Discussion on resistances in hydrogen-terminated diamond MOSFETs

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Diamond is considered to be an ultimate semiconductor material for the high-power, high-frequency, and high-temperature applications [1]. However, because activation energies of diamond dopants are much higher than thermal energy at room temperature, most of diamond-based metal-oxide-semiconductor field-effect transistors (MOSFETs) are fabricated on hydrogen-terminated diamond (H-diamond) channel layers, which can accumulate holes on the surface with sheet hole density of 10^{12}~10^{14} cm^{-2}.

For the usual planar-type H-diamond MOSFETs, total on-resistance (R_{ON}) is composed of Ohmic contact resistance (R_C) for the metal/H-diamond, surface resistance (R_S) for the H-diamond epitaxial layer at interspaces between source/drain and gate electrodes, and channel resistance (R_{CH}) for the H-diamond epitaxial layer under oxide insulator. Since there are no interspaces between source/drain and gate electrodes for the T-type H-diamond MOSFET, the R_S is zero. Because the R_{ON} can affect the current output, extrinsic transconductance (g_m), and output power of the H-diamond MOSFETs greatly, in this study, we fabricate planar-type and T-type H-diamond MOSFETs to investigate their R_C, R_S, and R_{CH}. We will also analysis the effects of resistance on the electrical properties of the H-diamond MOSFETs [2].

The planar-type and T-type MOSFETs are fabricated on the same H-diamond epitaxial layer, which was grown by a microwave plasma-enhanced chemical vapor deposition system. The Au/Ti/Pd Ohmic contact metals with thicknesses of 100/20/10 nm were formed on the H-diamond using an electron-gun evaporator system. Here, the Pd metal contacts with the H-diamond surface. The Al_2O_3 gate oxide and Au/Ti gate cover metals were formed using an atomic layer deposition and the electron-gun evaporator systems, respectively. Deposition temperature for the Al_2O_3 was 120 °C. Thickness of the Al_2O_3 was confirmed by an ellipsometer to be 32.3 nm.

Figures 1(a) and 1(b) show surface morphologies of planar-type and T-type H-diamond MOSFETs, respectively. Their schematic diagrams are demonstrated in Figs. 1(c) and 1(d), respectively. Gate length (L_G) values for the planar-type and T-type H-diamond MOSFETs are 2.0 and 2.1 μm, respectively. Interspaces between source/drain and gate electrodes for the planar-type H-diamond MOSFET are 3.3 and 4.5 μm, respectively, which generate the R_S. Its R_{ON} is composed of three parts of R_C, R_S, and R_{CH}. There are no interspaces for the T-type MOSFET ($R_S = 0$). The R_{ON} is composed of two parts of R_C and R_{CH}.

By considering relationships between R_{ON} and 1/|gate voltage-threshold voltage| ($1/|V_G-V_{TH}|$), the R_C and R_{CH} for the T-type H-diamond MOSFET at gate voltage of –10.0 V are determined to be 13.8 and 21.8 Ω mm, respectively. Since the R_C for both MOSFETs is the same, the R_S and R_{CH} for the planar-type H-diamond MOSFET are deduced to be 90.0 and 15.8 Ω mm, respectively. The R_S accounts for 75.3% in the R_{ON} for the planar-type H-diamond MOSFET, which is the main reason for its lower $I_{D,max}$ and $g_{m,max}$ than those for the T-type one. Although the R_S is suppressed for the T-type H-diamond MOSFET, the R_C occupies of 38.8% in the R_{ON}. In order to further improve the performances of the H-diamond MOSFETs, it would be important to eliminate the R_S and to decrease the R_C.

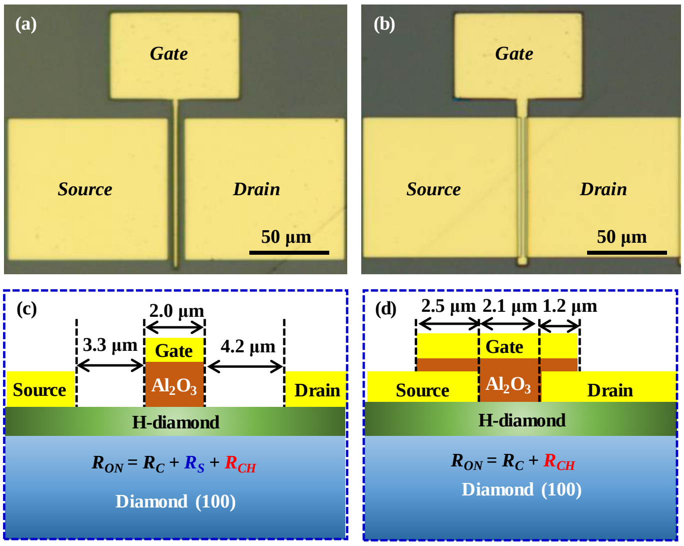

Figure 1. Surface morphologies of (a) planar-type and (b) T-type H-diamond MOSFETs, respectively. (c) and (d) Schematic diagrams of them, respectively.

References

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