



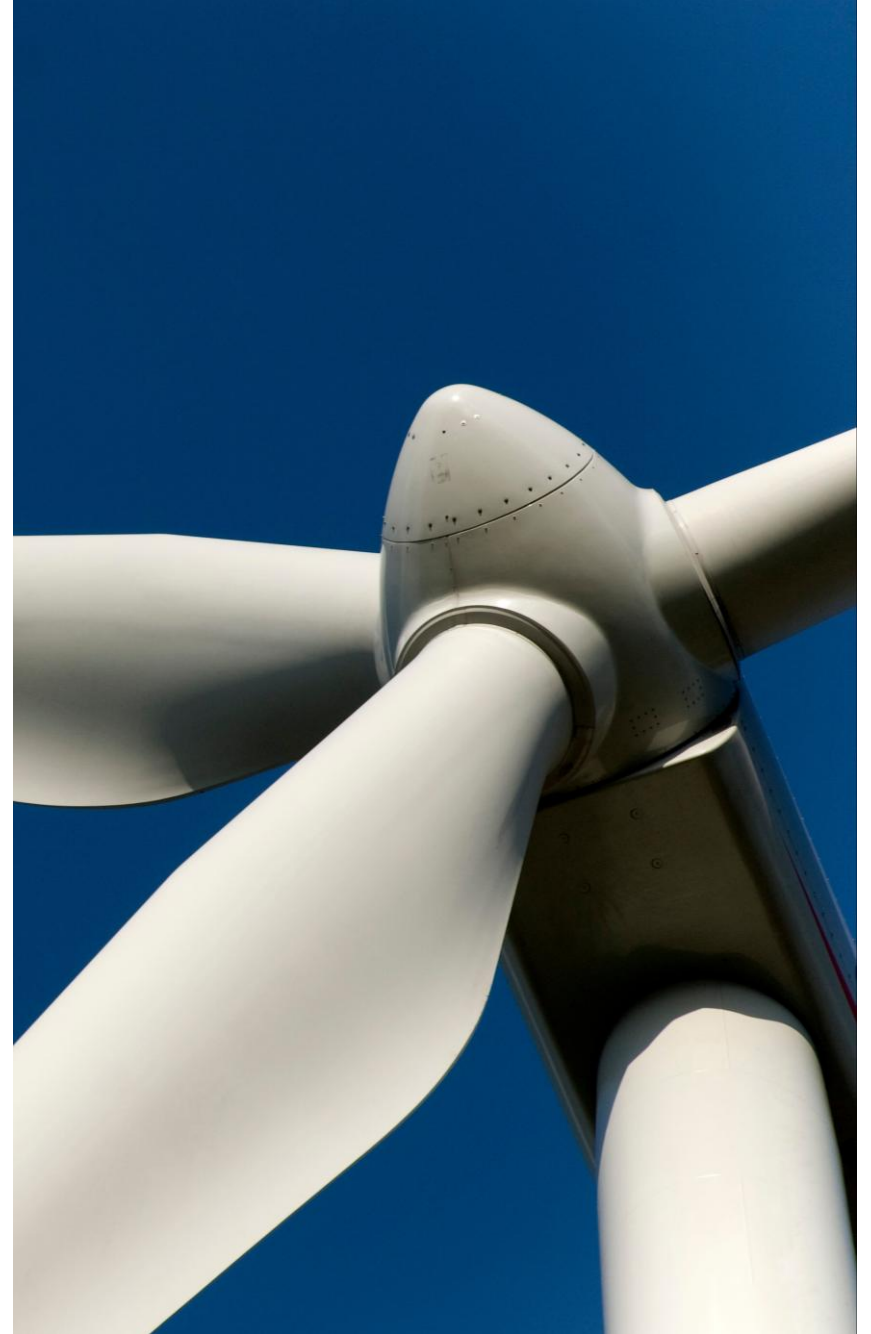
SiC Power Electronics: The Emerging Role of the UK in a Critical EV Sector

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CENEX EXPO – Electrification Technology

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SiC Power Electronics: The Emerging Role of the UK in a Critical EV Sector



- 1 Power Electronics and Silicon Carbide
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- 3 UK Market for Silicon carbide
- 4 Conclusions



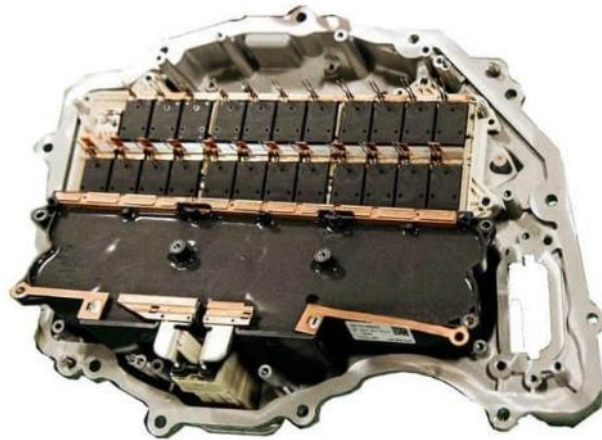
Power Electronics and Silicon Carbide



- The **Electrification Agenda**, required to meet global carbon reduction targets, typically concentrates on the renewable generation of power, and the electrification of transport, particularly cars.
- “**Power**” **Electronics** is playing a critical role in the electrification agenda by enabling electrified applications (including EVs) and in minimising energy lost on route from the generation to use.

