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Electrical parameters of a DC sputtered Mo/n-type 6H-SiC Schottky barrier diode

Sezai Asubay [a], Mustafa Fatih Genisel [b,c], Yusuf Selim Ocak [b,c,*]

[a] Department of Physics, Faculty of Science, Dicle University, 21280 Diyarbakir, Turkey
[b] Department of Science, Faculty of Education, Dicle University, 21280 Diyarbakir, Turkey
[c] Science and Technology Application and Research Center (DUBTAM), Dicle University, 21280 Diyarbakir, Turkey

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ABSTRACT

A Mo/n-type 6H-SiC/Ni Schottky barrier diode (SBD) was fabricated by sputtering Mo metal on n-type 6H-SiC semiconductor. Before the formation of Mo/n-type 6H-SiC SBD, an ohmic contact was formed by thermal evaporation of Ni on n-type 6H-SiC and annealing at 950 °C for 10 min. It was seen that the structure had excellent rectification. The electrical parameters were extracted using its current–voltage (*I–V*) and capacitance–voltage (*C–V*) measurements carried out at room temperature. Very high (1.10 eV) barrier height and 1.635 ideality factor values were reported for Mo/n-type 6H-SiC using ln *I–V* plot. The barrier height and series resistance values of the diode were also calculated as 1.413 eV and 69 Ω from Norde's functions, respectively. Furthermore, 1.938 eV barrier height value of Mo/n-type 6H-SiC SBD calculated from *C–V* measurements was larger than the one obtained from *I–V* data.

1. Introduction

Metal-semiconductor (MS) contacts have an important place in semiconductor device technology and have been still investigated by researchers [1–4]. They have been used in a number of applications including gates for MS field effect transistors, solar cells and detectors [5]. The main characteristic parameters of MS contacts or Schottky contacts are barrier height and ideality factors.

Although silicon carbide (SiC) was one of the earliest discovered semiconducting materials, it did not have an important place with respect to its counterparts in modern technology owing to difficulties of growing conditions. The high Si–C bonding energy value makes SiC chemically resistive and stable at high temperatures [6]. Because of relatively high band gap value (2.3, 2.9 and 3.3 eV for 3C-SiC, 6H-SiC and 4H-SiC, respectively) [7], very good thermal conductivity and large avalanche breakdown voltage, SiC has been used for the fabrication of high temperature electronics, high power microwave applications and high-radiation environments [6].

There are many ways for growing thin films on different substrates including thermal evaporation, DC and RF magnetron sputtering, e-beam evaporation, pulsed laser deposition and sol–gel methods [4,8–11]. Among the other methods, DC magnetron sputtering of refractory metals is very powerful to obtain their homogeneous thin films on surfaces. Sputter deposition involves the bombardment of the target with positive gas ions and leads to the bombardment of the growing film by energetic particles [4].

In this study, Mo metal was DC sputtered on n type 6H-SiC substrate to obtain Mo/n-6H-SiC Schottky barrier diodes (SBD) after forming Ni back contact on the substrate. Electrical properties of the diode were analyzed by the aid of current–voltage and capacitance–voltage measurements.

* Corresponding author. Tel.: +90 412 248 80 30 8889.
E-mail addresses: yusufselim@gmail.com, yusufselim@dicle.edu.tr (Y.S. Ocak).

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2. Experimental procedures

A Mo/n-type 6H-SiC/Ni Schottky barrier diode was prepared using a n-type 6H-SiC semiconductor (MTI Corporation). The wafer was boiled in trichloroethylene and exposed to ultrasonic vibration in acetone and isopropanol for 5 min to remove organic contaminations from the surface. The wafer was dipped into solution of H_2O/HF (10:1) for 30 s in order to remove native oxide layers on the surfaces. The wafer, then, were dried under N_2 atmosphere. An ohmic contact was formed by thermal evaporation of Ni on n-type 6H-SiC and annealing at 950 °C for 10 min. After formation of the ohmic back contact, the native oxide layer formed during previous processes was removed by solution of H_2O/HF (10:1) and dried under N_2 atmosphere. The structure was then immediately loaded into a vacuum chamber. Mo target (Kurt J. Lesker) was used for sputtering process. Mo/6H-SiC/Ni MS contact was formed by DC magnetron sputtering of Mo metal on a n-type 6H-SiC/Ni structure. The area of diode was 0.0176 cm^2. The electrical parameters were extracted using its current–voltage (I–V) and capacitance–voltage (C–V) measurements carried out at room temperature by the aid of a Keithley 2400 sourcemeter and an Agilent 4294 A impedance analyzer, respectively.

