Effect of Interaction of Deep Level Defects with Quantum Well States on Detrapping Transients in High-Voltage AlGaN/GaN HEMTs

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AlGaN/GaN High-Electron-Mobility Transistors (HEMTs) have traditionally been the device of choice in RF electronics. More recently, the ease of achieving a low on-state resistance due to high channel mobility (μch) coupled with a wide bandgap (Eg = 3.4 eV) has led to significant advancements in developing the GaN HEMT as a device for the next generation of high voltage power electronics (1)-(2). Understanding the characteristics of HEMTs as a device for the next generation of high voltage power devices requires significant advancements in developing the GaN HEMT for transient characteristics.

Quantum well levels is usually not considered to influence conduction band. Interaction of trapped carriers with the AlGaN/GaN HEMTs exhibit strong dependence on stress. In switching applications, traps that are much slower (like a Schottky diode) or in a device such as the HEMT under realistic operation conditions, trapped carriers are assumed to be thermally or optically emitted to the thermal excitation is used to study emission of the trapped carriers. Following this, optical or electrical excitation are used to study the trap response time. However, in an idealized material stack (like a Schottky diode) or in a device such as the HEMT the conduction band energy becomes progressively slower as the stress time is increased. This behavior is shown to be consistent with electrical field on the AlGaN barrier which is high and may be influenced strongly by the electric field normal to the AlGaN barrier.

In switching applications, traps that are much slower than the switching time constants lead to parametric shifts such as threshold voltage (Vth) drift or increase in on-state resistance (Ron) over time. Faster traps (with time constants on the order of the switching time) lead to distortions in the switching waveform, affecting output power quality (3)-(4). Electric field management is generally understood to be important for breakdown voltage enhancement in power devices. However, the strong influence of electric field on the trap response time indicates that electric field management might have an equally important role in the switching performance of the AlGaN/GaN HEMT.

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REFERENCES:

Figure 1. Detrapping transients (Vth = 1V, Vbg = 0) in a passivated Al0.15Ga0.85N/GaN HEMT (Lg = 2μm, Wg = 100μm, Ld = 10μm), following blocking voltage stress (Vbg = -6V, Vth = 200V) for 1s, 10s and 100s respectively on (a) linear and (b) log scales.

Figure 2. (a) Simulated conduction band profile, ground state energy E0, and trap position E - 0.6 eV for trapping in AlGaN from heterointerface to 7.5 nm and 10 nm respectively, consistent with short and long duration stress times. Simulated wavefunction in the AlGaN barrier for the two cases is shown on a linear (b) and log (c) scales.

Figure 3. Simulated conduction band profile, ground state energy E0, and trap position E - 0.6 eV for trapping in AlGaN from heterointerface to 7.5 nm and 10 nm respectively, consistent with short and long duration stress times. Simulated wavefunction in the AlGaN barrier for the two cases is shown on a linear (b) and log (c) scales.