Pushing high-power, high-frequency performance of GaN HEMTs on silicon

Singapore researchers claim a record Johnson figure of merit of 8.32THz-V for conventional AlGaN high-electron-mobility transistors.

Singapore's Nanyang Technological University has developed conventional aluminium gallium nitride (AlGaN) high-electron-mobility transistors (HEMTs) with record-breaking figures-of-merit (FOMs) for frequency and breakdown performance [Kumud Ranjan et al, Appl. Phys. Express, vol7, p044102, 2014].

The Johnson FOM is defined as the product of the unity current gain cut-off frequency and the off-state breakdown gate-drain voltage ($f_T x BV_{gd}$). The J-FOM is designed to reflect the needs of high-power microwave devices. The Nanyang device achieved 8.32THz-V, which is claimed as a record for conventional T-gate AlGaN/GaN HEMTs on silicon substrates (Figure 1). Using much more expensive silicon carbide (SiC) substrates, researchers in Japan produced HEMTs with 12.9THz-V J-FOMs.

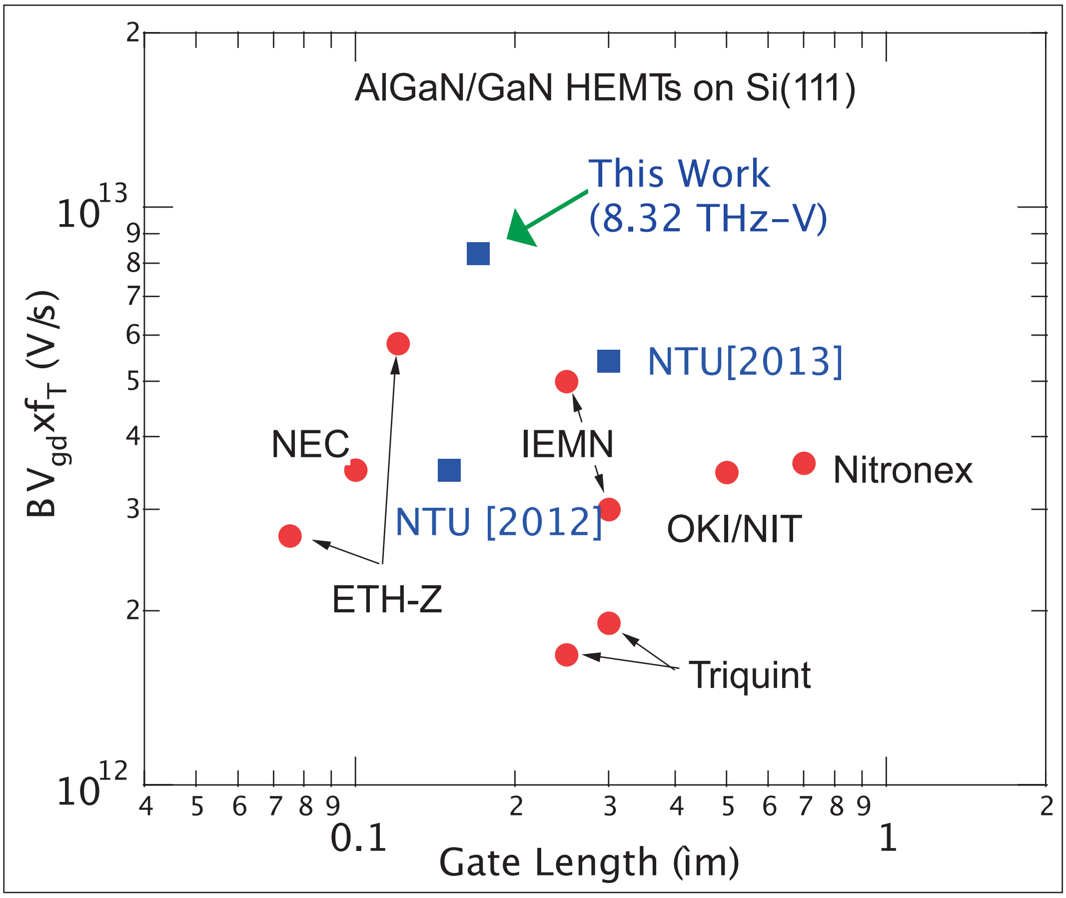

Figure 1. Benchmarking with state-of-the-art J-FOMs ($BV_{gd}xf_T$) versus L_g for AlGaN/GaN HEMTs on Si substrates.

The conventional AlGaN/GaN HEMT structures (Figure 2) were grown on 100mm high-resistivity (111) silicon substrates using metal-organic chemical vapor deposition (MOCVD). The resulting two-dimensional electron gas (2DEG) channel had a carrier density of $0.87x10^{13}/cm^2$ with mobility of $1940cm^2/V$-s.

