SiC Power Device Development for Clean Energy Applications

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SemiSouth

Business Strategy

SemiSouth Laboratories is a clean energy enabler

specializing in the design & manufacture of silicon carbide (SiC) Devices and power modules used to harvest and transfer power in renewable energy systems, telecom server farms & hybrid electric vehicles.

Solar

Servers

HEV

Wind

SemiSouth

Corporate Snapshot

- **First & only company to offer cost effective SiC technology for power management**
- **Corporate & Sales Offices: Austin, Texas**
- **Manufacturing Facility: Starkville, Mississippi**
  - Brick-and-Mortar revenue capability = $60M annualized
- **Total Employees:** 50 employees
- **Ownership:** Privately owned by strategic investors (II-VI, Schneider Electric Ventures), venture capital, and employees

Experienced Fab Personnel

Multiple Etch & PECVD systems

Significant Investment in equipment being qualified for production <u>NOW</u>

- ~25% cycle time reduction expected

Multiple Metal systems

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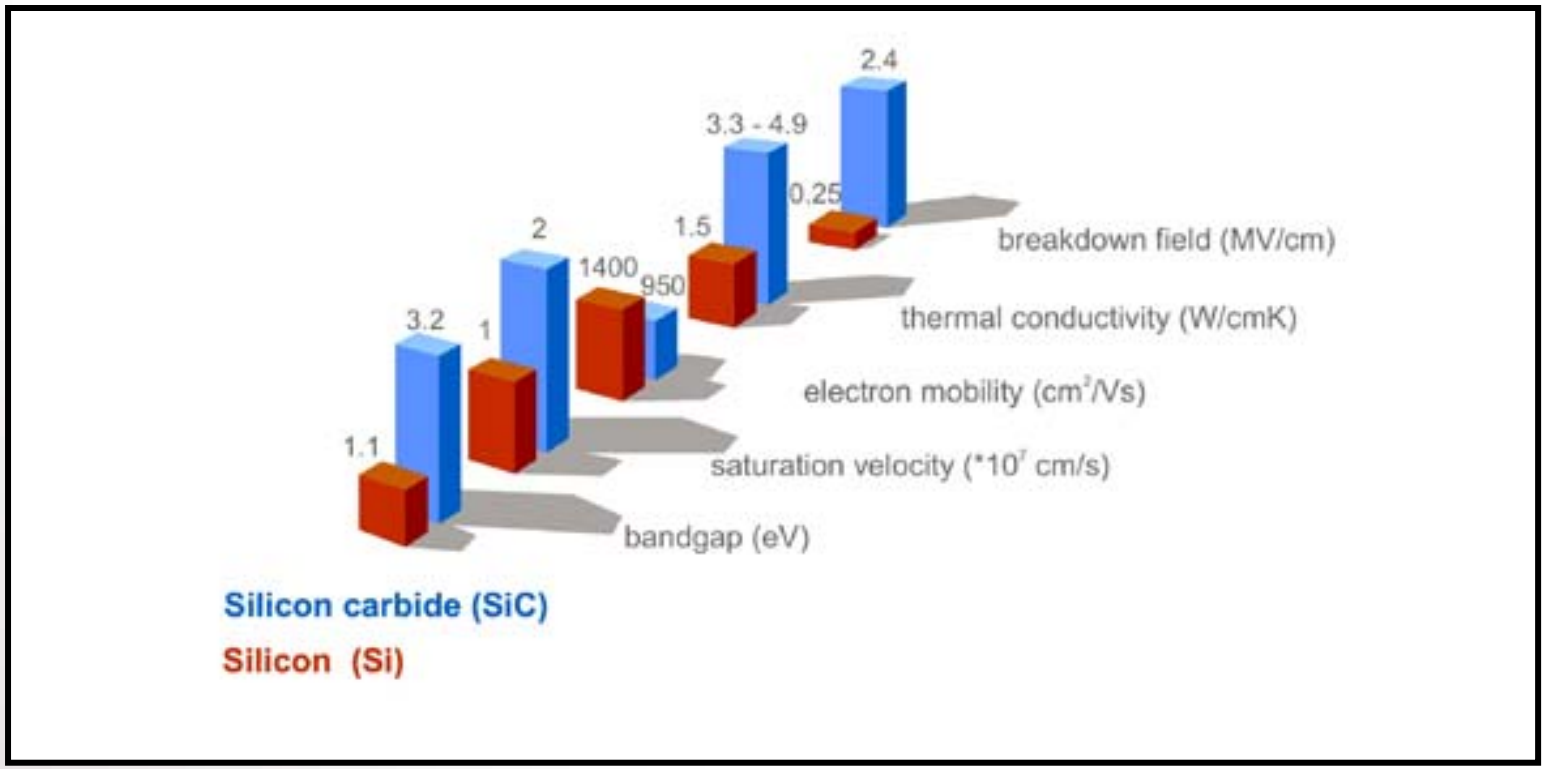
Why Silicon Carbide?



