Optimization of Source-connected Field Plate in AlGaN/GaN HEMTs : A Simulation Study

Tae-Sung Kim, Jae-Hun Lee, Chae-Yun Lim, Yeong-Hyun Won, and Hyun-Seok Kim
Division of Electronics and Electrical Engineering, Dongguk University-Seoul, Korea
E-mail: hyunseokk@dongguk.edu

Over the past several decades, silicon has maintained its position as a major focus of the semiconductor industry [1-2]. However, in recent years, wide bandgap semiconductors such as silicon carbide (SiC) and gallium nitride (GaN) offer superior performance compared to silicon-based semiconductors, owing to their high breakdown field and electron saturation velocity, making them ideal for operation in high-frequency and high-power conditions [3]. SiC substrates are frequently employed in AlGaN/GaN high-electron-mobility transistors (HEMTs). The lattice constant and thermal expansion coefficient of SiC closely match those of GaN, minimizing stress during the growth process and improving the device's performance and reliability [4]. Despite these advantages offered by SiC, the power industry still demands high-frequency performance and operational reliability in high-power applications, which is why the introduction of a field plate in AlGaN/GaN HEMTs aims to enhance the device's operational reliability in these conditions. However, the addition of a field plate inevitably increases the device capacitance, which directly degrades RF performance. Fig 1. shows the cut-off frequency (f_T), and parasitic gate-to-source capacitance (C_{gs}) with and without field plate structure. Results indicate that the introduction of the field plate leads to an increase in parasitic capacitance, which results in a reduction of f_T by 23.26 %. Therefore, it is crucial to optimize the field plate configuration to improve RF performance while minimizing the reduction in the device's breakdown voltage (V_{BD}). In this study, we systematically investigate the impact of top field plate length (L_{TFP}) on both electrical characteristics and transient responses of AlGaN/GaN HEMTs using technology computer-aided design (TCAD) simulation. Fig. 2 illustrates the field plate configurations in AlGaN/GaN HEMT device. To assess the effect of L_{TFP}, we first compare the f_T and C_{gs} and analyze how these variations affect the RF characteristics. Then, simulations are conducted to investigate the V_{BD} and transient responses. Finally, we propose the optimal top field plate configuration considering Johnson's figure-of-merit (JFOM), which can be expressed as JFOM = $V_{BD} \times f_T$, and the transient responses. As a result, we propose valuable insights for optimizing top field plate design to balance electrical performance and reliability, thus contributing to the advancement of AlGaN/GaN HEMTs for high-frequency and power electronic systems.

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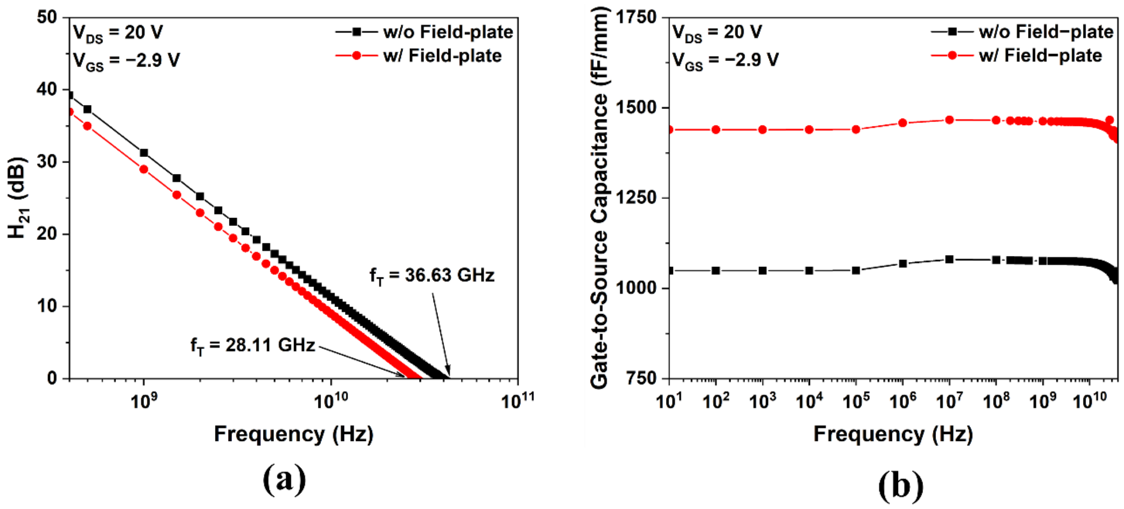

Fig. 1. RF simulation for AlGaN/GaN HEMTs comparing with and without the field plate at a drain bias (V_{DS}) of 20 V and a gate bias (V_{GS}) of -2.9 V : (a) current gain; (b) gate-to-source capacitance

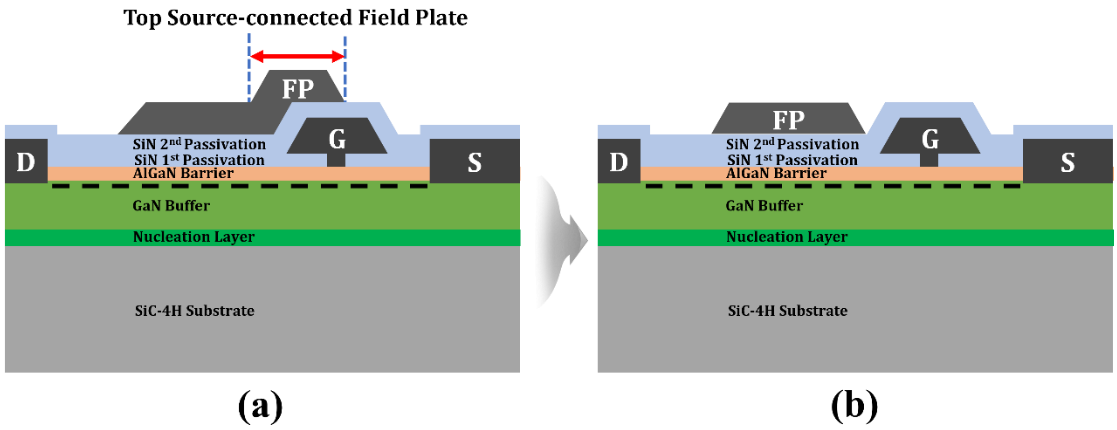

Fig. 2. Investigated cross-sectional views of AlGaN/GaN HEMTs on SiC substrate : (a) source-connect field plate; (b) optimized field plate configuration