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Electrical and interface state density properties of the 4H-nSiC/[6,6]-phenyl C_{61}-butyric acid methyl ester/Au diode

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ABSTRACT

The electrical and interface state density properties of the Ni/4H-nSiC/PCBM/Au diode have been investigated by current–voltage, capacitance–voltage and conductance–frequency methods. The ideality factor, barrier height and series resistance values of the diode were found to be 2.28, 1.10 eV and $3.76 \times 10^4\ \Omega$, respectively. The diode shows a non-ideal *I–V* behaviour with an ideality factor greater than unity that could be ascribed to the interfacial layer, interface states and series resistance. The obtained barrier height (1.10 eV) of the Ni/4H-nSiC/PCBM/Au diode is lower than that of Ni/4H-nSiC diode (1.32 eV). This indicates that the PCBM organic layer induces a change of 160 meV in the barrier height of the Ni/4H-nSiC diode. The interface state density of the diode was determined from G_p/ω–f plots and was of order of $5.61 \times 10^{12}\ \mathrm{eV^{-1}\ cm^{-2}}$.

1. Introduction

The wide-band gap semiconductors such as SiC and GaN have been a subject of extensive investigations for several years and increased the demand for better understanding and control of the metal contacts, for making both good ohmic and rectifying Schottky contacts [1–7]. SiC is a very promising semiconductor due to its physical and electrical properties and it has excellent material properties, which makes it superior to Si in a wide range of applications. Metal–silicon carbide (SiC) interfaces play very important roles in many high-performance devices in optoelectronic, high temperature, high-frequency, and power applications. Organic semiconductors have a wide application in electronic technology. The electrical properties of metal–semiconductors contacts can be modified by organic semiconductors, when an organic layer is inserted between the inorganic semiconductor and metal. The studies made in literature have shown that the barrier height could be either increased or decreased by using organic thin layer on inorganic semiconductor [8–12]. The new electrical properties of the metal–semiconductor contacts can be promoted by means of the choice of suitable organic semiconductor. [6,6]-phenyl C_{61}-butyric acid methyl ester (PCBM) organic material has been considered as one of the most stable organic semiconductors for various electronic and optoelectronic applications and has been used for the fabrication of different electronic devices [13–14]. Our aim is to investigate the electrical properties of Ni/4H-nSiC diode by the insertion of PCBM organic layer between SiC semiconductor using forward bias *I–V* characteristics and impedance spectroscopy measurements and is to compare the parameters of the Ni/SiC/PCBM/Au structure with those of conventional metal/semiconductor diodes. Furthermore, we used conductance method to obtain valuable information about the parameters of interface states of the device. Because, understanding the nature of the interfacial layer is a key point in the study of SiC devices [15].

2. Experimental

The Schottky diodes have been prepared using n-type 4H-SiC (as received from the manufacturer) with $7.07 \times 10^{17}\ \mathrm{cm^{-3}}$ carrier concentration. The wafer was chemically cleaned using the Radio Corporation of America cleaning procedure [16]. The back ohmic contact was fabricated by evaporating Ni on the n-type 4H-SiC, followed by heat treatment at 950 °C for 5 min in N_2 atmosphere [16]. The solution of the PCBM was prepared and the solution was homogenized for 15 min by mixing with rotation before the deposition. Then, the film of the PCBM was prepared by deposition of blend solution on the 4H-SiC wafer by dip coating technique. The thickness of the PCBM film was determined using high-frequency capacitance–voltage characteristics and the capacitance of the organic layer C_{org}, was found to be 1404 pF. Thus, the thickness of the PCBM layer was calculated to be 19.29 nm using $C_{org} = \varepsilon A/\delta$ relation [17]. The Schottky contacts were formed by evaporating Au on the PCBM organic layer deposited on the front of the n-type 4H-SiC. The Au metal was evaporated using PVD-HANDY/2S-TE (Vaksis Company) vacuum thermal evaporation. The current–voltage

