POWER GaN 2017: EPITAXY, DEVICES, APPLICATIONS, AND TECHNOLOGY TRENDS 2017

Market & Technology report - October 2017

The GaN power device supply chain is acting to support market growth.

KEY FEATURES OF THE REPORT

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- In-depth analysis of GaN's penetration in different applications including power supplies, PV, EV/HEV, UPS, LiDAR, wireless power and electrical transmission
- State-of-the-art GaN power devices, including product charts and device descriptions
- Description of the GaN power industrial landscape, from epitaxy and device design to device processing
- Discussion of GaN power market dynamics
- State-of-the-art for power GaN packaging
- Reliability overview on GaN
- Market projection for the GaN epitaxy market through 2021 by value and volume

WHAT'S NEW

- Updated Yole Développement market segmentation
- Updated power supply section
- Comprehensive overview of the power supply segment, including GaN power supplies for data center applications
- Technological analysis and impact in the value chain
- Packaging roadmap
- Status of GaN's reliability

COMPLEMENTARY REPORT

GaN-on-Silicon Transistor Comparison 2018

Structural, Process & Costing Report by System Plus Consulting – April 2018

Dive deep into the technology and cost of GaN-on-silicon HEMTs from EPC, Transphorm, GaN Systems, Panasonic and Texas Instruments.

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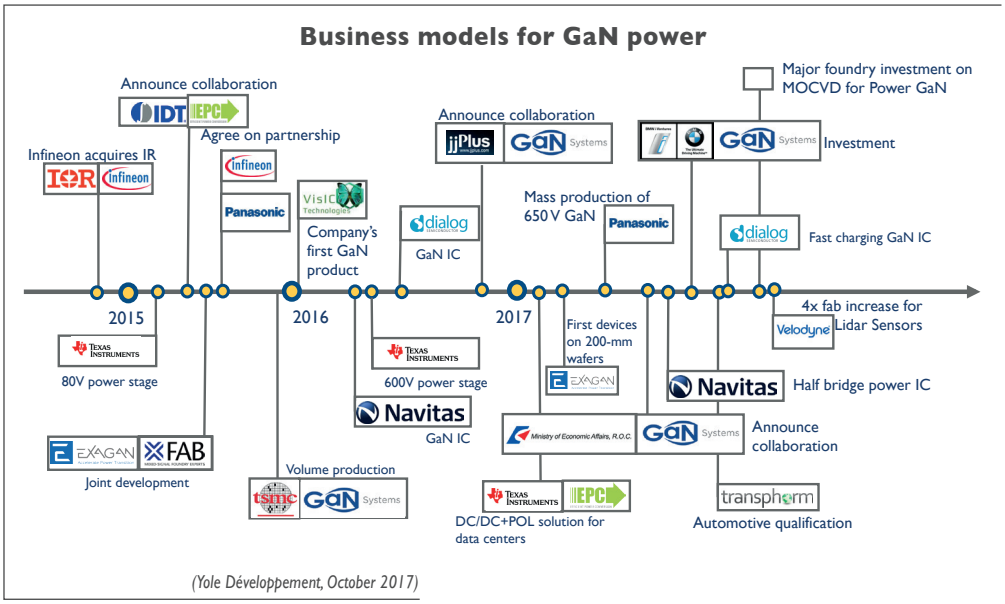
THE POWER GaN SUPPLY CHAIN PREPARES FOR PRODUCTION

The supply chain is close to being settle for the Power GaN market and deals during 2017 show confidence that GaN will be a successful market. First of all, there have been big investments from the main foundries to increase their capacity to handle mass production. Navitas just announced the partnership with TSMC and Amkor to ramp production capacity. Moreover, BMW i Ventures has just invested in GaN Systems. The Taiwan's Ministry of Economic Affairs is also interested in using GaN for clean and green technologies, also in collaboration with GaN Systems.

GaN manufacturers continue developing new products and provide samples to customers, as is the case with EPC and its wireless charging line. During 2017, Panasonic announced the mass production of its 650 V products and Exagan successfully produced its first high voltage devices on 8-inch wafers. Other players are in the final phase of R&D or qualification for their GaN products to be launched in 2018. In both cases, manufacturers and clients are pushing to use GaN HEMTs in emerging technologies.

Yole Développement differentiates the power GaN supply chain into two main models: the Integrated Device Manufacturer (IDM) model and the foundry model. We think that both IDM and foundry models will co-exist while there are different needs on the market, for example in consumer and industrial applications. In addition to the existing models, China is introducing a model with an R&D research center or design center, an external epitaxial supplier and a foundry for manufacturing, to support large-scale demand in the future.

