600V GaN Power Device: The long journey to market success

Alain Charles
Infineon Technologies Americas Corporation, Technology Development Center, USA
Alain.charles@infineon.com

It has been now 25 years that the proof of a two dimensional electron gas at the AlGaN / GaN interface was disclosed. Over the years, claims of superior performance of AlGaN/ GaN based HEMT power devices vs. silicon incumbent, have created excitement. Yet the market success of 600V GaN based power devices has been slow to materialize and market forecaster had sadly to revise their numbers down year after year.

Besides the fact that competition for GaN 600V got stronger due to the impressive improvements of Superjunctions, like CoolMOS^{TM}, and the advent of SiC power MOSFETs, the main delays in adopting GaN HEMT power devices were primarily instigated by HEMT devices not meeting the market expectations in terms of overall performance gain at the system level but also and mainly because of reliability. In this keynote we will go through the different key attributes that are the must have for GaN to become successful in the market and show that Infineon's CoolGaN^{TM} meets all requirements for market success.

All starts with the device type choice (Cascoded HEMT, MIS-HEMT, p-GaN HEMT, GIT, HD-GIT) and the optimization of that device. The figure of merit (threshold voltage, on resistance, capacitances, saturation current), the stability of these under stress (current collapse, Rdson shift), the gate drive scheme and its constraints or limitations, are all factors to consider carefully. The presentation will show why the choice of HD-GIT was made for our 600V CoolGaN^{TM} device, as well as some of the work done to ensure optimum device performance. We will show that the HD-GIT device basically allows eliminating Rdson shift. The gate drive of our Ohmic p-GaN gate GIT might be complex due to the Dc current drive and negative gate voltage requirements, but that is offset by the reliability it provides as the Schottky breakdown voltage limitation is avoided and no clamp circuitry, which induces more drive loss, is required. We will also show that the gate drive power vs. frequency is very comparable to Schottky gate device requiring complex clamp circuitry.

Having a good and stable device is a necessary condition but it is not sufficient for success. Evidently, reliability is paramount to GaN adoption. Most commercially available GaN devices have been released based on "JEDEC" Silicon device qualification standards. This is clearly insufficient to ensure the device will meet a targeted lifetime in customer application and at a customer tolerable failure rate. The paper will describe the methodology employed by Infineon so as to allow prediction of useful life in customer application with target cumulative failure. Example will be shown through a comparison of High Temperature Reverse Bias (HTRB) result between our former normally on Cascoded device and our current e-mode HD-GIT pointing to the strength of the latest.

Once the device performance and reliability are achieved, the value proposition will come from the potential advantage in the application, meaning either better efficiency, or higher power density or overall lower bill of material cost, or any combination of these three attributes, as the higher component cost of the GaN device must be offset. In this keynote we will show some applications results using our 600V CoolGaN^{TM} device. It is clear here that the next stage is to push the potential advantage that GaN can bring when using resonant topologies at high frequencies due to low gate charge and low and linear Qoss. We will show that our 600V CoolGaN^{TM} HD-GIT properties provide great flexibility to route high current and as such has great capabilities at high frequencies even without integrating the gate drive and switch monolithicaly thus leaving ability to tune gate drive circuit for EMI.

Through these past year learnings, tremendous rate of progress of GaN based 600V power devices has been achieved and our 600V CoolGaN^{TM} platform provides a very credible solution for market success.