GaN based Power Devices Make Possible A New Paradigm in Power Conversion

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From planar HEXFETs to TrenchFETs and superjunction FETs, silicon power MOSFETs have continued to evolve for the last 30 years to satisfactorily serve numerous markets. In fact, during that period, there have been some two orders of magnitude improvement in performance. However, this silicon power device is rapidly approaching maturity. That means further enhancements are incremental, while the cost of advancements are increasingly uneconomical. Concurrently, next generation and emerging applications are demanding further significant leaps in power conversion performance.

Accordingly, new materials and transistor structures are needed. Although, silicon carbide (SiC) FETs have emerged on the scene in the past 10 years to address these issues, they suffer from significant cost premiums due to limited quality material supply, as well as the inherent cost structure of the material. Additionally, SiC based technology is not highly scalable in substrate size, material supply and device fabrication manufacturing platforms.

Likewise, gallium nitride (GaN) based power devices have also been in development for more than 10 years, especially in Japan. Most likely, the results of this work have been deployed internally within industrial Japanese organizations like Fuji Electric, Matsushita Electric, Oki and Hitachi. IR is unaware of significant merchant product offerings in the market today.

Consequently, foreseeing a window of opportunity, scientists and engineers at IR have developed a revolutionary GaN based power device technology platform that promises to deliver cost effective performance that is at least ten times better than existing silicon devices to enable dramatic reductions in energy consumption in end applications in a variety of market segments such as computing and communications, consumer appliances, lighting and automotive.

In fact, over five years of R&D has resulted in a proprietary GaN-on-silicon epitaxial process and device design and fabrication technology platform, referred to as GaNpowIR, that heralds a potential new era in power conversion. Due to intrinsic mismatch in lattice constants and thermal expansion coefficients between the substrate and the epitaxial films, the solutions to the hetero-epitaxial process were not trivial. However, significant engineering efforts have resolved these issues, allowing for volume deposition of GaN based material on low cost silicon wafers costing about 100 times less than SiC. Silicon wafers also provide much larger diameter substrates (6-, 8- and 12-inch) and in higher volumes than are available with either sapphire or SiC.

In addition to providing high quality, reliable and cost effective CMOS compatible manufacturing process, IR’s GaNpowIR technology platform also delivers power devices with dramatic improvements in three basic figure of merits (FOMs), namely specific on-resistance RDS(on), RDS(on)*Qg and efficiency*density/cost.

For instance, with regards to the power switch static FOM of on-resistance x area or specific on-resistance, the improvement of GaN is driven predominantly by the 10 fold increase in critical electric field of the material over that of silicon. Fundamental physics shows that an improvement in RDS(on) of more than a factor of 10 can be achieved using GaN based power devices versus silicon MOSFETs in the 100 to 300 V application range. In the 600 to 1200 V application range, GaN based devices have the potential of improving RDS(on) by more than a factor of 100 over silicon MOSFETs.

The power device switching FOM RDS(on) Qg (RQ) is also dramatically improved using GaN based power devices. In fact, the first generation 30 V GaNpowIR devices are expected to represent about 33% improvement over state of the art silicon MOSFETs. Continuous improvements envisioned for GaN based devices promise an order of magnitude reduction in the RQ FOM within 5 years of introduction of the GaNpowIR platform in 2009.

These enhancements in switch RQ FOM are expected to enable efficient high ratio power conversion to greater than 50 MHz in the near future. Correspondingly, the DC-DC converter size will decrease, without compromising power conversion efficiency. Additionally, when the frequency is high enough (20 to 60 MHz), it eliminates external components and undesired distance between the converter and the load, resulting in a significant reduction in parasitic related power loss. This therefore, offers a ground-breaking performance of high density, higher efficiency and lower system cost. Combined with improved packaging and drive technologies, an order of magnitude improvement is expected in the power conversion application FOM, efficiency*density/cost, within five years of commercial introduction of the GaNpowIR platform.

Prototype power conversion systems have been used to demonstrate some of the capabilities of the GaN based power device technology. Plans are underway to offer a broad range of commercially viable products (for applications requiring 20 to 1200 V device ratings) supporting discrete as well as circuit solutions (modules and chipsets) for a variety of DC-DC and AC-DC converters, lighting, class D audio and motor drives. First commercial products are scheduled for production release by the end of 2009.

Biography

Dr. Michael A. Briere, former Executive Vice President of Research and Development and Chief Technology Officer, joined International Rectifier in November 2003. Prior to his promotion in September 2007, he served as the Executive Vice President, Research and Development, and prior to that, Vice President of Integrated Circuit Development. Among his duties, Dr. Briere was responsible for IR's GaN development between 2005 and 2007.

Before joining IR, Dr. Briere held technical and leadership roles at IBM, Cherry Semiconductor, ON Semiconductor, and Vicor, where he led a start-up IC subsidiary, Picor. In addition to his time in the semiconductor industry, Dr. Briere has performed research in physics as a member of the staff at leading research institutes including Hahn-Meitner-Institute (HMI) in Germany and Lawrence Livermore National Laboratory (LLNL) in the United States.

Currently Dr. Briere has formed his own executive scientific consulting company, ACOO Enterprises LLC.

Dr. Briere earned his Dr. rer. nat. (Doctorate of Science) in Solid State Physics from the Technical University of Berlin and his MS in Physics and BSEE from Worcester Polytechnic Institute in Massachusetts. He served as Associate Adjunct Professor in Physics at the University of Rhode Island. Dr. Briere is an active member of the IEEE and served on the program committee of the International Symposium for Power Semiconductor Devices and ICs (ISPSD).