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MARKET FORECASTS FOR SILICON CARBIDE & GALLIUM NITRIDE POWER SEMICONDUCTORS
IHS TECHNOLOGY

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Richard Eden, Senior Analyst
Richard Eden looks after the discrete power semiconductors area, including power modules. His previous report focus included Power Semiconductor Discretes & Modules and SiC & GaN Power Semiconductors, as well as contributing to the Power Management Quarterly market watch.

Richard joined IHS in December 2010 after 5 years at distributor RS Components in Corby, where he ran the UK Marketing program for electronic components. Prior to this, he spent 15 years at Rohm Electronics (now Rohm Semiconductor) in a variety of customer facing, sales & product management roles. Before that, he was a design engineer at Plessey Microwave Ltd, working on military and high-end microwave components.

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Jonathan Liao, Senior Analyst
Jonathan Liao is a senior analyst with IHS Technology and is responsible for the power management market. He was responsible for delivery of the quarterly Market Trackers, Competitive Landscape Tool, and Market Share & Supplier Analysis Annual Report for the Power Management segment.

Before joining IHS, Jonathan Liao was a product engineer at Microchip Technology Inc. developing microcontroller products for switch mode power supply, motor control, general purpose, and USB applications. During his six years at Microchip, Jonathan gained expertise in analog and mixed signal devices utilized for various end markets. Jonathan originally joined Microchip as a quality engineer to oversee the Fab quality standard and qualify new processes.

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Contents

INTRODUCTION
A brief history of the SiC & GaN power market
Device manufacturers and developers

SIC AND GAN MARKET FORCES AND TRENDS
Market drivers and barriers
Device cost trends
The substrate wafer market
Key applications

CONCLUSIONS
Market forecasts by technology, product and sector
IHS estimates the global power semiconductor market excluding power ICs will be $30 Billion Dollars in 2025.
The SiC & GaN market in 2016

• Price dropped
• Supply
• Demand
Introduction

• History of SiC & GaN in power
• Device manufacturers
GaN Power Semiconductor Timeline

- **2009**: First GaN Power Device released by International Rectifier
- **2010**: EPC launches 20V-200V GaN transistors (eGaN™)
- **2011**: MicroGaN announces 600V GaN HEMT
- **2012**: Transphorm launches 600V GaN-on-SiC transistor
- **2013**: Transphorm releases 600V GaN-on-Si transistor
- **2014**: Panasonic announces N-off 600V GaN transistor (GaN)
- **2015**: MicroGaN closes
- **2016**: Transphorm and Fujitsu combine GaN activity
- **2017**: Exagan spins out of Soitec
- **2018**: GaN Systems release first commercial devices
- **2019**: Infineon buys IR
- **2020**: Cambridge Electronics spins out of MIT
- **2021**: VisIC announces world's lowest Rdson 650V GaN transistor
- **2022**: Panasonic and Infineon agree partnership on GaN transistors

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Device manufacturers and developers

- Silicon Carbide:

  - Danfoss
  - Fairchild Semiconductor
  - Fuji Electric
  - GeneSiC
  - GlobalPower
  - Infineon
  - Microsemi
  - Mitsubishi Electric
  - Monolithic
  - Rohm
  - Renesas
  - Raytheon
  - Semikron
  - STI
  - USCI
  - Vincotech
  - Wolfspeed

- Gallium Nitride:

  - Alpha & Omega
  - Avogy
  - Cambridge Electronics
  - EPC
  - Exagan
  - Infineon
  - NXP
  - Panasonic
  - Powdec
  - Transphorm
  - VisIC
SiC and GaN Market Forces and Trends

• Market drivers and barriers
• Key applications
• Device cost trends
• The substrate wafer market
Key drivers and barriers for growth

Drivers
- Lower losses
- Higher switching frequencies
- Higher operating temperature
- Enables smaller systems; size, weight and cost reductions
- Robust, reliable, radiation-hard
- High breakdown voltage
- GaN prices nearer to Si
- GaN has no body diode
- Device integration on Si

Inhibitors
- High SiC material costs
- Design inertia: the reluctance to change
- Not drop-in swap for Si
- Normally-off switches required
- Proof of reliability
- High-temperature, high-frequency packaging
- Availability; few 2nd sources
- GaN defects
- GaN-on-Si material mismatch
What has changed?

In 2015, a dramatic pricing shift occurred for SiC discrete pricing, especially MOSFETs.

