Powering the SiC Revolution with Vertical Integration

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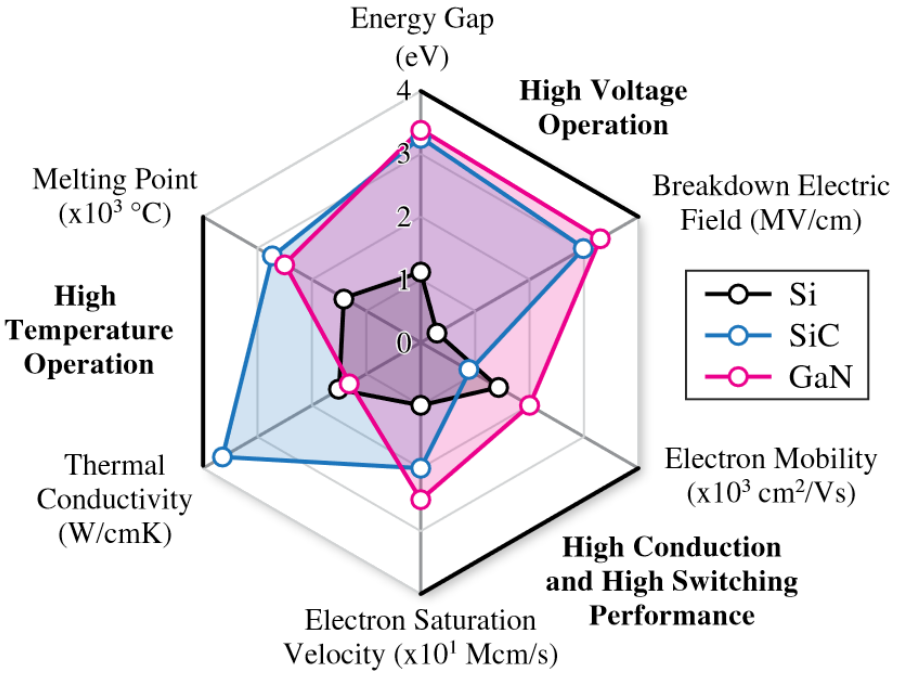
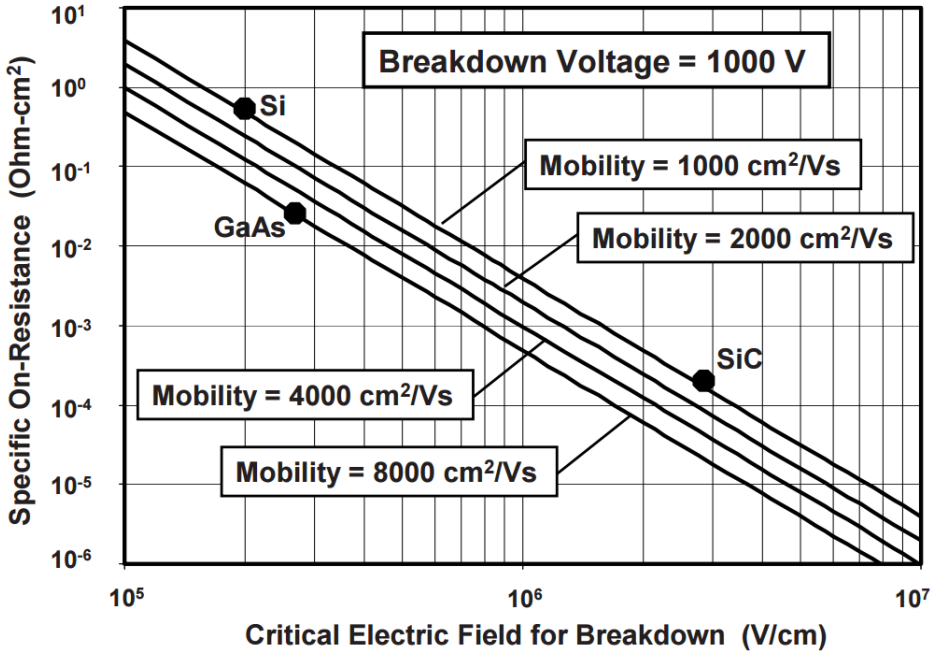
20 YEARS IN COMPOUND SEMICONDUCTOR INNOVATION
2000 / 2020

