Electrical properties of H-terminated diamond field effect transistors with AlN gate material sputter-deposited under Ar+N_2 atmosphere

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Diamond has attracted strong interest as next-generation semiconductor, while AlN is explored as promising insulating gate material for the realization of hybrid devices based on AlN/diamond heterojunction for high frequency and high power field effect transistors (FETs). Recently, we have demonstrated AlN/H-diamond metal-insulator-semiconductor (MIS) FETs with bilayer gate structure fabricated by radio-frequency sputtering deposition (RF-SD) and atomic layer deposition (ALD) showing good electrical properties [1]. The results indicated that the electrical properties are strongly correlated to the crystalline quality of AlN. Previously, this AlN was deposited by RF-SD under pure Ar atmosphere. The ~200-nm-thick SD-AlN/ALD-Al_2O_3/H-terminated diamond MIS diode exhibited a leak current density (J_{leak}) as low as 1.6×10^{-5} A/cm^2 at –8 V gate bias. The drain-source current maximum ($I_{DS,MAX}$) obtained from the MISFET with ~4 µm gate length (L_G) was around –8.9 mA/mm. However, the C–V hysteresis curve is shifted toward the negative gate bias, which could indicate the presence of positive charges in the gate material. To eliminate these unwanted impurities, here, we report on the electrical properties of MISFETs using AlN which is sputter-deposited under Ar+N_2 atmosphere. The ~200-nm-thick SD-AlN/ALD-Al_2O_3/H-terminated diamond MIS diode exhibited a J_{leak} as low as 1.25×10^{-6} A/cm^2 at –20 V gate bias (Fig. 1). Moreover, no shift of the C–V hysteresis curve was observed, which could indicate the elimination/reduction of the deposition-related impurities. The $I_{DS,MAX}$ from MISFET with L_G ~4 µm is around –5.58 mA/mm. Furthermore, the breakdown voltage (V_B) from ~200-nm-thick MISFET was studied. No breakdown occurred at 200 V, which is the maximum operating voltage of the present experimental set-up (Fig. 2). Thus, it is expected that the V_B is higher than 200 V and can be further increased by changing the gate-to-drain distance (L_{GD}). On the other hand, the MIS diode with thinner AlN gate (~30 nm) exhibited a J_{leak} as low as ~3.08×10^{-6} at –8 V gate bias and MISFET obtained an $I_{DS,MAX}$ as high as 19.0 mA/mm. The results indicate that the SD-AlN was further improved under Ar+N_2 atmosphere due to the reduction/elimination of deposition-related defects, hence improving the electrical properties as indicated above.

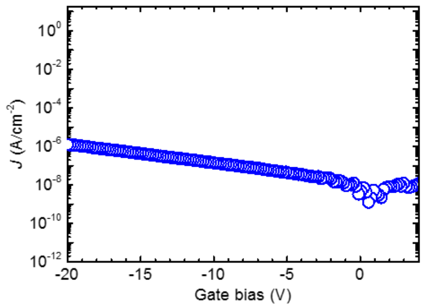

Fig. 1: Current density of ~200 nm SD-AlN/ALD-Al_2O_3/H-terminated diamond MIS diode.

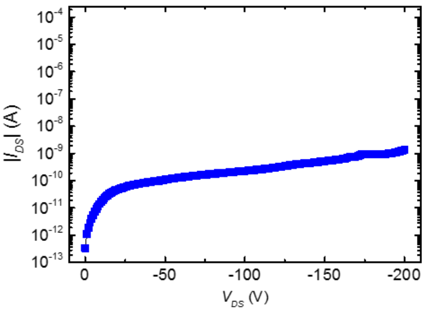

Fig. 2: Breakdown characteristics of SD-AlN/ALD-Al_2O_3/H-terminated diamond MISFET at off-state.

Reference: [1]. R. G. Banal et al., *submitted.*