It's three to ten times better than silicon for power efficiency!
It enables system performance which is IMPOSSIBLE in Si!

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SiC Enables Clean Energy

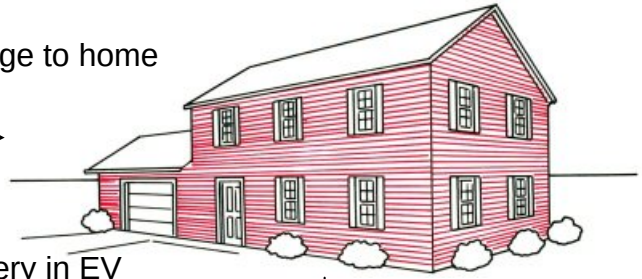
DC voltage (400 V to 2 kV)

DC voltage (400 V to 2 kV)

AC voltage back to grid for distribution and storage

Inverters (DC-AC)

AC voltage to home

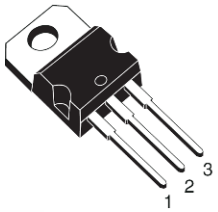
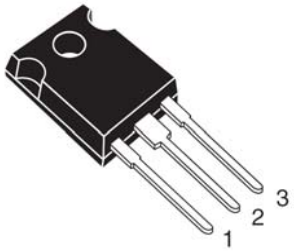
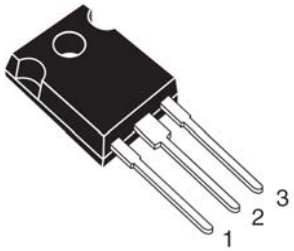
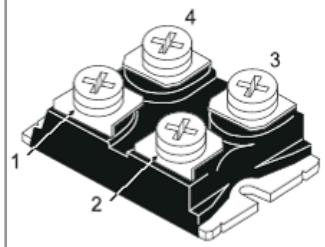


AC to battery in EV

On-board DC from battery to AC in motor

SILICON CARBIDE ENABLES SOLAR, WIND, EV inverters
– 50% reduction in energy distribution losses and reduced equipment costs

