New Radiation Hardened GaN HEMT for Next Generation Space Missions

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The demand for greater communication bandwidth on a global scale is insatiable and undeniable. As a result, next-gen satellites must deliver higher data throughput for digital payloads. Among in-orbit configuration, edge-computing, and other advanced needs, current FPGAs and ASICs call for greater and more innovative power requirements. The shift to digital payloads requires engineers to reassess key design parameters, such as material needs, operational factors, and radiation robustness, to ensure optimal performance in their space power systems.

For generations, Silicon (Si) has been the industry's material of choice in power applications, but in recent years, Gallium Nitride (GaN) has shown real promise offering a multitude of advantages in applications where reaching high switching speeds and efficiency are just as important as minimizing the size and weight of a power system. Continue reading to learn more about GaN for space applications, the benefits of using a wide band gap semiconductor to optimize operations, and its performance as a radiation hardened (rad hard) High Electron Mobility Transistor (HEMT). Discover the industry's first internally manufactured rad hard GaN transistor with Joint Army Navy Space (JANS) qualification from Infineon IR HiRel.

Technological Architecture of GaN

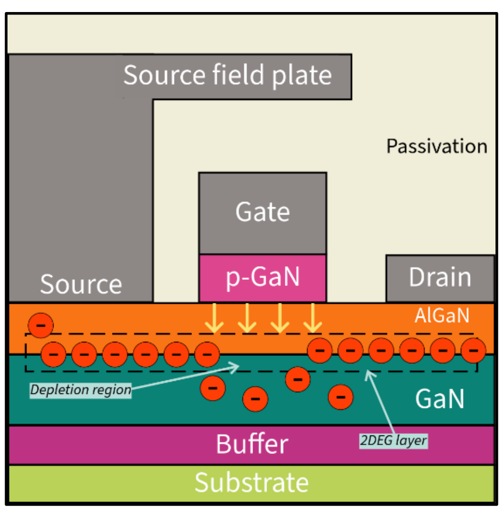

Figure 1: Cross-sectional material of GaN HEMT (Infineon IR HiRel)

GaN holds a wide bandgap energy of ~3.4 eV. In comparison, legacy technology, such as Si, has a wide bandgap energy of ~1.1 eV. The material properties of wide bandgap semiconductors such as GaN make the technology attractive as power transistors. **Figure 1** illustrates the general design of Infineon IR HiRel's lateral GaN HEMT, IG1NT052N10R. Electrons move from source to drain through a "2-dimensional electron gas" (2DEG) layer formed at the AlGaN and GaN epi heterojunction layer. This is a result of a piezoelectric effect that occurs at the interface between the two layers. A layer of positively doped GaN, p-GaN, is integrated between the gate and AlGaN layer to produce a depletion region. The inclusion of a p-GaN layer allows the transistor to face a low, positive threshold voltage and perform as an enhancement-mode device. This structure plays a role in the benefits of GaN as a power transistor technology. The source field plate contributes to the improved breakdown voltage as it reduces the peak electric fields found on the gate. The 2DEG layer allows high mobility of electrons with minimal drain-source resistance ($R_{DS(on)}$), a key parameter to account for in power transistors. Low V_{th}, such as 1.5 V for IG1NT052N10R, results in higher switching speeds. The structure of a lateral GaN HEMT also lacks a gate oxide that is typically observed in Si MOSFETs. As a result, GaN has a slight robustness to radiation inherent to its design. Rad hard by design is still applicable to GaN as there are some parameters that need to be mitigated under radiation.

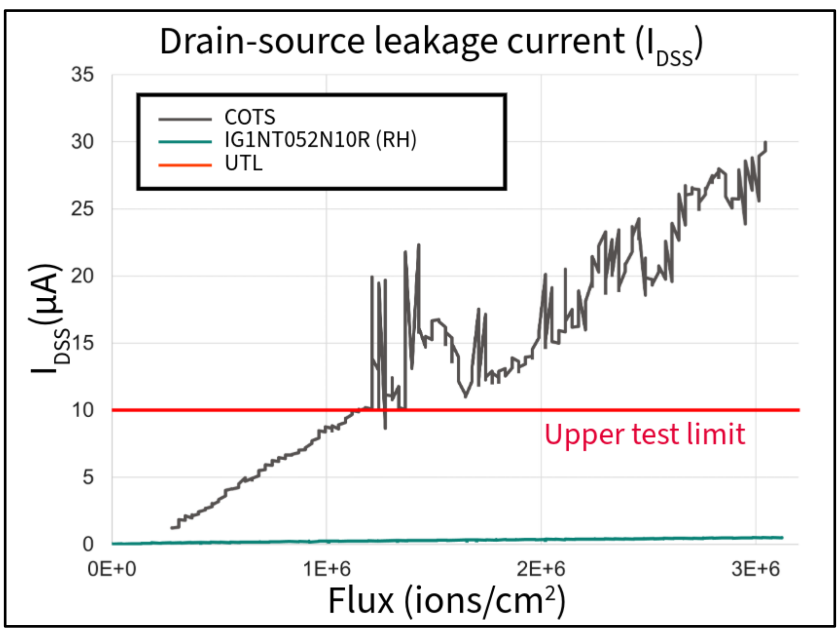

Figure 2: SEE Flux radiation vs Drain-source leakage current (Infineon IR HiRel)

Optimized Radiation and Power Performance

There is some inherent robustness to GaN under various radiation effects due to the absence of a gate oxide. GaN faces no trapped charge nor $V_{GS(th)}$ shift under Total Ionizing Dose (TID) radiation and does not suffer from Single Event Gate Rupture (SEGR) under Single Event Effect (SEE). Even though GaN boasts inherent radiation resistance, there is still an advantage to choosing radiation hardened solutions over commercial-off-the-shelf (COTS) parts for space applications. **Figure 2** demonstrates the importance of creating a GaN transistor radiation hardened by design. Comparing a COTS-graded GaN to a rad hard GaN, we see the COTS device significantly drift while the rad hard GaN remains relatively stable over the entire duration. Rad hard by design will almost always ensure the reliability required in extreme environment applications.

