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E-mode reverse p-i-n junction gate GaN HEMT with high V_{TH} and enhanced gate drive voltage

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Appendix A Growth epitaxy and device fabrication

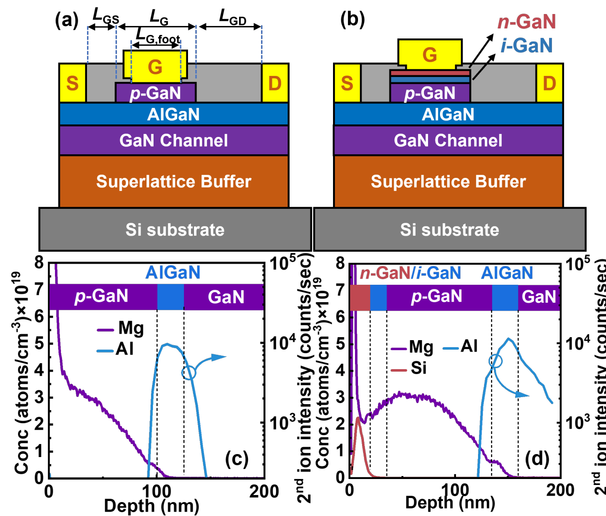

Figure A1 Schematic diagram for the (a) P-HEMTs and (b) PIN-HEMTs. Secondary ion mass spectrometry results of (c) P-HEMTs and (d) PIN-HEMTs.

The epitaxial layer grown by metal organic chemical vapor deposition (MOCVD) consists of a 6-inch Si-based substrate, a AlN/GaN superlattice buffer layer and a 1.6 μm GaN channel layer, $Al_{0.15}Ga_{0.85}N$ barrier layer and 100 nm p-GaN layer with a Mg doping concentration of $3 \times 10^{19} cm^{-3}$. Figure A1(a) shows the structure of conventional p-GaN HEMT under test, which features a p-GaN gate length (L_G) of 1.5 μm, a gate–drain distance (L_{GD}) of 13 μm, a gate-source distance (L_{GS}) of 1 μm, and a gate width (W_G) of 100 μm. The length of gate metal foot is 0.7 μm. For PIN-HEMTs, the p-GaN layer is capped with a 15 nm i-GaN and 20 nm n-GaN doped with Si at $2 \times 10^{19} cm^{-3}$ are above the p-GaN layer, as shown in Figure A1(b). The corresponding secondary ion mass spectrometry (SIMS) results for the two epitaxial structures are presented in Figure A1(c-d). The preparation process is as follows. First, the PIN-GaN layer in the active region is removed by atomic layer etching (ALE). Subsequent Hall effect measurement results show an electron mobility of 1380 $cm^2/(V \cdot s)$ and a carrier concentration of $4.41 \times 10^{19} cm^{-3}$ at room temperature. The Ti/Al/Ni/Au (20/160/55/45 nm) was deposited by electron beam evaporation, followed by rapid annealing for 60 s in a nitrogen atmosphere at 860 °C to obtain good ohmic contacts. After device isolation by ion implantation, TiN/Au was deposited as gate metal. According to a transmission line model measurement (TLM), the contact resistance (R_C) and sheet resistance (R_{SH}) of these devices are approximately 1.1 $\Omega \cdot mm$ and 572 Ω/sq. Then, 120 nm SiN was deposited on the wafer as passivation layer using PECVD. Finally, F-based inductively coupled plasma (ICP) etching was used to complete the via-hole opening step of the metal pad.

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