Tesla Model 3 Inverter; 211 kW

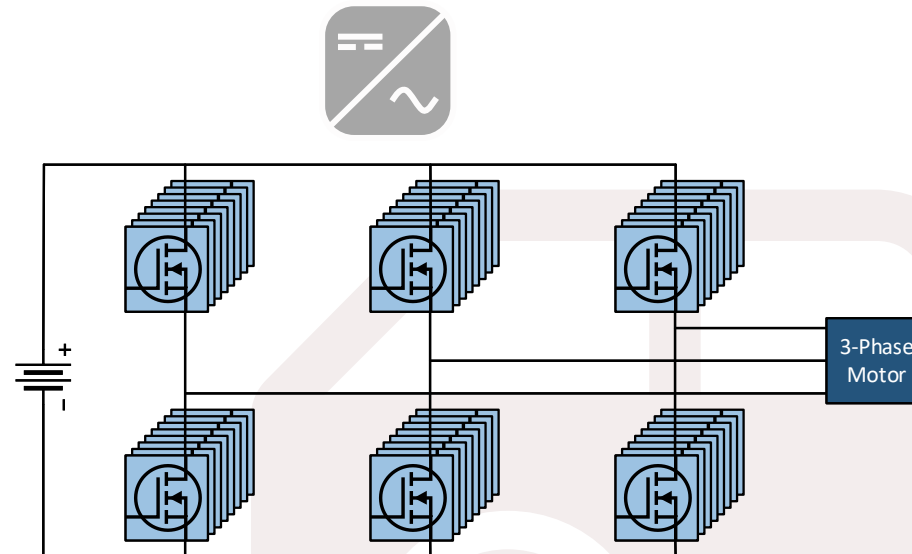
Source: Munro Associates



**UNIVERSITY
OF WARWICK**



DC to 3-Phase AC H-Bridge



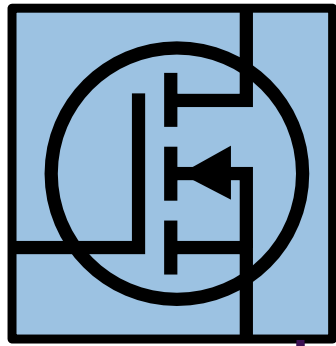
6 Switching locations; 48x 650V SiC MOSFETs*

*Telsa Model 3/211kW; scales with motor power

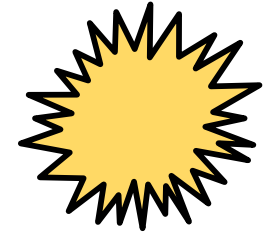


Power Electronics and Silicon Carbide

A power device has three key roles:



In the **OFF State**, it must block a voltage high enough for the application...
i.e. a large **breakdown voltage**.



In the **ON State**, it must allow current to pass with minimal waste...
i.e. **minimal resistance**.



It must switch between the ON and OFF states as fast as possible.
i.e. **maximum switching frequency**.