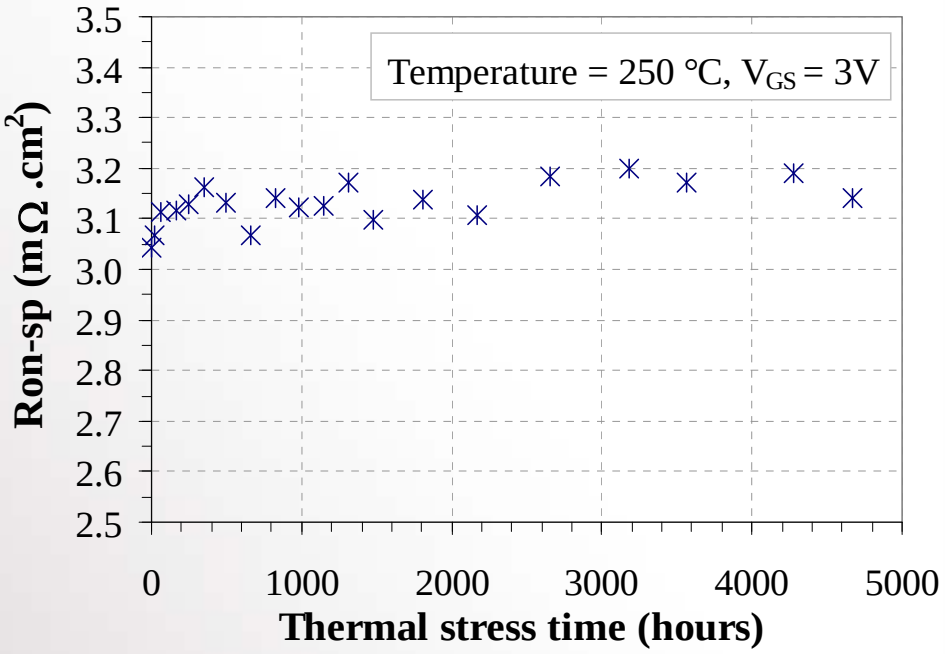
SemiSouth Near-term Product

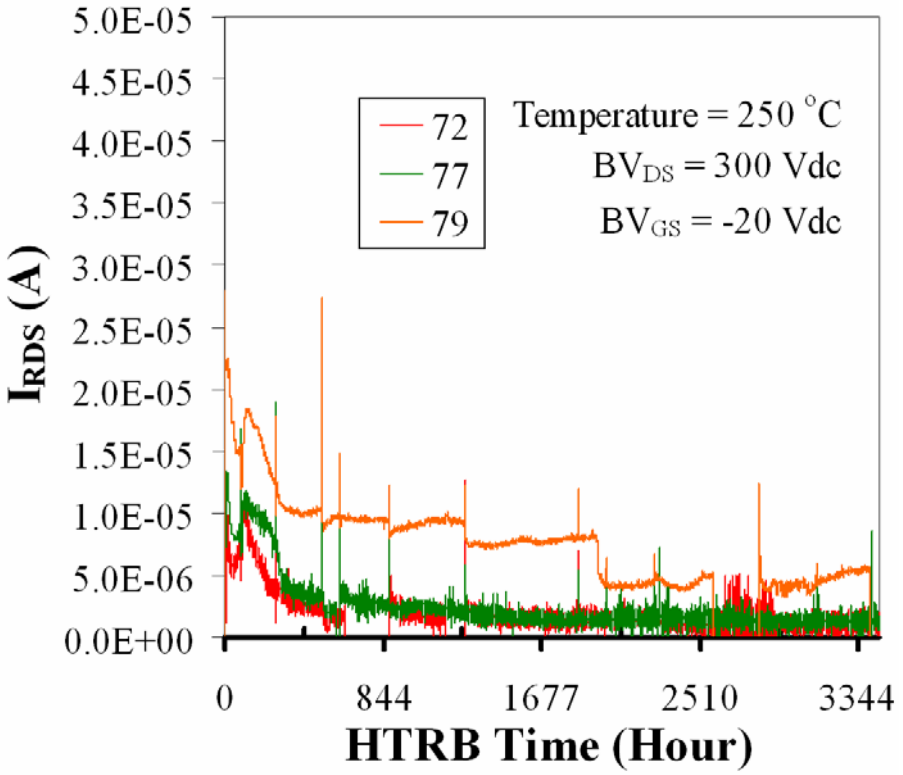
Part Number	SJEP120R200	SJEP120R125	SJEP120R63	SJEP120R32
Package				
Id (cont)	**5A**	**15A**	**30A**	**50A**
Rds (0n)	**200 mOhm**	**125 mOhm**	**63 mOhm**	**32 mOhm**
Samples	**Q4 08**	**Now**	**Q3 08**	**Q4 08**

1200 V Class Products for power level applications from 300 W to 30 kW approaching commercialization

SemiSouth offers normally-off SiC JFET's (OFFET™) and normally-on SiC JFET's

JFET Reliability (Pre-Qual)

