

Fabrication of High Performance 4kV SiC Schottky Barrier Diode

Background

Silicon carbide (SiC) is a promising material for high-voltage and low-loss power semiconductor devices because of its high critical electric field. Schottky barrier diodes (SBDs)^{*1} using SiC have been commercially available, however these SiC-SBDs have low performance in comparison with ideal performance of SiC. To fabricate high performance (high-voltage, high current capacity, and low-loss) SiC-SBDs, we have achieved a reduction of defects in SiC epilayer and a fabrication of high-voltage SiC-SBD.

Objectives

To develop Schottky contact fabrication technique for high-voltage and low-loss, and to fabricate high performance SiC-SBD using the technique.

Principal Results

We applied the new Schottky contact fabrication technique to SiC-SBDs using high quality SiC epilayers fabricated by our group and evaluated the SiC-SBDs.

1. Development of Schottky contact fabrication technique

We found that high temperature (> 600°C) annealed Mo Schottky contact shows superior properties (Schottky barrier height = 1.2-1.3 eV and ideality factor < 1.1^{*2}) for reduction of power loss in high-voltage SiC-SBD.

2. Performance of fabricated SiC-SBD using high temperature annealed Mo Schottky contact

We fabricated SiC-SBDs using Mo Schottky contact annealed at 600°C as shown in fig.1 (Schottky contact areas are 1 and 9 mm²). Figure 2 depicts current voltage characteristics of the SBDs. The SBDs showed specific on resistances (R_{on}) of 9.07 and 12.20 mΩ/cm², breakdown voltages (V_b) of 4.15 and 4.4 kV, forward voltages (at 100 A/cm²) of 1.89 and 2.16 V, and reverse leakage currents (at -4 kV) of 0.96 and 0.66 mA/cm². We also confirmed a forward current conduction of 20 A in the 9 mm² SiC-SBD.

3. Evaluation of fabricated SiC-SBD using high temperature annealed Mo Schottky contact

We evaluated high temperature annealed Mo SiC-SBDs using the V_b^2/R_{on} value^{*3}. The V_b^2/R_{on} values were 1898 and 1586 MW/cm² (Schottky contact area 1 and 9 mm²), which are considerably higher than the established world record of 1196 MW/cm². To evaluate a performance as a large Schottky contact area SBD, we calculated $V_b^2/(R_{on} \cdot A)$ value (A is Schottky contact area). The $V_b^2/(R_{on} \cdot A)$ of 142.8 MW was obtained in 9 mm² Mo SiC-SBD. This value is about 10 times higher than the established world record of 14.2 MW (see fig.3 and 4).

Future Developments

We will abstract limiting factors for enlargement of Schottky contact area. We will also fabricate and evaluate 1 cm² SiC-SBD.

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Reference

T. Nakamura, et.al., 2005, "A 4.15 kV 9.07-mΩ · cm² 4H-SiC Schottky-Barrier Diode Using Mo Contact Annealed at High Temperature", IEEE Electron Device Letters, Vol. 26, No. 2

* 1 : One of rectifiers using a metal/semiconductor contact.

* 2 : Schottky barrier height indicates the difference of potentials at an interface between a metal and a semiconductor. This parameter is important to determine a forward voltage and a leakage current. Ideality factor depicts a quality of the interface. In general, the ideality factor is from 1 to 2, this parameter shows below 1.1 in a high quality interface.

* 3 : V_b^2/R_{on} value is usually used as figure of merit for SBD. High performance SBD shows higher value.

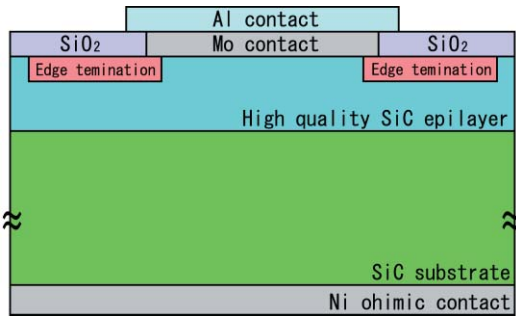


Fig.1 Schematic illustration of fabricated high performance SBD

To obtain high-voltage, edge termination was placed on the edge of Mo contact.