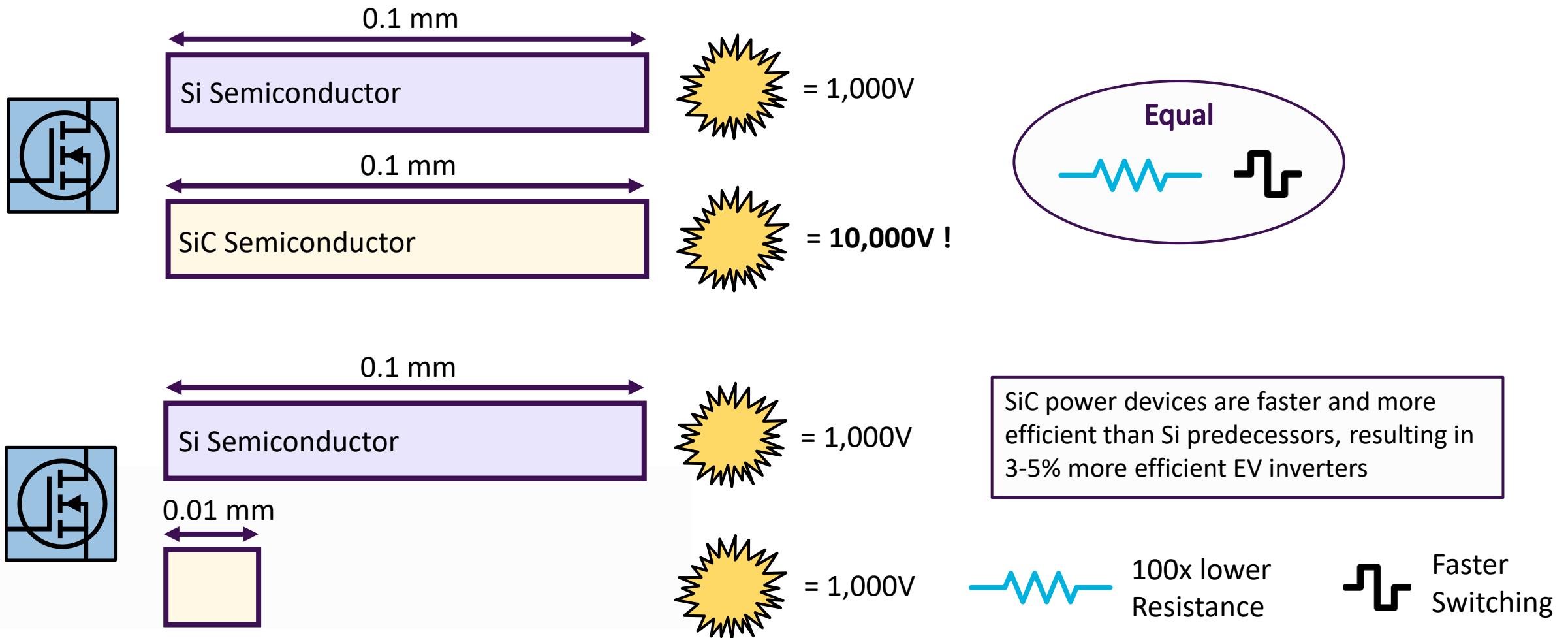


Advantage Silicon Carbide



SiC has one crucial parameter: a **high critical electric field**

This is the voltage it can withstand in a unit length measured in **volts per cm**

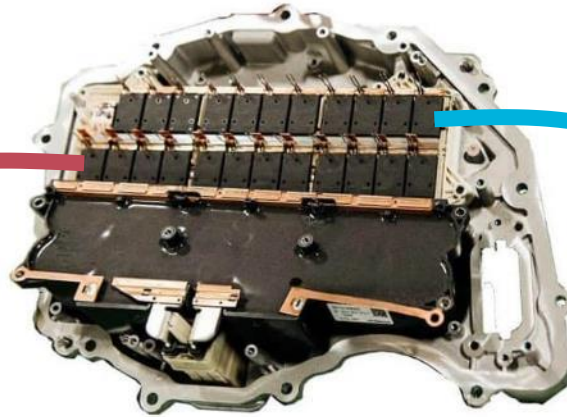
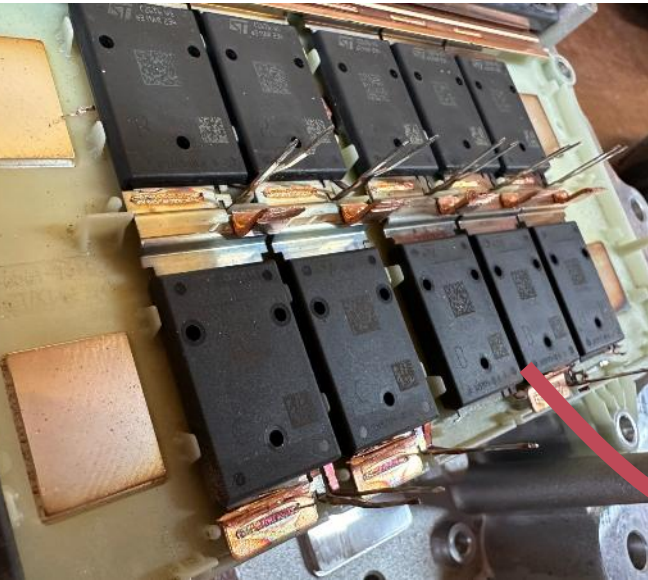


