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

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Abstract

Silicon Carbide (SiC) has been characterized by means of capacitance spectroscopy. The capacitance voltage measurement of respective schottky diode is performed by standard method available in our DLTS setup. The capacitance voltage measurements of SiC are obtained at various temperatures under the similar reverse biasing conditions for material. From these measurements the following parameters were evaluated: The doping concentration of SiC at room temperature was calculated 5.2061×10^{12} cm^{-3}. Its value increased with increase in temperature and showed no significant temperature effect. The built-in potential calculated for SiC at room temperature was 1.49V. Its value gradually decreased with increase in temperature. The depth profile of SiC became more uniform with increase in temperature and showed no change as the temperature varied from room temperature to lower values. Comparison of the data with the literature showed that the sample was affected by native and/or intrinsic point defects developed during growth or metallization process.

Keywords: Semiconducting Silicon Carbide materials, C-V characteristics, Deep level transient Spectroscopy of the material, Schottky Diode.

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INTRODUCTION

There is significant interest in developing semiconductor electronic devices capable of operating over a higher temperature range and with higher tolerance against ionizing radiation than currently available. Wide band gap materials are the potential candidates to fulfill such requirements and SiC is one of them. SiC include high-power high-voltage switching applications, high temperature electronics, and high power microwave applications in the 1 - 10 GHz region. SiC is attractive for these applications because of its extreme thermal stability, wide band gap energy, and high breakdown field (Powell and Rowland, 2002). Because of the wide band gap energy (3.0 eV and 3.25 eV for the 6H and 4H poly types respectively), leakage currents in SiC are many orders of magnitude lower than in silicon. Furthermore, SiC is the only compound semiconductor which can be thermally oxidized to form a high quality native oxide (SiO_2). This makes it possible to fabricate MOSFETs, insulated gate bipolar transistors (IGBTs), and MOS-controlled thyristors (MCTs) in SiC (Ikeda, 1988; Hidayet and Enise, 2005).

MATERIALS AND METHODS

Sample preparation

The sample wafer used for this research was 6H-SiC n-type wafer prepared at Linkoping

(Sweden). An epilayer of ~35 μm thick was grown on the SiC substrate by chemical vapor deposition (CVD) growth. Nitrogen dopant atoms were incorporated during the epitaxial growth sequence (Lin and Chang, 1995; Suzuki and Koizumi, 2004). Circular Schottky contact of 0.8mm diameter using Au and Ni separately was 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/[$q\varepsilon_m$* slope] (1)

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

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

And

D(C) = ε_mA/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 SiC

The typical C-V characteristics of n-type 6H-SiC as grown at different temperatures 295K to 400K are shown in Figures 1 to 12. In the graphs of Voltage (V) and (A/C the straight line 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 for depth profile using equation (3) we calculated the following parameters shown in table below.

Temperature (T) K	Doping Concentration (N_d) cm^{-3}	Built in potential (V_{bi}) V
295K	5.2061´ 10^{12}	1.49
320K	1.1402´ 10^{13}	0.90
340K	2.8920´ 10^{13}	0.72
360K	7.8894´ 10^{13}	0.52
380K	1.3945´ 10^{14}	0.60
400K	2.5968´ 10^{14}	0.54

Table: 1 Parameters calculated from CV measurements of 6H-SiC

From table 1 we observed that the doping concentration and built-in potential was effected by temperature. The value of Nd at room temperature was determined 5.2061 ´ $10^{12}cm^{-3}$ which increased with the increase in temperature. While the value of Vbi at room temperature calculated as 1.49V and gradually lowered on increasing temperature and measured 0.54V at 400K also an unsequence value of Vbi determined at 360K.

