Demonstration of Record-High mm-Wave Power Performance using N-Polar Gallium Nitride HEMTs

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Gallium Nitride high electron mobility transistors (GaN HEMTs) are proven to be well suited devices for highly efficient solid-state radio frequency power amplification, especially when high output power is desired. Existing GaN transistor technologies using the Ga-polar crystal orientation (0001) have been demonstrated operating at millimeter-wave frequencies (30 to 300 GHz). While these Ga-polar devices have demonstrated good large signal functionality, their performance has largely saturated. With growing interest in communication and imaging applications operating at mm-wave frequencies there is a need for transistors technologies with higher performance at these frequencies. This work focuses on the development and demonstration of mm-wave N-polar GaN HEMTs using a deep recess device structure. The internal polarization electric fields that are characteristic of c-plane GaN are inverted in the N-polar GaN orientation (000-1) relative to the Ga-polar orientation. This enables the deep recess device structure used in this work where a GaN cap layer is added into the access regions of the device. This GaN cap mitigates the impact of DC-to-RF dispersion and improves the conductivity of the access regions leading to the demonstration record-high output power density and power-added efficiency at operating frequencies ranging from 30 to 94 GHz. At 94 GHz, an unprecedented 8 W/mm of output power density with an associated 26.9% power-added efficiency has been obtained.