Advantage Silicon Carbide

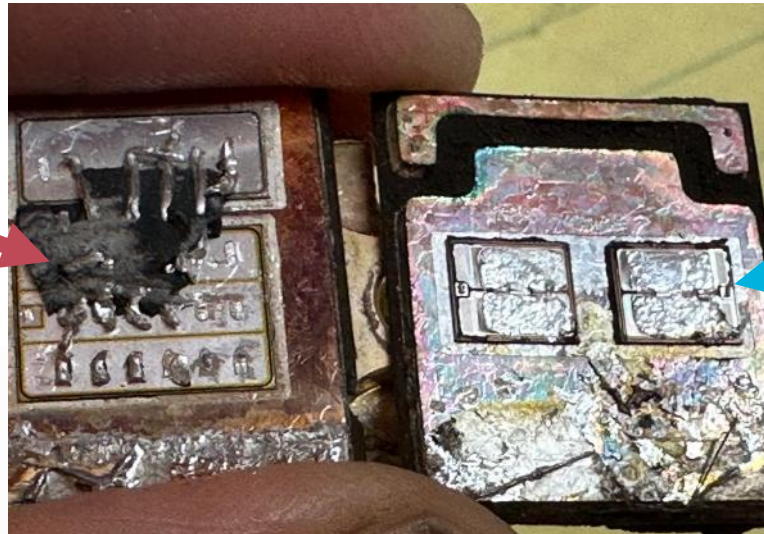
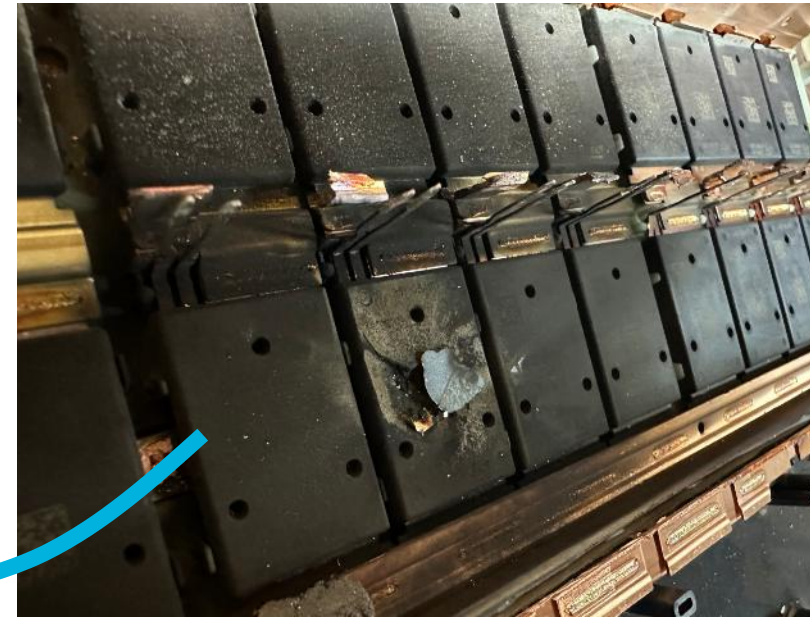
The difference in die size can be seen in Tesla teardowns.



Si IGBT based inverter



SiC MOSFET based inverter



Pictures courtesy of Kevin Matocha's teardowns:
<https://www.linkedin.com/pulse/choose-your-own-adventure-tesla-inverter-teardown-episode-matocha-nfapc/>

Advantage Silicon Carbide



When a SiC MOSFET replaces a legacy Si IGBT in an inverter they can be exploited for...

Reduced losses = increased efficiency

Lower switching and conduction losses



Increased switching speed / smaller solution

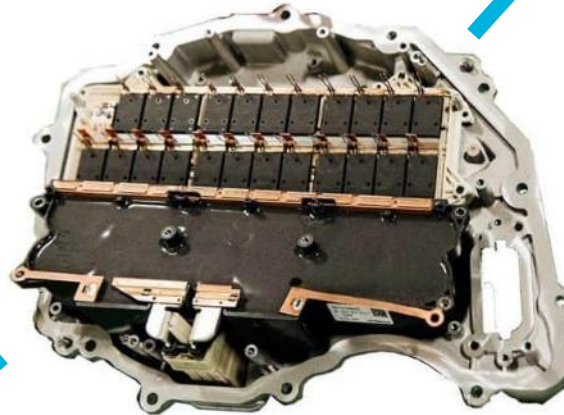
Fast unipolar switching
smaller die = lower capacitance



Or a mix of the three...



SiC MOSFET
~~Si IGBT~~ **Inverter**



Increased operating temperatures / smaller solution

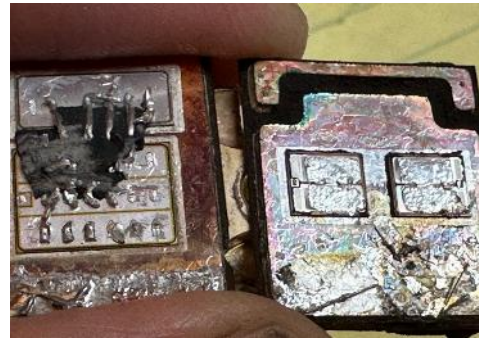
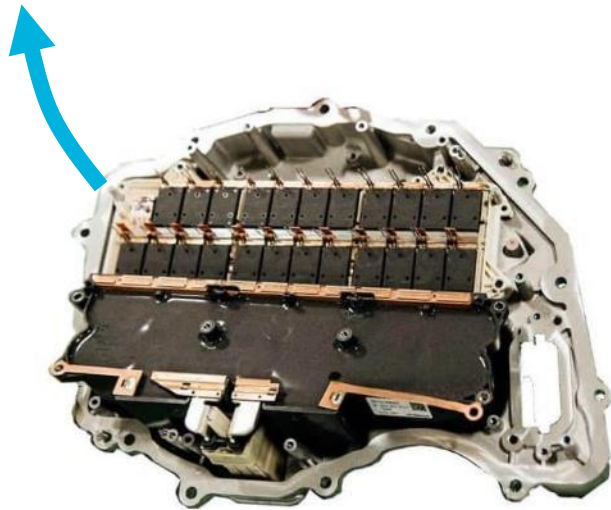
Reduced losses, high thermal conductivity, wide bandgap

