Wide-Bandgap p-Channel Transistors Based on GaN/AlN

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Primary CNF Tools Used: SC4500 evaporator, PT 770 ICP/RIE etcher

Abstract:

Wide-bandgap (WBG) p-channel transistors, which can be monolithically integrated with WBG *n*-channel transistors, are the missing piece to the construction of WBG CMOS circuitry, which could provide tightly-integrated control over power and RF electronics. This report demonstrates high on-current *p*-channel devices based on one of the most promising platforms: the GaN/AlN heterojunction.

Summary of Research:

Though gallium nitride (GaN) electronics have advanced rapidly over the last decade to become a major player in the RF and power electronics spaces, *p*-channel devices in GaN have proven difficult to produce. The low hole mobility, poor acceptor efficiency, and hard-to-contact deep valence bands have limited device performance. This highlight celebrates advances on this front achieved in the Cornell NanoScale Science and Technology Facility and reported at the 2019 International Electron Devices Meeting [1].

An epitaxial stack consisting of a p^{++} InGaN cap on a GaN channel on an AlN buffer was grown by molecular beam epitaxy. Pd/Ni ohmic contacts were formed by e-beam evaporation in an SC4500 evaporator. After mesa isolation, the contacts were used as a mask to perform a global recess of the InGaN layer in the PT 770 ICP/RIE etcher. A SiO_2 hard mask was deposited using the Oxford 100 PECVD and patterned to reveal gate recess regions, which were then etched by the PT 770. After mask removal, the SC4500 evaporator was used to put down Mo/Au based gate contacts. All photolithography was performed in the GCA Autostep 200.

Finally, p-channel devices with 600 nm gate recess lengths were measured with up to 100 mA/mm on-current and 1-2 orders of on-off modulation, limited by the Schottky gate leakage. While this leaves significant room to improve upon the gating, the overall device performance compares well with the state-of-art in this field, as shown in Figure 1, demonstrating the promise of GaN/AlN based electronics for a wide-bandgap CMOS future.

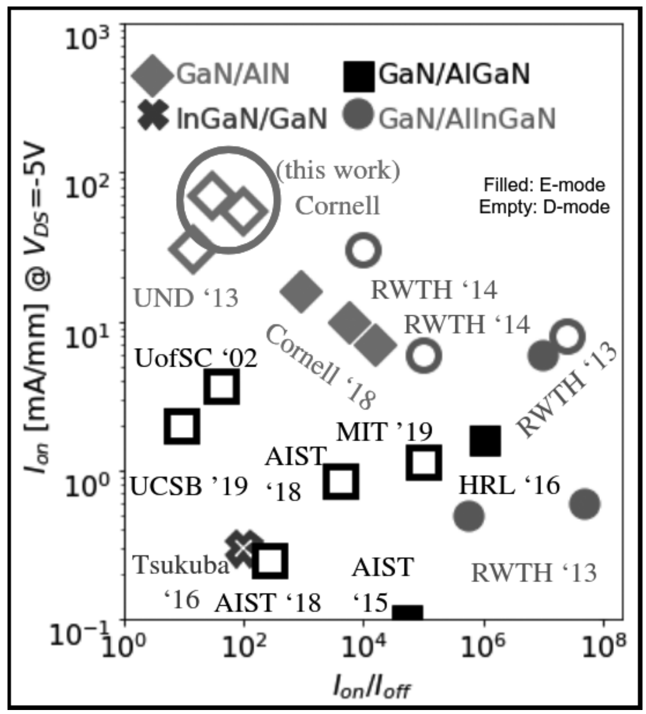

Figure 1: Current-levels and modulation ratios achieved for various p-channel device demonstrations in the III-Nitrides. Noting that this is a rapidly advancing field, it is critical to timestamp this benchmark as drawn from only the publicly available literature as of July 2019. It is seen that GaN/AlN devices enable some of the highest on-currents possible. (See pages vi-vii for full color version.)

References:

[1] S. J. Bader, et al., "GaN/AlN Schottky-gate p-channel HFETs with InGaN contacts and 100 mA/mm on-current," in International Electron Devices Meeting. DOI: 10.1109/IEDM19573.2019.8993532 (2019).