CURRENT-VOLTAGE PROPERTIES OF SCHOTTKY CONTACT FORMED BY COPPER LAYER DEPOSITED ON ION-IMPLANTED P-TYPE DIAMONDS

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Abstract

We have formed a Schottky contact on p-type diamond substrates doped only by boron ion implantation process. The doping concertation in the drift layer was 4×10^{18} cm^{-3} and that beneath the Ohmic contact layer was about 1×10^{21} cm^{-3} in order to reduce the contact resistance at the Ohmic contact. We investigate the rectifying properties for the Schottky electrode fabricated by copper layer. The observed current between two Ohmic electrodes linearly depended on the applied voltage. From the *I-V* characteristics between the Ohmic and Schottky contacts, the rectification behavior was not clearly observed for the case of copper electrode, and rectification ratio, which is the current ratio of forward direction to reverse direction, was considerably low.

I. Introduction

Diamond is expected for a candidate of future power devices due to excellent material properties such as wide band gap, high carrier mobility, and high break-down electrical field [1-5]. One of the main subjects in the device fabrication on diamond is the impurity doping with well controlling p-type and n-type conduction. Here, the impurity doping with ion-beam technology is known as an essential process in semiconductor fabrication to dope impurities in the designated area and depth with an accurate concentration, being widely used in Si technology today. However, the electrical activation of impurities doped in diamond with ion implantation technique has not succeeded for a long period. In 2019, we practically realized the impurity activation of the p-type B-implanted diamond by well controlling the conditions of implantation and activation annealing [6]. Moreover, we fabricated Schottky barrier diode (SBD) consisting of an Al layer on p-type diamond formed by B-implantation and confirmed rectifying properties in *I-V* measurements [7]. In this study, we investigated SBD properties analyzed by *I-V* measurements for various kinds of metals.

II. Experiment

We purchased high-quality type IIa diamond substrates synthesized by chemical vapor deposition (CVD) method from Element Six Ltd. B ions at the incident energies from 5 to 60 keV were implanted in the chemically cleaned diamond substrates at room temperature (RT) with a uniform doping concentration of 3.5×10^{18} cm^{-3} from the surface to 100 nm depth. In addition, we excessively implanted B ions in the area of Ohmic electrodes with a high concentration of 10^{21} cm^{-3} to obtain good Ohmic contact. Fig. 1 shows the simulated B depth profile according to TRIM calculation [8]. After the above B-doping process, the sample surface was covered with a thin SiO_2 film with about 100 nm

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thick by a RF sputtering deposition method to protect the surface roughness generated in high-temperature annealing. The activation annealing was performed at 1300°C for 2 h in Ar ambience. The capped SiO_2 layer was then removed by diluted HF solution with 5 % concentration after the activation annealing. The detailed process can be shown in the previously published papers [6,7, 9,10].

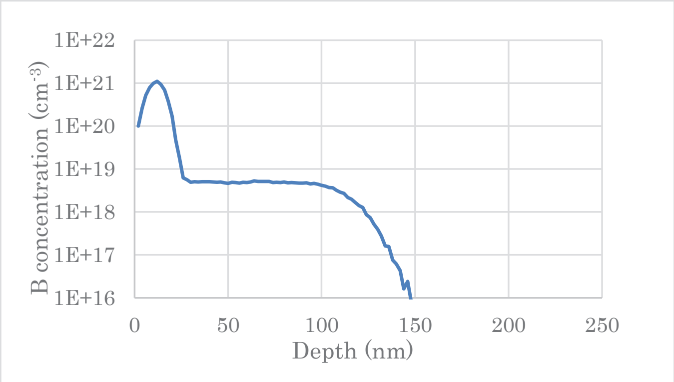


Fig. 1: Simulated B depth profile according to TRIM calculation.

The B-implanted substrate was finally deposited Ohmic and Schottky electrodes by a magnetron sputtering method on the designated area through precisely processed mask patterns. The optical microscope image of the diamond substrate deposited with Ohmic and Schottky electrodes is shown in Fig. 2 and the schematical cross-sectional image depicted along the dashed line in Fig. 2 is shown in Fig. 3. The roundly shaped pattern existent in the center of the sample corresponds to the Schottky electrode consisting of a Cu layer covered with a thick Au layer with the layer thickness of 0.5 μm and 1 μm, respectively. The electrodes surrounding the Schottky electrode are Ohmic ones consisting of Au/Ti bilayer with thickness of 200 and 50 nm, respectively. The Ohmic electrode was deposited through a horseshoe-shaped mask at the substrate temperature of 400°C, and the Schottky electrode was then deposited through a roundly opened mask at RT. We first measured electrical properties at RT based on current-voltage (*I*-*V*) measurements between two Ohmic electrodes and Ohmic and Schottky electrodes.

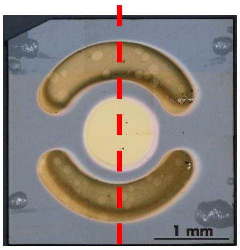


Fig. 2: The optical microscope image of the diamond substrate deposited with Ohmic and Schottky electrodes. Round-shaped electrode in the center of the sample corresponds to the Schottky electrode and two horseshoe-shaped electrodes surrounding the Schottky electrode are Ohmic ones.