Sanan Semiconductor

Silicon Carbide offers many advantages for Power Semiconductors



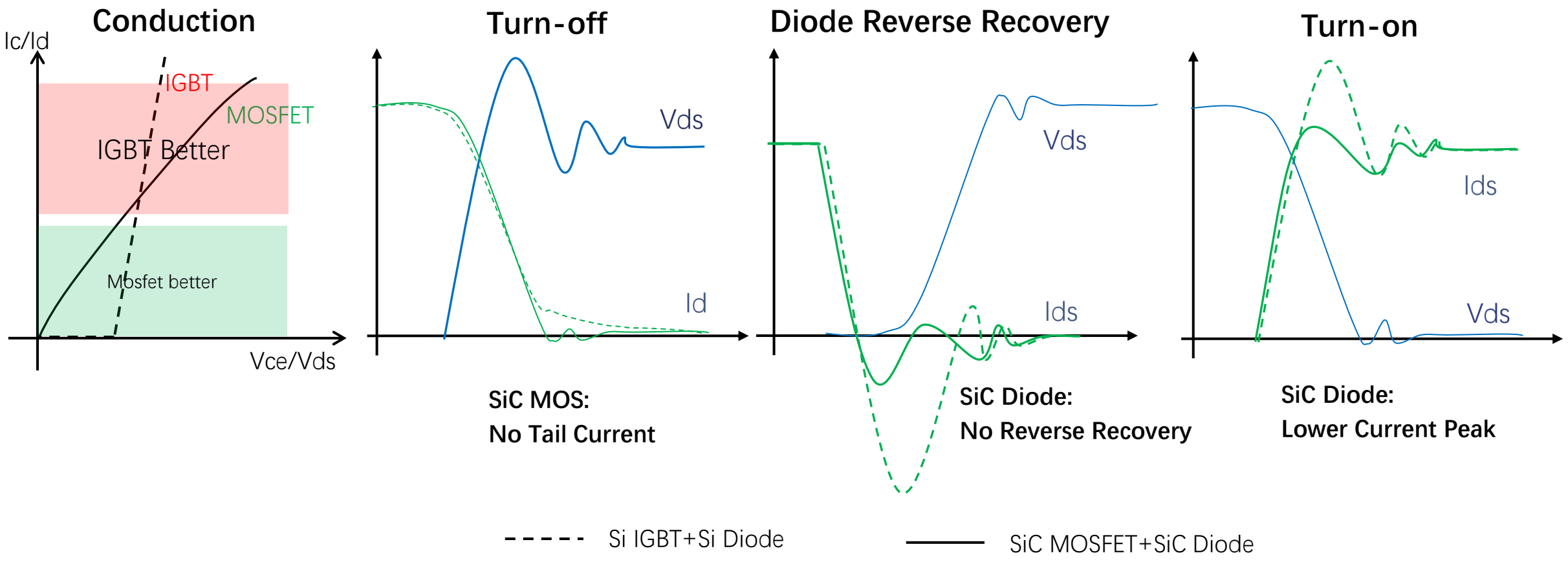
Source: D. Cittanti et al., New FOM-Based Performance Evaluationof 600/650 V SiC and GaN Semiconductorsfor Next-Generation EV Drives



Source: J. Baliga, Fundamentals of Power Semiconductor Devices, Springer Link

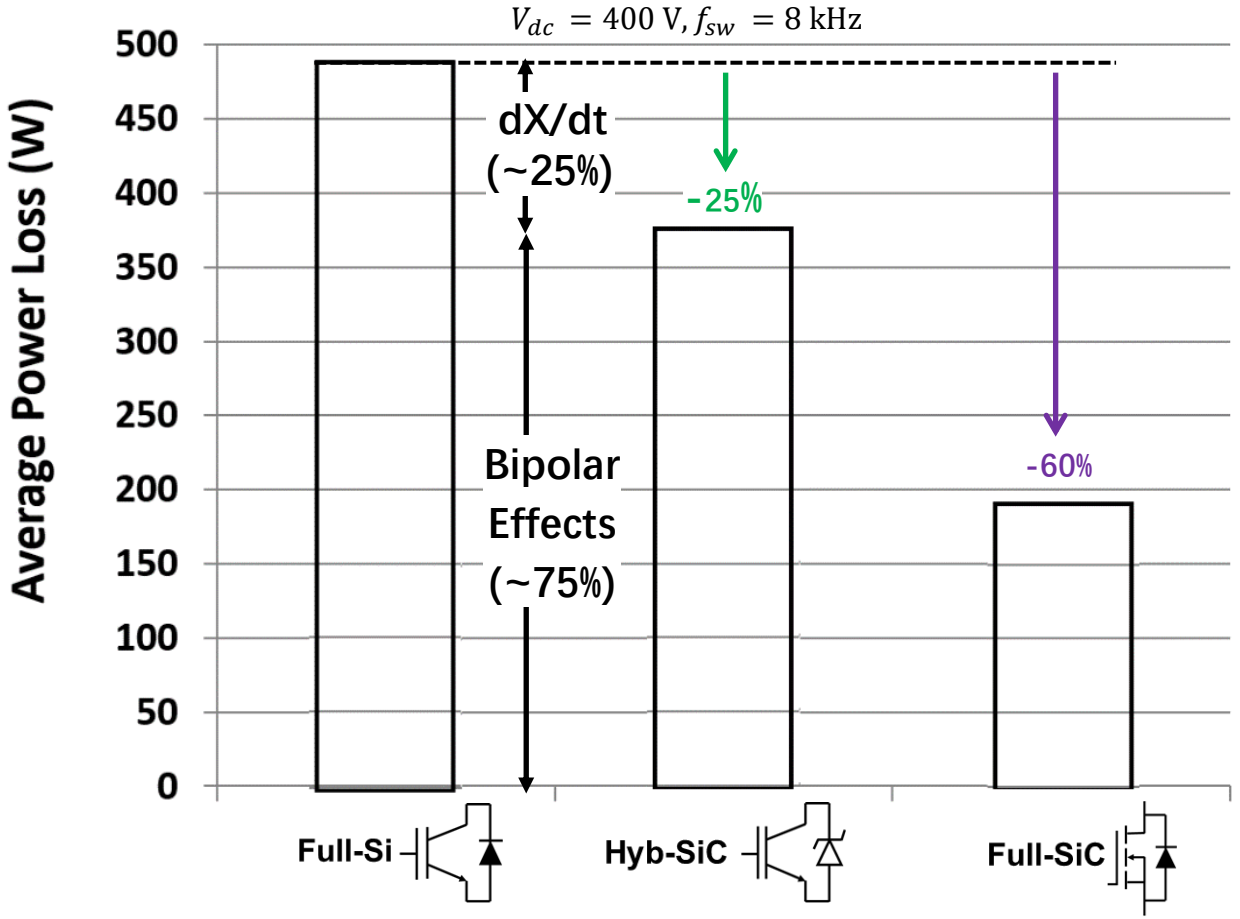
- Thinner drift layer for the same V_{br} → Lower $R_{on,sp}$, but also possibility to build unipolar devices in the kV range
- Faster Switching
- Higher junction temperature operation
- Better Thermal Conductivity

