MONOLITH SEMICONDUCTOR INC.

# Redefining Power Conversion with Cost-Effective Silicon Carbide Technology


## SiC Manufacturing – The Fabless Approach

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# Fabless Silicon Carbide Power Device Company

MONOLITH SEMICONDUCTOR INC.

150mm SiC Wafer Supplier

150mm Silicon Foundry

Assembly

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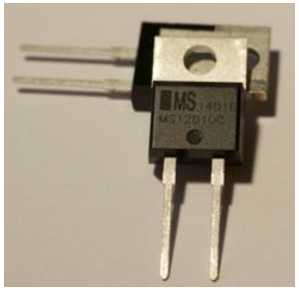
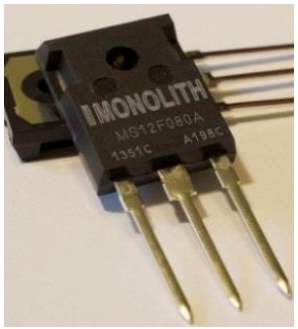
Design and Process IP
Application Knowledge

Customer







- SiC diodes and MOSFETs: 650V-900V-1.2kV-1.7kV+
- Monolith owns all SiC design and SiC process IP.
- Silicon compatible process; fabless, using high-volume 150mm CMOS foundry for manufacturing; low-cost.

# 150mm SiC Wafers – Game Changer

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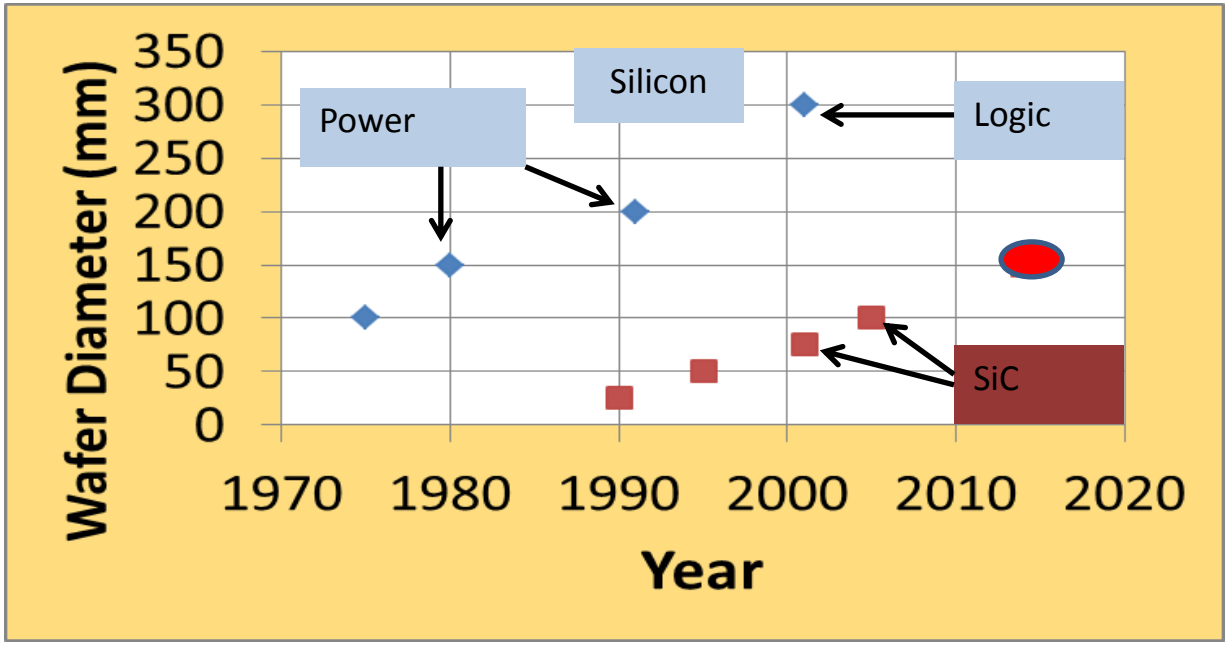


