Leading The GaN Revolution

SuperGaN's Performance Advantages Challenging SiC's Long-Term Use

Philip Zuk

Transphorm

SVP Marketing, Applications and Business Development

transphorm

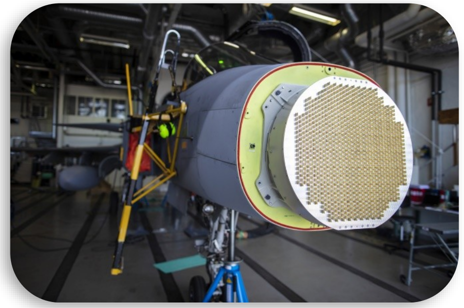
Highest Performance, Highest Reliability GaN

Introduction

- Why GaN
- Why Transphorm
- Comparison: SuperGaN vs. SiC
- Comparison: SuperGaN vs. e-mode (abbreviated)
- Limitless innovation
- Summary

Solid State Lighting

Displays



Airborne Radar

5G Base station

transphorm

GaN Advantage and Value Proposition

Smaller, Lighter, Cooler Power Systems Drive Increased Value

Faster Switching Speed

- 2x to 4x faster than Silicon
- Reduced switching losses over Si and SiC

Efficient Power Delivery

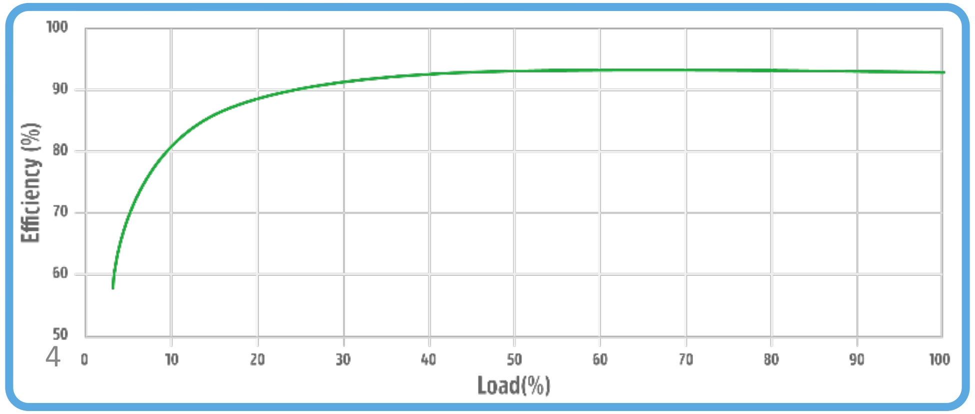
- Totem-pole PFC enablement
- Reduced component count

Smaller, Lighter, Cooler

- Increased power density
- Lower overall system cost

SuperGaN® vs. Silicon: 60% Reduction in 3 KVA UPS

Specification	Value
Power Level (max)	3 kVA
Output voltage (max)	120 Vac
Efficiency (peak)	93.3%
Power density	2.5x higher (2U→1U)
SuperGaN® Technology	**Quantity**
TP65H015G5WS	DCDC x 2
TP65H035G4WS	DCAC x 12



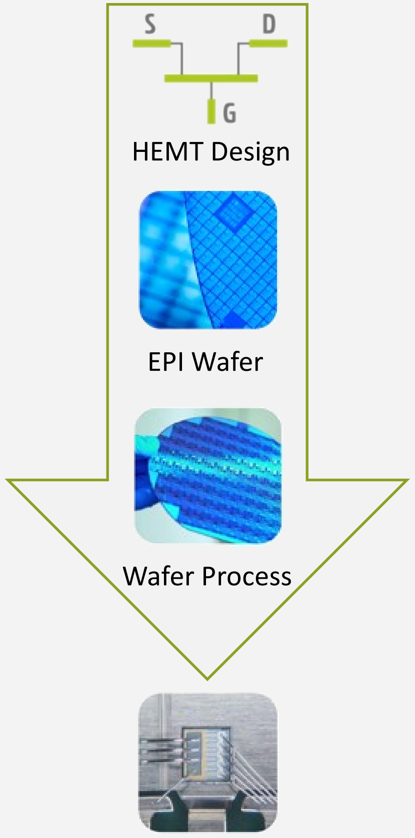
Data Center (in production)
3 KVA Uninterrupted Power Supply

Why Transphorm?

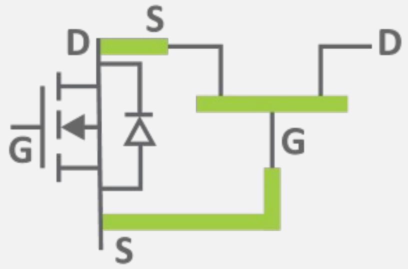
Transphorm's Critical Differentiation

Manufacturability

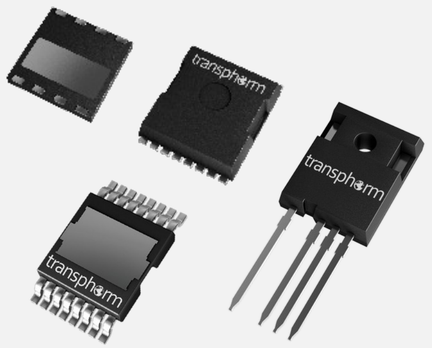
Vertically Integrated



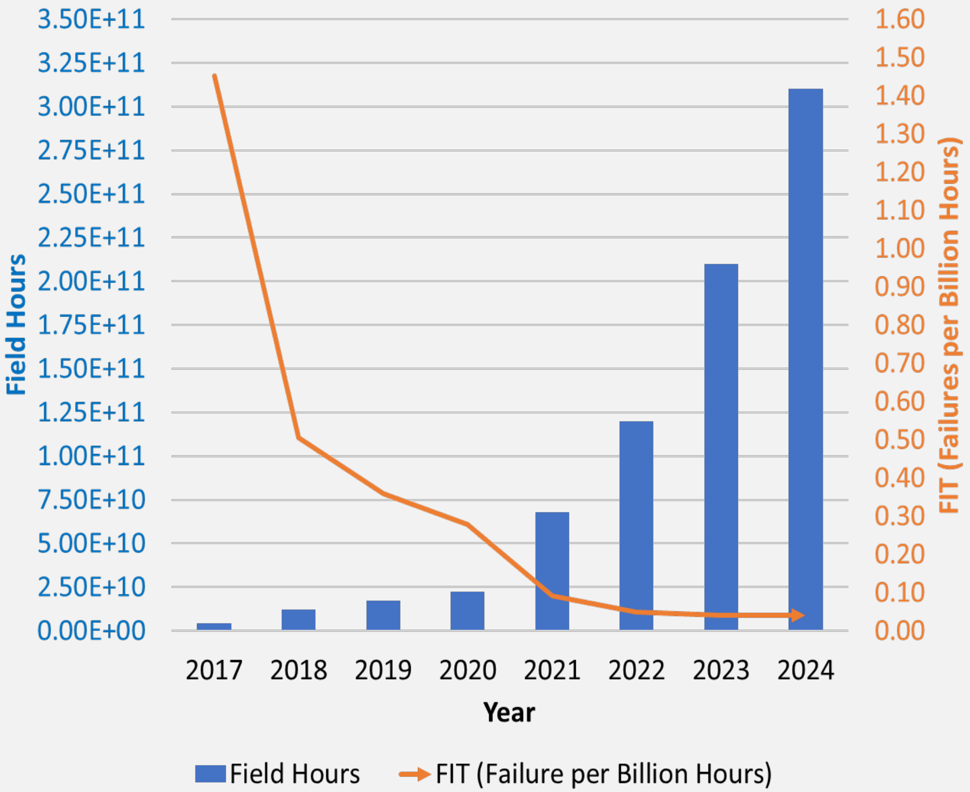
Ease "Drivability"



Ease "Designability"



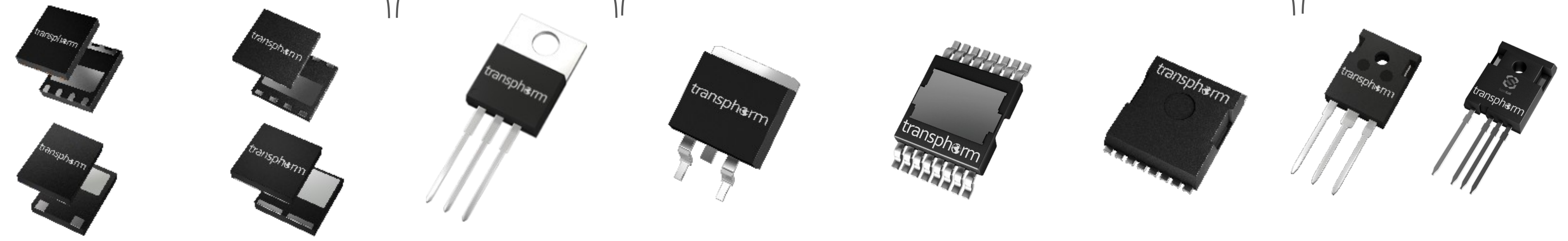
Best-in-class Reliability



Product Offering Based on Power Ratings

Widest GaN Package Offering in the Market – Multiple RDS(ON) per package for scaling