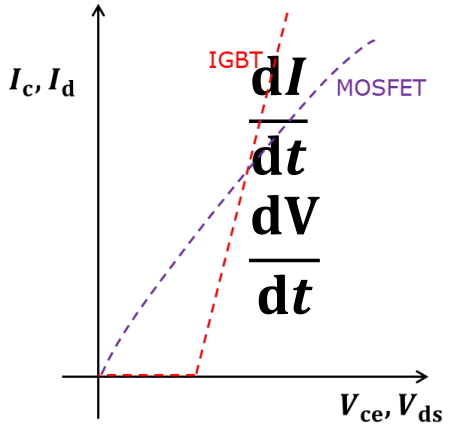
By enabling Unipolar devices in the kV Range, SiC helps in reducing power losses significantly



Source: A. Pai, PhD Thesis „Impact of SiC based semiconductors on the mission profile efficiency of Automotive traction inverters“

SiC enables upto 60% reduction in power losses in Automotive Traction Inverters (Artemis Highway Mission Profile)

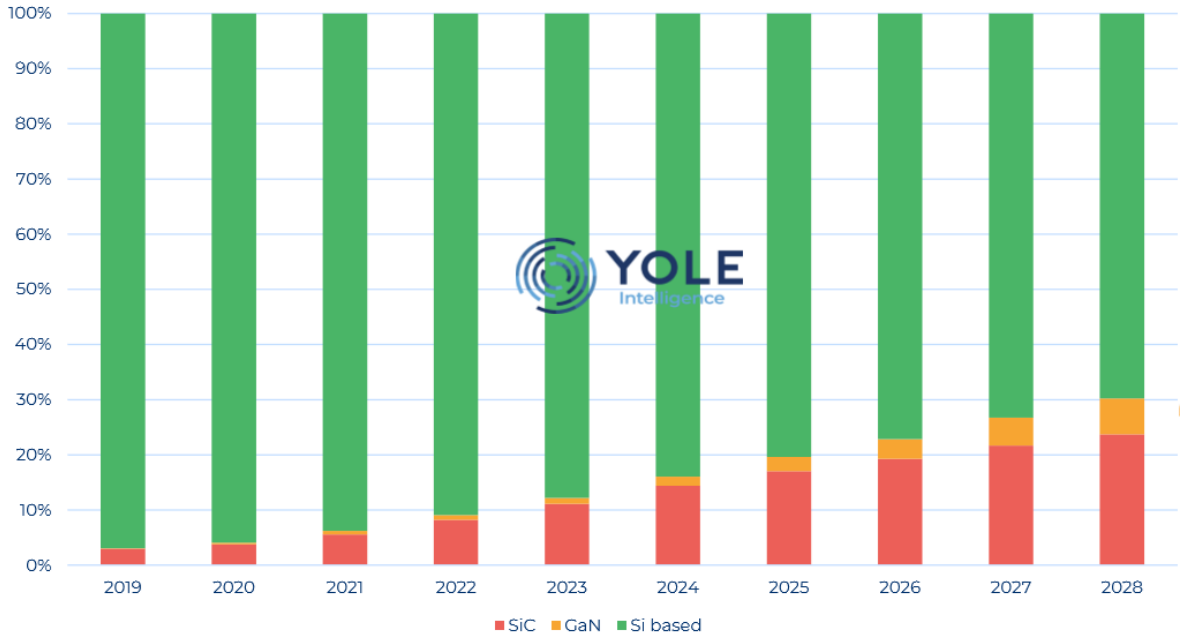




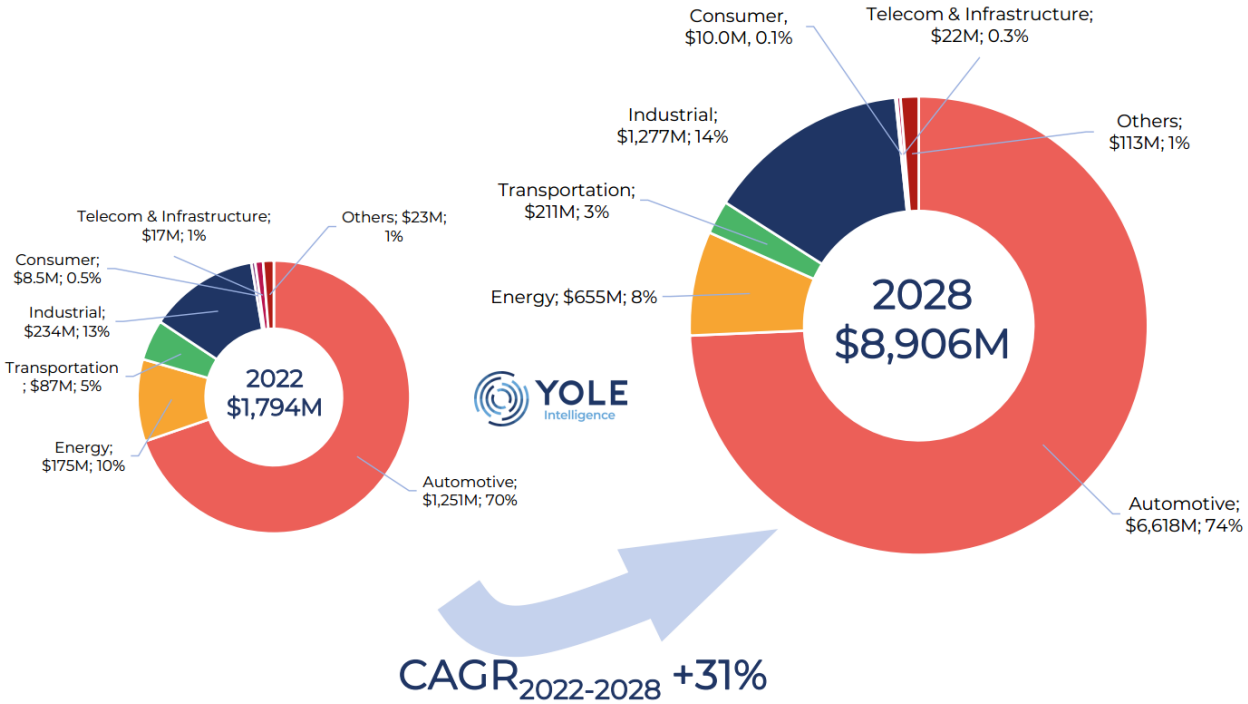
- SiC Mosfets reduce inverter power losses by around 60% compared to IGBT, at similar di/dt, dv/dt