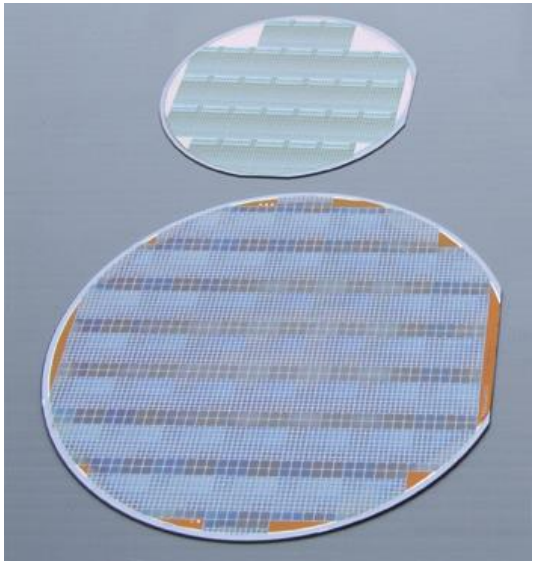

**6": 225% the area of 4"**

- **SiC power devices can be manufactured in 150mm silicon fabs.**
- **This is a technology that can be manufactured in US cost effectively.**
- **Monolith was formed with this vision.**
- **XFab, Texas is our foundry partner. It is a high-volume, BiCMOS fab primarily supplying automotive customer; excellent manufacturing systems.**

# Fabless Manufacturing Model

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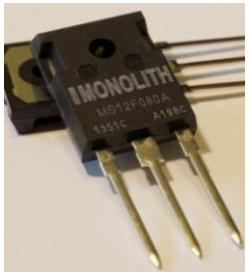
150mm Wafer Supplier

Starting Wafers

150mm Silicon foundry


Assembly House




Wafer specs

Design & Process

Processed wafers with switches

Tested wafers

Packaged parts

MONOLITH SEMICONDUCTOR INC.

- Device Design IP
- Process Technology IP
- High-voltage testing know-how
- Product qualification know-how

- Application Knowledge
- Product definition
- Design support
- Customer relation

Customer

# Fabless model – Advantages and Challenges

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**Advantages :**

- **Lower cost – piggyback on large silicon volumes**
- **Don't have to reinvent the wheel**
- **Matured manufacturing and quality systems – think automotive**
- **Fast time to market and scaling to high volume as demand picks up**

**Challenges :**

- **Convincing a high-volume silicon automotive fab to run a new material**
- **Lack of flexibility of processes**
- **Lack of SiC-specific tools**
- **IP control**
- **Risk allocation**