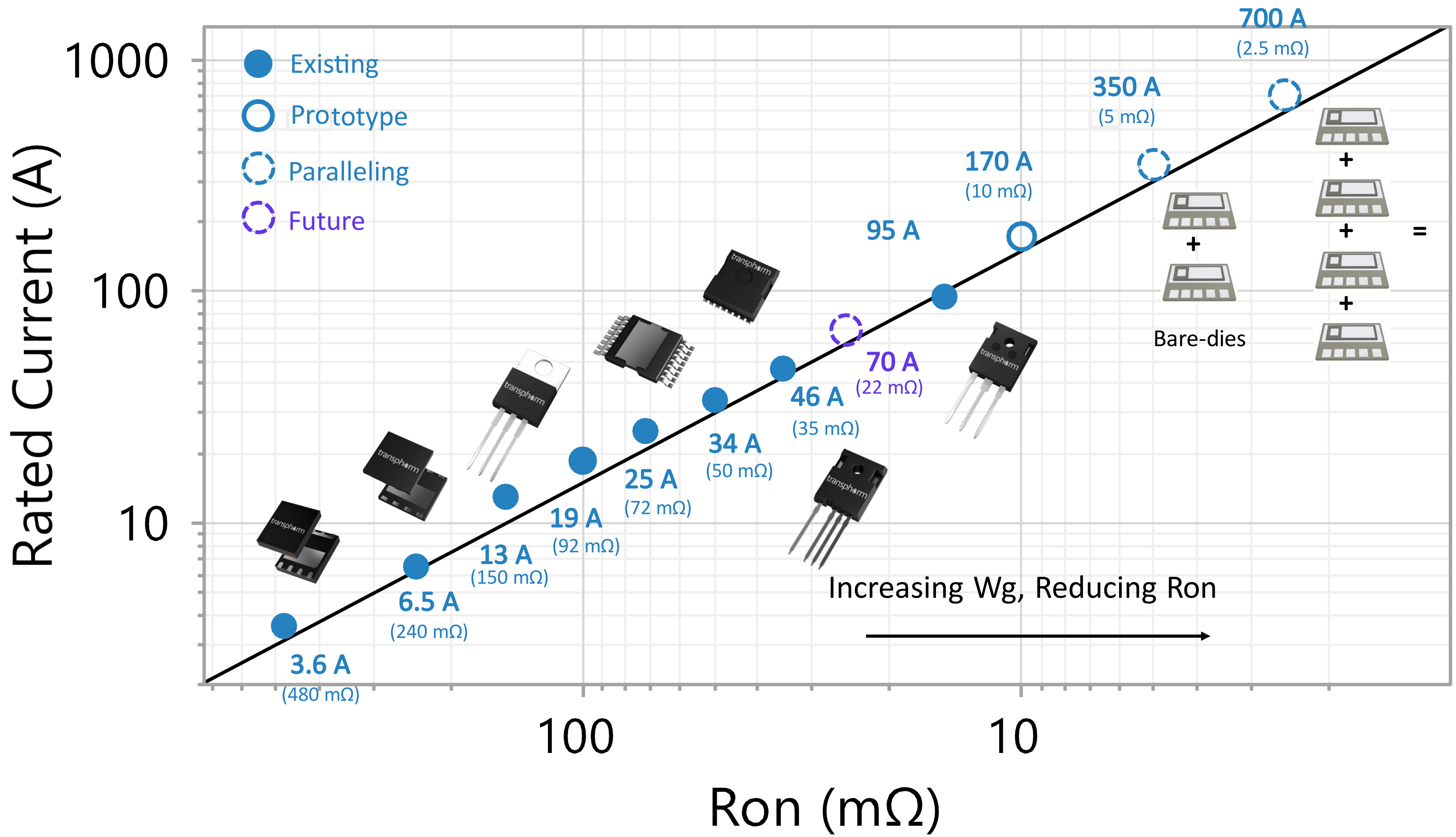
30 W to 250 W | 0.3 kW to 2 kW | 1 kW to 3 kW | 1 kW to +10 kW



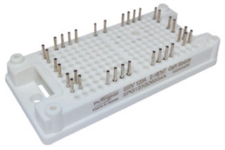
PQFN56	PQFN88	TO-220	D^2PAK	TOLT	TOLL	TO-247-3	TO-247-4
480 mΩ	240 mΩ	150 mΩ	50 mΩ	72 mΩ	72 mΩ	50 mΩ[1]	50 mΩ
240 mΩ	150 mΩ	92 mΩ		50 mΩ[2]	50 mΩ	35 mΩ[1]	35 mΩ
150 mΩ	92 mΩ	72 mΩ		35 mΩ[2]	35 mΩ	15 mΩ	
	72 mΩ						

1 Includes AEC-Q101
2 Future option based on demand

Product Offering Based on DC Current Rating



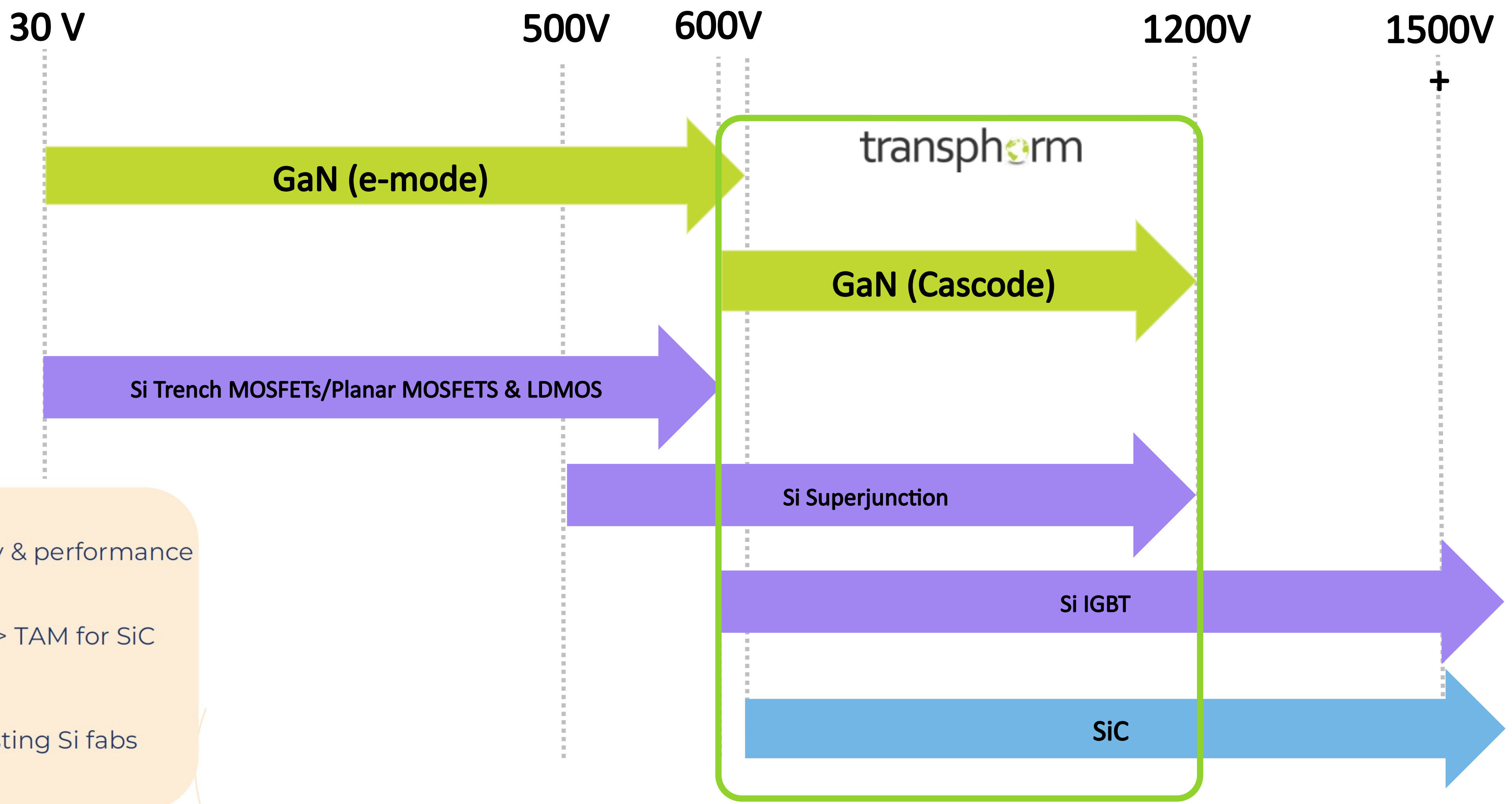
Module Examples



Semi PowerEx
½ and FB
Up to 223 A

Fujitsu General
2 and 3 Leg
Up to 40 A
(with drivers)

Transphorm GaN TAM +$8B in 2028



YOLE Group

- Higher efficiency & performance
- TAM for GaN >> TAM for SiC
- Leverage existing Si fabs

