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Improved drain current of diamond metal-semiconductor FET by selectively grown P+ contact layer

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Abstract

To maximize the drain current of diamond MESFET, reduction of parasitic resistance is an effective solution. In this study, heavily boron-doped (p+) contact layers were formed under the source-drain contacts. By introducing the layer, the drain current was successfully increased up to 3 times. The contact resistance between p+ contact and drift layer was also analyzed by transmission line model (TLM).

1. Introduction

Diamond is an ultimate semiconductor material that own superlative physical properties, high carrier mobility, high breakdown strength, and high thermal conductivity, etc. Therefore, the device operation in harsh conditions, i.e. high temperatures and high radiation environments, are expected [1]. Currently, diamond device research including Schottky barrier diodes, p(i)n diodes, metal-oxide-semiconductor, and MESFET [2] are actively progressing.

In order to improve the output power of FET, reduction of parasitic resistance is important. In this study, p+ heavily B-doped epitaxial layers were introduced under souce/drain contacts by selective CVD growth.

2. Experimental procedures

The fabrication procedure of diamond MESFET is as follows. The high-pressure and high-temperature (001) type-Ib diamond substrate was used as a substrate. Firstly, lightly B-doped (p-) drift layer with a thickness and B concentration of 3 μm and ~10^{16} cm^{-3}, respectively, was grown on the substrate by microwave plasma assisted chemical vapor deposition (MWCVD). Then, p+ contact layer with a thickness of 300 nm was formed by selective-area growth with metal masks via hot-filament CVD [3]. The B concentration was ~10^{21} cm^{-3}. After the metal removal by acid solution, Ti/Pt/Au Ohmic contacts were deposited using photolithography and lift-off techniques above p+ contact layers. They were annealed at 450°C in Ar atmosphere to form TiC at metal/diamond interface. Finally, Pt/Au Schottky gate metal were fabricated. Figure 1 shows schematic cross-sectional view of (a) diamond MESFET (b) with p+ contacts. Corbino-shape FET structure was utilized as shown in Fig. 1(c). The MESFET without contact layer was also fabricated for comparison purpose. Electrical characteristics were measured using a semiconductor parameter analyzer (Agilent 4156C). Also, the contact resistance was evaluated by circular-type transmission line model (cTLM).

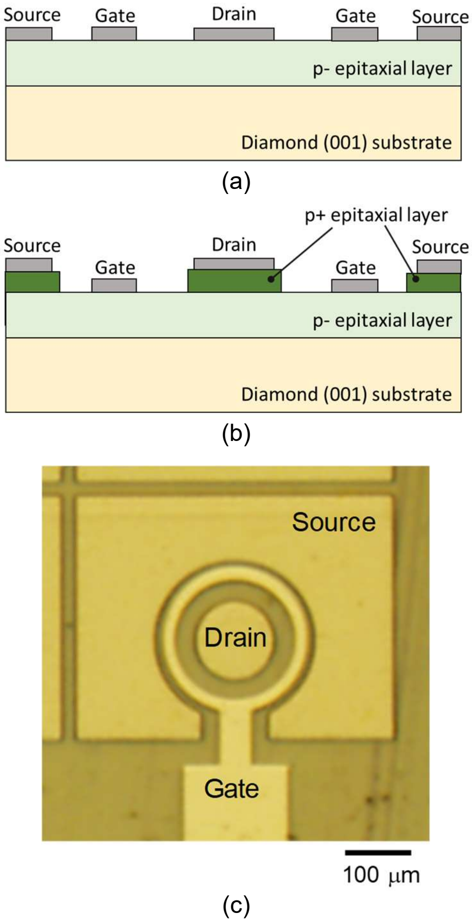

Figure 1. Cross sectional view of diamond MESFET structure. MESFET (a) without and (b) with p+ contact layer are fabricated onto identical sample. (c) Photograph of the MESFET structure (Corbino-shape).

3. Results and discussion

Figure 2 (a) shows drain current (I_{DS}) - drain bias (V_{DS}) characteristics of diamond MESFET without p+ contact layer, and figure 2 (b) shows that with p+ contact layer. For these MESFETs, the gate length (L_G) was 20 μm and the gate-drain length (L_{GD}) was 30 μm. The gate bias (V_{GS}) was varied from 0 to 30 V with a voltage step of 5 V. the channel is pinched off at V_{GS} = 30 V. The maximum I_{DS} of The MESFET without p+ contact layer was -0.06 mA/mm, whereas that with p+ contact layer was -0.2 mA/mm. As compared with MESFET without p+ contact layer, drain current increased nearly 3 times in MESFET with p+ contact layer.