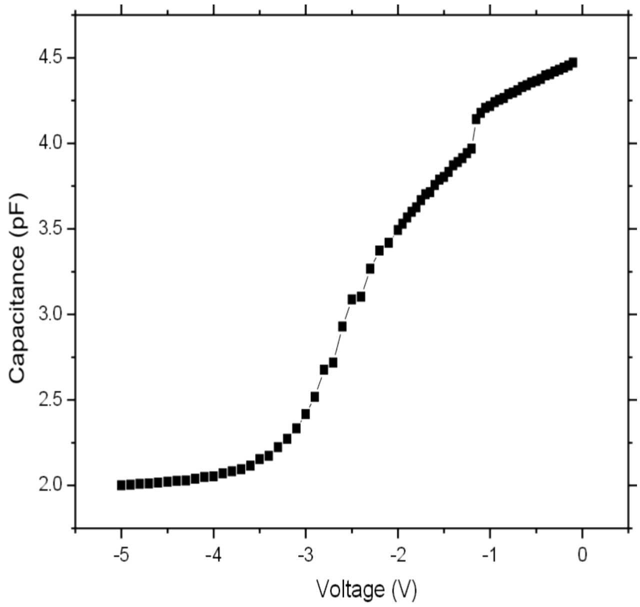

Fig 1. The graph between C-V of SiC at T=295K.

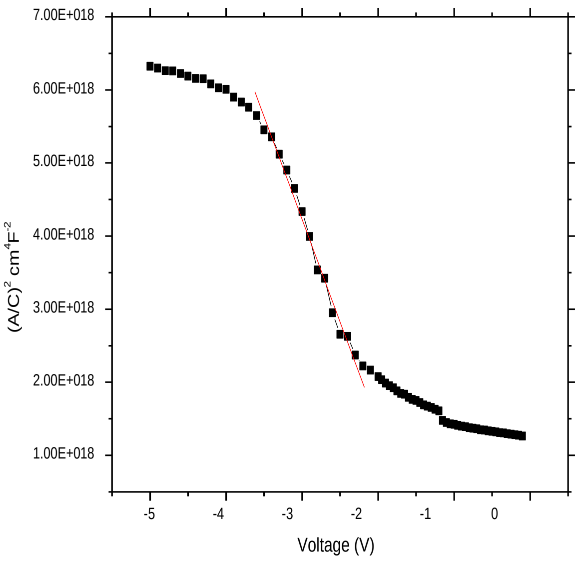

Fig 2. The graph between V and $(A/C)^2$ of SiC at T=295K.