# Monolith's SiC MOSFETs - Prototype

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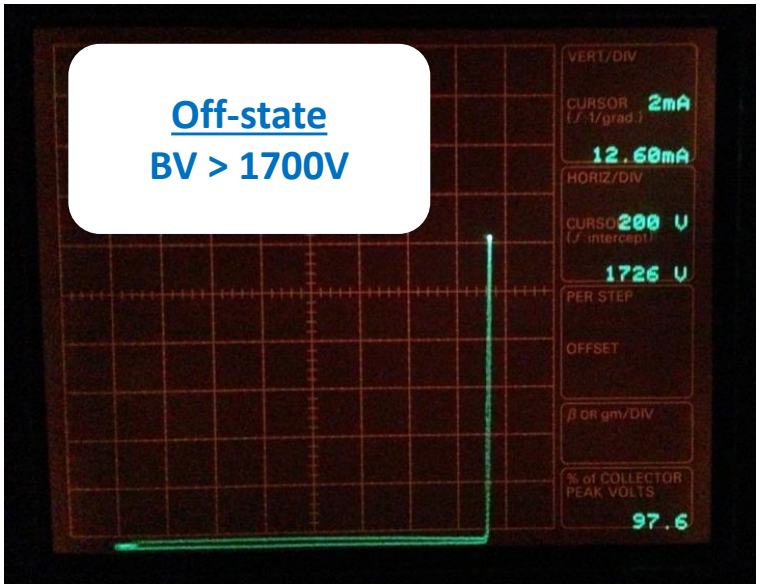
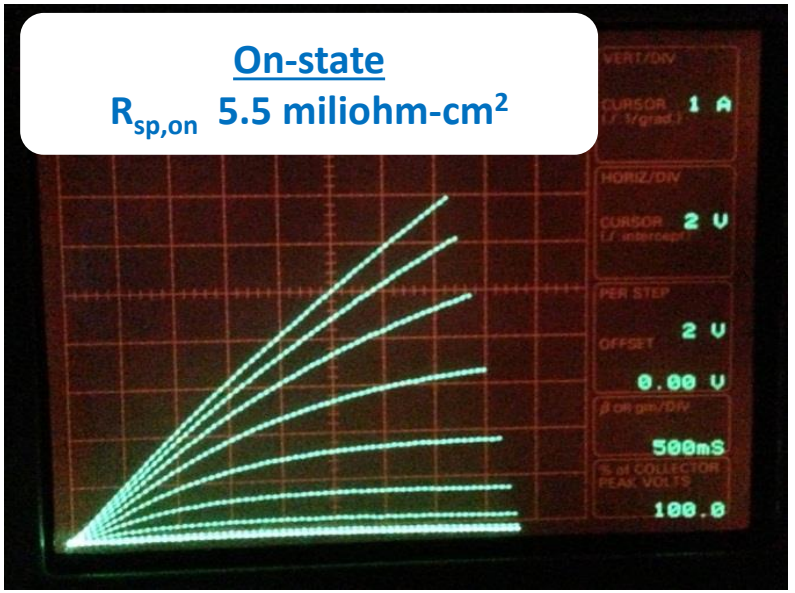
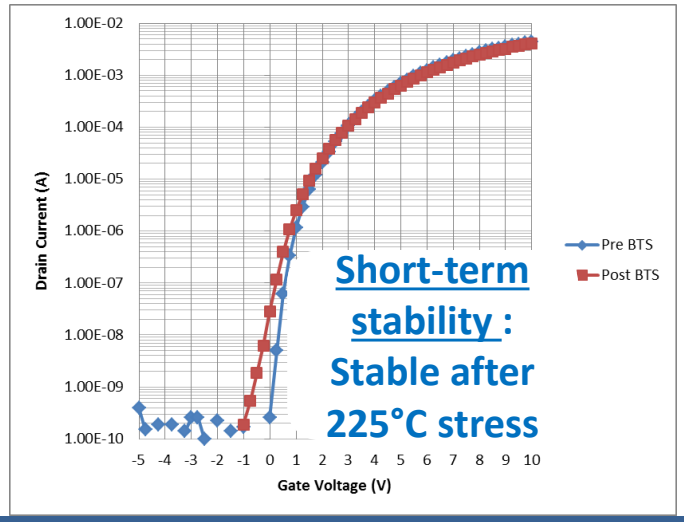