- Most benefits of SiC Mosfets are actually coming due to going from bipolar behaviour to unipolar behaviour
- In contradiction to literature, switching speed (di/dt, dv/dt) does not bring down the power losses drastically

Source: A. Pai, PhD Thesis „Impact of SiC based semiconductors on the mission profile efficiency of Automotive traction inverters“

SiC Device Market is projected to reach $9B in 2028 with a market share of >20%



Source: Yole Power SiC/GaN Monitor Q3-2023



Source: Yole Power SiC 2023 Report

SiC is revolutionalizing the power semiconductor Market!

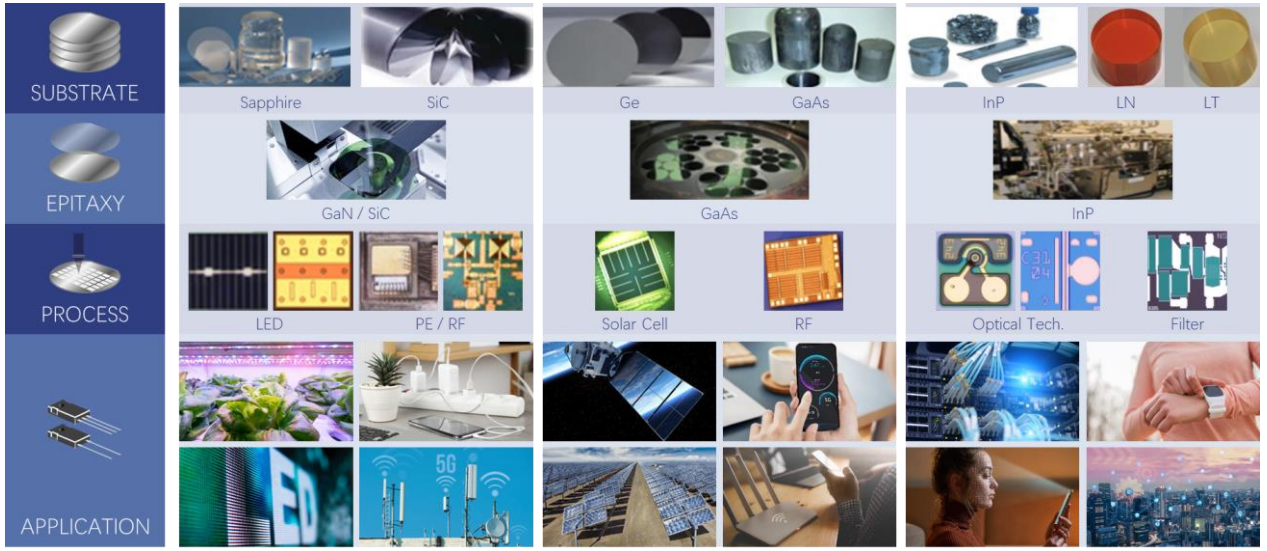
How can Sanan Semiconductor help to Power this Revolution?

