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Can an Efficient Metal-Oxide-Semiconductor Device be Made from Aluminium Nitride Ultra-Wide Bandgap Semiconductor?

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ABSTRACT

The question of whether one can make an efficient metal-oxide-semiconductor (MOS) device using wurtzite Aluminium Nitride semiconductor is answered in this short communication.

Keywords: Mass-Energy equivalence, MOS device, AlN, Tunnelling

SHORT COMMUNICATION

The answer to the above question is NO. The answer is based on the theoretical calculation of the conduction band (CB) and valence band (VB) offsets at the silicon dioxide/AlN semiconductor interface by utilizing the universal mass-energy equivalence relation discovered by the author recently given as dE/E = dm/m. Here, dE is the differential potential energy from the intrinsic Fermi energy level E_i in the semiconductor to the semiconductor CB, E is the semiconductor bandgap as the total potential energy of the electrons, dm is the differential mass as the longitudinal electron effective mass in the materials, and m is the free electron mass [1-5]. The experimental bandgap of wurtzite AlN is found to be 6.28 eV and the longitudinal electron effective mass is about 0.33m [6]. These two parameters with E as 6.28 eV and dm/m as 0.33 when substituted in the above mass-energy relation give the position of the intrinsic Fermi energy level E_i in the semiconductor as dE to be equal to 6.28 x 0.33 = 2.07 eV below the AlN CB. This E_i will align to the E_i in SiO_2 due to charge neutrality. E_i in SiO_2 is 3.75 eV from its CB given that the dm/m for SiO_2 is 0.42 and the oxide bandgap E is 8.93 eV giving dE as 8.93 x 0.42 =3.75 eV in the oxide. Since the E_i in AlN and SiO_2 are aligned due to charge neutrality, the CB offset at the oxide/AlN interface will be 3.75-2.07 = 1.68 eV. The VB offset will be 8.93-1.68-6.28 = 0.97 eV. Thus, the CB offset and the VB offset at the oxide/semiconductor interface are 1.68 eV and 0.97 eV. These band offsets are very small and will produce large electron and hole Fowler-Nordheim tunnelling leakage currents in the metal-oxide-semiconductor (MOS) device. Therefore, an efficient MOS device on AlN semiconductor will not be possible. Perhaps a high electron mobility transistor (HEMT) is more feasible.

Recently, the author has published a generalized MIS characterization technique of finding band offsets and effective mass in a metal-insulator-semiconductor device which is simple and accurate, and utilizes only electrons in place of photons [7]. The above discussion forms part of this technique. There is a small technical error in this publication in the equations (7) and (8) that needs to be corrected. The units of these two equations should be square of the unit of MV/cm. This error however does not affect the calculations of band offsets at the

oxide/semiconductor interface of the 4H-SiC MOS device and the effective masses in the oxide which are correct.

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