*Price drop = improved SiC adoption!*
SiC Device price trends

In 2012;
- SiC Diodes cost x5 – x7 Si Schottky Diodes
- SiC MOSFETs cost x10 – x15 Si MOSFETs
- SiC JFETs cost x4 – x7 Si MOSFETs

2015 saw dramatic price falls as compared to 2012;
- SiC Diode prices fell by -35%
- SiC MOSFET prices fell by -50%
- SiC JFET prices fell by -39%
- SiC BJT prices fell by -49%
The SiC substrate wafer supply base

• Multiple suppliers have entered the market, increasing competition
  • Dow Corning, II-VI, Nippon Steel, Showa Denko, SiCrystal, Sumitomo et al
• Cree’s market domination is shrinking, so wafer prices are falling
• Moving from 4” to 6” SiC wafers should reduce device costs by 20-50%
• 6” SiC wafers are widely available but adoption has been slow (<15%)
• They will start to become mainstream during 2016 onwards, resulting in device prices falling in 2017-2018
• SiC wafer quality is improving, so yields are increasing, which will also enable device prices to decrease

• So, SiC material costs should continue to fall for the next few years
The GaN substrate wafer supply base

• Many GaN device companies carry out in-house epitaxy on Si wafers
• However, GaN epiwafer supplier numbers are increasing:
  • IQE, DOWA, NTT, EpiGaN, Enkris, Soitec, Sumitomo and others
• 6” GaN-on-Si epiwafer volumes are ramping up
• 8” GaN-on-Si epiwafers will not be widely available until 2017-2018
• Improved performance, mismatch and repeatability are still required

• Bulk GaN (GaN-on-GaN) wafers are very expensive, but prices are falling due to the collapse of the GaN laser diode market.

• Overall, GaN-on-Si wafer costs are falling and supplier numbers rising
Key applications

- Automotive/HEV
- Industrial Motor Drives
- PV Inverters
- Power Supplies & UPS
- Traction
- Wind Turbines

- Others applications include: HEV charging infrastructure, wireless charging, military & aerospace, downhole drilling, etc.
Automotive

• Driver for substantial growth:
  • EU standard for emission
  • US standard for MPG
  • Big potential penalty for non-compliance

• SiC & GaN key considerations
  • Size benefit, reduced cooling, efficiency
  • Battery charger for EV and Plug-in
  • DC-DC voltage conversion
  • Power Train
  • Charging network and fast charging
Industrial motor drive

- Largest market for Si power
- SiC & GaN key considerations
  - Reduced cooling
  - Cost-sensitive
  - Reliability critical
  - Efficiency is not as critical
  - Switching and system size not critical
PV inverters

• SiC & GaN key considerations
  • System efficiency
  • Fall in solar-panel module pressured SiC device prices
  • Lower cost manufacturers in China and Japan
  • GaN could replaced HV MOSFET in the 600V system
  • SiC transistors to replace Si IGBT in 900V – 1200V, > 5kW
  • SiC modules are projected to be used in three-phase central inverters, not single-phase inverters or micro-inverter
Traction

• SiC & GaN key considerations
  • 690V remained standard
  • 1700V – 6.5kV rating
  • Efficiency
  • Reduced system size and weight
Wind Turbine

• SiC & GaN key considerations
  • No market currently
  • SiC power modules will be used in wind turbines
  • Efficiency
  • Reliability
Power Supply

• SiC and GaN key considerations
  • Efficiency for High end power supply
  • UPS: small but large interest
  • Consumer market: little adoption
Others Applications

• Military and aerospace
  • High power density applications
  • Lighter, smaller, efficient systems
  • Less sensitive to price
  • Reliability most critical

• Downhill drilling
  • High temperature, harsh environment
  • Reliability critical
Forecast & Conclusions

• Market forecasts by technology, product and sector

• Conclusion and Q&A
The SiC power semiconductor market

The GaN power semiconductor market

The overall SiC & GaN power semiconductor market

Report conclusions

• Versus Si, SiC offers most benefit at >1000V and GaN offers most benefit at <1000V
• Decreasing prices are triggering adoption NOW
• SiC Module revenues will exceed SiC Discretes
• SiC will be used in industrial niches and HEVs within 10 years
• 600V GaN transistor prices should match Si equivalents in 2018-2019
• GaN diode development has stopped: no benefits over SiC Schottky
• GaN will become established in high-end computing & telecom power supply applications first (in fact, it has already started)
• GaN must demonstrate reliability before industrial sectors will adopt
• Overall, SiC is turning the corner now in 2016 and GaN is sure to follow

Questions