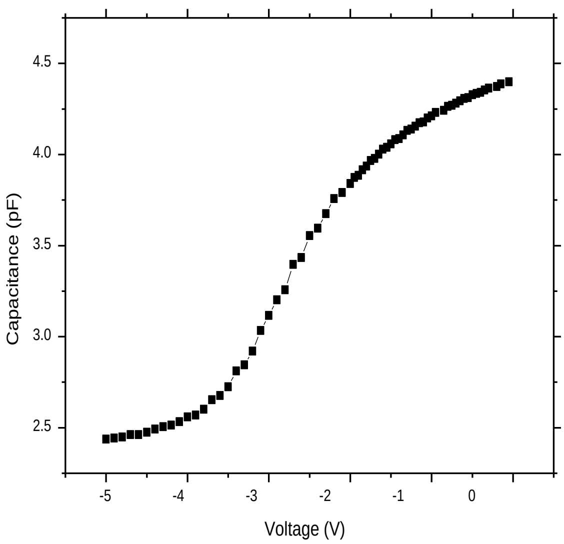

Fig 3. The graph between C-V of SiC at T=320K

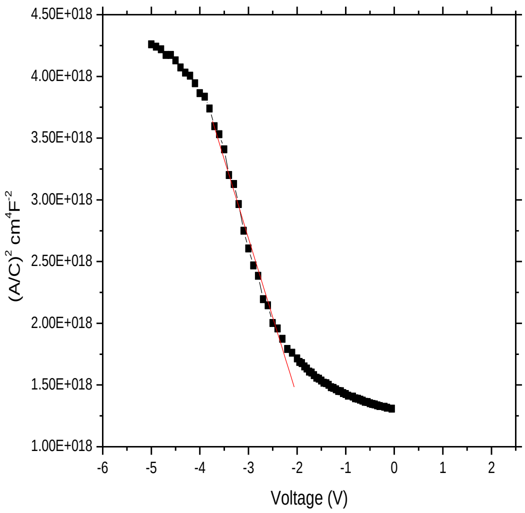

Fig 4. The graph between V and $(A/C)^2$ of SiC at T=320K

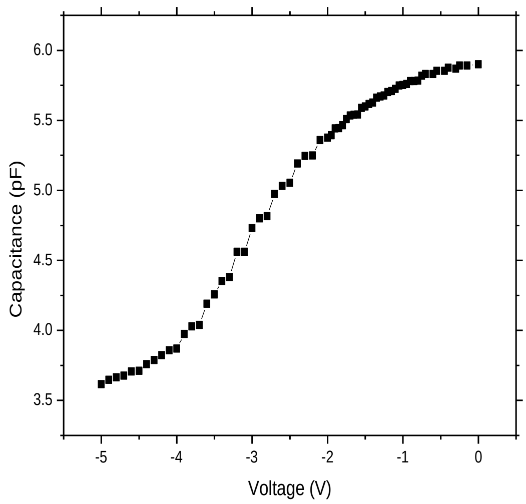

Fig 5. The graph between C-V of SiC at T=340K.

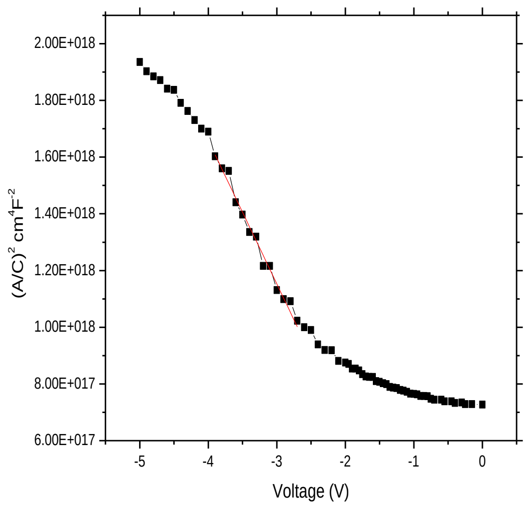

Fig 6. The graph between V and $(A/C)^2$ of SiC at T=340K

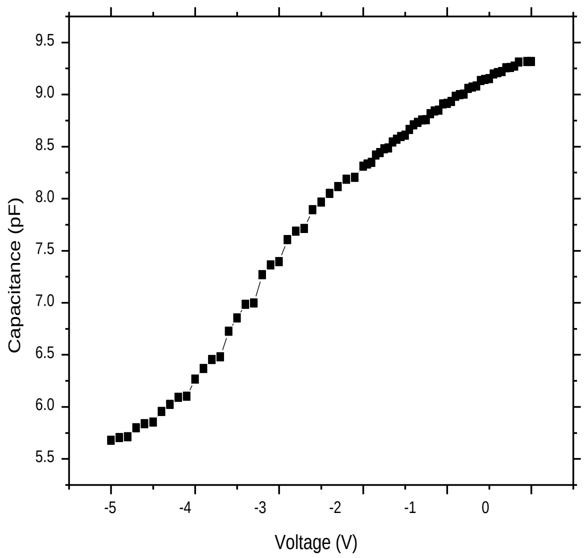

Fig 7. The graph between C-V of SiC at T=360K.

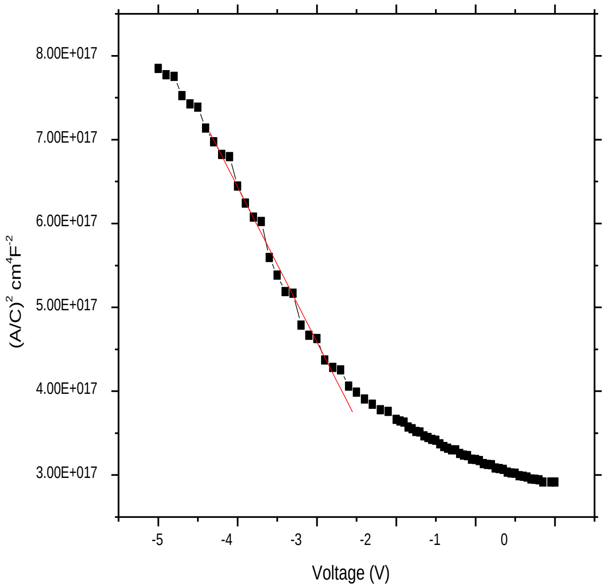

Fig 8. The graph between V and $(A/C)^2$ of SiC at T=360K.

