Study of Current-voltage Characteristic Using Deep Level Transient Spectroscopy Technique of Schottky Diode Made of SIC

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Abstract

Current spectroscopy was employed to investigate Silicon Carbide (SiC). DLTS standard setup was performed to study the current voltage measurement of respective schottky diode. The current voltage measurement of SiC schottky diode was carried out at different temperatures keeping the same biasing setting. From these measurements the behavior of the material is: The ideality factor of SiC at room temperature was found to be 1.9894 that was little bit improved i.e. ~ 1.7268 when temperature was increased ~400K. However values increased with decrease in temperature for the material. The higher value of ideality factor is attributed to high diffusion or tunneling current. The barrier height of SiC at room temperature was calculated as 0.995eV which remained nearly constant with increase in temperature. The change in the barrier height is related to the effective leakage current at high temperature. Reverse saturation current calculated for SiC at room temperature was 6.5706 $\times 10^{-13}$A. Its value increased up to 1.72$\times 10^{-9}$A at 400K.

Key words: Semiconducting Silicon Carbide materials; I-V characteristics; Deep level transient spectroscopy (DLTS) of the material; Schottky diode

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INTRODUCTION

Semiconductor devices usually operate over a temperature range. With development of electronics industry electronics devices with high performance at high temperature has become the need of the hours, especially in satellite communication. Where in space devices have to face ionization radiation which alter the performance. Devices being operated over a higher temperature range with wide band gap have attracted the scientists 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 (Elhaji et al., 2014). Because of the wide band gap energy (3.0 eV and 3.25 eV for the 6H and 4H polytypes 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 (Duman et al., 2009).

MATERIALS AND METHODS

Sample preparation

The sample wafer used for this research is 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 (Ciechonski, 2005) Circular Schottky contact of 0.8mm diameter using Au and Ni separately was made by thermal evaporation (Ahmad and Asghar).

Current-Voltage I-V Measurements

In most device applications, the linear range of the forward I-V characteristics is the most important. For low semiconductor doping levels, the dominant electron transport mechanism is the harmonic emission (Gilani et al., 2015). The I-V curve measurements functioned both as a diagnostic tool to determine the quality of the device contacts as well as a characterization technique for the evaluation of the diode properties. Several I-V measurements were made to verify the rectifying behavior of the Schottky contacts. I-V measurements were performed by DLS-83D system at different temperatures. From the I-V measurement we calculated the following parameters of the assumed junction: Ideality factor, Saturation current and Barrier height.

$$\text{n (Ideality factor)} = \frac{q}{Slope \times kT} \quad (1)$$

Where q = Charge = Boltz man constant

$$\text{Intercept} = \ln(I_s). \text{ Where } I_s = e^{\text{Intercept}} \quad (2)$$

$$\Phi_B = \frac{KT}{q} \ln[A^* \, T^2 / J_s] \quad (3)$$

RESULTS AND DISCUSSION

Here we discuss the measurement of the I-V characteristics over a voltage range of -5V to 1.9V at different temperatures 295K to 400K. The typical I-V characteristics of as grown n-type 6H-SiC at different temperatures are shown in Figures 1 to 12. The straight line in semi log I-V characteristics shows the theoretical linear fitting of the curves. Using equations (1), (2) and (3) we have calculated the values for Ideality factor, Saturation current and Barrier height:

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

Temperature (T) K	Ideality Factor (n)	Saturation Current (Is) A	Barrier Height (φ_B) eV
295	1.9894	6.57×10^{-13}	0.995
320	2.0897	6.57×10^{-12}	1.021
340	2.4051	1.29×10^{-10}	1.000
360	2.1149	1.19×10^{-9}	0.994
380	1.8920	1.04×10^{-9}	1.057
400	1.7268	1.72×10^{-9}	1.003

From the table 1 we deduced that SiC is a good schottky diode because of its ideal behavior. The value of ideality factor calculated in the range of 1.7 to 2.4 at various temperatures. The ideal behavior of SiC improved with increased in temperature up to 400K. The value of barrier height calculated in the range of 0.994 to 1.057 eV. Our results show that it remains approximately equal to 1 at various temperatures. Third factor calculated by I-V is saturation current which increases with increase in temperature from room temperature to 400K. These results verify that on increasing thermal agitation the value of reverse saturation current also increases. From literature the test results of Ramon C. (Lebron-Velilla et al., 2004) showed that at high temperature, the forward voltage drop for SiC Schottky diodes is higher (Ciechonski, 2005).