The specific contact resistance between metal and p+ contact layer is 7.4 μΩ-cm^2 which was sufficiently low as high-power devices. On the other hand, there was a specific contact resistance of 18 mΩ-cm^2 between the p- drift layer and the p+ contact layer, and this contact resistance was dominant. This resistance is considered to be caused by the potential barrier (~0.36 eV) at the interface between the p- drift layer and the p+ contact layer.

4. Conclusions

By providing the contact layer between the ohmic electrode and the drift layer, the parasitic resistance of the diamond MESFET was reduced. This structure is effective for improving S/N. In another case, when aiming at lower threshold operation, the concentration and thickness of the drift layer must be suppressed, and the drain current becomes small. In terms of current increase, p+ contact layer is effective even with the lower threshold structure.

Acknowledgements

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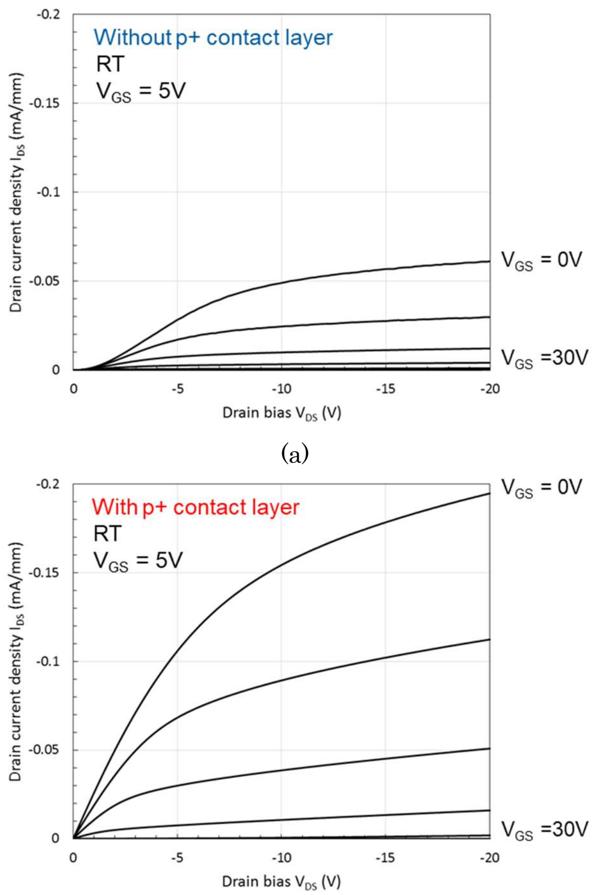

(b)

Figure 2 I_{DS}-V_{DS} characteristics of the diamond MESFETs (a) without p+ contact layer and (b) with p+ contact layer.

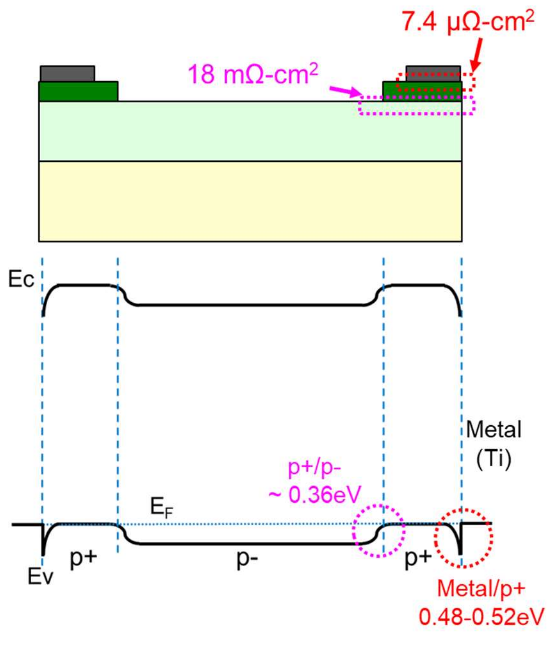

Figure 3 Specific contact resistance of each interface.