University of Notre Dame (UND) in the USA and epiwafer maker IQE have claimed record-breaking balanced frequency performance for a nitride semiconductor high-electron-mobility transistor (HEMT) using indium aluminium gallium nitride (InAlGaN) barriers [Ronghua Wang et al, IEEE Electron Device Letters, published online 23 January 2013].

Nitride HEMTs with rectangular gates can have high-performance current-gain cut-offs (fT), while power-gain cut-off frequencies (fmax) are enhanced by using T-shaped gate profiles. Ideally the two cut-off frequency characteristics should be close to one another for best performance. Using a rectangular gate reduces parasitic capacitance; T-gates are more conductive.

The UND/IQE devices used InAlGaN barriers to enhance the channel mobility, allowing a T-gate to be used. The epitaxial structure (Figure 1) was grown on silicon carbide (SiC) using metal-organic chemical vapor deposition (MOCVD). The ohmic contact metal electrodes consisted of titanium/gold on 140nm-thick n-GaN source-drain regions re-grown using molecular beam epitaxy (MBE). The source-drain distance was 0.8μm.

T-gates were produced that consisted of nickel/gold. There was no passivation. The width of the T-gate was 2μm x 2μm. The stem height was ~100nm. The head of the T was 350–400nm and the foot was 40–100nm.

Hall measurements gave the epitaxial material a sheet resistance of 195Ω/square, a carrier density of 1.8x10¹³/cm², and mobility of 1770cm²/V-s.

The maximum drain current for a 40nm gate device was 1.8A/mm at 1V gate potential. The peak extrinsic transconductance of the same device was 770mS/mm. The current-gain (fT) and power-gain (fmax) cut-off frequencies (Figure 2a) were 230GHz and 300GHz, respectively (133/260GHz before de-embedding). The drain bias for the transconductance and frequency measurements was 5.6V.

The geometric mean of fT and fmax (square root of product) was 263GHz. The balanced frequency performance is claimed as a record for devices with InAlGaN barriers (with no back-barrier)...

Incorporation of re-grown contacts with a lower contact resistance and use of shorter gate lengths in conjunction with back-barriers (provided this is done without compromising the channel mobility) promise fT/fmax near 350GHz reference as the previous best a 30nm-gate device with InAlN barrier that achieved fT/fmax of 205/220GHz, reported in 2011 by Switzerland’s ETH Zurich. They also compare their device with a range of other reports from the research literature (Figure 2b).

The UND/IQE devices did show larger extrinsic parasitic delay effects due to the capacitance arising from the T-head of the gate compared with rectangular gates. The researchers believe this effect can be reduced by lengthening the T-stem to more than 200nm. Also, gate recessing would be beneficial in increasing transconductance.

The researchers add: “Furthermore, incorporation of re-grown contacts with a lower contact resistance and use of shorter gate lengths in conjunction with back-barriers promise fT/fmax near 350GHz reference as the previous best a 30nm-gate device with InAlN barrier that achieved fT/fmax of 205/220GHz, reported in 2011 by Switzerland’s ETH Zurich. They also compare their device with a range of other reports from the research literature (Figure 2b).
lengths in conjunction with back-barriers (provided this is done without compromising the channel mobility) promise $f_t/f_{\text{max}}$ near 350GHz."

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