Advances in Wide Bandgap, High Power Density Semiconductor Devices

Widebandgap (WBG) semiconductors present a pathway to push the limits of power conversion efficiency beyond that available from Silicon (Si)-based devices, enabling significant energy savings. Recent progress in Gallium Nitride (GaN)-based power electronic devices has been compelling. Reducing conversion losses is not only critical for minimizing consumption of limited resources, it simultaneously enables new compact architectures, the basis for a new industry offering increased power conversion performance at reduced system cost. This is because GaN devices enable power electronics with 1) higher efficiency at higher frequency of operation and 2) higher efficiency over a wider range of operating temperature, compared with what is possible with Si, which is approaching its physical material limit in power conversion. High efficiency operation at higher operating frequency reduces the size, weight and cost of the overall system by reducing the size of the passive components and the heat sink. GaN-based Photovoltaic (PV) inverters have achieved efficiency above 98% at a pulse-width modulation frequency of 50 kHz (vs. 96% with Si at 15 kHz), reducing loss by 50%, thereby shrinking the PV inverter size by 40%. While **Lateral GaN** HEMTs are more matured in technology and have entered the medium power conversion market (up to 10 kW), **Vertical GaN** devices are evolving to address high power conversion (10 kW-10 MW).

Owing to the high electron mobility in the channel GaN HEMTs have provided excellent technology platform to realize high frequency RF RADAR amplifiers. It is critical that the power density and Power Added Efficiency (PAE) of RF RADAR amplifiers be maximized to reduce chip size and thermal cooling requirements. This enables new RADAR amplifier classes such as switched mode amplifiers, reduces electrical and thermal system complexity and cost while simultaneously simplifying deployment. Vertical GaN-based transistors uniquely harness the high breakdown field of GaN because the electric field distribution is uniform, easily designed and contained in the bulk of the device, compared to peaked surface/interface electric field distribution in lateral devices. Coupled with the reduced dispersion at high voltage, they provide the desired high-power density and PAE not possible with current technology. The novelty of the device design can be extended beyond GaN to other wider bandgap materials like Gallium Oxide, Aluminum Nitride and Diamond for more futuristic power amplifiers and converters.

It is always exciting to be at the beginning of a new technological revolution, which has tremendous ecological impact. WBG electronics offers just this opportunity both with its promise of superior solutions to pressing problems while simultaneously opening the possibilities of providing functionality that we have not even thought of.