Committed to be a World-Class Compound Semiconductor R&D and Manufacturing Service Platform

20 YEARS IN COMPOUND SEMICONDUCTOR INNOVATION (2000 / 2020)

Parent Company: Sanan Optoelectronics (SSE: 600703)

- Established in 2000, Xiamen, China
- ~$ 2B Revenue in 2022
- The largest LED Chip/Epitaxial Wafer Manufacturer in China
- >14,000 Employees
- Scale: >600 MOCVD Reactors
- Capacity: 12M Wafers/Year
- IP Portfolio: >3,000 patents and proprietary processes
- 1st in China as SAW Filter Vertical manufacturer
- Largest shipments in APAC of GaN RF foundry manufacturer
- Largest-scale of in-house developed GaAs wafer foundry manufacturer

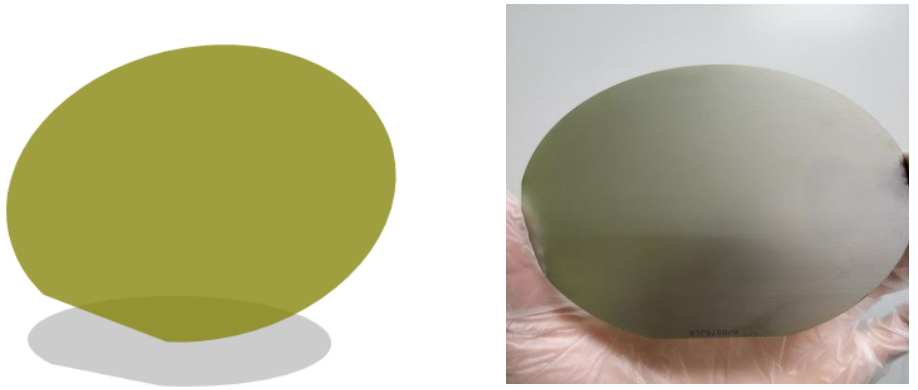


Sanan Semiconductor

- China's First Vertically Integrated SiC manufacturer
- Experience in SiC since 2014
- Mega Factory established in 2020, Changsha, China
- Capacity: ~500k Wafers/Year after ramp up
- IP Portfolio: >700 patents (granted and pending) and proprietary processes
- R&D in China (Xiamen & Changsha), Germany (Munich), Japan (Tokyo)
- 800+ Global Customers and Partners

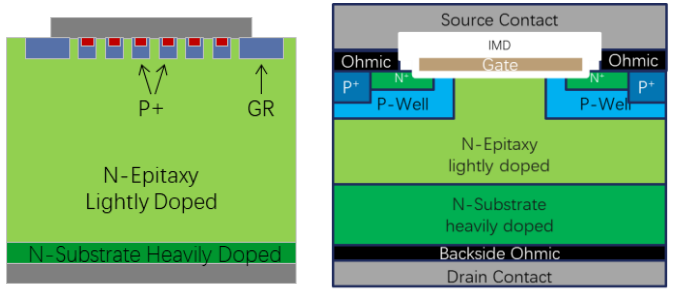
How can Sanan help to power this SiC Revolution?

SiC Crystal/Substrate Growth

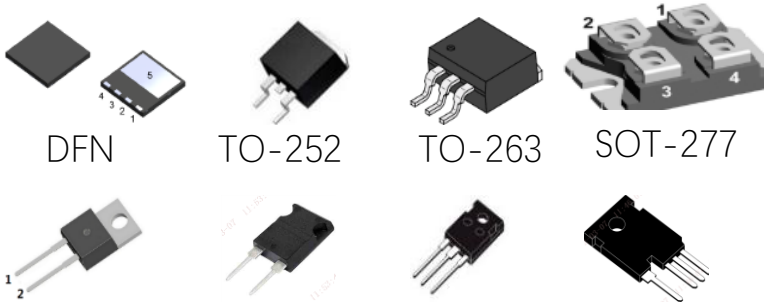


SiC Epi-wafer / Epi –growth

Device Fabrication



Packaging



DFN TO-252 TO-263 SOT-277

TO-220 TO-247-2 TO-247-3 TO-247-4

and Customer-specific packages

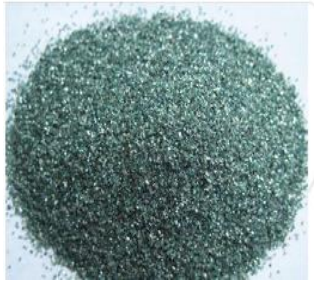
Due to **Vertical Integration**, Sanan Semiconductor maintains control of the complete supply chain including capacity, cost and qualification of all materials including wafers and devices