In more detail, the layer structure consisted of 100nm AlN nucleation, 1400nm transition, 800nm GaN buffer/channel, 1nm AlN spacer, 8nm Al0$_{.26}$Ga$_{0.74}$N barrier, and 2nm GaN cap. The AlN spacer improved the mobility of the 2DEG to allow higher frequencies and transconductance. The thin AlGaN barrier reduced short-channel-effect performance degradation.

The HEMT fabrication used plasma etch for mesa isolation, annealed titanium/aluminium/nickel/gold for ohmic source-drain contacts, ammonium sulfide ($(NH_4)_2S_x$) treatment, T-gate formation, titanium/gold transmission lines, and silicon nitride passivation. The T-gate footprint measured 0.15μm. The T-head was 0.5μm. Further device dimensions were 0.8μm source–gate, 2x75μm gate width, and 3μm gate–drain.

The maximum DC current of the device was 800mA/mm. The peak extrinsic transconductance was 346mS/mm. The threshold voltage was −1.7V. The drain-induced barrier lowering (DIBL) was "negligibly small" at

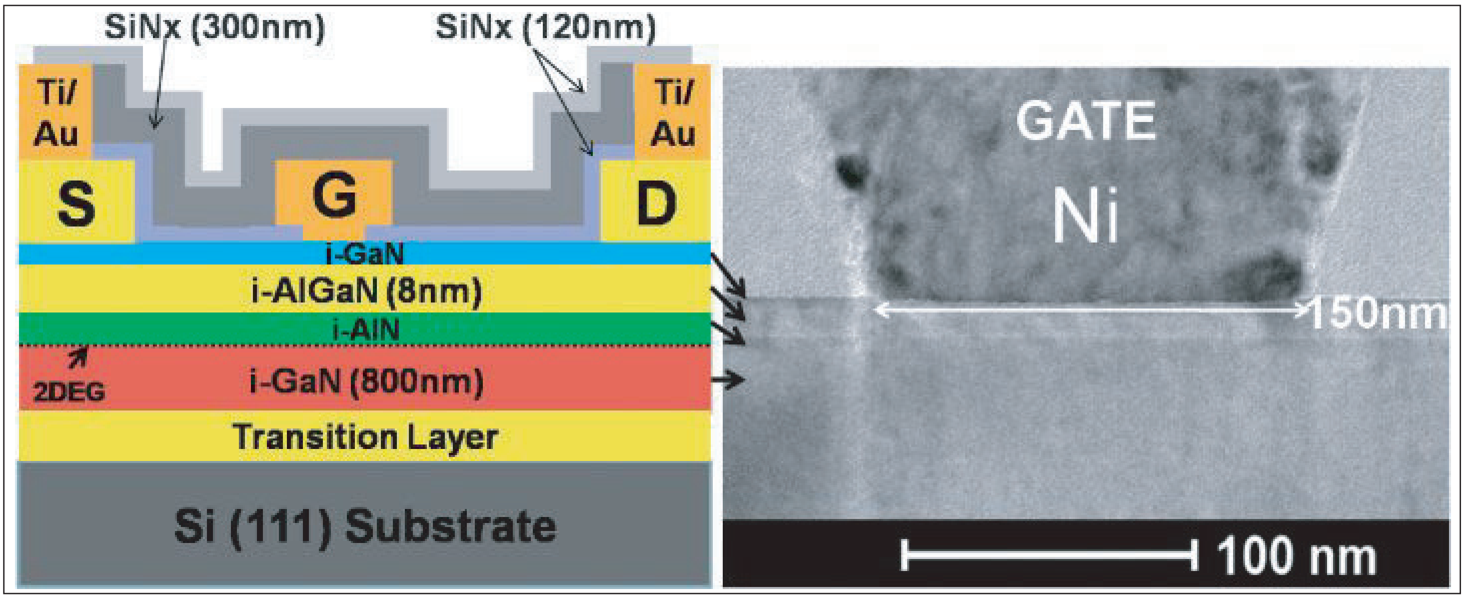

Figure 2. Schematic cross-section and high-resolution cross-sectional transmission electron micrograph (TEM) (gate region) of Nanyang AlGaN/GaN HEMTs on Si substrates.

1.5–3.0mV/V. This compares with DIBL values an order of magnitude greater achieved with ~0.15μm gates and InGaN or AlGaN back barriers. The researchers comment on their device: "The observed low DIBL is due to the large gate-to-channel aspect ratio ($L_g/d_{gc} \sim 15$)."

Small-signal high-frequency measurements gave estimates for the cut-off frequency (f_T) of 63.1GHz and the maximum oscillation/unity power gain (f_{max}) of 124GHz for 6V drain and −0.8V gate biasing. The three-terminal off-state 1mA/mm breakdown (BV_{gd}) occurred at 132V.

Current collapse under gate- and drain-lag pulsed operation was 6% and 8%, respectively. The researchers comment: "These values are closely matched with or even better than those in other reports on AlGaN/GaN HEMTs on Si substrates. The suppression of current collapse is mainly due to the ammonium sulfide treatment plus SiN passivation." ■

http://iopscience.iop.org/1882-0786/7/4/044102/article

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