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Wide-Bandgap Nitride- and Oxide-Based Electronics – Vision, Challenges, and Opportunities

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The high electron velocity, high breakdown field, and large 2-D electron gas (2DEG) density of wide-bandgap polar III-nitride heterostructures have enabled devices possessing wide bandwidth and high breakdown voltage simultaneously. GaN high electron mobility transistors (HEMTs) have found important applications in microwave and millimeter-wave power amplification. The large current density and high-speed performance of GaN HEMTs also render these devices suitable for integrated digital or control functions. N-polar $(000\bar{1})$ GaN is envisioned to effectively address the device scaling challenges and associated gain degradation encountered by the mainstream Ga-polar (0001) technology. Due to the absence of inversion symmetry in *c*-plane III-nitride materials, the polarization of N-polar crystals is opposite to that of Ga-polar crystals, inducing a 2DEG above instead of below the Al(Ga)N barrier layer. Therefore, these inverted N-polar heterostructures address the scaling challenges of GaN HEMTs by offering the intrinsic engineering advantages of stronger back-barrier carrier confinement and lower Ohmic contact resistance. The principles of polarization engineering for designing N-polar HEMT structures will be outlined. The performance, scaling behavior, and challenges of microwave power devices as well as highly-scaled depletion- and enhancement-mode devices employing self-aligned processes, *n*+ (In,Ga)N ohmic contact regrowth, and high aspect-ratio T-gates will be discussed.

The worldwide quest for innovative technologies beyond Si for efficient power switching has driven intensive research into widegap power devices with materials such as GaN and the emerging Ga_2O_3 semiconductor, which will advance the frontiers of power electronics by providing miniaturized semiconductor-based alternatives for consumer, automotive, and industrial high power systems. The subsequent reduction in conversion losses and cooling requirements promise to improve cost and energy efficiencies. Highlights of GaN and β-Ga_2O_3 power field effect transistor technologies including materials development and device architecture will be reviewed.

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