Modulation Doping of MoO_3 on hydrogen Terminated diamond with HfO_2 interfacial layer.

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1. Abstract

Diamond transistors are promising as high-power and high-frequency devices having higher efficiencies than GaN and SiC-based transistors. Diamond possesses superior electronic properties, such as a high bandgap (5.47 eV), high breakdown voltage (>10 MV cm^{-1}), high electron and hole mobilities [4500 and 3800 $cm^2\ V^{-1} \cdot s^{-1}$, respectively], high electron and hole saturation velocities (1.5×10^7 and 1.05×10^7 cm s^{-1}, respectively), and high thermal conductivity [22 W $cm^{-1} \cdot K^{-1}$], compared to conventional semiconductors. Reportedly, the diamond field-effect transistors (FETs) have shown transition frequencies (f_T) of 45 and 70 GHz, maximum oscillation frequency (f_{max}) of 120 GHz, and radiofrequency (RF) power densities of 2.1 and 3.8 W mm^{-1} at 1 GHz. A two-dimensional hole gas (2DHG) surface channel forms on H-diamond by transfer doping from adsorbates/dielectrics in contact with H-diamond surface. However, prior studies indicate that charge transfer at dielectric/ H-diamond interface could result in relatively low mobility attributed to interface scattering from the transferred negative charge to acceptor region.

H-terminated diamond (Eg=5.47) exhibits a negative electron affinity (NEA) of -1.1 to -1.3 eV. To overcome these limitations, we propose modulation doping, that is, selective doping, that leads to spatial separation of the MoO_3 acceptor layer from the hole channel on H-diamond. molybdenum oxide (MoO_3) was used as dielectric as it has electron affinity of 6.7eV and could align its conduction band minimum (CBM) below the valence band maximum (VBM) of H-terminated diamond. The band alignment provides the driving potential for charge transfer. Hafnium oxide (HfO_2) was used as interfacial layer since it is high-k oxide insulator (∼16 to 19), having large Eg (5.8 eV), high critical breakdown field, and high thermal stability. This study presents photoemission measurements of the electronic band alignments of the MoO_3/HfO_2/H-diamond layer structure to gain insight into the driving potential for the negative charge transfer and the location of the negative charges near the interface, in the HfO_2 layer or in the MoO_3 layer. The diamond hole concentration, mobility, and sheet resistance were characterized for MoO_3/HfO_2/H-Diamond with HfO_2 layers of 0, 2 and 4 nm thickness.

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2. References:

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