Improved Gate leakage and Microwave Performance by Inserting A Thin Erbium oxide layer on AlGaN/GaN/Silicon HEMT Structure

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We report on AlGaN/GaN/Silicon heterostucture Metal-Oxide-Semiconductor high electron mobility transistor (MOS-HEMT) using electron-beam (e-beam) deposited high dielectric constant (High-K) erbium oxide layer as the gate, the Er_2O_3 inserted layer dielectric constant developed in this study was 12.4. Moreover, exhibit improved device characteristics performance, as compared with the conventional high electron mobility transistor (HEMT). An excellent reduction of the leakage current up-to more than four orders of magnitude lower than the conventional HEMT under similar bias condition. The drain current on-off ration of MOS-HEMT is more than four orders of magnitude with a sub threshold swing of 125mV/decade and Schottky gate reversed breakdown voltage enhance from -86V to -127V, and performance device maximum oscillation frequency ($f_{\max}$) characteristics form 14.8 GHz to 24GHz. The high-power/high-frequency high electron mobility transistor based on GaN and its related heterostructure has demonstrated that they are suitable devices for next generation high-density communication system. However, gate leakage current always limits the performance of high electron mobility transistor device especially under a high input power swing. In this study, we are particularly interested in improving the Schottky gate performance by inserting a thin erbium oxide layer on the bottom of convention Ni/Au gate in AlGaN/GaN HEMT fabrication. The Er_2O_3/AlGaN/GaN MOS-HEMT demonstrated in this study. The epitaxy structure were grown by metal-organic chemical vapor deposition (MOCVD) on highly resistive (>6000Ω) 6 inch Silicon (111) substrate. Standard low temperature AlN nucleation layer and 1um GaN as buffer layer, together with channel layer, the 26nm AlGaN barrier layer. All (Al)GaN layer are undoped. Atomic force microcopy (AFM) has been used to reveal the surface morphology of the Er_2O_3/AlGaN/GaN on-Si heterostructure. Excellent root-mean-square (rms) roughness of 1.375nm observed in a 1×1 um^2 area. The erbium oxide thin film can be obtained by using electron-beam evaporated erbium with oxygen flow rate in high vacuum chamber (2×10^{-6} toor). The device isolation was accomplished by mesa dry etching down to undoped-GaN layer in BCl_3 plasma reactive ion etcher chamber. Ohmic contacts of Ti/Al/Ni/Au (19/120/40/70 nm) metals were formed by electron-beam evaporation, followed by 850℃ rapid thermal annealing for 30 s in a nitrogen-rich chamber. After gate lithography pattern formation and surface clean, the samples were immediately loaded into the electron-beam deposition chamber. Then 10nm thick erbium was first evaporated with an optimal oxygen flow rate. During this stage, the chamber pressure increases to around 10^{-4} Torr. After the chamber pressure was reduced to 2×10^{-6} Torr, the convention Ni/Au (20/100nm) gate metals were deposited. For comparison, the conventional Ni/Au Schottky gate AlGaN/GaN-HEMT was also fabricated. Device performance was measured at room temperature in the dark using an Angilent B5100A semiconductor parameter analyzer for DC characteristics, an Angilent N1301AT CV analyzer for CV characteristics.

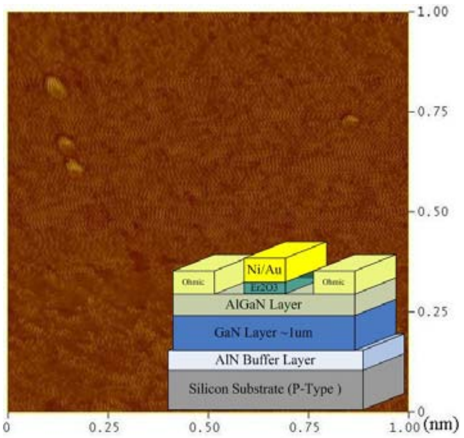


Fig.1. AFM top view in a 1x1 μm^2 area showing the surface morphology of Er_2O_3/AlGaN/GaN grown on Silicon; The Schematic cross of the Er_2O_3 MOS-HEMT structure.