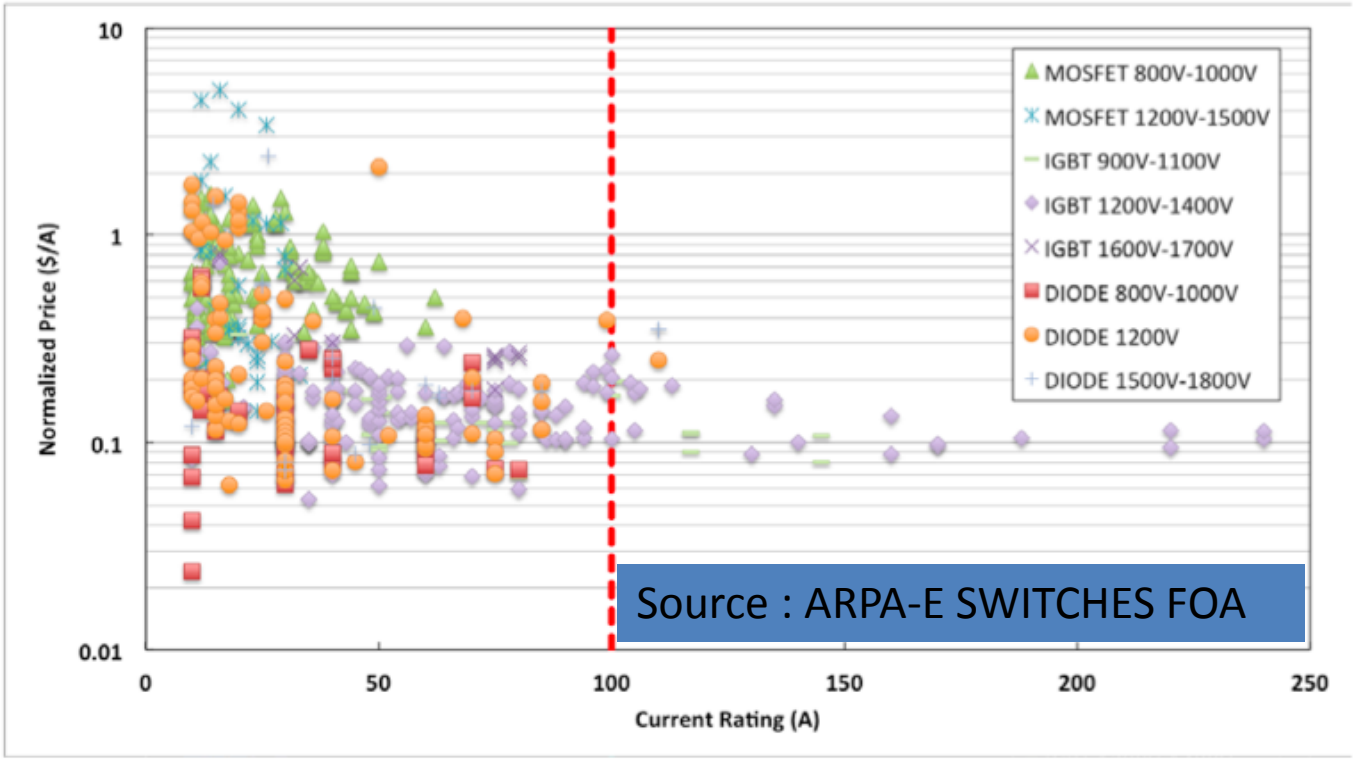




- **Prototypes built at Cornell University**
- **State-of-the-art performance**
- **Promising reliability results**

Supported by the Cornell Nanofabrication Facility and National Science Foundation (Grant ECCS-0335765)


Develop technology to manufacture wide bandgap switches at cost-parity with silicon IGBT prices < 10¢/A

**Figure 2: Si Power Semiconductor Prices**




Monolith Semi approach:

- Improve the performance (shrink die) through design and process innovation
- Utilize fabless business model to reduce production cost (depreciation costs)
- Manufacture on 150mm SiC wafers

Navigation +

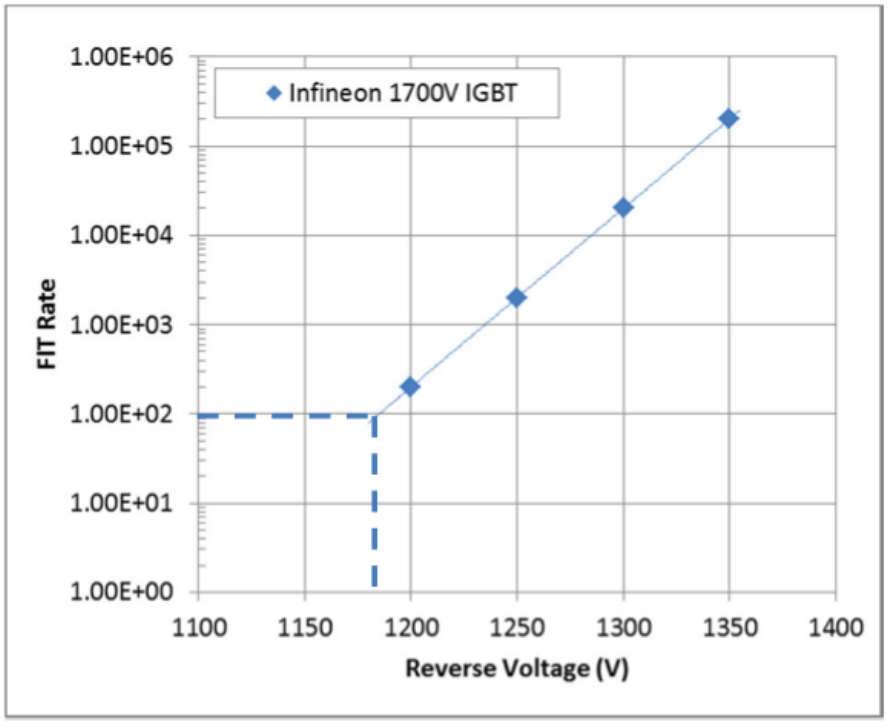
NC STATE UNIVERSITY

# MANUFACTURING INNOVATION


## THINK AND DO.

President Barack Obama and the U.S. Department of Energy (DOE) have tapped NC State to lead a $140 million advanced manufacturing institute that will unite academic, government and industry partners in an effort to revolutionize energy