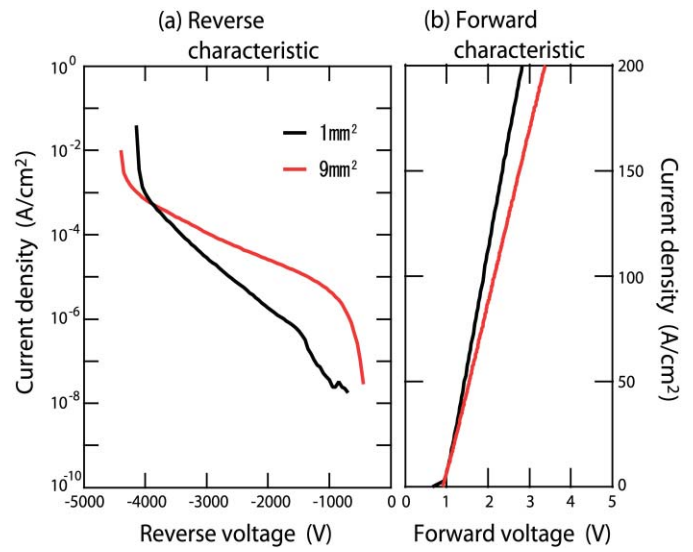


Fig.2 Current-voltage characteristics of 1 and 9 mm² SiC-SBD using high temperature annealed Mo contact

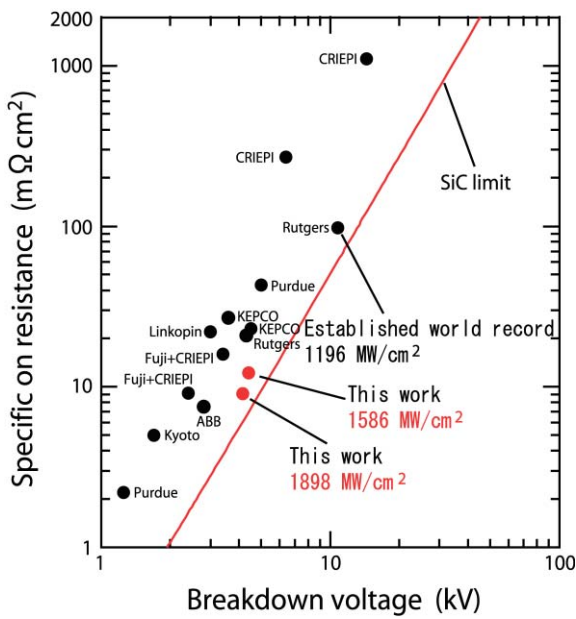


Fig.3 Relationship between V_b and R_{on}

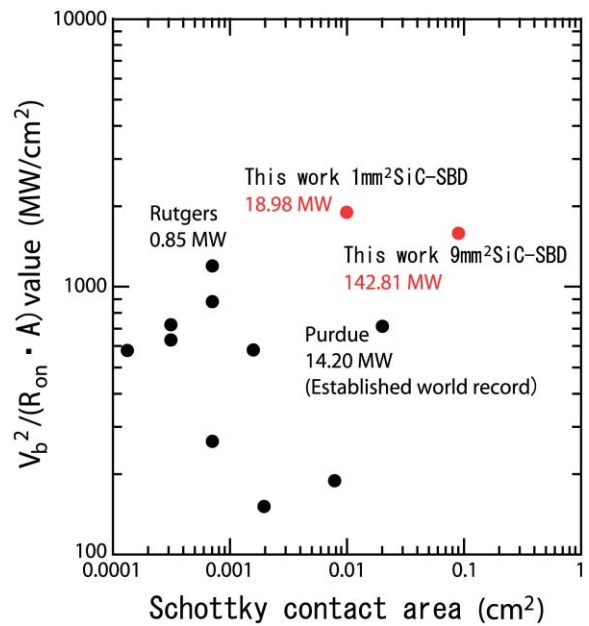


Fig.4 Relationship between Schottky contact area and $V_b^2/(R_{on} \cdot A)$ value