This report furnishes an overview of the GaN power industry, covering the value chain from epitaxy and device design to device processing. It updates the supply chain and there is an overview of the year's investments.



THE GaN MARKET PROMISES IMMINENT GROWTH

The GaN power market remains small compared to the $30B Silicon power semiconductor market. However, it has an enormous potential in the short term due to its suitability for high performance and high frequency solutions. The GaN power business was worth about $14M in 2016, but Yole projects that it will reach $460M by 2022, witha compound annual growth rate (CAGR) of 79%.

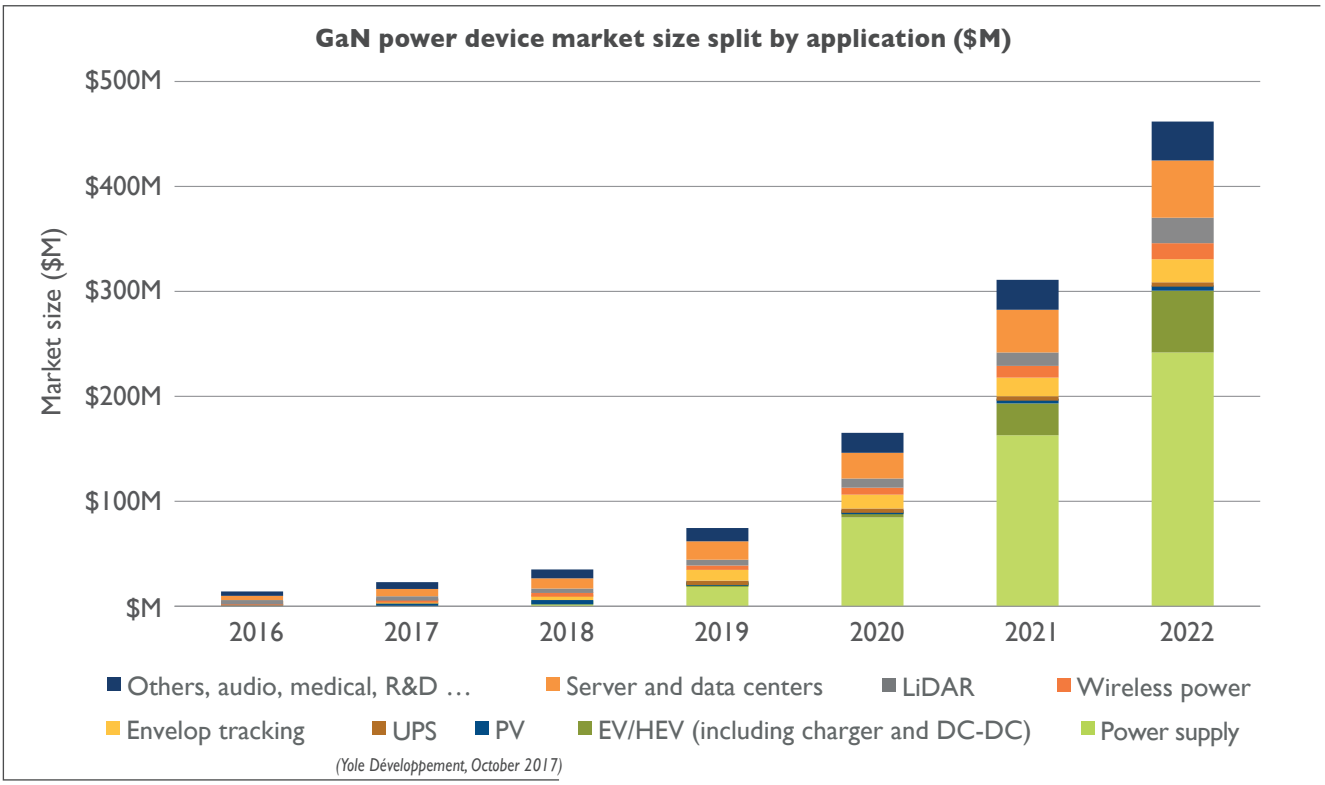
LiDAR, wireless power and envelope tracking are high-end low/medium voltage applications, and GaN is the only existing technology able to meet their requirements. In January, Velodyne LiDAR opened a 'megafactory' to ramp up the latest 3D sensor for LiDAR manufacturing and this October they already announced a fourfold production increase. Other major companies,

like Apple and Starbucks, started offering wireless charging solutions. Moreover, since 2016, EPC has been working with Taiwan's JJPlus Corporation to accelerate the wireless charging market's growth.

