Normally Off AlGaN/GaN MIS-High Electron Mobility Transistors Fabricated by Using Low Pressure Chemical Vapor Deposition Si3N4 Gate Dielectric and Standard Ion Implantation

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Abstract

This paper presents a fabrication technology of enhancement-mode (E-mode) AlGaN/GaN metal insulator semiconductor high electron-mobility transistors (MIS-HEMTs) using 10 keV fluorine ion implantation. An 8 nm low pressure chemical vapor deposition (LPCVD) silicon nitride layer was deposited on the AlGaN as gate dielectric and energy-absorbing layer that slows down the high energy (10 keV) fluorine ions to reduce the implantation damage. The E-mode MIS-HEMTs exhibit a threshold voltage as high as 3.3 V with a maximum drain current over 200 mA/mm (250 mA/mm for depletion-mode (D-mode) MIS-HEMTs) and a high on/off current ratio of 109. Meanwhile, the E-mode MIS-HEMTs dynamic RON is only 1.53 times than the static RON after off-state VDS stress of 500 V.

Full Text

Preamble

Device characterization was performed at a sweep rate of 1.2 V/s. The transfer characteristics, shown in Figure (a), compare depletion-mode (D-mode) and enhancement-mode (E-mode) MISHEMTs with extracted threshold voltages of $V_{th} = -4.4$ V and $V_{th} = 3.3$ V, respectively. These measurements were conducted at $V_{DS} = 6$ V, plotting drain current I_{DS} (mA/mm) and transconductance G_m (mS/mm) as functions of gate-source voltage V_{GS} (V). Both device types exhibit maximum drain currents of approximately 4×10^9 mA/mm. The subthreshold characteristics, presented in Figure (b), reveal subthreshold slopes of 71 mV/dec for the E-mode device and 201 mV/dec for the D-mode device.

The output characteristics demonstrate an on-resistance of $R_{on} = 17.2$ Ω·mm for the E-mode MISHEMT, measured with V_{GS} stepped from 0 V to 9 V in 1 V increments, achieving a breakdown voltage of $BV = 573$ V. The D-mode MISHEMT, characterized with V_{GS} stepped from -5 V to 1 V, exhibits a comparable on-resistance of $R_{on} = 14.9$ Ω·mm and a similar breakdown voltage of $BV = 575$ V.

The relationship between implantation dose and threshold voltage was investigated, with dose values of 1.3×10^{13} cm^{-2}, 2.0×10^{13} cm^{-2}, and 2.7×10^{13} cm^{-2} corresponding to threshold voltages of -0.74 V, 0.14 V, and 0.92 V, respectively. The threshold voltage extraction was performed at the $I_{D(min)}$ point for each dose condition.

The device geometry was defined with $L_{GD} = 15$ μm, $L_{GS} = 4$ μm, and $L_G = 4$ μm. Under these conditions, the dynamic on-resistance measured in the ON-state ($V_{GS} = 8$ V) is 1.53 times the static on-resistance obtained in the OFF-state ($V_{GS} = 0$ V).

Note: Figure translations are in progress. See original paper for figures.

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