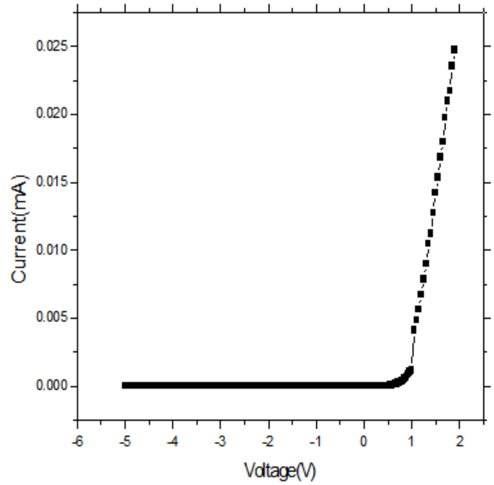

Figure 1: The graph between I-V of SiC at T= 295K.

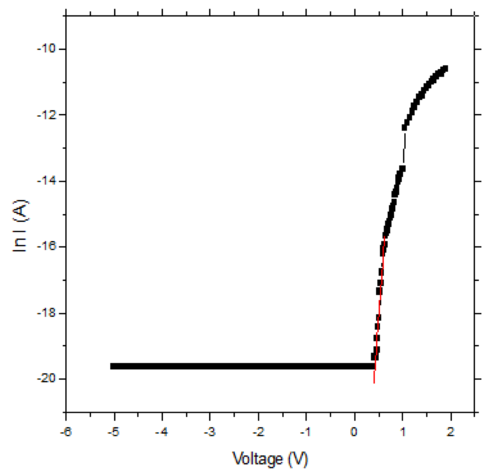

Figure 2: The graph between V and ln(I_s) of SiC at T= 295K

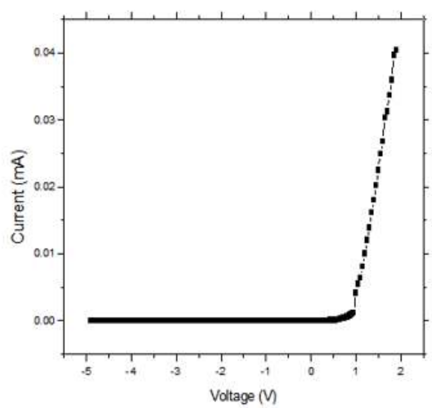

Figure 3: The graph between I-V of SiC at T= 320K.

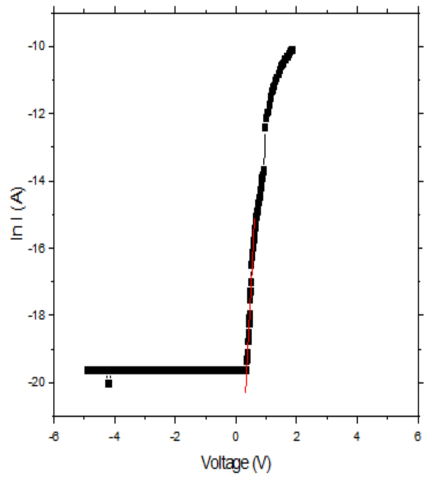

Figure 4: The graph between V and ln(I_s) of SiC at T= 320K.

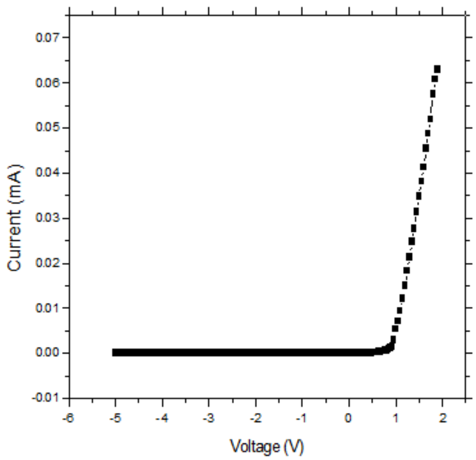

Figure 5: The graph between I-V of SiC at T= 340K.

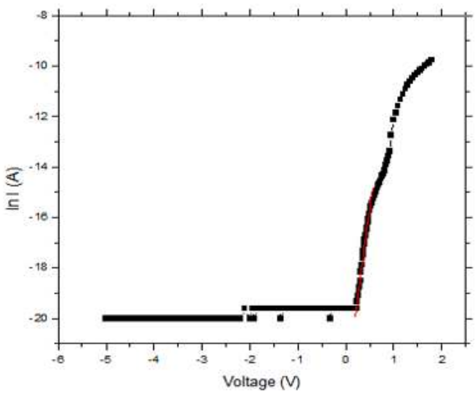

Figure 6: The graph between V and ln(I_s) of SiC at T= 340K.