Advantage Silicon Carbide

When a SiC MOSFET replaces a legacy Si IGBT in an inverter they can be exploited for...

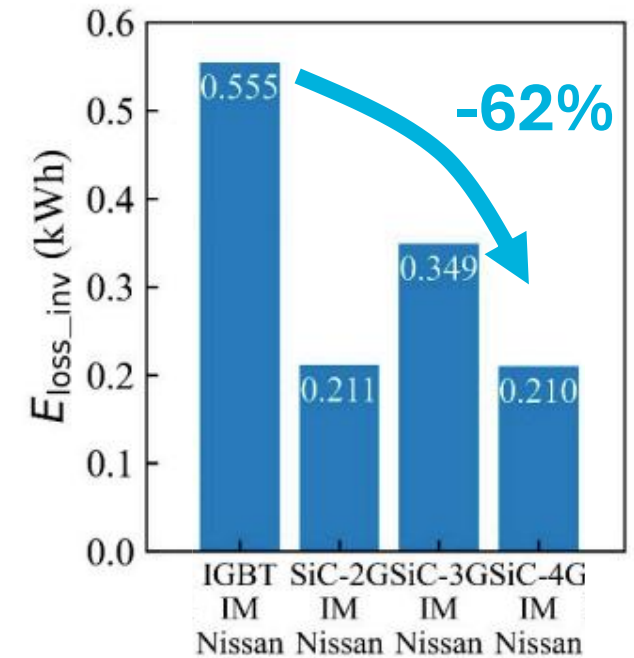
Reduced losses = increased efficiency

Lower switching and conduction losses



Rohm SiC MOSFETs vs Si IGBTs

- Nissan Leaf motor test-bed emulation
- Comparing 1200V/450A Si and SiC modules
- Each driving 100 kW at 800V and 10kHz Switching speed
- Losses averaged over WLTC Class 3b drive cycle

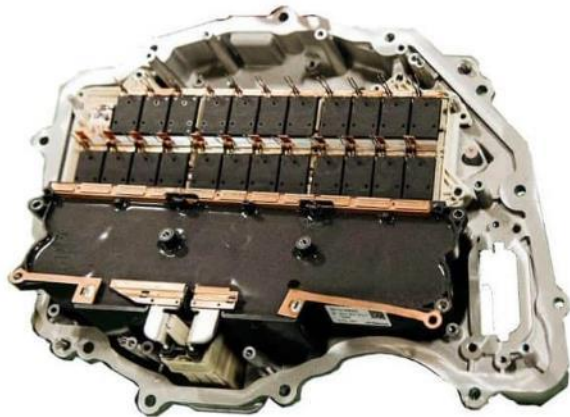


Advantage Silicon Carbide

When a SiC MOSFET replaces a legacy Si IGBT in an inverter they can be exploited for...



Source: Rohm

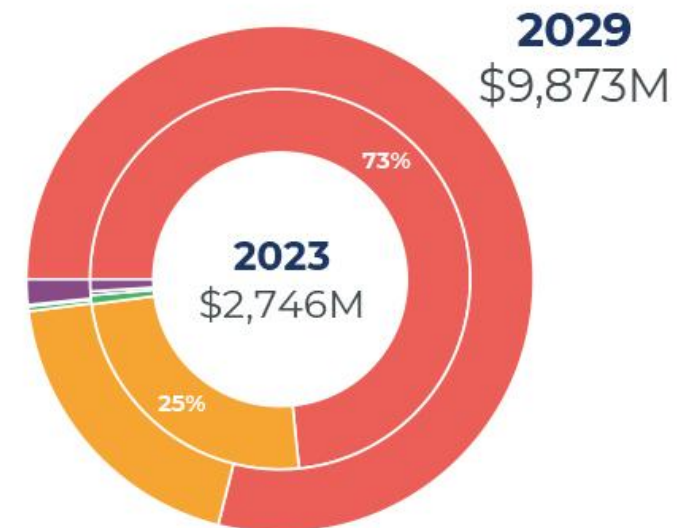


SiC Market



2023-2029 power SiC device market (\$M)

(Source: Power SiC - Markets and Applications 2024, Yole Intelligence, September 2024)



CAGR₂₀₂₃₋₂₀₂₉ : 24%

© Yole Intelligence 2024

UK Perspective

UK Industrial Strategy and Semiconductor Strategy

- Recognition in the strategy of UK's strength in **Compound Semiconductors**; of which SiC has the largest market and the most UK infrastructure.