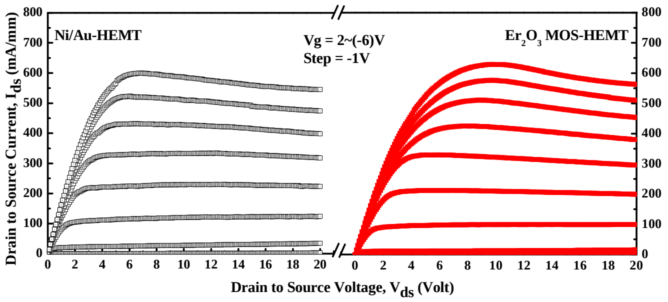
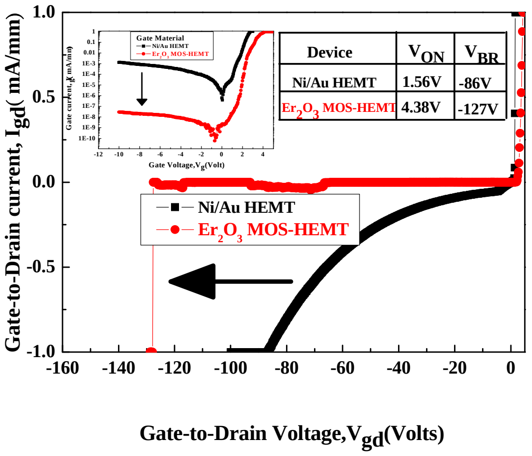


Fig.2. I_{ds}-V_{ds} characteristics of both devices.



Device	V_{ON}	V_{BR}
Ni/Au HEMT	1.56V	-86V
Er_2O_3 MOS-HEMT	4.38V	-127V

Fig.3. Comparison of the Schottky diode characteristics for Er_2O_3-MOS HEMT and HEMT; the gate leakage current for Er_2O_3-MOS HEMT and HEMT in the inset.

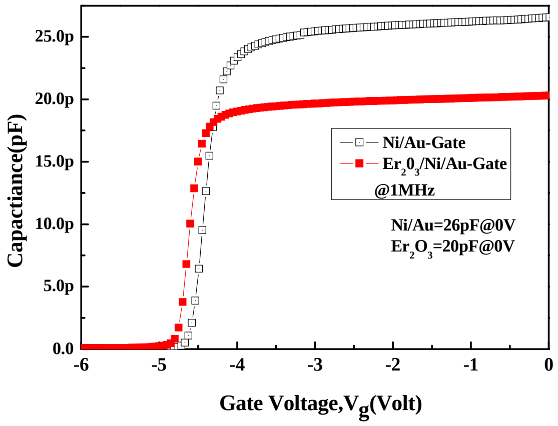


Fig.4. Measured C-V characteristic of the Er_2O_3 -MOS HEMT and the HEMT.

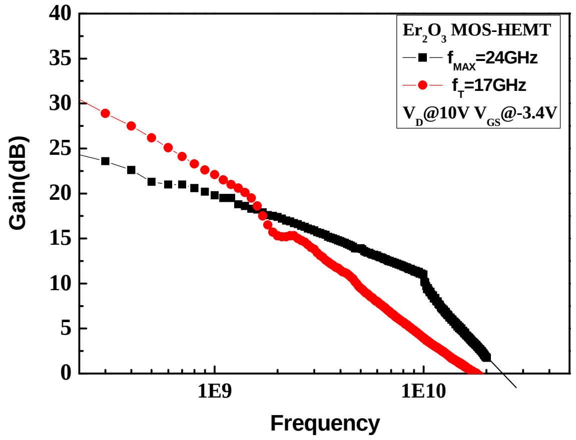
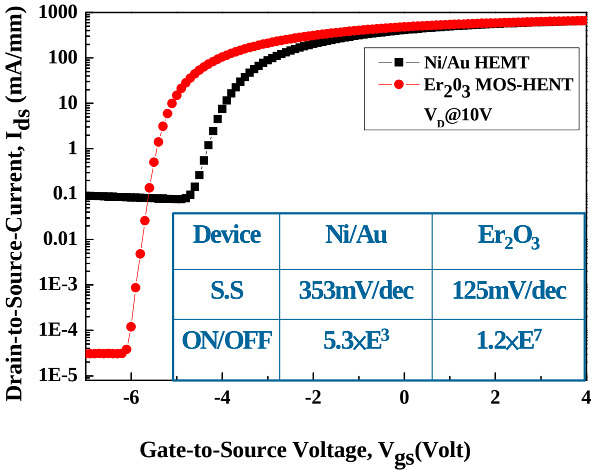


Fig.5. The current cut-off frequency (f_T) and the maximum oscillation frequency (f_{max}) extracted from S-parameters.



Device	Ni/Au	Er_2O_3
S.S	353mV/dec	125mV/dec
ON/OFF	$5.3xE^3$	$1.2xE^7$

Fig.6. The drain-current on the gate-source voltage of the Er_2O_3 MOS-HEMT and HEMT.