ZrO_2 on hydrogenated-diamond: breakdown electric field, interfacial band configuration, and gate-drain distance scaling effect for electrical property of MISFET

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Wide band gap semiconductors such as SiC, GaN, and diamond have been developed in order to replace silicon partly for power devices due to their high carrier mobility and high breakdown field. In particular, the diamond is considered to be an ideal material for the application of power electronic devices due to its theoretical low power-loss at a high voltage. Most of diamond-based metal-insulator-semiconductor field effect transistors (MISFETs) have been fabricated on hydrogenated-diamond (H-diamond) epitaxial layers [1, 2], which can accumulate two-dimensional hole gases (2DHGs) on the surface with sheet hole density as large as ~10^{14} cm^{-2}.

In order to control such the high-density carrier, a MIS gate structure composed of dielectric with large capacitance is required. Recently, for this purpose, high dielectric constant (high-*k*) insulators were deposited on the H-diamond to fabricate the MISFETs [3]. The high-*k* oxide insulators with a bilayer structure were fabricated by atomic layer deposition (ALD) and radio-frequency sputtering deposition (SD) techniques. The thin ALD-insulator with a thickness around 4.0 nm played a role of preventing the hydrogen surface from plasma discharge damage during the SD-insulator deposition. The high dielectric constant values for the SD-ZrO_2/ALD-Al_2O_3 bilayer and single SD-ZrO_2 layer were determined by capacitance-voltage (C-V) characteristic to be 12.8 and 15.4, respectively [4]. A small flat band voltage shift and a sharp dependence in the depletion region were observed in the C-V curve of the MIS capacitor, which suggested low-density fixed and trapped charges existing in the SD-ZrO_2/ALD-Al_2O_3/H-diamond structure. Meanwhile, the SD-ZrO_2/ALD-Al_2O_3/H-diamond MISFETs were also operated well.

In the study, we have continued to clarify other properties for the ZrO_2 on the H-diamond. The breakdown electric field of SD-ZrO_2/ALD-Al_2O_3 bilayer, interfacial band configuration of SD-ZrO_2/ALD-Al_2O_3/H-diamond structure, and the gate-drain distance ($d_{G\text{-}D}$) scaling effect for electrical property of MISFET [Figure 1] will be shown.

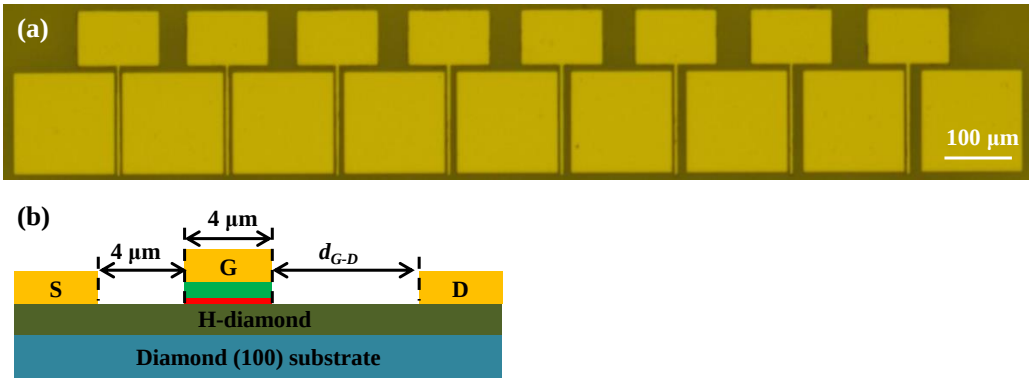

Figure 1 Top view and schematic cross-sectional structure of SD-ZrO_2/ALD-Al_2O_3/H-diamond MISFET with different gate-drain distance ($d_{G\text{-}D}$)

Reference

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