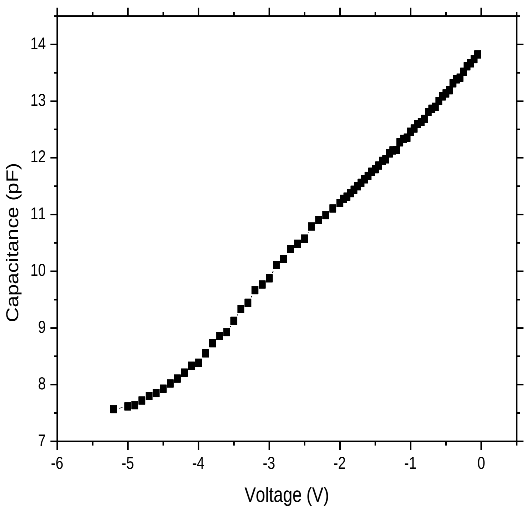

Fig: 9 the graph between C-V of SiC at T=380K.

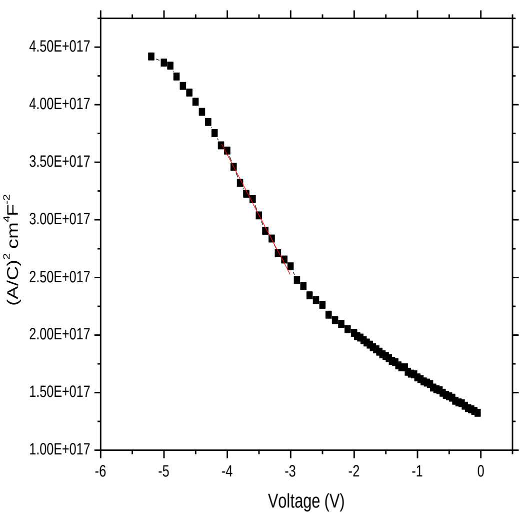

Fig: 10 the graph between V and $(A/C)^2$ of SiC at T=380K.

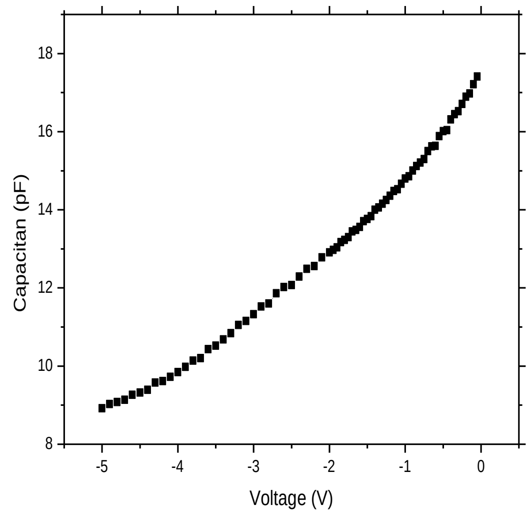

Fig: 11 the graph between C-V of SiC at T=400K.

