Diamond Power MOSFETs using 2D Hole Gas with >1600V Breakdown

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Stabilizing 2 dimensional hole gas (2DHG) on H-terminated (C-H) diamond surface opens a way to high power and high frequency device application of diamond. We have realized the thermal stability (up to 800K) of 2DHG at the interface between Al_2O_3 and H-terminated diamond (C-H) diamond by high temperature atomic layer (ALD) deposition of Al_2O_3 [1,2]. Using the ALD Al_2O_3 as gate insulator and The C-H diamond lateral MOSFETs shows very wide temperature (10K-673K) and high voltage operation (~1600V) [3,4].

At off-state, breakdown voltage V_B as a function of gate-drain length L_{GD} shows high-voltage durability in planar FET. In recent power FETs like AlGaN/GaN FETs, their properties are often evaluated by V_B/L_{GD}. In wide bandgap semiconductors, the V_B/L_{GD} with 1 MV/cm is a critical value for lateral power devices. The V_B - L_{GD} relationship of C-H diamond MOSFETs is shown in Fig.1. The L_{GD} of 2-10 μm, the $V_{B,}/L_{GD}$ is on the line of 1 MV/cm up to V_B ~1000 V. At L_{GD} >10 μm, V_B exceeds 1000 V and reached 1646 V at L_{GD} of 22 μm (Fig.1and 2). It shows the best performance in diamond FETs and is equivalent to those of SiC or AlGaN/GaN planar FETs. In diamond FTs, equivalent V_B of 1500 V was only reported in a MESFET composed of boron doped channel and drift layer with L_{GD} of 30 μm [5]. The V_B/L_{GD} is 0.5 MV/cm for diamond MESFET [5], 0.8 MV/cm for SiC planar MOSFETs [6], 1.0 MV/cm for AlGaN/GaN FETs [7], and 1.6 MV/cm for an AlGaN/AlGaN FET [7] , respectively. 1.6 MV/cm is the highest for planar FETs at present. In the C-H MOSFET, the V_B/L_{GD} is above 2 MV/cm up to 2μm L_{GD}, 1.0 MV/cm in 2-10 μm, 0.75 MV/cm above 10-22 μm. The values of C-H MOSFETs without field plate structure now become comparable to SiC, GaN or AlGaN planar FETs with field plate. Diamond has a potential to exceed 3 MV/cm as indicated at 365 V at L_{GD} of 1μm (Fig.1). Field plate or super junction will realize V_B/L_{GD} >3 MV/cm up to V_B ~2000 V.

At on-state, current density is an important parameter. Drain current density normalized by gate width reaches 100mA/mm in the C-H MOSFET with V_B of ~1500V. This value is higher than those of diamond MESFET (1mA/mm) [5] using boron-doping, SiC planar MOSFETs (90mA/mm) [6] and comparable to those of AlGaN/GaN (~300mA/mm) [7] and AlGaN/AlGaN (~200mA/mm) [7]. Between 100K-600K C-H diamond MOSFETs can preserve almost the same FET performance indicating a wide temperature power device application. High current density at wide temperature can be achieved by 2DHG, not by boron-doping layer.

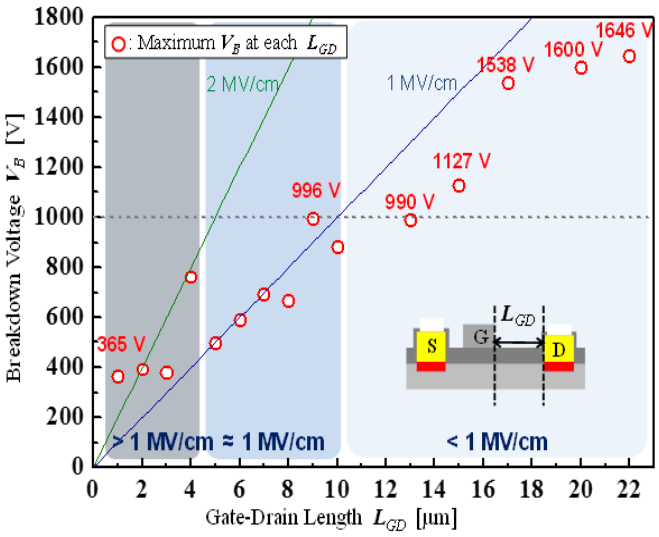

Fig. 1 Maximum breakdown voltages V_B of C-H diamond MOSFETs as a function of gate to drain length L_{GD}.

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