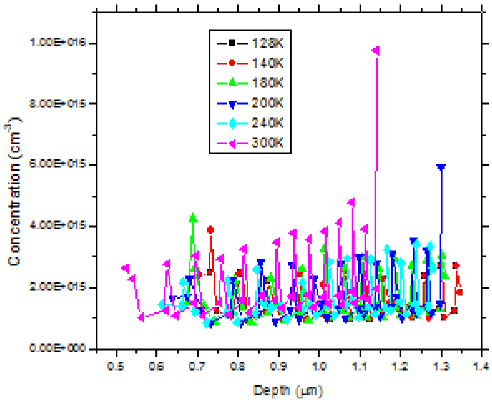

Figure 14: Depth profile of ZnO at various temperatures.

CONCLUSION

We studied the characterization of ZnO by means of capacitance spectroscopy. Doping concentration (Nd), buit-in potential (Vbi) and depth profile were determined by C-V measurements. The p-type sample of ZnO 400nm thick deposited on p-Si (111) by thermal evaporation. C-V measurements N_d and V_{bi} at R_T were $1.7979\times10^{15}cm^{-3}$ and 0.58V respectively. From C-V measurements the depth profiles of all materials remain uniform.

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