Enhancement mode AlGaN/GaN MISHEMT on Silicon for Energy Efficient Power Conversion

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GaN based high electron mobility transistors (HEMTs) are excellent devices for application in power electronics. To realize high-efficiency and high-power inverters, low-on-resistance, high drain current and high breakdown voltage devices are needed. AlGaN/GaN high electron mobility transistors are very promising for realizing such efficient electron devices. High-power devices should be operated in the normally off mode to realize a fail-safe system. However, most of the AlGaN/GaN HEMTs are operated in the normally on mode. Normally off p-type gate GaN HEMTs are promising for the realization of high power and low-loss switching devices because the leakage drain current is very low at zero gate-source bias. To realize fail-safe operation, the threshold voltage of normally-off mode transistors should be higher than +2 V to prevent an incorrect action. Normally-off HEMTs based on metal-insulator-semiconductor (MIS) gate structure with full recess AlGaN have been already reported by several groups. There is low gate leakage, threshold voltage higher than one volt. But the main drawbacks of this approach are the threshold voltage instability and poor reliability due to the border traps in the thin insulator/AlGaN barrier interface.

In this study we presented the novel MIS structure with p-GaN gate to increase the threshold voltage and reduce gate leakage of enhancement mode AlGaN/GaN MISHEMTs.

p-GaN/AlGaN/GaN epitaxial structures produces by MOCVD on silicon substrates were used in experiments. The SiN or Al_2O_3 layer (gate insulator) with thickness form 0 to 15 nm was deposited by PECVD or e-beam evaporation in vacuum on full wafers. Then gates were directly e-beam evaporated on insulator layer. After that insulator was etched away by reactive ion etching using gate metal as hard mask. p-GaN layer was selective etched in BCl_3/SF_6 plasma to form the self-aligned MIS-gate structure. Low temperature (550 ^{o}C) ohmic contacts are e-beam evaporated followed by PECVD SiN. The device size is a gate length of 1 um, a gate width of 100 um and a gate-drain distance of 6 um. The source-gate separation is 1 um. The DC parameters of the fabricated GaN transistors were measured by HP4156A Semiconductor Parameter Analyser.

It was shown that gate insulator introduced into p-GaN gate HEMT lead to increase the threshold voltage up to +6.8 V. The threshold voltage can be controlled by changing the thickness of insulator layer. The sub-threshold and on-state gate currents were decreased. The fabricated self-aligned AlGaN/GaN MISHEMT with 15 nm gate insulator demonstrates the maximum drain current I_{ds} = 0.25 A/mm and low on-state gate current I_{gs} = 0.1 µA/mm at V_{gs} = 15 V. Therefore, it can be used for develop the ultra low loss DC-DC power convertors.

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