Note: Dimensions Not to scale

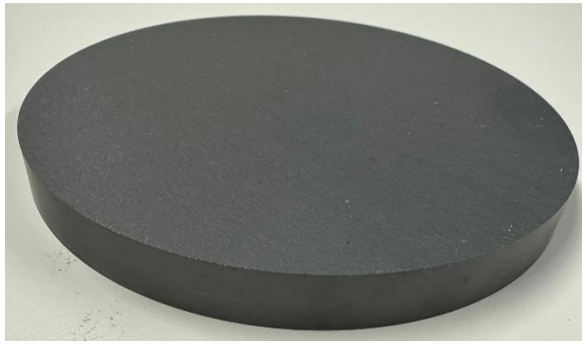
State-of-the art Vertically Integrated MegaFab setup with an investment of $2.3B

Sanan Semiconductor is China's first Vertically Integrated SiC Company.

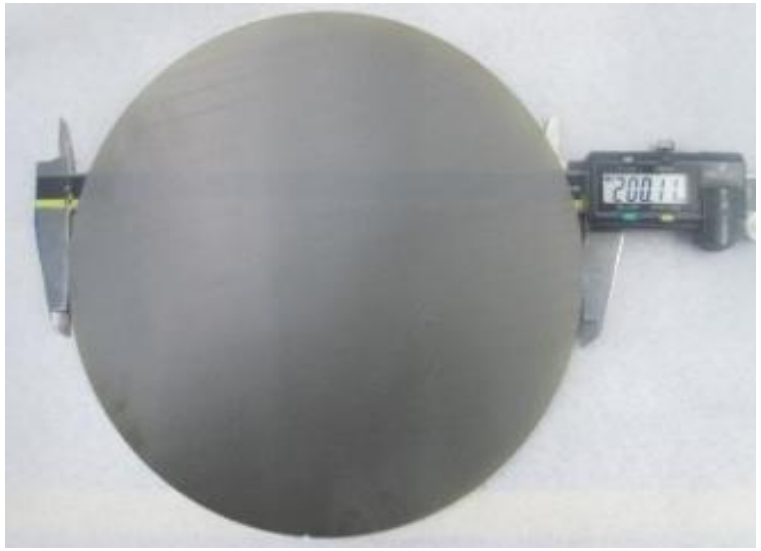
6” SiC Substrates are in Mass Production and 8” Substrate Development is on track



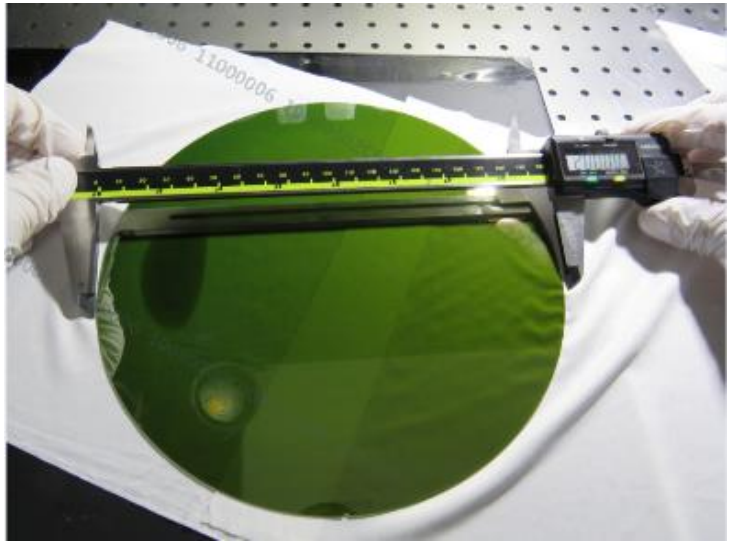
SiC powder



SiC 6” Boule



SiC 8” Boule



SiC 8” Epi-wafer

- In-house process for SiC Powder to reach 6N purity grade
- Optimal temperature field control and gradient adjustment to limit crystal defects
- In-house cutting and grinding processes to reach low TTV (Total Thickness Variation) values
- **6” Substrates are in Mass production**
- **8” Substrates development is on track, Mass production planned e/o 2024. (Samples b/o 2024)**

Note: Dimensions Not to scale

ST and Sanan announced a Joint Venture for 200mm SiC Device Manufacturing in China

[No Title]

STMicroelectronics and Sanan Optoelectronics to advance Silicon Carbide ecosystem in China

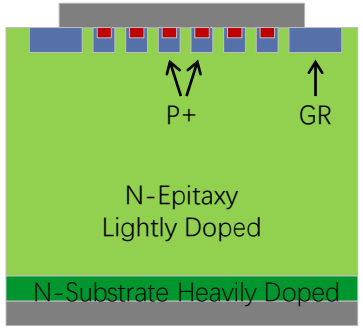
Jun 7, 2023 Geneva (Switzerland) and Xiamen (China)