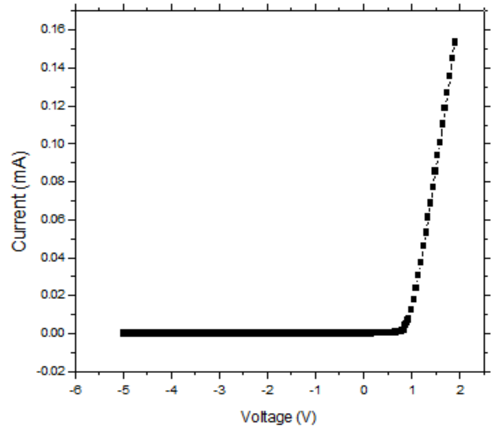

Figure 7: The graph between I-V of SiC at T= 360K.

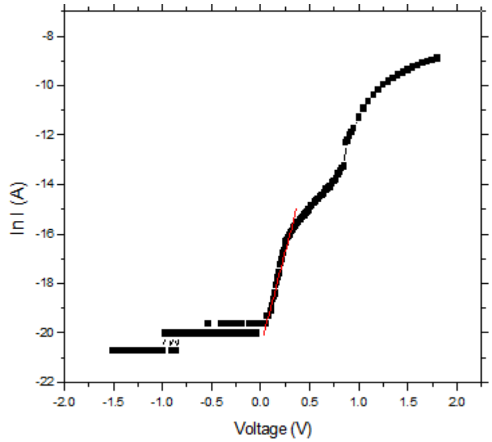

Figure 8: The graph between V and ln(I_s) of SiC at T= 360K

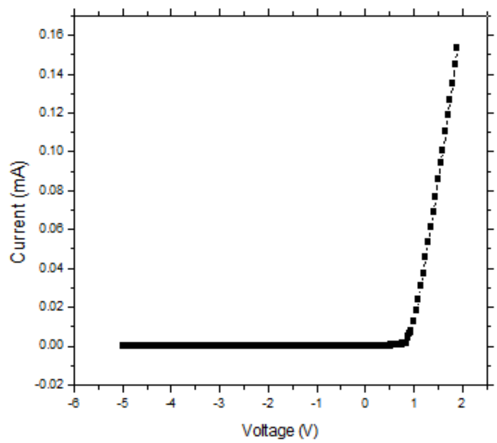

Figure 9: The graph between I-V of SiC at T= 380K

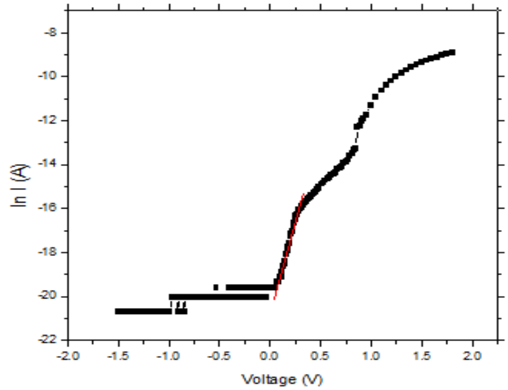

Figure 10: The graph between Vand ln(I_s) of SiC at T= 380K.

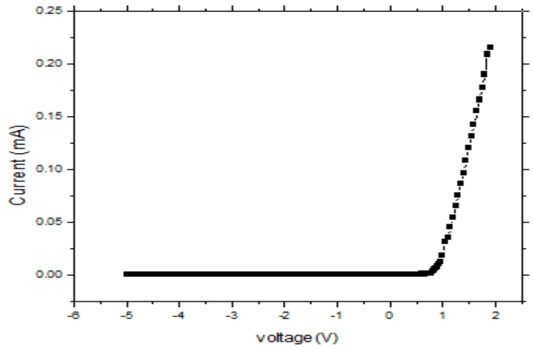

Figure 11: The graph between I-V of SiC at T=400K.

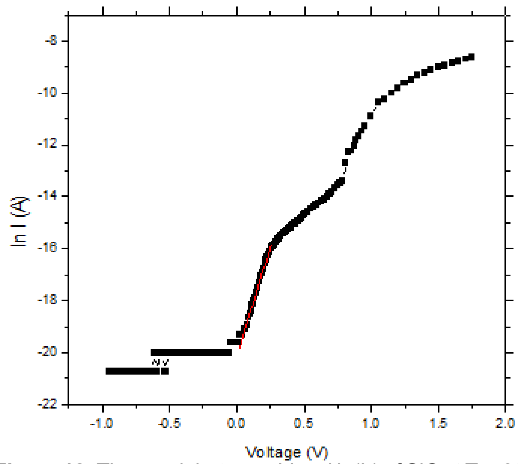

Figure 12: The graph between V and ln(I_s) of SiC at T=400K.

CONCLUSION

We studied the characterization of SiC by means of current voltage spectroscopy. 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.

The n-type 6H-SiC sample was grown on SiC substrate ~35μm thick by chemical vapors deposition technique. I-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. 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 (Duman et al., 2009), (Gür et al., 2011).

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