High-Speed AlInN/GaN HEMTs on SiC and (111) HR-Silicon (INVITED)

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AlGaN/GaN high electron mobility transistors (HEMTs) have greatly matured after more than a decade and a half of frantically paced development. The current interest in extending GaN -based HEMTs to millimeter-wave frequencies requires thinner top barriers to maintain a favorable channel aspect ratio L_G/d. Unfortunately, AlGaN/GaN two-dimensional electron gases (2DEGs) are subject to surface depletion when the top barrier thickness is thinner than ~15 nm [1]. This issue can be circumvented by using AlN thin top barriers to boost channel sheet densities [2]. An alternative solution relies on nearly lattice-matched AlInN/GaN heterostructures, as originally proposed by Kuzmík [3]. This material system potentially offers a solution to strain-related device reliability concerns associated with conventional AlGaN/GaN heterostructures. Furthermore, surface depletion effects should be far weaker for the AlInN/GaN system, which should maintain excellent channel aspect ratios down to very short gate lengths. The feasibility of ultrathin barrier AlInN/GaN HEMTs was indeed verified down to 3 nm thick AlInN barriers [4].

In the present paper, we review the progress [5-6] in extending the bandwidth of AlInN/GaN HEMTs well into the millimeter-wave régime for AlInN/GaN HEMTs grown on semi-insulating SiC and on (111) high-resistivity silicon (HR-Si) substrates. At the time of writing, these devices offer the highest bandwidths available for nitride transistors. 55 nm gate devices on SiC feature cutoff frequencies as high as $f_T = 205$ GHz with a simultaneous $f_{MAX} = 191$ GHz, while 80 nm gate HEMTs on (111) HR-Si show $f_T = 143$ GHz with a simultaneous $f_{MAX} = 178$ GHz. These numbers represent the highest bandwidths attained by GaN HEMTs on silicon substrates as well.

The performance of our AlInN/GaN HEMTs on HR-Si will be contrasted to state-of-the-art results achieved in our lab with recessed gate AlGaN/GaN HEMTs on HR-Si. Some of the above mentioned world-records will fall with new announcements from competing groups at IEDM, and we hope to have new results to show at MANTECH.

References:

[1] M. Higashiwaki, T. Mimura, and T. Matsui, Proc. SPIE, vol. 6894, no. 1, p. 68941L, 2008.
[2] Y. Cao and D. Jena, Appl. Phys. Lett., vol. 90, no. 18, p. 182 112, May 2007.
[3] J. Kuzmík, IEEE Electron Device Lett., vol. 22, no. 11, pp. 510–512, 2001.
[4] F. Medjdoub, M. Alomari, J.-F. Carlin, *et al*., IEEE Electron Device Lett., vol. 29, no. 5, pp. 422–425, 2008.
[5] H.F. Sun, A.R. Alt, H. Benedickter, E. Feltin, *et al*., IEEE Electron Device Lett., vol. 30, no. 8, pp. 796–798, 2009.
[6] H.F. Sun, A.R. Alt, H. Benedickter, J.-F. Carlin, *et al*., IEEE Electron Device Lett., vol. 31, no. 4, pp. 293–295, 2010.

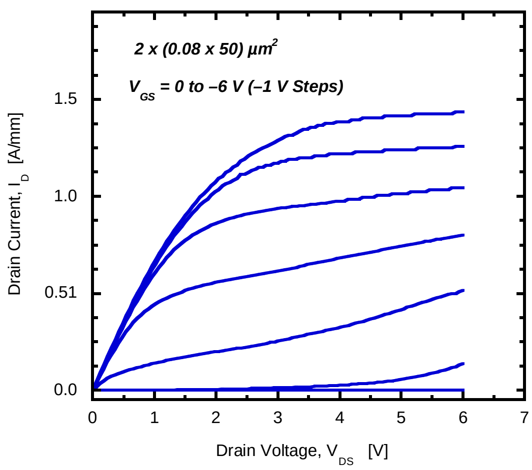

FIG. 1: *I-V* characteristics of 80 nm gate AlInN/GaN HEMT on (111) HR-Si.

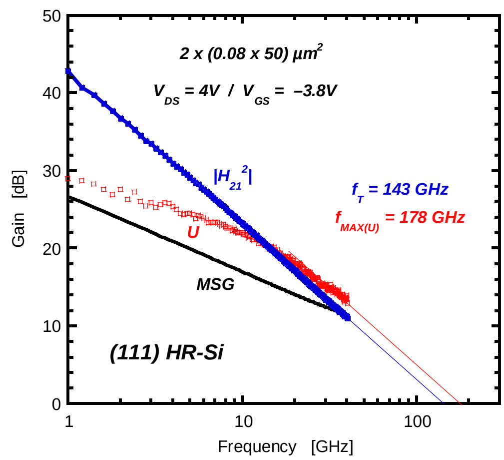

FIG. 2: Small-signal frequency response of 80 nm gate AlInN/GaN HEMT on Si at $V_{DS} = 4$ V and $V_{GS} = -3.8$ V.