"The UK has developed a strength across the compound semiconductor supply chain. We have world-leading research, development, innovation, and commercialisation of the technology."

National semiconductor strategy - 19 May 2023



UK SiC and Power Electronics Market

A strong UK ecosystem

UK SiC Epitaxy Capability

Expertise in **Vishay**, **ICEMOS** and **IQE**

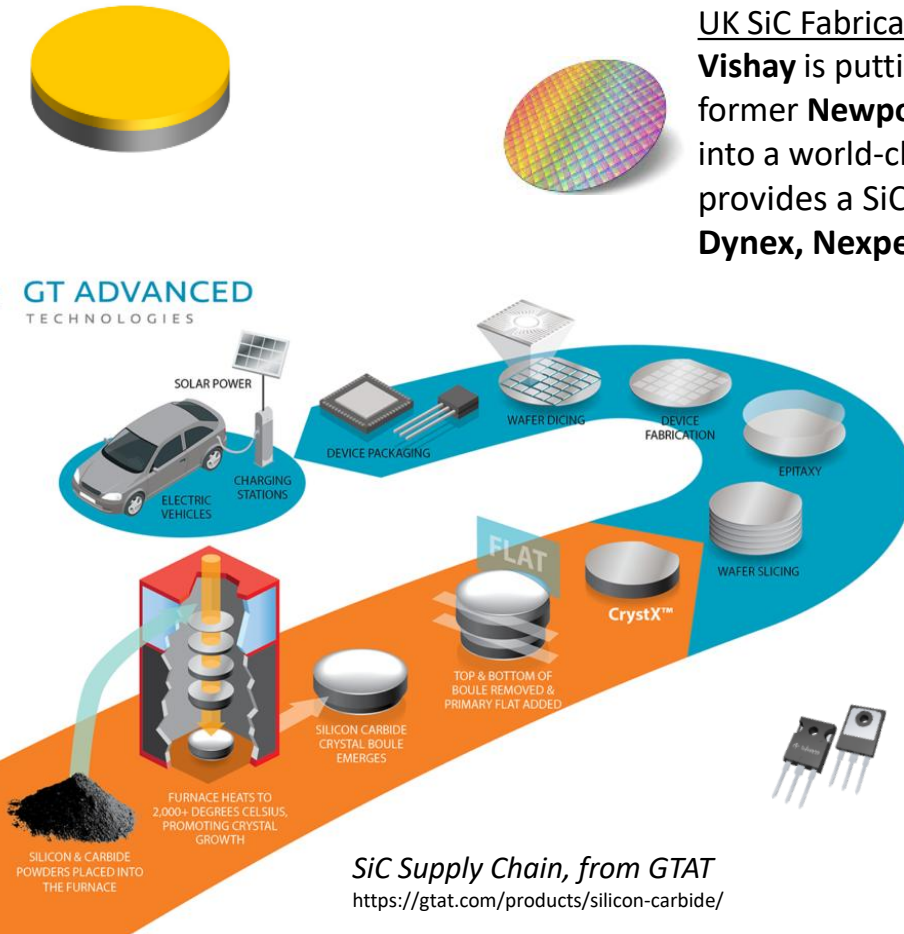


UK SiC inverter design

Motion Applied, **BorgWarner**, **CRRC**, **Ricardo**, **Turntide**, **TPS**, **ZF**, **Helix**

UK PEMD End users

Siemens, **Ford**, **Nissan**, **Alstom**, **JLR**, **BMW**, **Dyson**, **Rolls Royce**, **Bentley**.....



SiC Supply Chain, from GTAT
<https://gtat.com/products/silicon-carbide/>

UK SiC Fabrication Capability

Vishay is putting £100s millions into former **Newport Wafer Fab**, to turn it into a world-class SiC fab. **Clas-SiC** provides a SiC foundry device. **Dynex**, **Nexperia**, **ICEMOS**.

Semiconductor Equipment Suppliers

Oxford Instruments, **KLA**: provide bespoke tools for the SiC industry
Thermic Edge

UK SiC Packaging Capability

Custom Interconnect, **MicroChip**, **Dynex**, **CSA Catapult**, **TT Electronics**, **Micross**.



UK Perspective

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"The UK has developed a strength across the compound semiconductor supply chain. We have world-leading research, development, innovation, and commercialisation of the technology."

