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Vendor Positions in the High Voltage GaN Commercialization Race

High voltage GaN-on-Si HEMTs, ICs, and modules for power conversion applications

The race to commercialize GaN-on-Si technology for power conversion applications continues at an intensified pace. As of December 2012 more than twenty semiconductor vendors have participated in this race led by a group of about seven vendors. Vendor positions on the commercialization timeline are determined by a number of technology and business aspects.

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Technology aspects

On the path to commercialization each competitor faces a range of obstacles, which it has to mitigate. This requires technological know-how, financial resources, and time. The type and magnitude of these obstacles vary widely among the competing vendors.

Technology-related obstacles typically dominate the commercialization of new advanced technologies such as GaN-on-Si for use in power conversion applications. Technology barriers to commercialization vary among vendors depending on their core technology expertise.

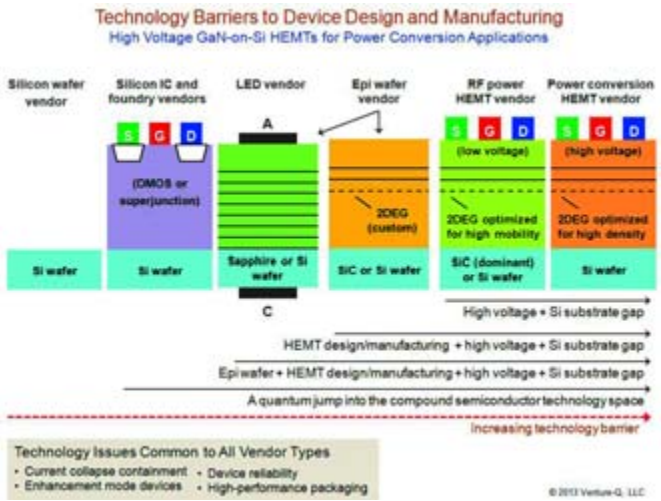

Figure1: Source: Technology Barriers, Venture-Q® LLC (www.venture-Q.com)

The figure 1 illustrates technology barriers to device design and manufacturing of high voltage (more than 600V) GaN-on-Si HEMTs for power conversion applications.

RF power HEMT vendors are the closest to commercialization of high voltage GaN-on-Si HEMTs for power conversion applications because they have to bridge only two technology barriers: (1) voltage (from less than 400V to 600V to 1,200V range), and (2) substrate type (from typically SiC to silicon).

The first commercially available RF power GaN-on-SiC devices emerged in 2004 (the formation of Eudyna, a Fujitsu spin-off). Eight years later there are no commercially available high voltage GaN power devices, either on silicon or on SiC wafers, for power conversion applications. This illustrates that even vendors closest to commercialization face a significant time to bridge only two technology barriers. All follow-up vendor types (e.g., epi wafer and LED vendors) face an even longer time to commercializing GaN-on-Si HEMTs for power conversion application.

Technology and manufacturing issues common to all vendor types could make a significant impact on the time-to-commercialization. They include:

- Current collapse containment, which since the late 1990s has remained a major obstacle to commercialization on high voltage GaN-on-Si HEMT power devices
- Development of enhancement mode (E-mode) devices versus the silicon MOSFET cascoded depletion mode (D-mode) devices
- Device reliability validation, which requires a significant amount of time
- Development of advanced high-performance device and module packaging required to fully exploit the benefits of the GaN HEMT power technology.

Business aspects
A competitor's business aspects also strongly influence the time-to-commercialization. These include the business model and strategy, commercialization motive (i.e., driver), allocated financial resources, R&D and manufacturing capabilities, and reliability validation.

Business model and strategy
Time-to-commercialization could differ significantly among vendors pursuing a foundry vs. merchant device vendor business. Similarly, a business acquisition and/or partnering vs. an organic growth strategy could also impact the time-to-commercialization, for example, acquisition of an epi wafer vendor.

Commercialization motive (the driver)
The primary near-term market for GaN-on-Si power HEMTs is replacement of superjunction (SJ) silicon power MOSFETs.
The commercialization motive of a well-entrenched and dominant SJ MOSFET vendor (e.g., Infineon and STM) could be defensive while that of a newcomer (e.g., IRF) could be offensive. This could result in a different time-to-commercialization.

R&D and manufacturing capabilities
A resolution of the above described technology issues requires substantial R&D expertise and effort as well as manufacturing capability, which could affect time-to-commercialization.