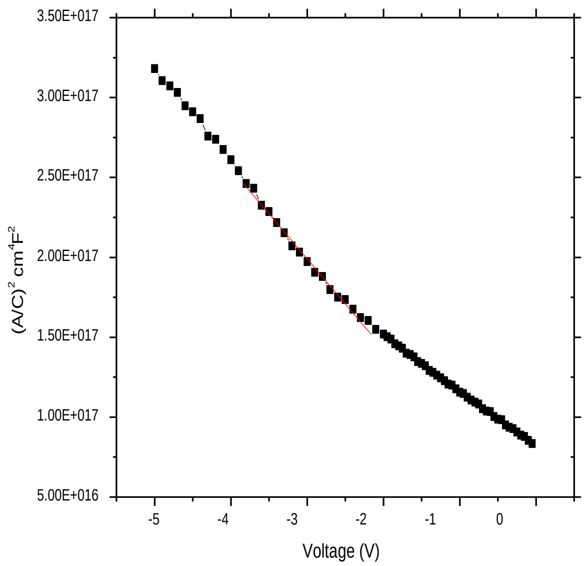

Fig:12 the graph between V and $(A/C)^2$ of SiC at T=400K.

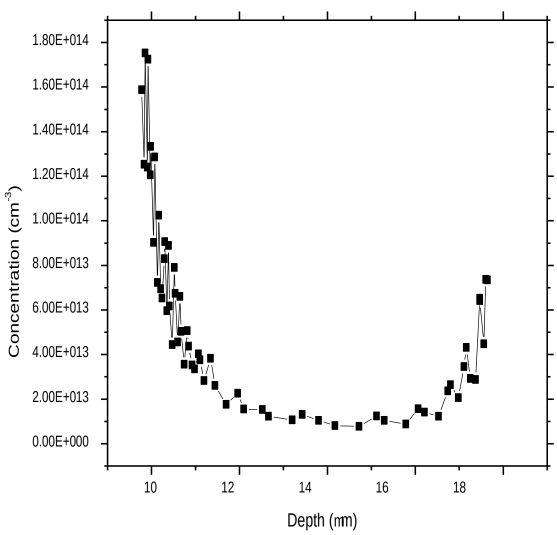

Fig 13 Depth profile of SiC at 320K.

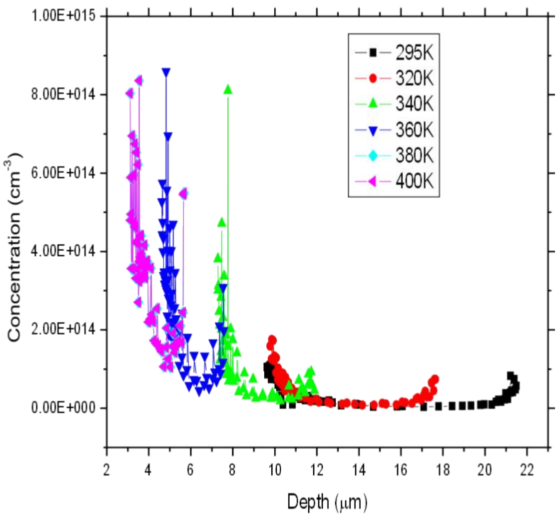

Fig: 14 Depth profile of SiC at various temperatures.

CONCLUSION

We studied the characterization of SiC by means of capacitance spectroscopy. The I-V characterization was performed to evaluate the rectifying behavior of the diode. The ideality factor (n), reverse saturation current (I_s) and barrier height (φ_B) of the diodes at various temperatures were evaluated. Doping concentration (N_d), built-in potential (V_{bi}) and depth profile were determined by C-V measurements.

The n-type 6H-SiC sample was grown on SiC substrate ~35μm thick by chemical vapors deposition technique. I-V and C-V measurements were taken at 295, 320, 340, 360, 380 and 400K. The calculated values of n, I_s, and φ_B at room temperature (R_T) were 1.9894, 6.57×10^{-13}A and 0.995eV respectively. N_d and V_{bi} at R_T were 5.2061×10^{12}cm^{-3} and 1.49V respectively. Over the temperature range, investigated I-V characteristics confirm that the conduction mechanism of the diode is controlled by thermionic field emission.

I-V measurements of SiC show ideality factor (n) to be close to unity at room temperature (R_T) indicating the main mechanism of current flow was thermionic emission. However, below the R_T, the ideality factor was bit higher which is understandable due to the freezing of carriers [3, 4, 5]. From C-V measurements the depth profiles of material remain uniform.

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