The power supply segment is still the biggest application for GaN, driving an 124% CAGR for power supplies through to 2022. The data center market is also adopting GaN solutions with a phenomenal speed. Existing solutions from Texas Instruments and EPC, consisting of a DC/DC converter and point of load supply that steps down the voltage from 48 V to 1.2 V in a single chip, will propel the market. Dialog Semiconductor also provides fast charging power adapters integrated with GaN power IC. The consumer market is expected to grow during coming years and Yole envisages two different scenarios, depending on the acceptance in key markets like AC/DC adapters for laptops and cellphones.

GaN needs to hurry to gain adoption in the electric and hybrid electric vehicle (EV/HEV) market because SiC MOSFETs are already replacing silicon IGBTs in the main inverters. However, a future market for the 48 V battery's DC/DC converter is still possible for GaN due to its high-speed switching capability. Some main players, as Transphorm, have already obtained qualification for automotive, and this would help to finally ramp-up GaN production for EV/HEV.

This report conveys Yole Développement's understanding of GaN implementation in different market segments and offers a comprehensive summary of GaN power device market data, broken down by application. It also outlines Yole's understanding of the market's current dynamics and future evolution.



GaN TO OVERCOME TECHNOLOGY CHALLENGES SOON

Technology maturity is one of the major challenges that GaN is still facing. The report therefore includes a section focusing on the supply chain from a technological perspective. Several examples are given of the importance of the supply chain, including the choice of the epitaxial layer supplier.

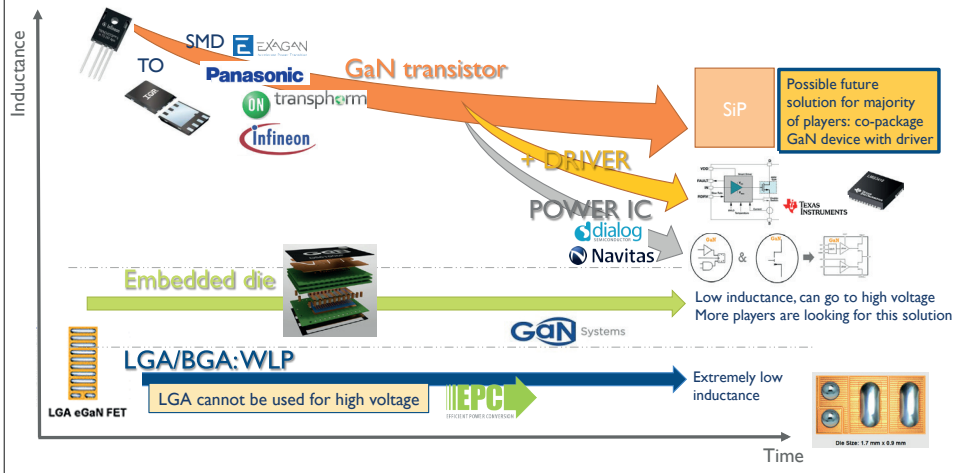
Packaging is important if manufacturers want to fully benefit from GaN's performance. Yole Développement has built a roadmap for Power GaN packaging where there is a clear trend to go from the discrete standard transistor outline package (TO) and surface mount device (SMD) solutions to co-packaged solutions, which includes the driver in the same chip. Co-packaging is also an option for cascode devices, even if most players are tending to develop enhancement-mode technology for future implementations. Developments of embedded and land grid array (LGA) packaging are also important trends since they lower circuit inductance. Power integrated circuits (ICs) are continually developing, with new product launches such as the first integrated half-bridge IC from Navitas, which enables higher efficiency systems.

Reliability and qualification are major concerns holding back GaN production in low-end applications. Manufacturers are doing the standard JEDEC tests conceived for silicon, plus extended tests including high temperature reverse bias (HTRB), high temperature gate bias (HTGB) and power cycling (PC) in highly aggressive conditions. They're also doing dynamic on-resistance tests (Rdson) or high temperature operating life (HTOL) to ensure reliability

in operation. The good news is that this year the official JC-70.1 committee (Under JC-70) has been established and is working in collaboration with the main companies in the field to ensure the right qualification processes for GaN devices.

Yole Développement has updated the technology section of the GaN report with an overview on qualification status and a detailed packaging roadmap.

Power GaN packaging roadmap



(Yole Développement, October 2017)

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