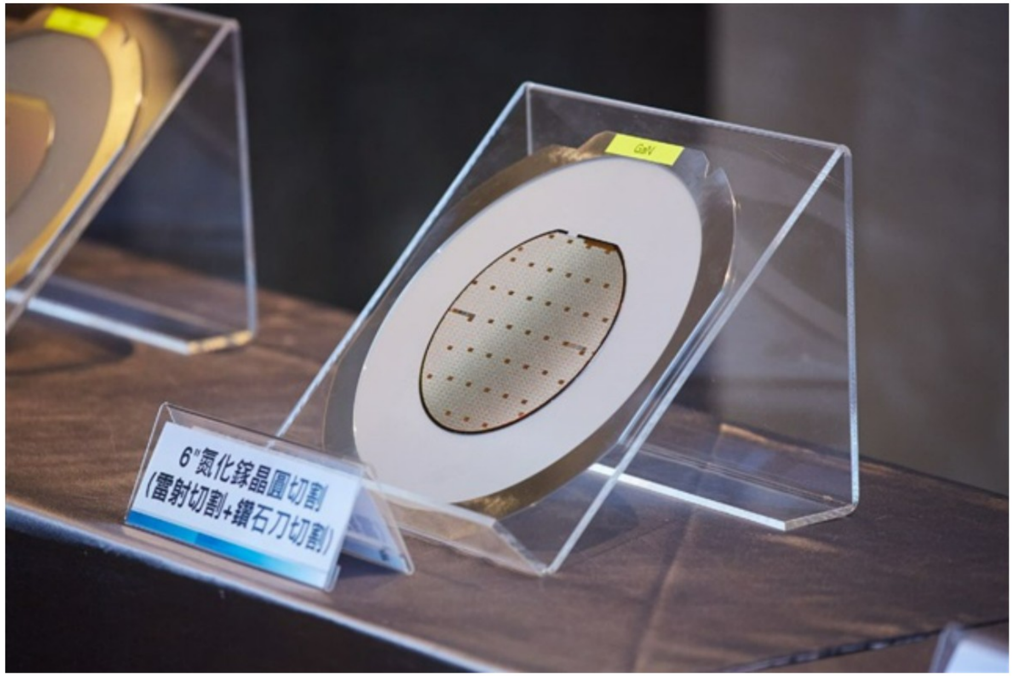
Definitive Agreement In Place For Acquisition

transphorm

Latest Information and News Pertaining to WBG

Poor volume and price stability of SiC substrates: TSMC's main reason for not entering the market?

Nuying Huang, Taipei; Jessie Shen, DIGITIMES Asia | Wednesday 21 February 2024 | 0 | Like 4



Credit: DIGITIMES

According to industry sources, TSMC's lack of interest in SiC technology could be attributed to the pricing and supply of SiC substrates.

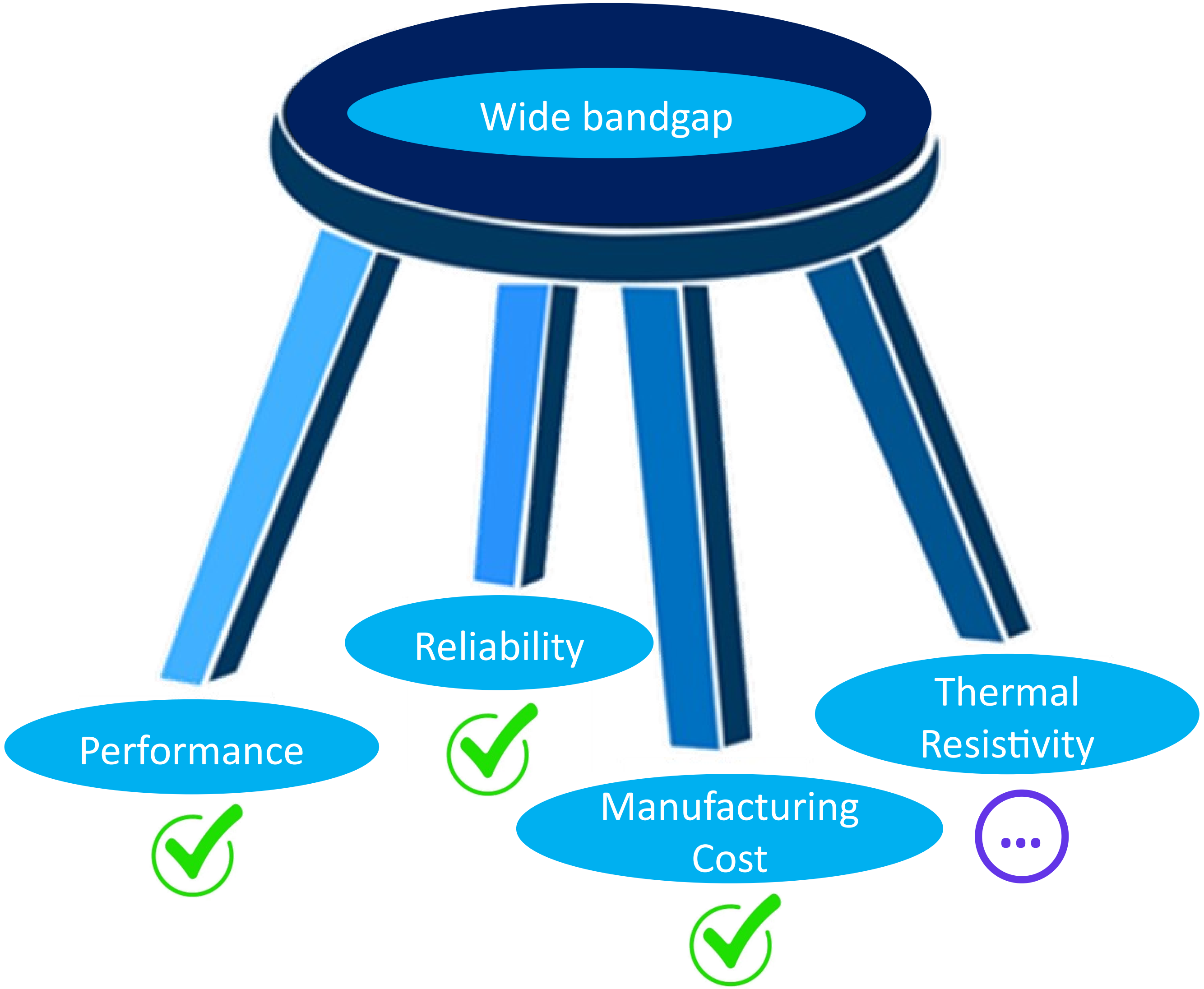
TI shifts 6-inch GaN process to 8-inch to reduce costs

"There is a perception that GaN semiconductors are more expensive than silicon carbide (SiC) semiconductors, but we are seeing a price reversal. We are building 8-inch fabs in Dallas, Aizu, Japan, and other places. When these are ready, we will be able to provide solutions that are significantly lower than the current price," Ju-Yong Shin, director of TI Korea, said in a recent interview.

"TI has traditionally produced gallium nitride semiconductors using a 6-inch process, and our Dallas factory is expected to transition to an 8-inch process by 2025. Taking the Aizu factory in Japan as an example, we are shifting existing silicon-based 8-inch production lines to GaN semiconductor production lines, but we cannot disclose the time required for conversion," Shin added.

Industry insiders said that TI's process transformation may lead to a decrease in the price of GaN semiconductors. Switching from a 6-inch production process to an 8-inch process is expected to reduce production costs by more than 10%. If TI shifts its power management integrated circuit (PMIC) production from an 8-inch process to a 12-inch process, it will also promote price reductions in the entire industry.

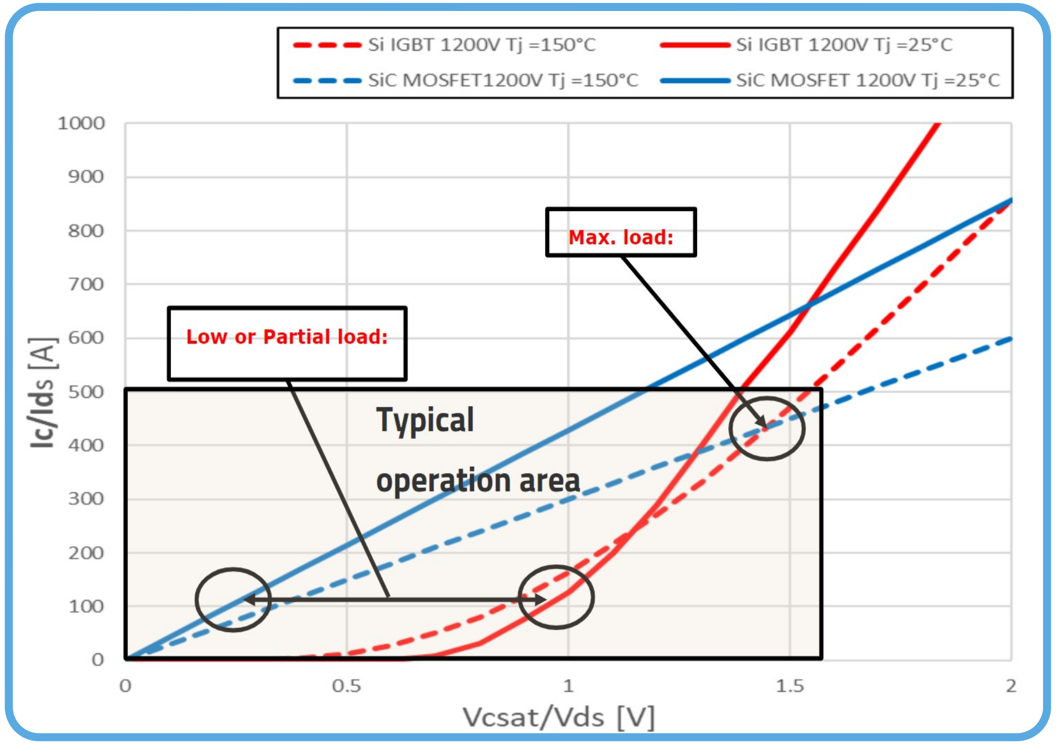
Important Wide Bandgap Discussion Points



Thermal Resistivity = L/(κA)