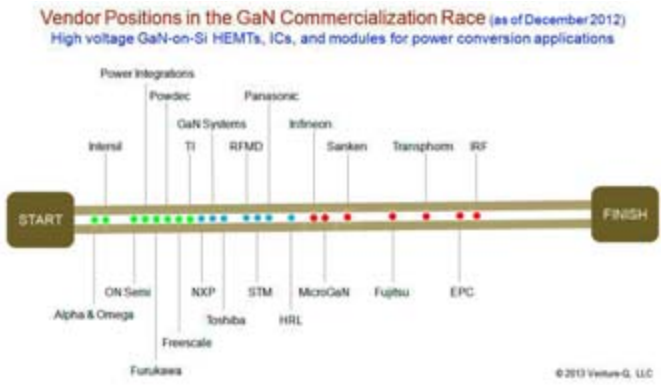

Figure 2: Vendor Positions, Source: Venture-Q® LLC (www.venture-Q.com)

Vendor positions on the High Voltage GaN commercialization timeline (as of Dec. 2012)
A vendor position on the commercialization timeline indicates how close a vendor is to selling high voltage GaN-on-Si devices for use in power conversion applications in the merchant market. This means offering products that could be purchased either directly from the vendor or from its distributor. As of December 2012, only Efficient Power Conversion (EPC) offers such products (sub-200V eGaN® devices sold by Digi-Key distributor).

Ten factors used for determining a vendor's position on the commercialization timeline as of December 2012 are:

1 Dynamic Rdson, <1.2 static Rdson representing a degree of containment of the current collapse phenomenon
2 650V or more operating BVds capability
3 Enhancement mode (E-mode) HEMTs (diodes don't count!)
4 Reliability validation
5 Commercial grade product availability (purchasable direct or via a distributor without NDAs, published datasheets)
6 Silicon wafer based devices (i.e., not SiC wafer based)
7 Business model (offensive vs. defensive)
8 Commercialization motive (i.e., driver)
9 R&D capability relevant to GaN-on-Si power devices for power conversion applications
10 Manufacturing capability relevant to GaN-on-Si power devices (e.g., in-house epi wafer manufacturing)

Vendors in the GaN commercialization race differ in degree of how they mitigate each of the ten commercialization factors. An aggregate rating of each of the ten factors provides a strong indication of a vendor's position on the commercialization timeline (shown in the figure below approximately scaled by the total rating values).

The shown 22 vendors are, as of December 2012, engaged in commercialization of high voltage GaN-on-Si HEMTs, ICs, and modules for power conversion applications. Their engagements range from patent filing activity to device manufacturing. Device types include discretes, ICs, and modules. IC types include monolithic integration of GaN HEMTs only and hybrid monolithic integration of GaN HEMT and silicon devices.

The figure reveals three major vendor groups:
Group 1 The leading seven vendors, International Rectifier (IRF), Efficient Power Conversion (EPC), Transphorm, Fujitsu Semiconductor, Sanken Electric, MicroGaN, and Infineon, focus on discrete power devices and modules for power conversion applications.

Group 2 A group mainly consisting of the current RF power GaN vendors, including: HRL Laboratories, Panasonic, STMicroelectronics (STM), RF Micro Devices (RFMD), Toshiba, GaN Systems, and NXP. GaN Systems is the only pure-play GaN device vendor addressing power conversion applications.

Group 3 A group mainly consisting of silicon IC vendors, including, Texas Instruments (TI), Freescale, Powdec, Furukawa, Power Integrations, ON Semiconductor, Intersil, and Alpha & Omega Semiconductor (AOS). Powdec and Furukawa are the only non-IC vendors. Silicon IC vendors explore and/or develop monolithically integrated GaN HEMTs with silicon devices for power conversion applications.

Time-to revenue and profit implications
The high voltage GaN commercialization race, unlike its low voltage counterpart, has significant time-to-revenue and profit implications for the participating vendors. An early entry into a market rich in power conversion applications would result in a highly differentiated competitive advantage with significant financial rewards. These applications range widely from general lighting to automotive, solar energy, and industrial power systems. Therefore, we expect the pace of the race to intensify in 2013 and beyond among the current participants and new vendors joining the race.

This article is based on the first two reports of a six-report set, titled "Competitive Landscape" and "Vendor Analyses," published by Venture-Q® LLC (www.venture-Q.com). The six-report set is the industry's first to exclusively focus on the commercialization of high-voltage GaN-on-Si technology for power conversion applications.