National semiconductor strategy 19 May 2023

However, the strategy also identified:

- The need for **Prototyping & Scale Up Infrastructure**:

"...better access to prototyping facilities for chip firms is needed to tackle barriers to innovation and grow the industry"

- The need for **Education and training**:

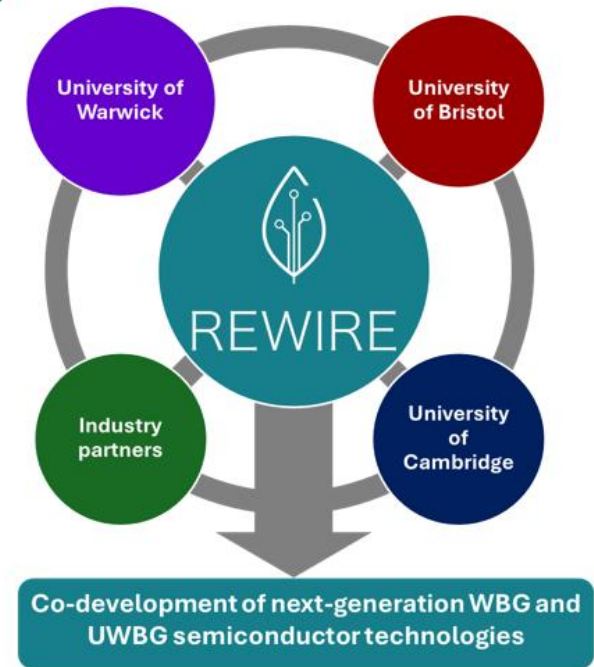
"Support innovation projects to address semiconductor skills shortages".



REWIRE Innovation and Knowledge Centre

- £12m funding awarded by UKRI to develop new WBG power semiconductors for a sustainable future
- As an *Innovation and Knowledge Centre*, REWIRE is focussed on commercialisation projects working on industry co-designed Case Studies.
- Utilising and sharing extensive design, fabrication and testing capabilities and expertise across three University partners.
- Opportunities to engage with REWIRE on the design, fabrication, reliability or utilisation of WBG semiconductors

Contact us for to find out more or join our mailing lists.