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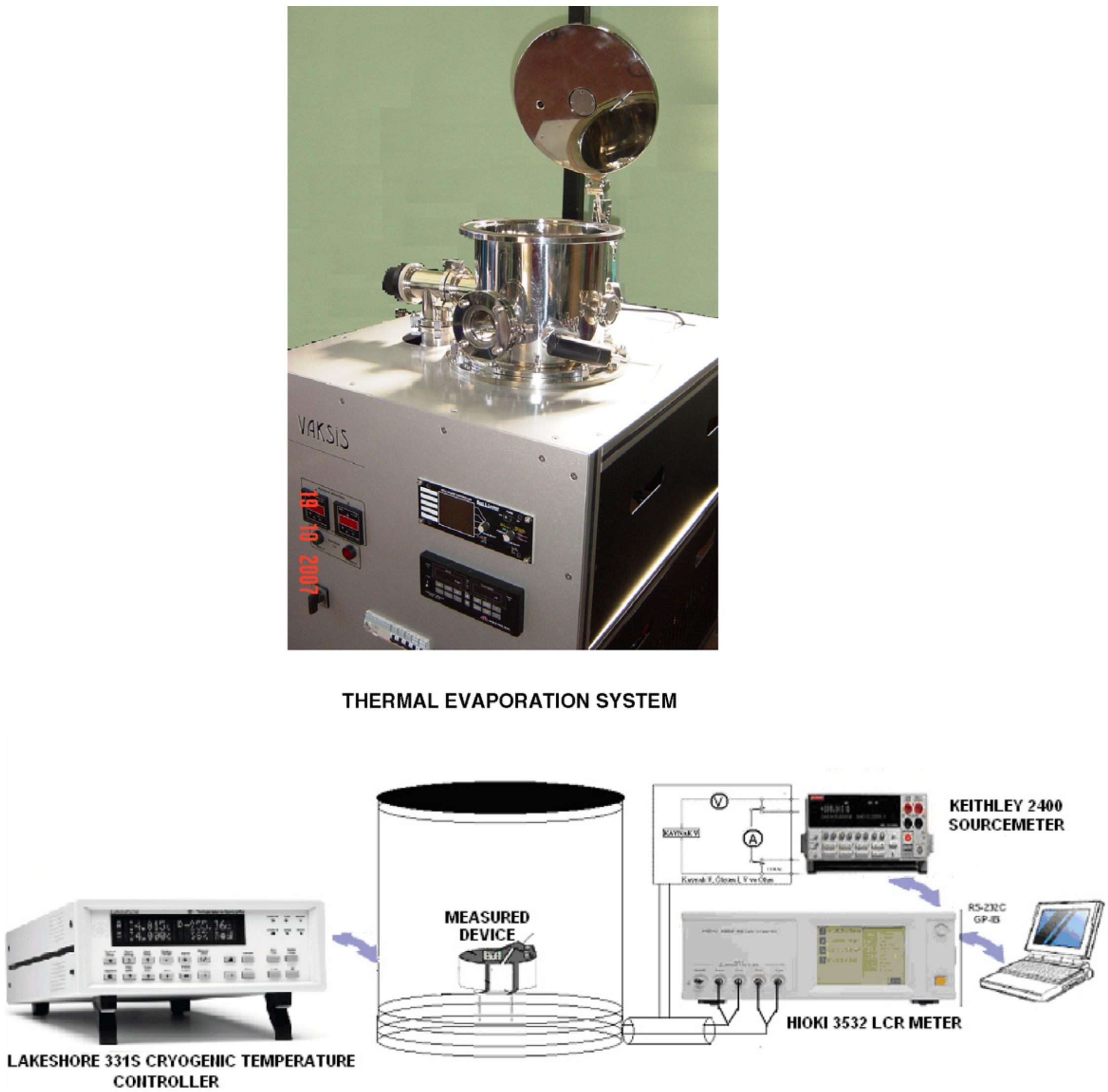

Fig. 1. The experimental system for diode fabrication and electrical characterization system.

(I–V) characteristic of the Ni/SiC/PCBM/Au diode was performed with 2400 KEITHLEY source meter and GPIB data transfer card for current–voltage measurements. The capacitance–voltage measurements were measured using a 3532 HIOKI HITESTER LCR. The experimental system for diode fabrication and I–V, C–V measurements is shown in Fig. 1.

3. Results and discussion

3.1. Current–voltage characteristics of Ni/4H-nSic/PCBM/Au diode

Fig. 2a shows the current–voltage (I–V) characteristics of the Ni/4H-nSic/PCBM/Au diode under dark and illumination conditions. The dark I–V characteristics indicate that the diode exhibits a rectifying behaviour. As seen in Fig. 2a, the current in reverse direction of the diode under 3500 lux illumination intensity is higher than under dark condition. i.e., the current in the reverse direction is strongly increased by the illumination. This suggests that the carrier charges are effectively generated in the junction by illumination due to electron–hole pair generation.

The current–voltage characteristic of the Ni/4H-nSic/PCBM/Au diode with the series resistance is expressed by the following relation [18],

$$I = I_o \exp\left(\frac{q(V - IR_s)}{nkT}\right)\left[1 - \exp\left(-\frac{q(V - IR_s)}{kT}\right)\right] \quad (1)$$

where R_s is the series resistance, V is the applied voltage, n is the ideality factor, k is the Boltzmann constant, T is the temperature, and I_o is the reverse saturation current given by

$$I_o = AA^* T^2 \exp\left(-\frac{q\phi_B}{kT}\right) \quad (2)$$

where I_o is the saturation current, A is the contact area, A^* is the Richardson constant (146 A cm^{-2} K^{-2} for 4H-nSic) [19]. The I_o value of the diode was found to be 2.14×10^{-15} A. This value is quite low due to the organic layer. This suggests that the organic PCBM layer modifies the electrical properties of the 4H-nSiC diode. The ideality factor and barrier height were determined from forward I–V characteristic and were found to be 1.96 and 1.16 eV, respectively. The