- STMicroelectronics and Sanan Optoelectronics to create a Joint Venture ('JV') for high-volume 200mm SiC device manufacturing
- JV will support rising demand for STMicroelectronics SiC devices in China for car electrification and industrial power and energy applications
- Sanan to build separately a 200mm SiC substrate manufacturing facility to fulfill the JV's needs

STMicroelectronics (NYSE: STM), a global semiconductor leader serving customers across the spectrum of electronics applications, and Sanan Optoelectronics (SHA.600703), a market leader in compound semiconductors in China, engaged in LEDs, SiC, Optical Communications, RF, Filters and GaN products, today announced that they have signed an agreement to create a new 200mm silicon carbide device manufacturing JV in Chongqing, China. The new SiC fab is targeting to start production in Q4 2025 and full buildout is anticipated in 2028, supporting the rising demand in China for car electrification as well as for industrial power and energy applications. In parallel, Sanan Optoelectronics will build and

Source: ST Newsroom

Sanan has shipped >100M SiC Diodes for various Applications in 2022



Note: Dimensions Not to scale

Datasheet parameter	Sanan Gen-3	Sanan Gen-4
V_F [10A, 25°C, Typ.]	1.30V	1.28V
V_F [10A, 175°C, Typ.]	1.55V	1.40V
Q_C [400V]	29nC	28nC
FOM (nC*V) [25°C]	37.7	35.8
FOM (nC*V) [175°C]	44.9	39.2
I_R [650V, 25°C, Typ.]	1μA	5μA
I_R [650V, 175°C, Typ.]	3μA	30μA

SiC Diodes

- Five (1-5) Generations released so far
- Voltage Classes: 650V, 1200V and 1700V
- Current Classes: 1-60A
- JEDEC and Automotive Qualified
- Packages: Bare Die, TO220, TO247, TO252, DFN, TO263, SOT227

Gen-3 "General Power" Series

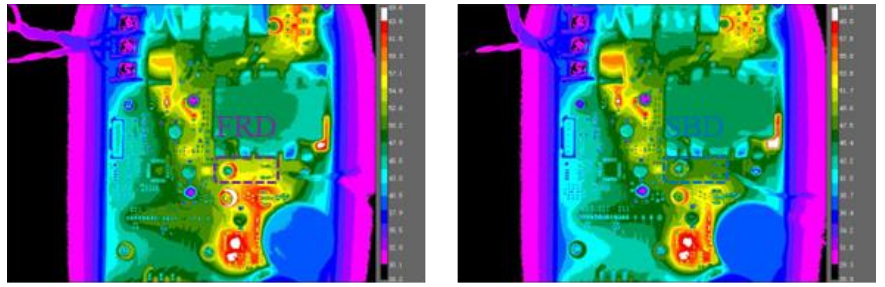
- Thinner Wafer Design, Reduced VF, Better Cooling
- Ultra Low Capacitive Charge,
- Surge 8x $I_{d,nom}$
- AECQ101

Gen-4- "Low Vf" Series

- Further Reduced V_F
- Ultra Low Capacitive Charge
- Ultra Low Power Loss
- Surge 6x $I_{d,nom}$
- AECQ101

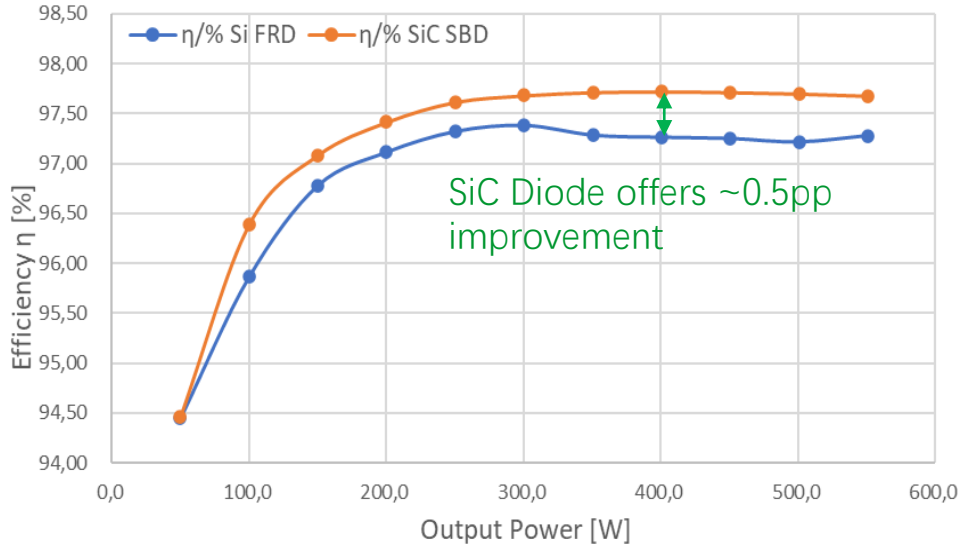
Gen-5 – "High Surge Capability" Series

- Thinner Wafer Design,
- Higher surge current for outdoor application;
- Surge 12x $I_{d,nom}$
- Industrial standard



