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Polarisation Junction based Super HFETs and derivatives in GaN

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Gallium Nitride (GaN) is a wide band gap semiconductor, which can be grown on Silicon, Sapphire, Silicon Carbide or Diamond. Its electric field strength is 10 times higher than that of Silicon. High density two dimensional electron gas (2DEG), arising due to polarization properties of the AlGaN/GaN hetero structure provides extremely low on-state resistance. The conventional GaN Hetero-junction Field Effect Transistors (GaN-HFET) available today are based on the use of the 2DEG with metal field plates to reduce the electric field crowding at the gate and drain ends to increase the breakdown voltage. Such approaches are non-ideal. In this paper, we will highlight the basics of Polarization Super Junction (PSJ) concept in GaN for power switching applications and highlight some of the device structures and electrical results. GaN PSJ-FETs are significantly superior to the GaN-HFETs for the following reasons:

• GaN PSJ-FET requires a significantly smaller area in comparison to a conventional GaN FET plus its external anti-parallel diode.

• The PSJ approach is the (only) viable approach for power devices to go beyond GaN's one-dimensional material limit in terms of its specific on-state resistance versus breakdown voltage. Simulation results show that, beyond 300 V, PSJ-FET can offer 1/10th of resistance of an equivalent conventional GaN-HFET, which increases to more than 1/100th beyond 2 kV.

• Unlike other wide band-gap materials, PSJ-FETs can operate from cryogenic temperatures to in excess of 250 C, as the polarization charges are temperature independent.

GaN PSJ devices such as diodes, FETs and bidirectional switches are ideal in applications from inverters in home appliances, automotive and aerospace applications, motor drives and harsh environment applications for more efficient, power dense and high temperature compliant electric power conversion and rad-hard space applications. From a manufacturing perspective, fabrication of GaN PSJ devices is simpler than the super-junction devices in Silicon – an important consideration. The system level reward is a step-change in electrical power conversion performance, with a clear reduction in energy consumption and reduction in CO_2 emission.