Despite the benefits GaN's technological set up has over Si, it is still crucial for engineers to design the device to perform efficiently under radiation. **Figure 3** highlights the radiation robustness of GaN under SEE for 3 different lots tested up to Au. In addition to how the GaN device under testing does not require derating when subjected to LET of 70 MeV*cm^2/mg (the LET Si equivalent to 86.5 MeV*cm^2/mg), the electrical operation of the device is up to standard with the industry's leading rad hard transistor standards. To make sure the device is suitable for power architectures in space systems, Infineon IR HiRel created a new package specifically for GaN, called the PowIR-SMD.

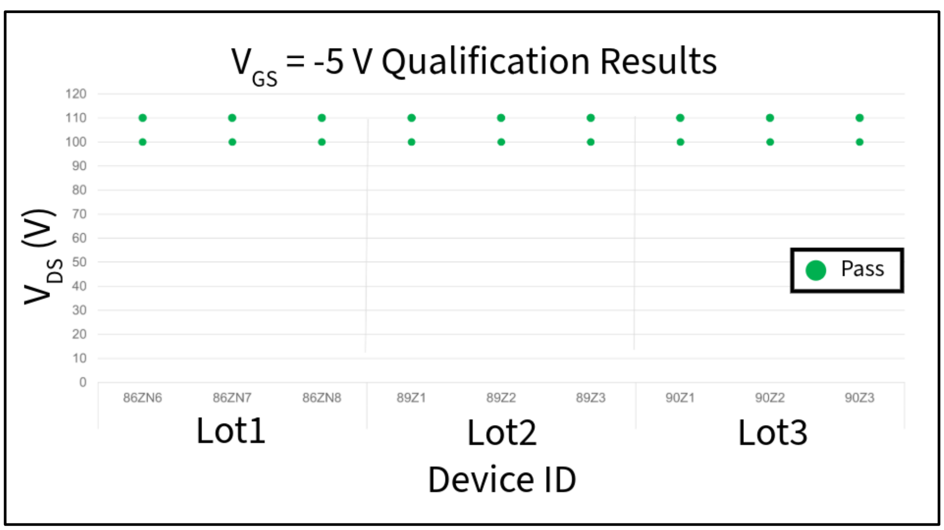

Figure 3: SEE SOA for IFX IR HiRel 100 V rad hard GaN HEMT (Infineon IR HiRel)

Best-in-class Packaging

Innovative semiconductor technology requires optimal packaging to perform at its best. Infineon IR HiRel developed a new surface mount package to ensure utmost reliability and robust operations for its rad hard GaN device.

Figure 4: A three-dimensional representation of the PowIR-SMD, a new space-grade, hermetic package dedicated for GaN design

Minimizing parasitic inductance is imperative in system design, especially because GaN is a fast-switching technology. With this in mind, we developed the PowIR-SMD to be a bondwire-free SMD package that has an extremely low inductance value of 0.1 nH. Additionally, this package allows a kelvin-source connection to decouple the gate drive from the power stage, lowering the common-source inductance of the device. Another factor to address is the CTE mismatch between the packaged device and the PCB. Occasionally, ceramics such as Alumina are developed into hermetic packaging to address such mismatches. This is seen with Si MOSFETs where the devices are large enough to dissipate the heat generated. The high density of GaN allows the technology to perform efficiently within a smaller form factor compared to Si MOSFETs. Consequently, packages dedicated to GaN would benefit from developing a package consisting of Aluminum nitride, AlN. The higher thermal conductivity of AlN compared to alumina, 150 W/m*K versus 12 W/m*k respectively, allows the device to dissipate heat more effectively. The size of GaN, in this case, is small enough to mitigate the thermal cycling mechanical stress concern that is considered when using AlN. The inclusion of AlN holds an additional benefit as it lessens the accumulation of free charges from environmental radiation, preventing system damage and contributing to inherent radiation robustness. **Figure 4** illustrates the surface mount packaging dedicated to addressing GaN usage in dpace.

Conclusion

The increasing demand for higher processing power in satellites has led to a growing need for advanced technologies that can efficiently handle complex tasks such as artificial intelligence, in-orbit reconfiguration, and more. High-power FPGAs and ASICs are being driven to their limits, and as a result, improved efficiency and reduction in size and weight are critical factors to consider in satellite design.

Infineon IR HiRel's rad hard GaN HEMT brings top-of-the-line radiation performance and electrical robustness to the high reliability market. Our 100 V rad hard GaN HEMT, now available under MIL-PRF-19500 JANS qualification, has been designed to optimize higher performances in power systems.

To learn more about Infineon Technologies IR HiRel (IFX IR HiRl)’s rad hard GaN product, please visit https://www.infineon.com/products/high-reliability/space/power/rad-hard-gan.

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