Technology	Voltage (V)	$R_{DS(ON)}$ (Ω) (100°C)	I_{DRAIN} (A) (100°C)	P_{COND} (W)	R_{thJC} (°C/W)	T_J (T_C = 100°C)	Comments
Si IGBT (std.)	650	1.55 $V_{ce(sat)}$	60	93	0.60	156	$V_{ce(sat)}$ stable over temperature
SiC MOSFET	650	**0.020**	60	73	**0.35**	126	Gen III technology
SiC MOSFET	650	**0.020**	60	70	**0.48**	134	Gen IV technology, **TCR increased**
SuperGaN	650	0.018	60	67	0.47	131	Comparable TCR to latest SiC

Key Factors	Si	SiC	SuperGaN
Performance	3	2	1
TCR	3	2	2
Manufacturing cost	1	3	2
Application size	3	2	1
Total	**10**	**9**	**6** (40% / 33%)



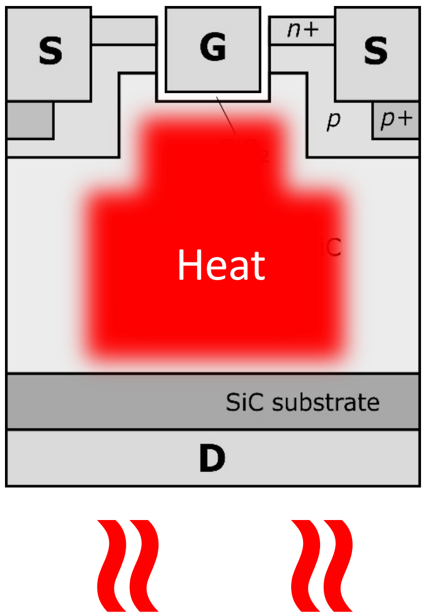
Efficiency Improvement of SiC Devices

SiC devices offer lower on-resistance and faster switching frequencies, leading to lower power losses. However, due to smaller chips, thermal losses per cm^2 increase

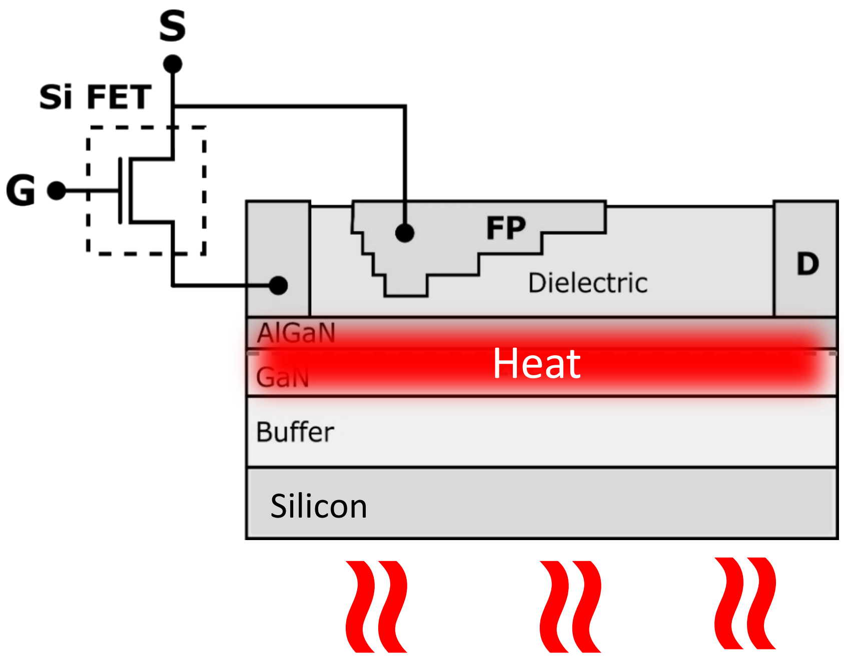
Source: Future of SiC Power Modules in Automotive and Industrial Applications; Semikron/Danfoss; ISES Conference; Italy 2023

GaN-on-Si Has Sufficient Heat Extraction

SiC MOSFET



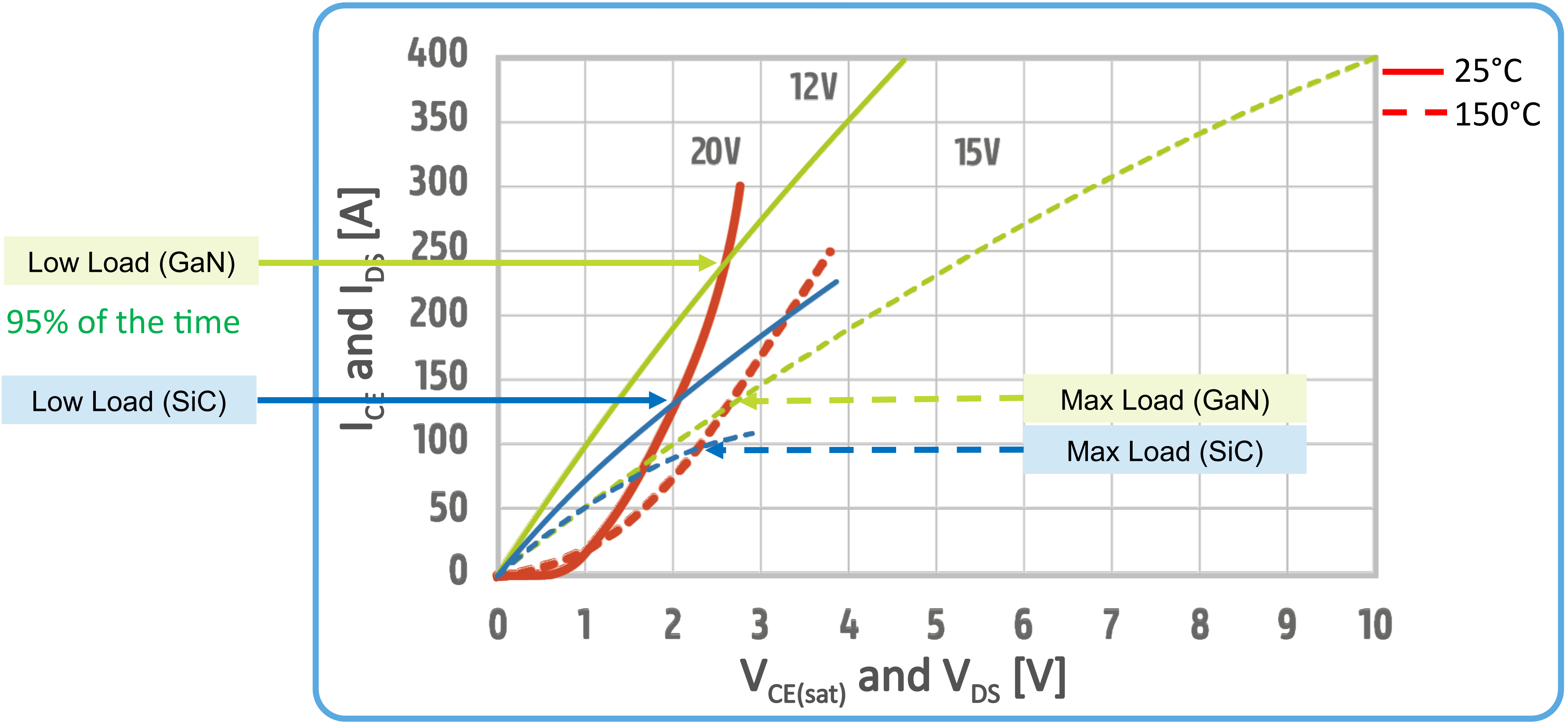
GaN HEMT



- lateral architecture = Good thermal dissipation: L/(κA)
- Lateral device is ~2x larger than SiC vertical for same on resistance
- Higher mobility, lower switching/crossover and output losses
- Lower manufacturing costs – standard silicon manufacturing fabs

Device Output Current vs. $V_{CE(sat)}$ and V_{DS}

SuperGaN outperforms SiC by 30% at low load, and 20% at maximum load



SuperGaN Technology In a 500 A Half-Bridge Module

Available in half-bridge module and B6 full bridge (OBC, Motor drives, EV charging….)

