Materials Science & Engineering Thesis Defense

Challenges in Modulation Doping of MoO3 on Hydrogen Terminated Diamond with HfO2 Interfacial Layer

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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 cm2 V−1 · s−1, respectively], high electron and hole saturation velocities (1.5 × 107 and 1.05 × 107 cm s−1, respectively), and high thermal conductivity [22 W cm−1 · K−1], compared to conventional semiconductors.

Reportedly, the diamond field-effect transistors (FETs) have shown transition frequencies (fT) of 45 and 70 GHz, maximum oscillation frequency (fmax) 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 MoO3 acceptor layer from the hole channel on H-diamond. molybdenum oxide (MoO3) 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 (HfO2) 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 MoO3/HfO2/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 HfO2 layer or in the MoO3 layer. The diamond hole concentration, mobility, and sheet resistance were characterized for MoO3/HfO2/H-Diamond with HfO2 layers of 0, 2 and 4 nm thickness.

February 13, 2024; 2:00 PM; ECG G114;

Arizona State University