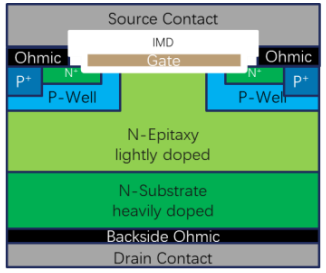
T_{FRD} = 62.4°C;
T_{MOS} = 69.6°C

T_{SBD} = 50.8°C;
T_{MOS} = 57.5°C



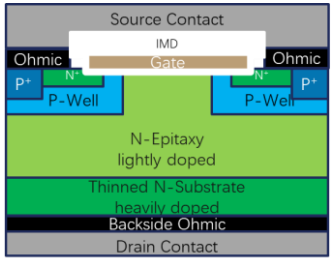
Measurements to compare a Si Diode vs SiC Diode in a Boost PFC Converter

SiC MOSFET Development is on track, lead version to be released in 2024



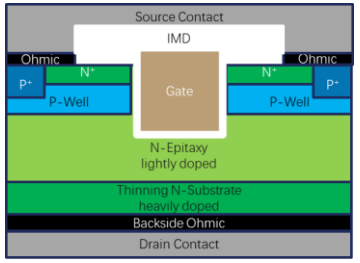
SiC MOSFET Gen1

- Planar structure
- Driving voltage (-5V ~ +20V)
- JEDEC standard



SiC MOSFET Gen2

- Planar structure
- Driving voltage (-5V ~ +15/18V)
- Chip thinning
- AEC Q101 standard

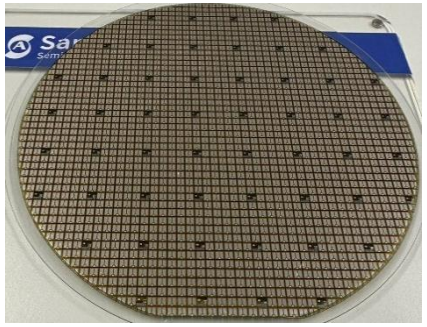


SiC MOSFET Gen3

- Trench structure
- Chip thinning
- AEC Q101 standard

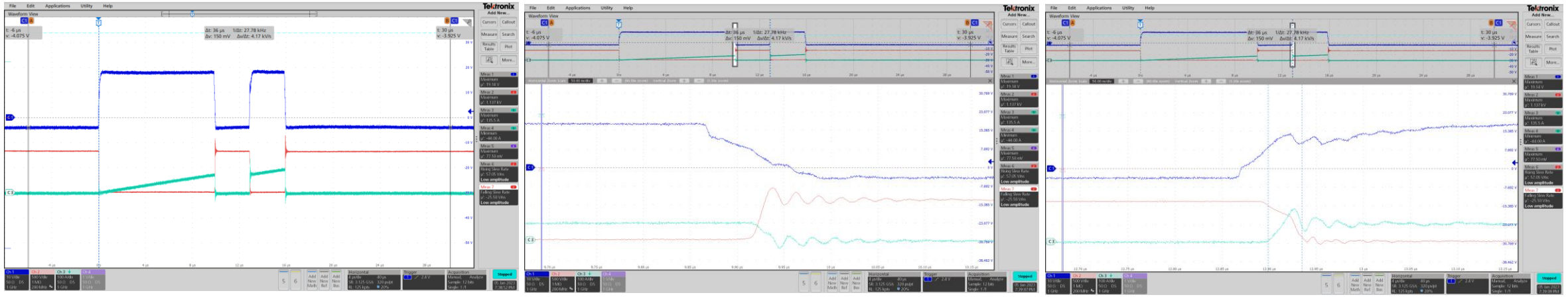
SiC MOSFET

- 3 Generations in Development
- Voltage Classes: 650V, 1200V & 1700V
- Rdson Classes: 13-1000 mΩ
- JEDEC and Automotive Qualified
- Packages: Bare Die, TO247, TO263



Note: Dimensions Not to scale

DPT Measurement of 1200V 16mΩ SiC Mosfet. Condition: Vdc=800V, Vgs=+18V/-4V, Id=75A, Ron/Roff=4.3Ω, 25℃



Sanan's in-house Packaging Capabilities fully Complement its Chip Capabilities

Package-Construction
Frame-based (Potted)
Molded

FS Connection
Aluminum wire bonds
Copper wire bonds/clips

Signal Pins
Press-fit
Solderable

Substrate
DCB Al2O3
AMB SiN

Sanan's Packaging Capabilities

Power Terminals
US Weld

Die Attach
Soldering
Sintering

Cooling
Direct (Pin-Fin)
Indirect Cooled

Topology
Single Switch (Discrete)
Half Bridge/B6 Bridge

Key Parameters of Packages in Development Today
L_{stray} <= 4.5 nH, R_{jc} <= 0.08 K/W,

THANKS

www.sanan-semiconductor.com