Specifications

- Nom. voltage: 470 V
- Max. breakdown voltage: 650 V
- Maximum current: 500 A
- Temperature: -40°C to 175°C

High power density

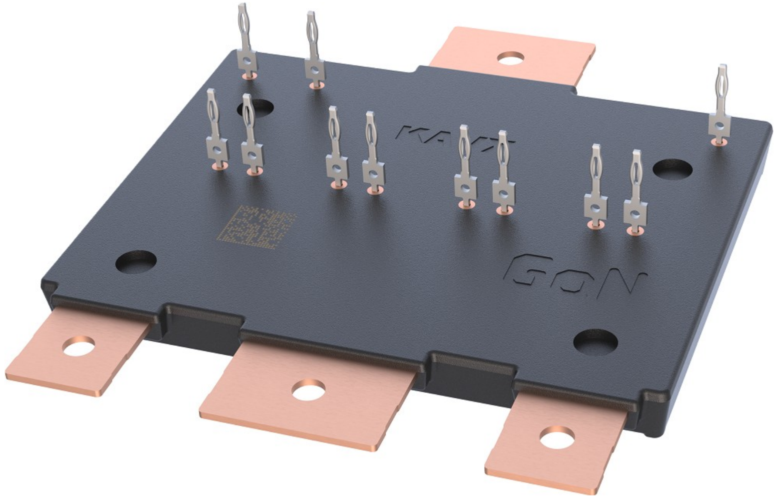
Switching frequency far beyond SiC

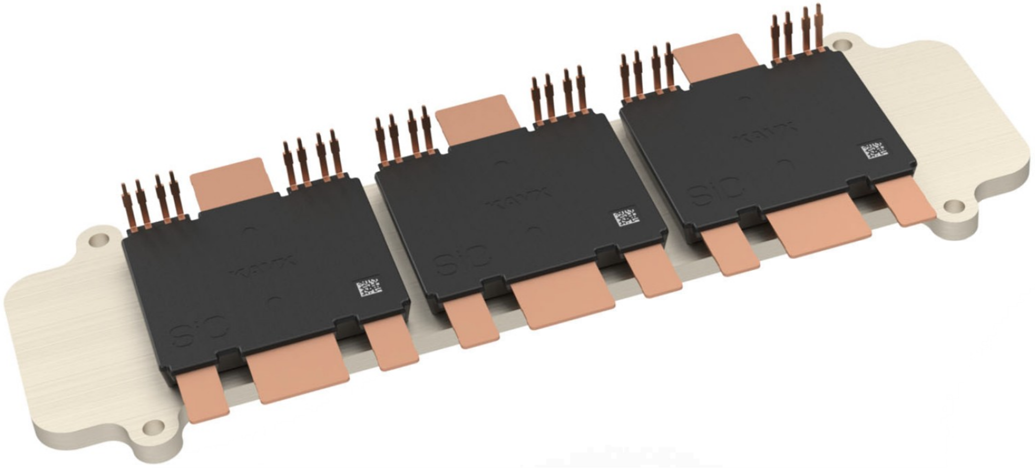
Ultra-low losses

High reliability at competitive costs

Stray inductance: 5nH

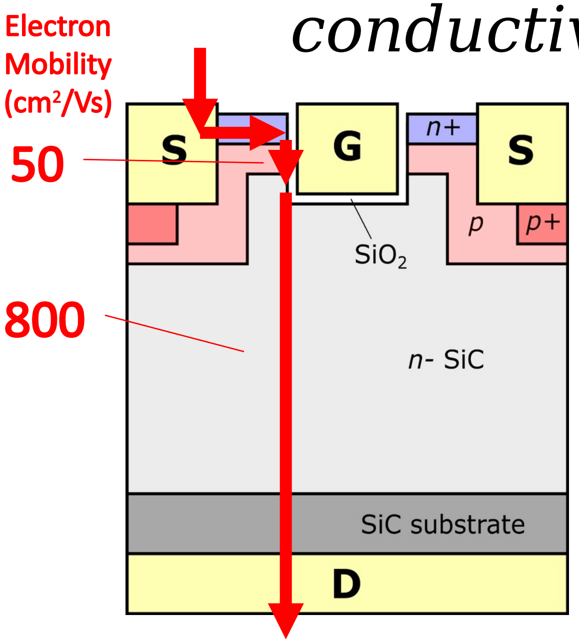
Clip bonding versus bond wires



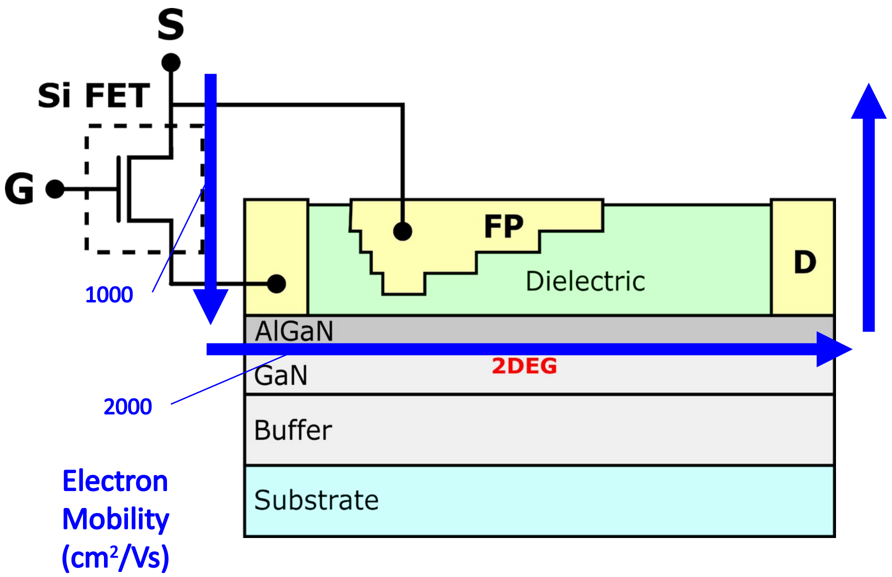


Higher Mobility, Less Stored Charge than SiC

$$conductivity = 1.6 * 10^{-19} * charge * mobility$$

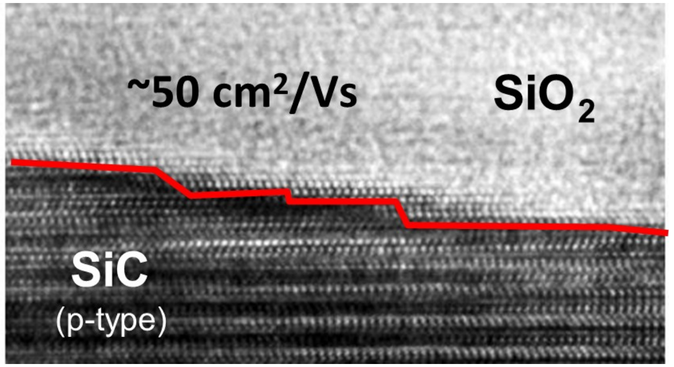


SiC MOSFET

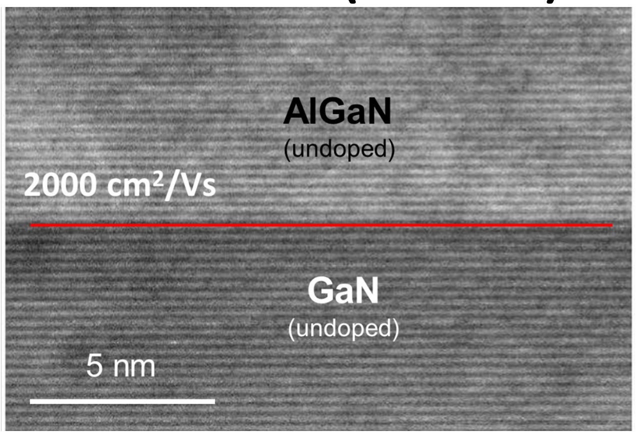


GaN HEMT (d-mode)

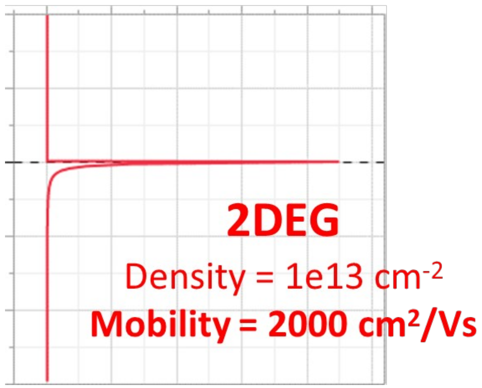
	SiC 1	GaN
Voltage Rating (V)	650	650
R_{on} (mΩ)	50	50
Q_G (nC)	63	16
Q_{GD} (nC)	20	5
Q_{FR} (nC)	252	120
$R_{th,j\text{-}c}$ (°C/W)	0.9	1.0
Material Cost	$$$	$



Low TCR 1.3



Electron Density



Thermal Resistance and TCR at 175°C

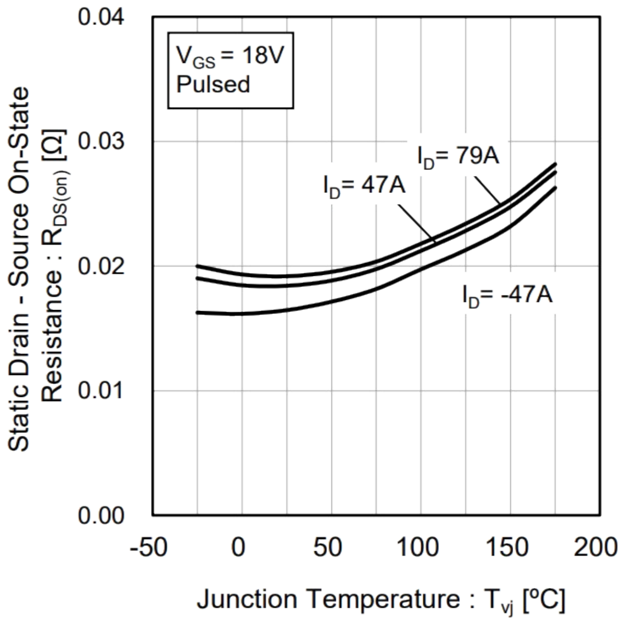
TCR ↑ 30% ↑ conduction losses; R_{thJC} ↑ ~50% ↓ heat spreading capabilities

SiC: Gen III; 17 mΩ; 118 A

R_{thJC}: 0.35 (typ.)