3. Results and discussion

The semi-logarithmic current–voltage (I–V) relationship of Mo/n-type 6H-SiC SBD is presented in Fig. 1. According to the thermionic emission theory, the forward bias current of a SBD with a series resistance is expressed as [12]

$$I = I_0 \exp\left(\frac{q(V - IR_S)}{nkT}\right) \tag{1}$$

where I_0 is the saturation current and written as

$$I_0 = AA^*T^2 \exp\left(\frac{q\phi_b}{kT}\right) \tag{2}$$

and q is the electron charge, R_S is the series resistance, n is the ideality factor, k is the Boltzmann constant, T is the absolute temperature, A is the effective diode area, A^* is the Richardson constant, and ϕ_b is the barrier height of the diode. The dimensionless ideality factor of a diode which shows how closely the diode follows the ideal diode equation can be determined from the slope of the linear region of the semi-log forward bias I–V characteristics using

$$n = \frac{q}{kT}\frac{dV}{d(\ln I)} \tag{3}$$

The ideality factor of Mo/n-type n-SiC MS contact was calculated as 1.635 from Eq. (3). The ideality factor which is greater than unity implies the deviation from ideal diode. This deviation can be attributed the effects of native thin oxide layer and interface states between metal and semiconductor. Similarly, Ocak et al. [4] fabricated Ta/Si MS contact by DC sputtering of Ta which is one of the refractory metals and reported the ideality factors of Ta/p-Si and Ta/n-Si as 1.25 and 1.15, respectively.

The barrier height (ϕ_b) of Mo/n-type n-SiC MS contact was executed as 1.10 eV using saturation current value obtained from Fig. 1 and Eq. (2). Romanov et al. [13] have obtained metal/n-6H-SiC diode structures with ideality factors of 1.28–2.14 and potential barriers from 0.58 to 0.62 eV on the semiconductor side by pulsed laser deposition of Au, Ag, Cu, Pd, Pt, W, and Zr metal films on n-6H-SiC substrates. Barrier height value of Mo/4H-SiC MS structure were reported as 1.39 eV by Boussouar et al. [14].

Deviation from linearity at relatively high voltages for Mo/n-type n-SiC MS in Fig. 1 implies the effect of series resistance and interface states on current–voltage characteristics of the device. The ideality factor, barrier height and series resistance values of the structure can be calculated by means of Cheung functions which are given as [15]

$$\frac{dV}{d(\ln I)} = IR_S + n\left(\frac{kT}{q}\right) \tag{4}$$

and

$$H(I) = V - \left(\frac{nkT}{q}\right)\ln\left(\frac{I}{AA^*T^2}\right) = IR_S + n\phi_b \tag{5}$$

The $dV/d(\ln I)$–I and $H(I)$–I plots should be linear at the series resistance region. Fig. 2 presents the $dV/d(\ln I)$–I and $H(I)$–I plots. The R_S and n values were executed from the slope and y-axis intercept of the $dV/d(\ln I)$–I graph as 43 Ω and 2.04, respectively. Furthermore, the R_S and ϕ_b values were extracted from the slope and y-axis intercept of the $H(I)$–I graph as 43 Ω and 1.08 eV, respectively. The series resistance values determined from both plots are used for the consistency of the method. The large difference between the ideality factor values calculated from the

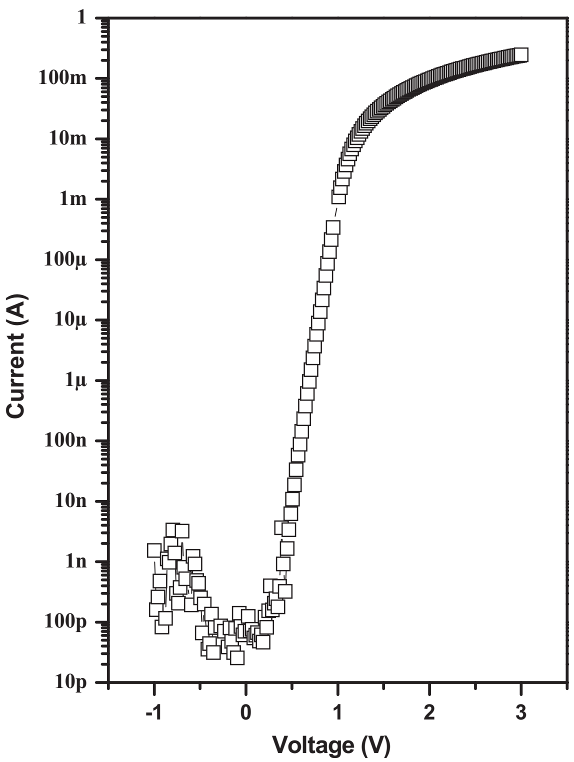

Fig. 1. The current–voltage plot of Mo/n-type 6H-SiC Schottky barrier diode.