# Project goal: Is de-rating necessary for SiC devices?




Reference: 'Selection of IGBT Modules and Safety Measures in Inverter Applications', www.infineon.com.

- Example 1700V Si IGBT data failure rate in FITs vs. reverse voltage data
- 1 FIT=1 failure in 1 billion hours
- Applied reverse voltage accelerates fails due to cosmic radiation
- Larger reverse voltage allows a smaller test time
- In this example, to limit failure rate to 100 FIT, maximum applied reverse voltage = 1175V

**Similar failure rate data needs to be generated for 1200V SiC MOSFETs**

# SiC Process Integration in Foundry

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1. Define process flow.

2. Identify toolset required for SiC process flow.

3. Modify tools to handle transparent SiC wafers.
   - Do not disrupt Silicon processing.
   - Lead time
4. Verify unit step process operation on SiC wafers.
   - Identify, develop and demonstrate process changes required to achieve required process capability on SiC wafers

5. Evaluate process capability for each unit step on SiC substrates and epiwafers

**Variations in wafer backside finish impact tool handling and processing/uniformity.**

# First SiC pin diode results on 150mm SiC wafers

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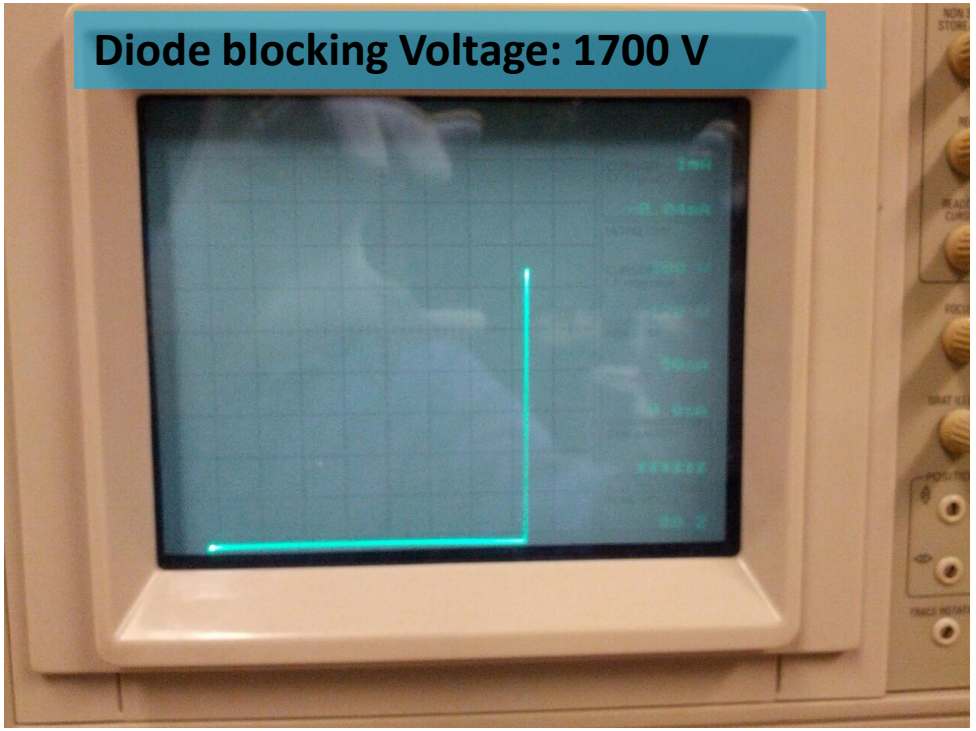
- Developed basic process steps for photo, oxides, etc.
- Required numerous tool modifications and changes to run SiC wafers.
- Demonstrated 1700V SiC diodes on 150mm wafers processed on a silicon line.