TCR: 1.4

Fig.16 Static Drain - Source On - State Resistance vs. Junction Temperature

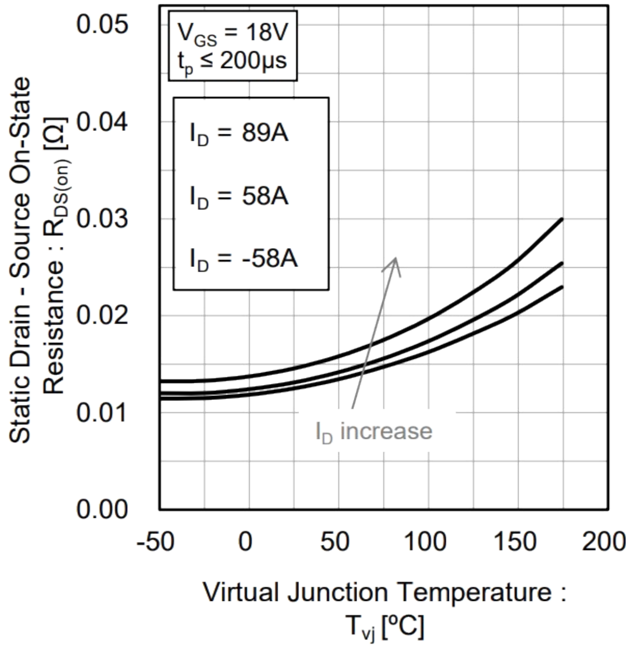


SiC: Gen IV; 13 mΩ; 105 A

R_{thJC}: 0.48 (typ.)

TCR: 2.0

Fig.14 Static Drain - Source On - State Resistance vs. Virtual Junction Temperature



GaN: SuperGaN; 15 mΩ; 100 A

R_{thJC}: 0.47 (typ.)

TCR: 2.0

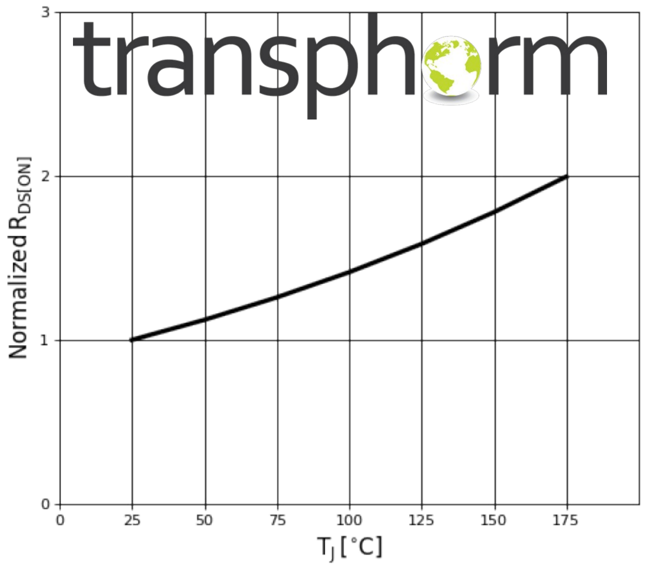
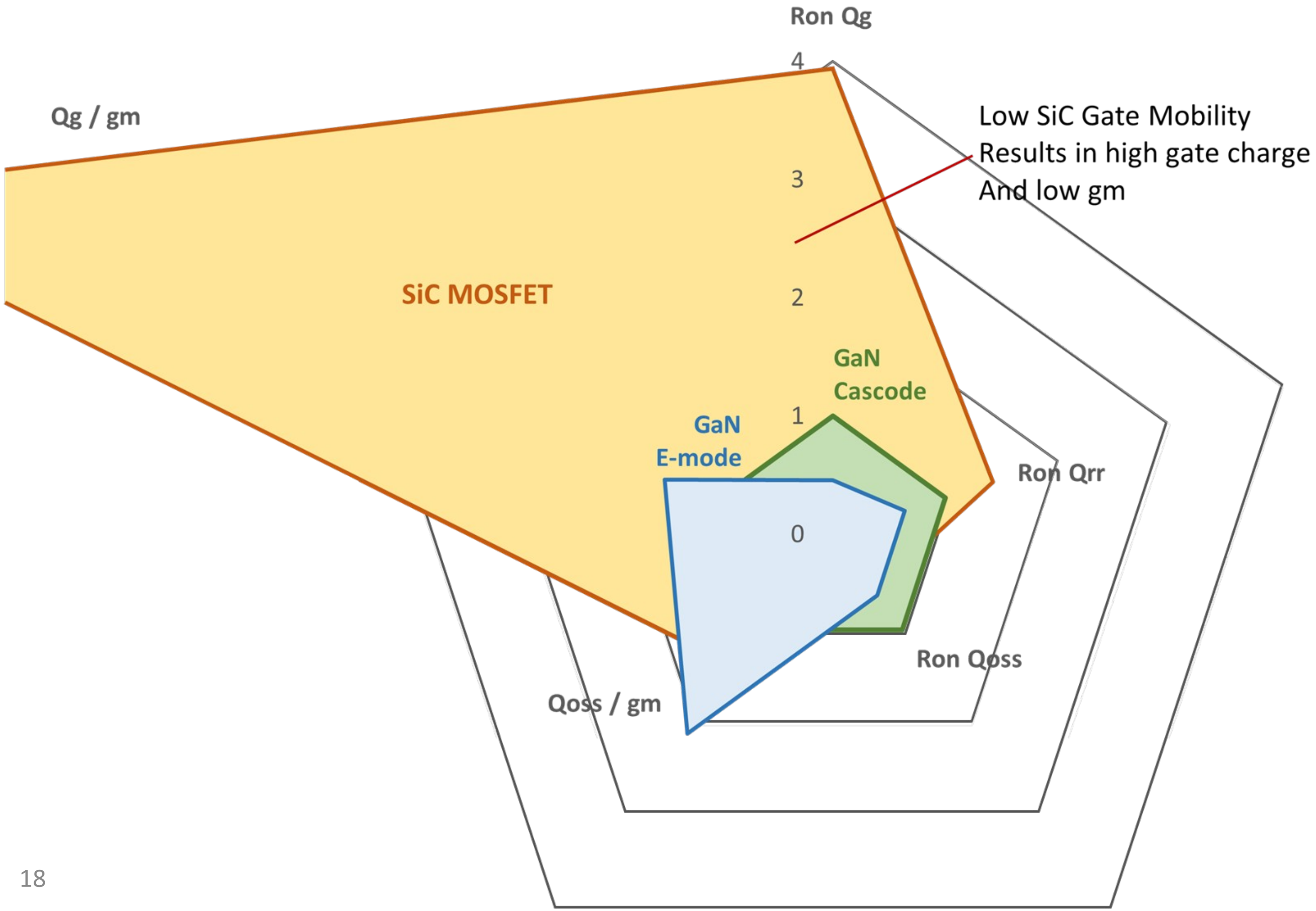


