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LARGE AREA 6H–SiC SCHOTTKY DIODE

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Abstract. This paper describes experimental investigation of a large area 6H–SiC Schottky diode fabricated with diffusion welding technology. A new model for the dependence of the barrier height on the temperature is presented.

Key words: SiC, Schottky structures, barrier height, temperature influence.

1. INTRODUCTION

Conductive films are used to provide interconnection between contacts in devices and between devices and the outside world. Usually the contact is a metal layer on a semiconductor substrate, which forms with the substrate a certain type of junction (interface). Depending mainly on the barrier height between the metal and the semiconductor, two extreme types of contacts from the point of view of the current are created – nearly linear type (ohmic contact) and strongly non-linear type (Schottky contact).

In this paper we describe briefly a new manufacturing technology of a large area 6H–SiC Schottky structure, protected by an Estonian patent [1]. For the same Schottky structure, the measurement scheme for defining the *U–I* characteristics at various temperatures is introduced and the barrier height dependence on the temperature is discussed.

2. MANUFACTURING OF THE SCHOTTKY STRUCTURE

Using our equipment UDS-5 for diffusion welding [2], we succeeded to produce during one high temperature step simultaneously two-sided metallization for a 6H–SiC substrate which has at the top surface a C-face and in the bottom surface a Si-face. For the metallization, the 99.99% clean Al film with the thickness of 0.05 mm and diameter of 8 mm was used (for both sides of the SiC pieces). The SiC wafers (diameter 35.0 mm, thickness 0.33 mm, net doping concentration 4×10^{18} cm^{-3} (N_D–N_A), orientation 3.5° off {0001}, polished surface on the C-face) were purchased from CREE Research Inc., USA. Before the metallization, the wafers were cut into pieces 1×1 cm. Among different surface treatment processes, the following proved to be the best. SiC pieces were first cleaned during 10 min in a $NH_4OH:H_2O_2:H_2O$ (1:1:5) solution, then 10 min in $HCl:H_2O_2:H_2O$ (1:1:5) solution at 70 °C, followed by ultrasound cleaning in acetone and ethanol. The Al film was cleaned during 1 min in H_3PO_4 (450 ml), CH_3COOH (90 ml), HNO_3 (18 ml), and H_2O (30 ml) solution at 60–70 °C, followed by ultrasound cleaning in acetone and ethanol. The duration of the diffusion welding process for metallization was 500 s under pressure of 50 MPa at a temperature of 600 °C. The formed contact had an excellent mechanical bond for both C- and Si-faces.

As a final result, at the C-face a Schottky contact was formed with the barrier height (*U–I* measurements; temperature 293 °K) Φ_{Bn} equal to 0.66 V, which is close to published data for unannealed Al-C-face-6H–SiC Schottky barriers [3]. At the Si-face (the bottom of the pieces) the Al film formed the ohmic contact. The contact areas in both cases were about 50 mm^2 (this was probably the first successful forming of large area contacts to a 6H–SiC substrate).

3. MEASUREMENT SET-UP

The determination of the *U–I* characteristic means defining of the function $U_{AK} = f(I_A)$ at constant temperature (U_{AK} is the applied anode–cathode voltage of the diode structure and I_A is the anode current). Simplified picture of the measurement set-up is presented in Fig. 1. Measured structure 1 is placed between press contacts 2 and 3. The whole block is placed in a thermal chamber.

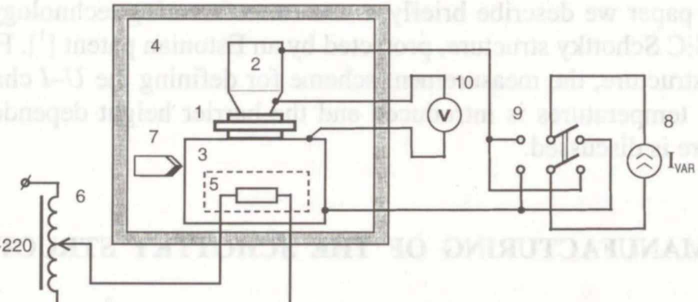

Fig. 1. Measurement set-up: 1 – SiC structure; 2, 3 – pressure contacts; 4 – thermal chamber; 5 – heating element; 6 – transformer; 7 – thermocouple; 8 – current source; 9 – switch; 10 – voltmeter.