<https://rewire-ikc.org/>
rewire-ikc@bristol.ac.uk

REWIRE Innovation and Knowledge Centre

elementsixTM
DE BEERS GROUP



REWIRE



SIEMENS **TOSHIBA**



Fraunhofer



Device packaging

Device manufacture

Scale up

End user

Substrates and materials



Device design tools

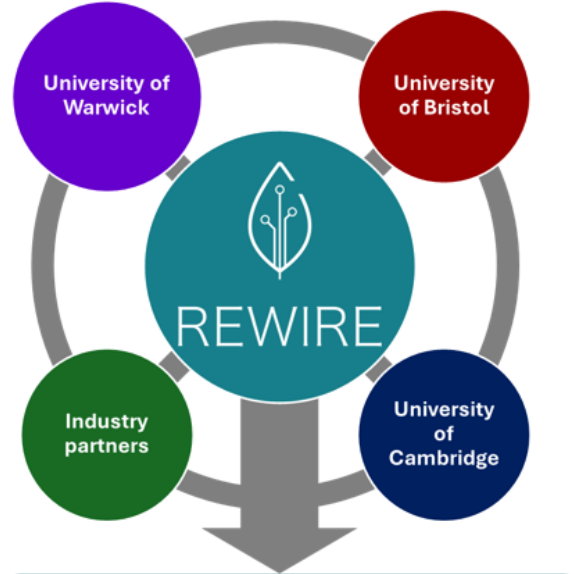
SILVACO

Cleanroom facilities



BOSCH

RENESAS

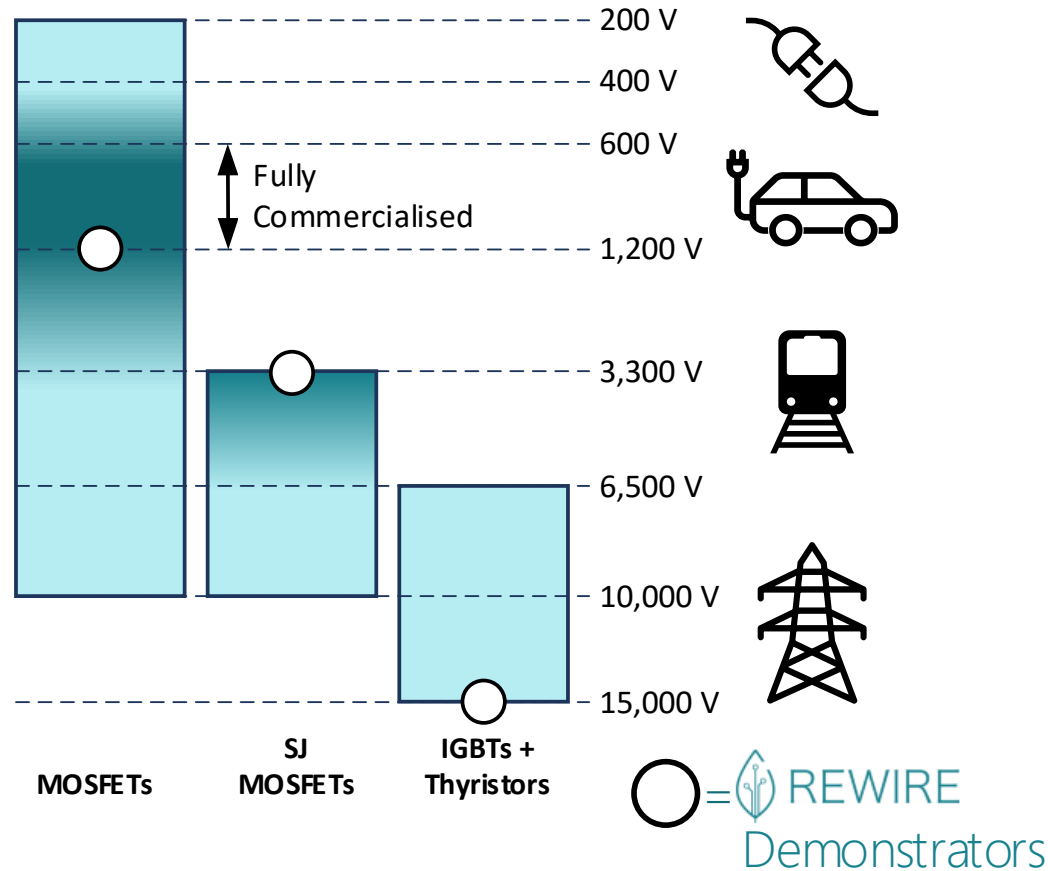


Co-development of next-generation WBG and UWBG semiconductor technologies



Use Case – SiC Power Devices

SiC Market by voltage, device type and commercialisation potential



- Demonstrators intended as **commercialisation platforms** for industrial partners.
- Power devices to serve today's automotive market and future electrification applications
- Intent to **lower the barrier** for fabrication process development and novel device design.

REWIRE SiC demonstrators

Structure	Voltage	Timeline
MOSFET	1200 V	Years 1-2
Superjunction MOSFET	3.3 kV	Years 3-5
IGBT & Thyristors	15 kV	Years 2-4

Use Case – SiC Reliability database



Reliability Testing

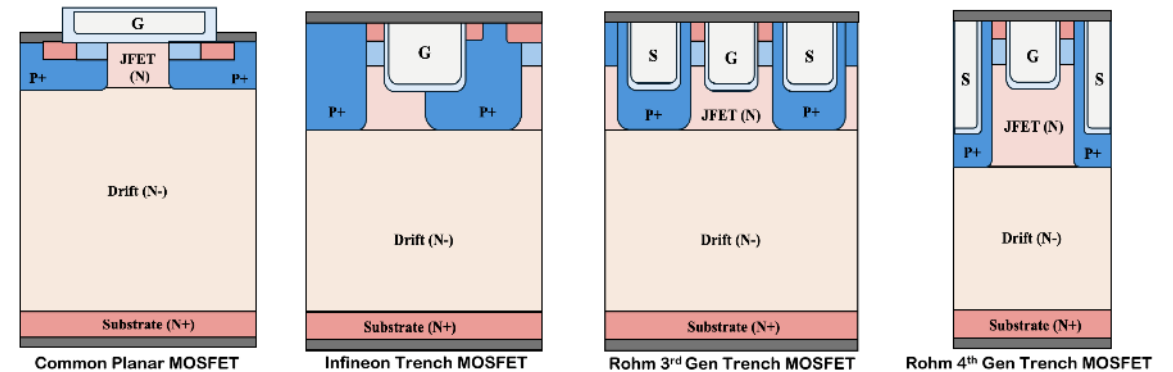
Equipment support from:



Short Circuit Testing
Avalanche
Bias Temperature Instability
Bipolar Degradation
3rd Quadrant Stress
Cosmic ray / neutron testing

- The REWIRE SiC **Reliability Database** will provide benchmark MOSEFT comparisons considering common failure modes.
- The latest **MOSFET variants** (trench vs planar) form all major manufacturers will be tested to, and beyond, industry standard testing

MOSFET Variants



TCAD
Simulation

REWIRE
Reliability
Database

Conclusions

A quiet revolution has been taking place with SiC power devices replacing legacy Si components driving increased inverter efficiency.

The boom in the SiC market continues, despite the EV slowdown.

The UK Semiconductor Strategy targeted compound semiconductors due in part to the credible supply chain for SiC within the UK.

Interventions such as the REWIRE IKC are bridging the gap from lab to fab, delivering IP translation, and industry engagement.

REWIRE will deliver new device technology, innovation platforms and a reliability database accessible by REWIRE partners.