Figure 4. Normalized On-resistance

I_D= 30 A, V_{GS} = 12 V

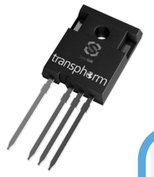
Wide Bandgap Technology Comparison

SuperGaN transconductance (gm) is ~ 5x higher than SiC

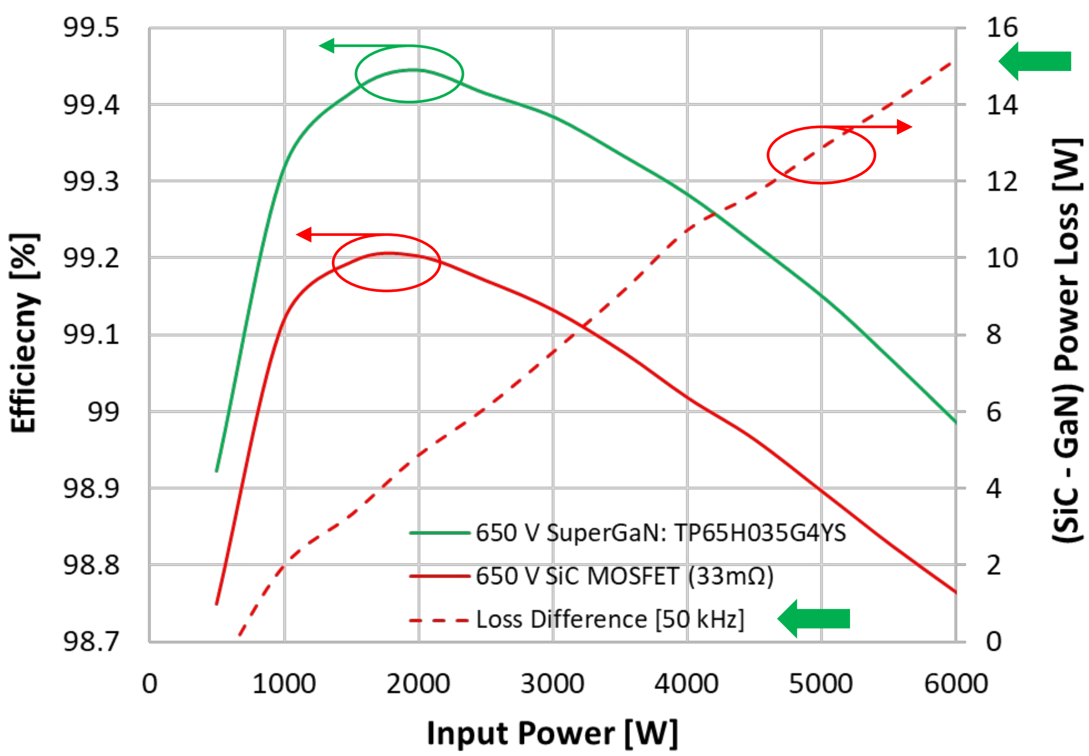


SuperGaN vs. SiC MOSFET: 50 kHz and 100 kHz

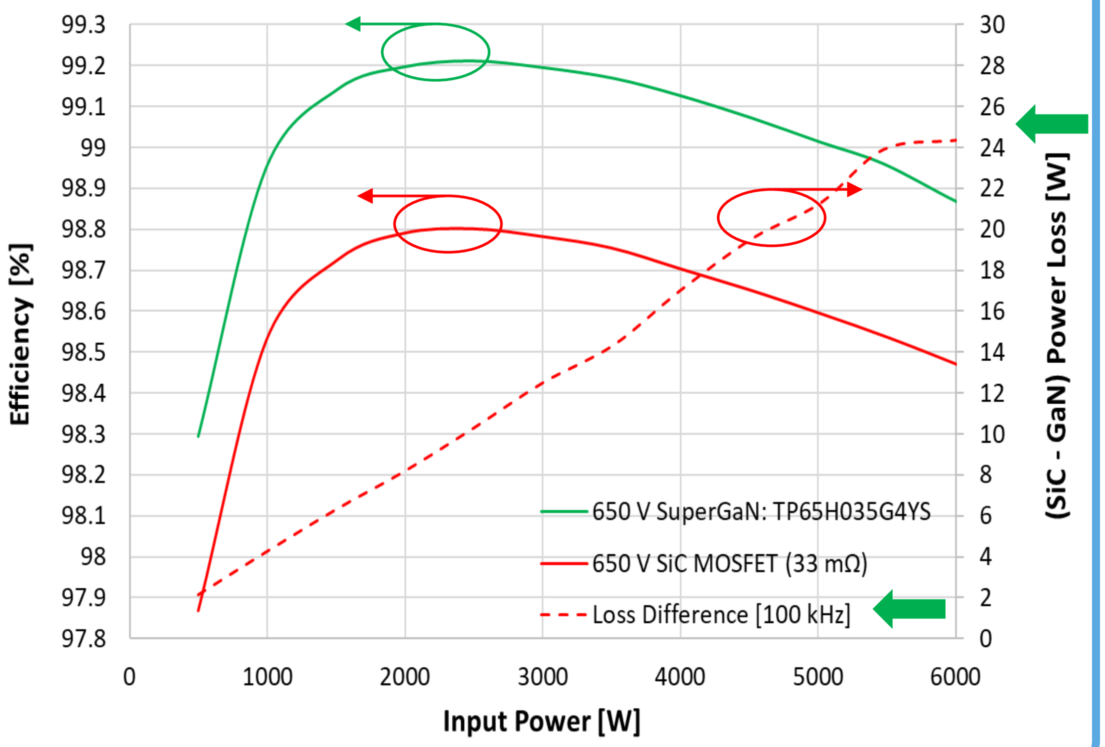
A 15% and 27% respectively decrease in power loss; 50 kHz and 100 kHz at full power (hard-switched HB)



Hard-switched 240V : 400V Half Bridge (50 kHz)

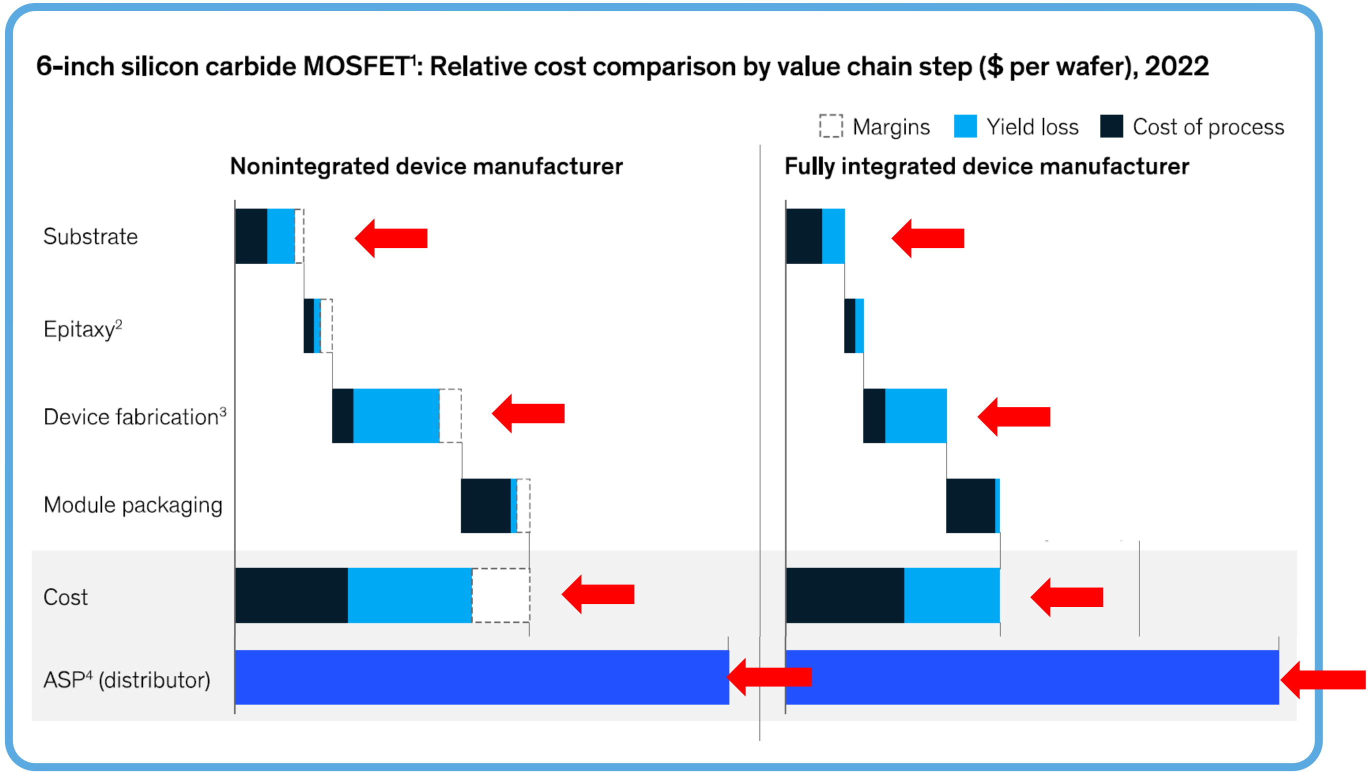


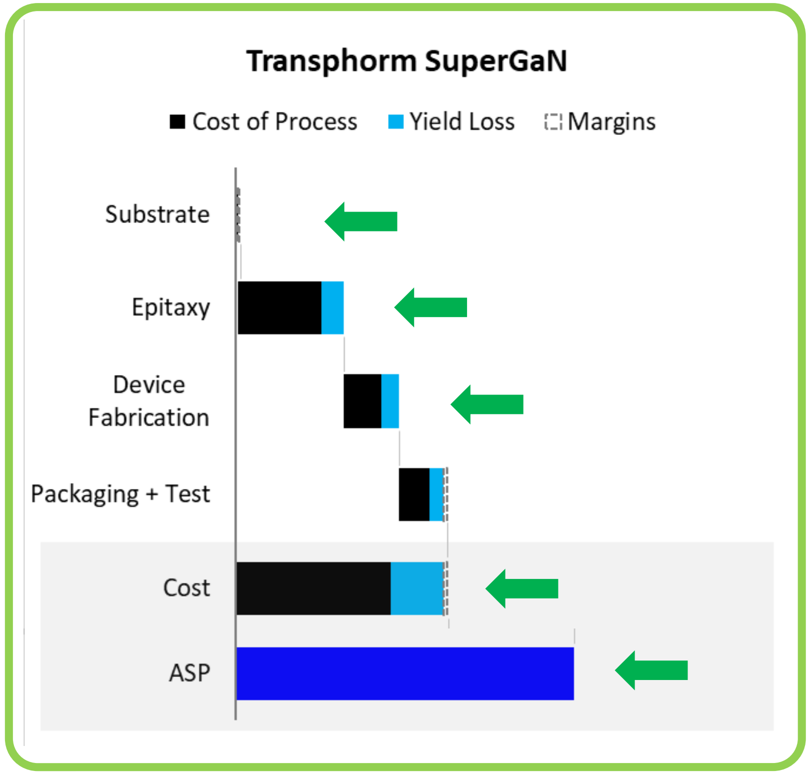
Hard-switched 240V : 400V Half Bridge (100 kHz)



GaN: Less Expensive Manufacturing Process

GaN-on-Si + SuperGaN Platform Design = Lower cost materials + Higher Yields = Low Costs



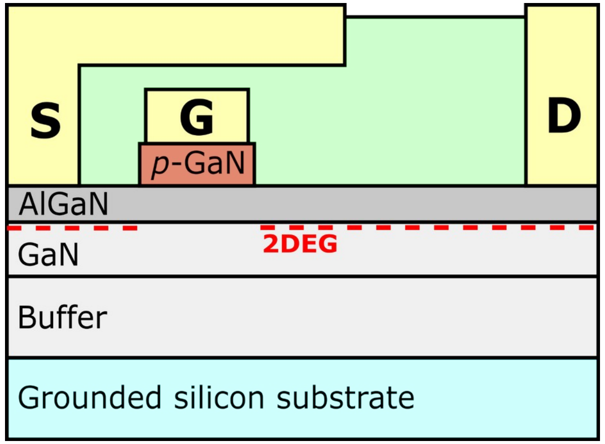


"All of our EV teams are ruthlessly focused on cost and efficiency in our EV products because the ultimate competition is going to be the affordable Tesla and the Chinese OEMs, Farley said.