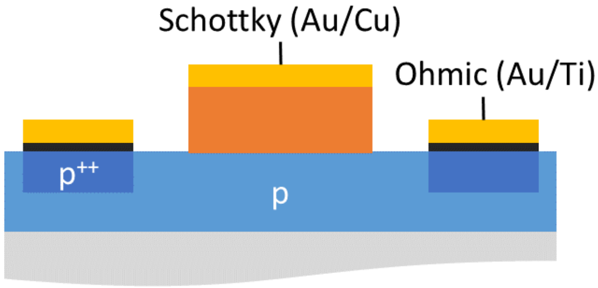


Fig. 3: Schematical cross-section-image depicted along the red dashed line drawn in Fig. 2.

III. Results and discussion

The *I-V* property measured between two Ohmic electrode comprised with Au/Ti layers is shown in Fig. 4. The *I-V* property was measured in the applied voltage range of ±50 V. As shown in Fig. 4, the current was almost linearly increased as a function of the applied voltage, indicating that the Au/Ti electrodes show Ohmic feature. The electrical resistance between them was about 50 kΩ. Fig. 5 shows the *I-V* property measured between the Au/Ti and Au/Cu electrodes with a linear (a) and a logarithmic (b) scale. It is found in the figures that rectifying property is not clearly observed in the *I-V* property. The rectifying ratio was only 2.5, which was considerably smaller than that for Al contact reported in the previously published paper [7]. It is suggested that Cu layer grown on diamond substrate could not be suitable for the Schottky contact.

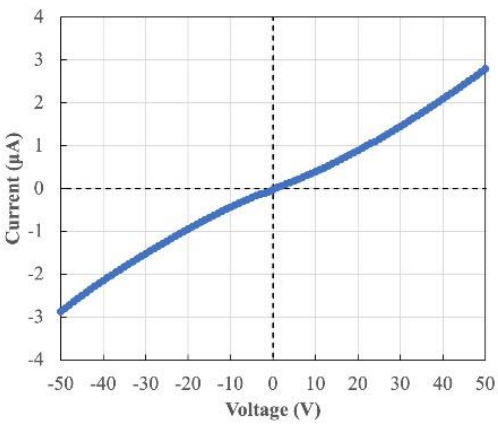
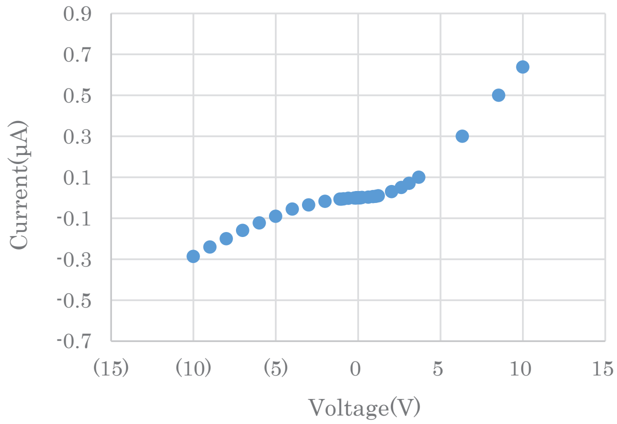
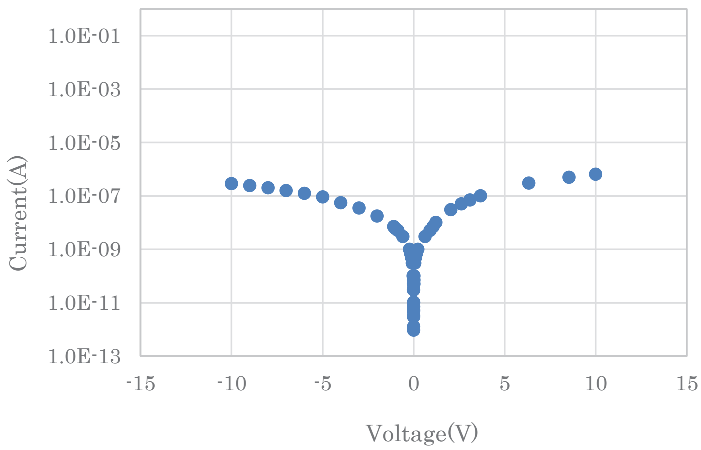


Fig. 4: *I-V* properties between two Ohmic electrodes consisting of Au/Ti layers.



(a)



(b)

Fig. 5: *I-V* properties between Au/Ti and Au/Cu electrodes with linear (a) and logarithmic (b) scale.

IV. Conclusions

We investigated a Schottky contact with Cu layer formed on the B-implanted p-type diamond substrate. All B-doping processes were performed by ion implantation technique. The doping concentration in the drift layer was 4×10^{18} cm^{-3}. The Ohmic contacts were formed on heavily B-implanted area with about 1×10^{21} cm^{-3} concentration. We investigated the rectifying property between Cu and Ti electrodes. As a result, the rectification behavior was not clearly observed, being different from the case of Al and Ti electrodes. It is indicated that Cu contact could not be suitable for the Schottky electrode of p-type diamond.

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