The Status of GaN based Power Device Development

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Abstract

The major advantages of higher efficiency at higher density for GaN based power devices for use in conversion circuits such as dc-dc or ac-dc power supplies and inverters are reviewed. The current status of the development and current performance of the required 20 to 600 V rated GaN on Si based devices are presented.

It has been well documented that the advent of wide bandgap semiconductor based power devices provides unprecedented opportunities to reduce both conduction (Rdson) and switching losses (Qsw) in a wide variety of power conversion circuits. Through the use of silicon substrates, together with CMOS based device fabrication technology platforms allowing the use of large volume silicon factories, the cost structure for GaN based HEMTs can be made close to that of the silicon incumbent technology platforms. In this way, the extraordinary advantages afforded by wide bandgap semiconductor based power devices to efficient energy conversion can be widely adopted.

The limitation in the availability of commercially viable 200 to 600 V GaN based power devices relates to the resolution of several key robustness limitation. In this presentation, it will be shown that these challenges have essentially been resolved. Finally, the desire for normally off operation has been met through several approaches, including the shifting of the Fermi level under the gate region, producing an enhancement mode device. It will be shown that the alternative approach of cascading a normally on high voltage HEMT with a normally off low voltage device has several distinct advantages.

Besides the significantly lower specific on-resistance for a given operating voltage capability afforded by the wide bandgap nature of the AlInGaN material system, the lower capacitance afforded by the lateral HEMT devices, provide for much lower switching times, and therefore lower power conversion losses, especially at higher switching frequencies. In order to take advantage of these inherent capabilities, improved packaging techniques must be developed. Figure 1 shows the remarkably fast and clean switching waveform obtained for a 600 V rated GaN HEMT in a QFN package compared to that of a state of the art superjunction device. Figure 2 provides an example of the essentially identical results obtained for GaN based 600 V rectifiers and state of the art 600 V SiC diodes, as used in a standard 430 W rated 100 kHz boost converter circuit for power factor correction applications. Figure 3 shows the significant improvements achieved in the stability of the device on resistance after high voltage switching.

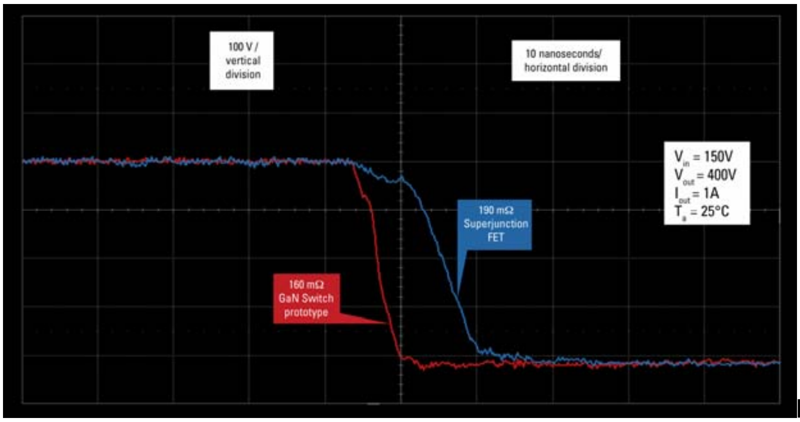

Figure1 : Turn-on waveform for 600 V rated GaN based switch showing nearly 100 V/ns dv/d compared a state of the art silicon based superjunction switch.

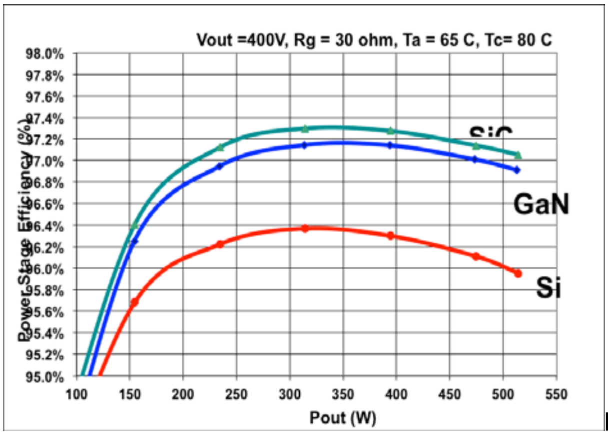

Figure 2: Measured power conversion efficiency for 150 Vin to 400Vout boost converter stage of a 430 W rated PFC converter comparing GaN, SiC and Si based rectifying devices. In all cases a silicon SJ switch was used.

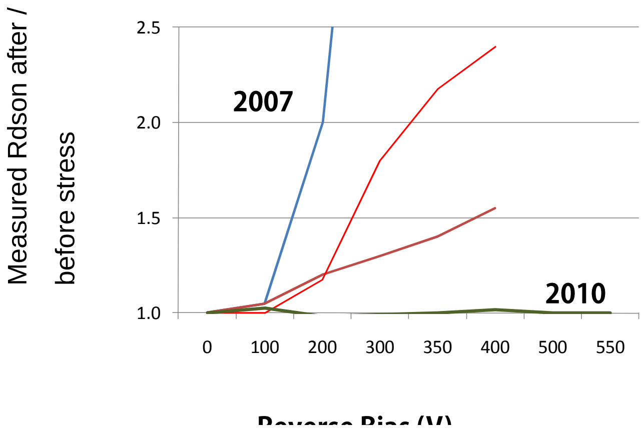

Fig 3: Measured Improvements in Dynamic Rdson (=Ron after / Ron before stress)