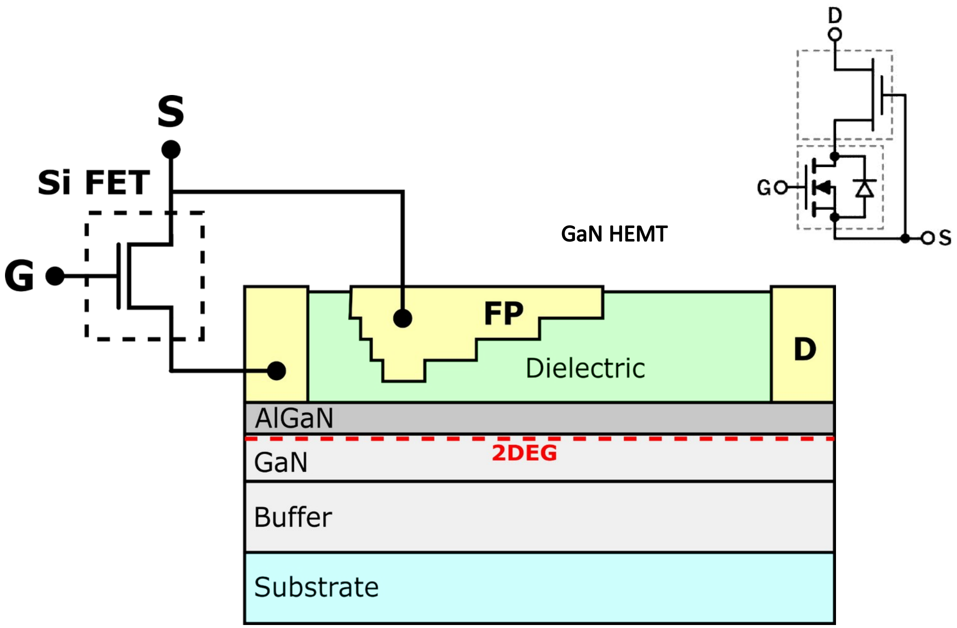
EVs are 30% more to make than vehicles with combustion engines, boosting prices beyond what the middle class can afford, Tavares said."

SuperGaN vs. e-mode

Normally-off GaN Platforms



EPC Efficient Power Conversion | Navitas | Innoscience
Infineon | ROHM Semiconductor | nexperia

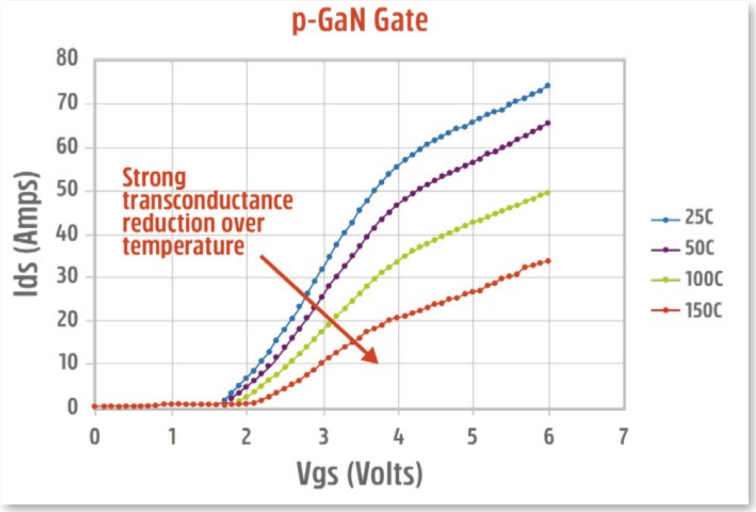


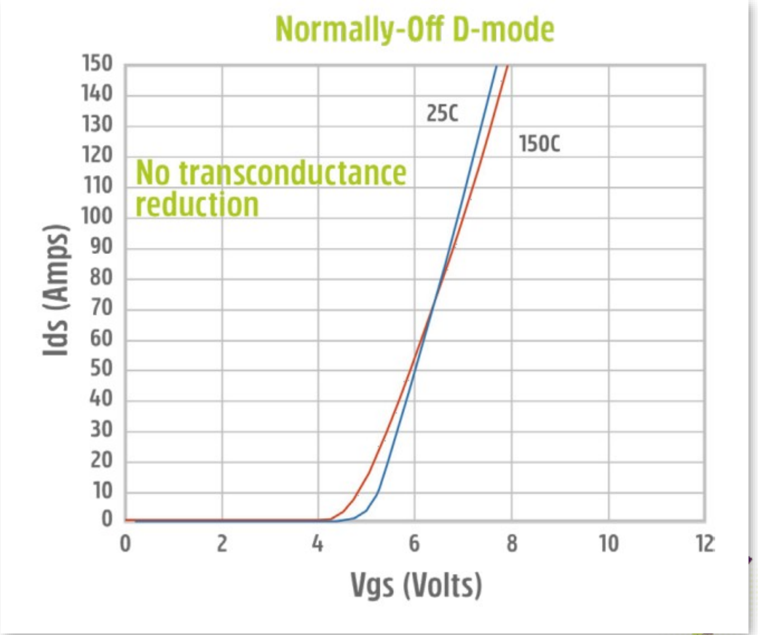
transphorm | nexperia
Power Integrations | Texas Instruments | VisIC Technologies

Direct drive (Texas Instruments)

Direct drive (VisIC Technologies)

Fundamental Advantages of D-Mode GaN





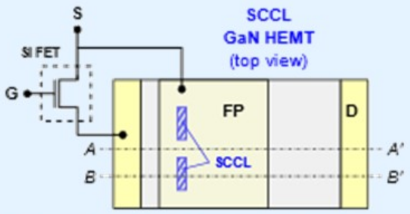
Normally-Off D-mode GaN Innovates Like No Other

Future-Proofed as Demonstrated by Innovation to Date

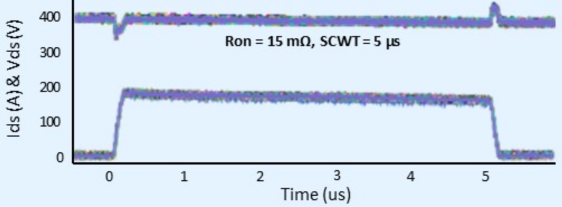
Short Circuit GaN

Opens up new markets in conventional topologies

- **Achieves what SiC, IGBTs can do but not other GaN** - Opens up complete Motor Control and Traction Inverter
- Achieved on **650V** (with Reliability Data), technology applies to **1200V**
- Funded by **#1** Servo/Robotics Co. (Yaskawa)



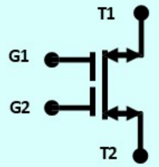
U.S. Patents 9443849, 8803246 & 9171910 (2015)



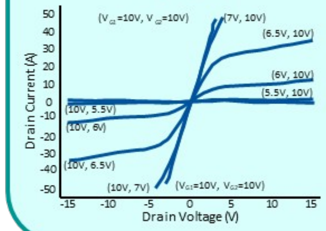
Four Quadrant (Bidirectional) GaN

Opens up markets in next generation charging and motor drives

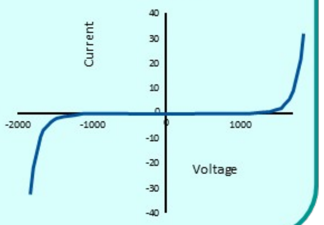
- **1 device vs. 2 and upto 50% smaller => 2-4x die/cost reduction** - Not possible with SiC devices
- Demonstrated on 650V (with initial Reliability Data)
- On roadmap of Enphase and OBC in Europe
- Opens up AC-to-AC motor drives (HVAC etc)
- Funded by ARPA-E



On-state



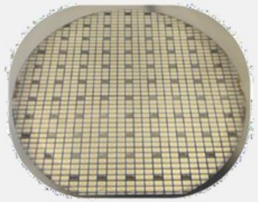
Off-state

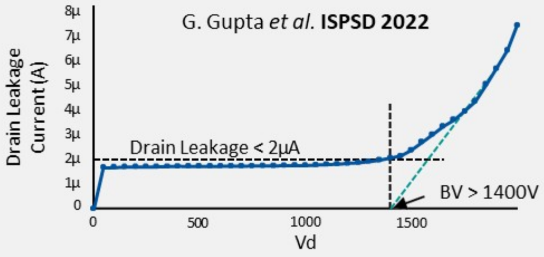


1200V GaN

Provides high-performance low-cost challenge to SiC with low supply chain risk

- **First extension of GaN Voltage node to 1200V with demonstrated competitive switching performance vs. SiC**
- **Opens markets in grid solar, 800V battery drive train, pole charging and other industrial markets**





Normally-Off D-mode GaN is Future Proof

SuperGaN vs. SiC

- Die size: Similar thermal resistance with larger die for additional thermal spreading
- Material challenges: Similar temperature coefficient of resistance based on SiC improved channel
- Performance: Higher mobility enabled by the 2DEG; lower switching losses
- Cost: Manufacturing efficiencies (lower cost structure); without the material issues
- Law of economics

SuperGaN vs. e-mode

- Added complexity to manufacture and design in, reduced performance, jeopardized reliability
- Vertical integration allowing for continued innovation (1200 V, SCCL, FQS)
- Broad power spectrum customer adoption


transphorm
Powered By
SuperGaN