Band alignment of sputtered Al_2O_3, MgO and ZrO_2 on GaN for MIS-HEMTs

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Gallium nitride (GaN) Metal Insulator Semiconductor High Electron Mobility Transistors (MIS-HEMTs) have been widely used for high frequency, high power and low noise applications [1,2]. There are significant challenges that must be addressed related to conventional GaN HEMT as it has relatively high gate leakage currents due to tunneling effects which limits the device performance and reliability. The use of a high permittivity dielectric material with a sufficient band offsets of over 1 eV can mitigate the problem of gate leakage. The band line-up studies of Al_2O_3 and ZrO_2 deposited by atomic layer deposition (ALD) and of MgO prepared by molecular beam epitaxy (MBE) on GaN have been reported [3–6], but not using sputtering techniques. In this work, Al_2O_3 and MgO were deposited on GaN substrate by radio frequency (RF) magnetron sputtering, while ZrO_2 by pulsed reactive sputtering. The GaN substrate was cleaned with a wet chemical method using 37 % HCl solution to remove the native oxide. The nominal thickness of Al_2O_3, MgO and ZrO_2 were 3 nm for the interfacial and 20 nm for the bulk reference. The band alignments of the oxides/GaN interfaces have been measured experimentally by X-ray photoelectron spectroscopy (XPS) and the Kraut's method [7]. The band gap of the GaN substrate was determined to be 3.39 ± 0.1 eV eV using variable angle spectroscopic ellipsometry (VASE). The band gap of Al_2O_3, MgO and ZrO_2 were extracted from the XPS O 1s energy loss spectra and found to be (± 0.15 eV) 6.48 eV, 7.36 eV and 5.01 eV, respectively. The estimated valence band offset (VBO) (± 0.2 eV) for Al_2O_3, MgO and ZrO_2 on GaN were 1.30 eV, 1.01 eV and 0.53 eV, respectively with corresponding conduction band offset of 1.79 eV, 2.96 eV and 1.09 eV, respectively. There is a good correlation of VBO for MgO/GaN with reported values [5,6]. The effect of band bending at oxide/GaN measured using angle-resolved XPS will be shown and discussed for each gate stack. The results have significance in choice of gate dielectric for future GaN-based HEMTs.

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