The heating of the structure up to the demanded temperature takes place with the help of a bottom electrode which has an electrically isolated built-in heater 5. The temperature of the heater is regulated with the transformer 6. The temperature is checked with the help of a thermocouple 7. The *U–I* characteristic is obtained by initializing the current through the structure and recording the corresponding voltage drop in the structure with a numerical voltmeter 10. The regime "on-off" is realized with the help of a switch 9. To avoid the self-heating effect of the structure during the measurement, the measurement time is limited to 3 seconds.

4. RESULTS AND DISCUSSION

To define the barrier height from the *U–I* characteristic, a standard procedure has been used. The temperature dependence of the Schottky barrier heights, given in the literature (e.g., [4]), is linear. Our experiments proved this conclusion. The dependence of the barrier height on the temperature is described as

$$\Phi_{\mathrm{Bn}}(T) = \Phi_{\mathrm{Bn0}} + \alpha T , \tag{1}$$

where $\Phi_{\mathrm{Bn0}} = 4.68 \times 10^{-4}$ V and $\alpha = 2.26 \times 10^{-3}$ 1/K.

The measured and calculated barrier height values are shown in Fig. 2.

The linear model [Eq. (1)] agrees fairly well with the measured results over the whole measured interval. In the literature, the values $\Phi_{\mathrm{Bn0}} = 0.37$ V and $\alpha = 1.1 \times 10^{-3}$ 1/K are reported for 6H–SiC Schottky barriers [4]. Figure 2 shows that at room temperature the linear models coincide ideally. The different slopes, we guess, is caused by the difference in the technology used for manufacturing the Schottky barrier. Therefore a serious question arises: how sensitive is the barrier height (interface area) to manufacturing technology? Our previous investigations [2,5,6] show that the diffusion welding technology (DWT) generates additional dislocations near the surface inside the interface area between the metal and the SiC substrate (thickness about 5 nm). Such type of interface area with increased number of dislocations is missing in contacts manufactured with

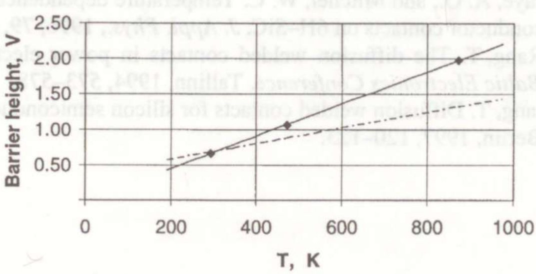

Fig. 2. Dependence of the barrier height on the temperature: — linear model, Eq. (1); – · – linear model [4]; ♦ – measured values.

traditional sputtering techniques. We guess that the temperature dependence of dislocations inside the interface area influences the temperature dependence of the barrier height and makes it nonlinear. Unfortunately, the temperature behaviour of dislocations is still unclear and needs basic material research.

5. CONCLUSIONS

The technology of manufacturing with DWT large area power 6H–SiC Schottky diodes and the *U–I* measurements have been described. Using the measured *U–I* characteristics, the barrier height and its temperature dependence have been determined. For the temperature dependence of the barrier height, a new model has been presented. An assumption has been made that the temperature dependence of dislocations inside the interface area influences the character of the dependence of the barrier height on the temperature. This assumption needs further microscopic and audio-frequency modulation investigations of the interface area.

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SUUREPINNALINE 6H–SiC SCHOTTKY DIOOD

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On kirjeldatud difusioonkeevituse meetodil loodava suurepinnalise 6H–SiC Schottky dioodi valmistamistehnoloogiat ning selle struktuuri pinge–voolu karakteristikute mõõtmistehnikat erinevatel väliskeskkonna temperatuuridel. Mõõtmistulemuste põhjal on määratud Schottky barjääri kõrguse temperatuurisõltuvus.