p-GaN Extension Engineering in E-mode p-GaN Gate AlGaN/GaN HEMTs

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With their high breakdown voltage (BV), fast switching speed, and low on-resistance (R_{ON}), AlGaN/GaN power transistors have become essential components in high-power, high-efficiency power conversion systems. These devices operate in a normally-on mode due to the presence of two-dimensional electron gas (2DEG) in the AlGaN/GaN heterostructure. However, normally-off (E-mode) devices are preferred for power-switching applications to meet failsafe criteria and simplify gate driver design. As a result, various normally-off AlGaN/GaN HEMT approaches have been developed, including recessed gate, F- ion implantation, p-type (Al)GaN gate, cascade configuration, and others. The p-GaN gate structure is currently a favored choice for commercialization in these systems. In addition to addressing the single voltage supply issue, achieving a suitably large and stable threshold voltage (V_{TH}) for normally-off behavior in AlGaN/GaN HEMTs is highly desirable [1]. The p-GaN gate raises the conduction band of the AlGaN/GaN structure in the channel area above the Fermi level, resulting in an E-mode operation with a positively charged V_{TH}. Utilizing a Schottky contact at the p-GaN gate can effectively reduce gate current. However, as leakage diminishes, the p-GaN region becomes ungrounded, leading to unstable operation due to charge accumulation within the p-GaN during device operation. These V_{TH} instabilities significantly impact device performance.

This talk will discuss various p-GaN extension engineering, including (1) the optimized recess depth in the AlGaN barrier under the extended region of p-GaN, which provides improved device characteristics [2], (2) the extended gate design redistributes the electric field, acting as a field plate to elevate the breakdown voltage [3], (3) a new p-GaN HEMT is proposed, which extends the region of p-GaN with different widths toward the source and connects it to the source electrode so that the 2DEG channel under the area between the gate and the source can be depleted to improve the threshold voltage of the device as well as to improve the field distribution at the gate to increase the breakdown voltage [4], and (4) to overcome the shortcomings of the AlGaN/GaN HEMT with p-GaN extended to the source, a new design of AlGaN/GaN HEMT with a p-GaN resistor connected to the source has been developed.

References:

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