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• **Supplementary File** •

High Power Density X-band Source-Connected Field Plate-Free AlGaN/GaN HEMT with Recessed Gate Oxidation Process

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Appendix A Device structure and fabrication process

The AlGaN/AlN/GaN HEMT structures were grown on a 3-inch semi-insulating 4H-SiC substrate by metal organic chemical vapor deposition (MOCVD). The epi-layers are consisted of cap layer, 26 nm $Al_{0.26}Ga_{0.74}N$, 0.7 nm AlN insert layer, 400 nm i-GaN, and buffer from top to bottom. Contactless Hall measurement at room temperature shows a carrier concentration of 1.03×10^{13}cm^{-2} and high carrier mobility of 2016 cm^2/V·s, resulting in a low sheet resistance of 297 Ω/sq. The GaN buffer layer is doped with Fe, having a concentration of 4×10^{17}cm^{-2}.

The fabrication process of the device commenced with the formation of the souce/drain ohmic contact, including the ohmic metal stack of Ti/Al/Ni/Au (20/140/55/45 nm), followed by rapid thermal annealing at 860℃ for 50 seconds. A transmission line method (TLM) measurement showed a low ohmic contact resistance of 0.3 Ω·mm. Subsequently, the device electrical isolation was performed through nitrogen ion implantation (N/I/I). The nitrogen ion implantation was performed with multiple energy level ion implantation of 90, 120, and 150 KeV with dose of 5×10^{14} cm^{-2}. Prior to the surface passivation processing, the device underwent treatment with a diluted ammonia solution at 55℃ for 5 minutes to eliminate surface contaminants [1]. Following this, a 120-nm SiN passivation layer was deposited using the plasma-enhanced chemical vapor deposition (PECVD) to mitigate current collapse. The gate stem was opened using CF_4-based plasma etching to remove SiN_x. Then the AlGaN barrier was recessed by BCl_3/Cl_2 plasma and treated by N_2O plasma using PECVD to form a recessed-gate architecture, followed by Ni/Au/Ni Schottky gate processing by metal e-beam evaporation. The purpose of this step was to decrease the distance of gate-2DEG to improve the electrostatic control of the gate over the channel and modulate the peak electric field. Finally, the fabrication process concluded with the incorporation of a Ti/Au metal stack for interconnections, forming the ground-signal-ground (GSG) probe pad for RF test. A T-shaped gate profile with gate length (L_g) of 250 nm was defined. The gate width is 2×50 μm in a π-shape layout. The devices reported here possess a source-drain spacing of L_{gd}= 4.5 μm and a source-gate spacing of L_{sg}=1.0 μm.

References

1 Dwiliński R., Wysmołek A., Baranowski J., et al. GaN synthesis by ammonothermal method[J]. Acta Physica Polonica A, 1995, 88: 833

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