**First SiC power device fabricated in US on 150mm SiC wafers in a silicon CMOS fab**

# SiC MOSFET Price Target at High Volumes (by 2019)

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# SiC MOSFET Price Roadmap at High-Volume

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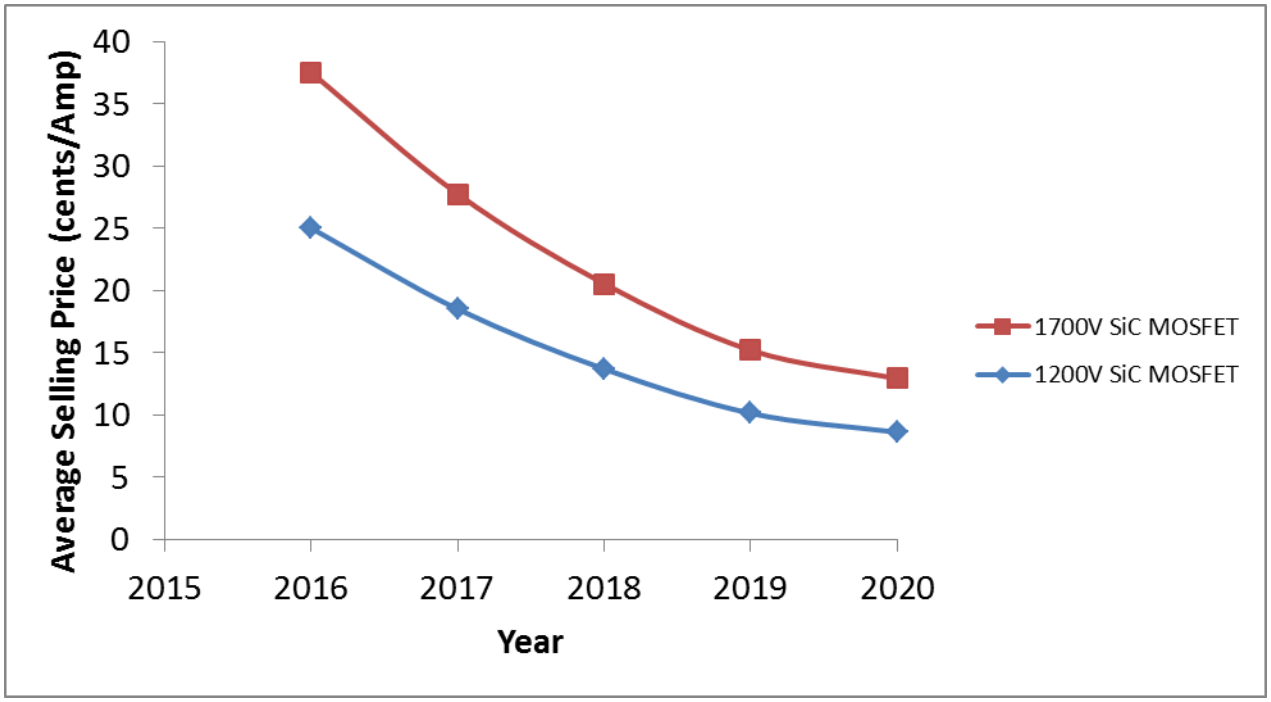


- **SiC power device price will drop rapidly over next 5 years, 1200V MOSFET price can be ~10cents/Amp at high volumes.**
- **The key is to generate the confidence in reliability and supply of parts from multiple sources. If we can achieve this, SiC devices will become mainstream and will take significant market share from silicon.**

# Summary

MONOLITH SEMICONDUCTOR INC.

Monolith Semi is a fabless SiC device supplier focused on 650-900-1.2kV-1.7kV+ SiC diodes and MOSFETs.

We have demonstrated 1200V, 5.5 mOhm-cm$^2$ SiC MOSFETs with stable operation at 225°C.

We are transferring our SiC processes into a high-volume, 150 mm silicon foundry. We are targeting to run SiC wafers in parallel with silicon wafers on the same process tools.

We have demonstrated initial SiC processes, including demonstrating 1700V SiC diodes.

# Acknowledgments


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