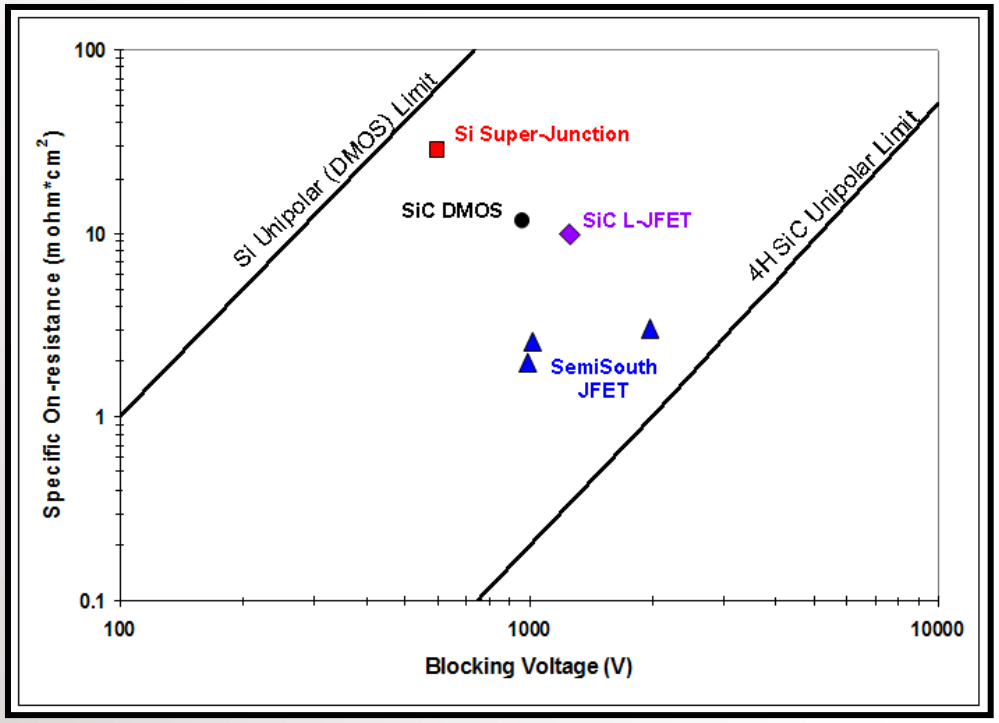


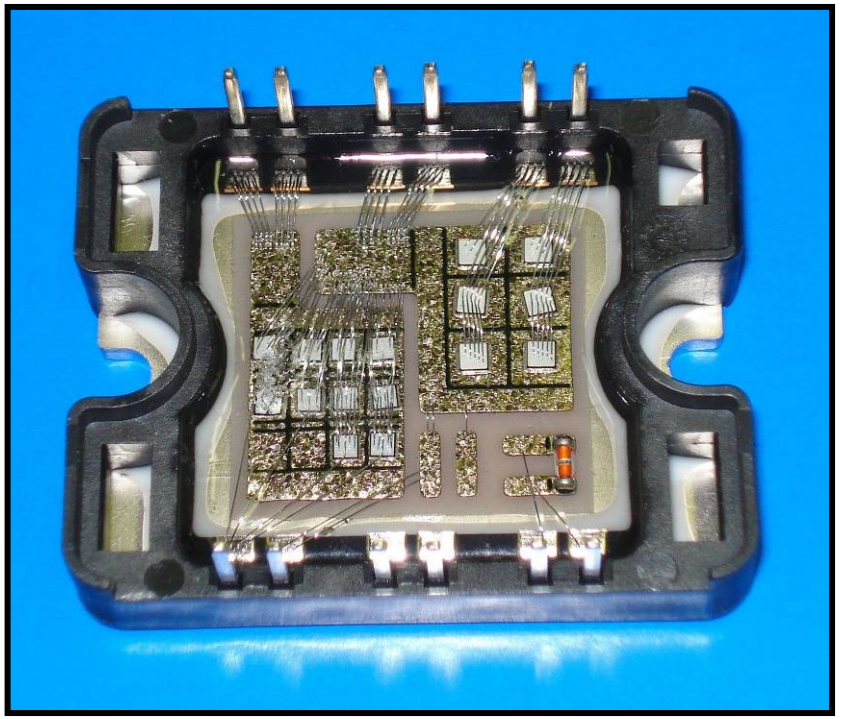


1200 V Class Products are Unipolar Devices and VERY RELIABLE

SemiSouth Progress in EV

6 kW drive demo demonstrated NOW – scaling to automotive power levels (60-200 kW)
Dramatic improvements in power density, efficiency, and thermal management





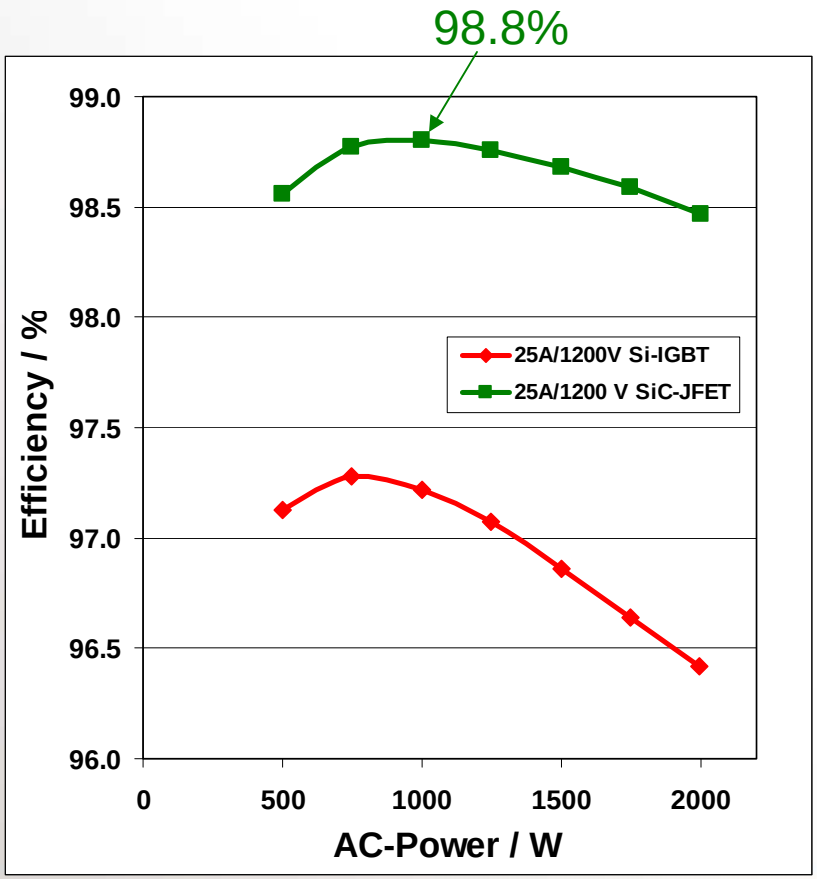
6 kW electric drive demo with SemiSouth SiC transistors and diodes

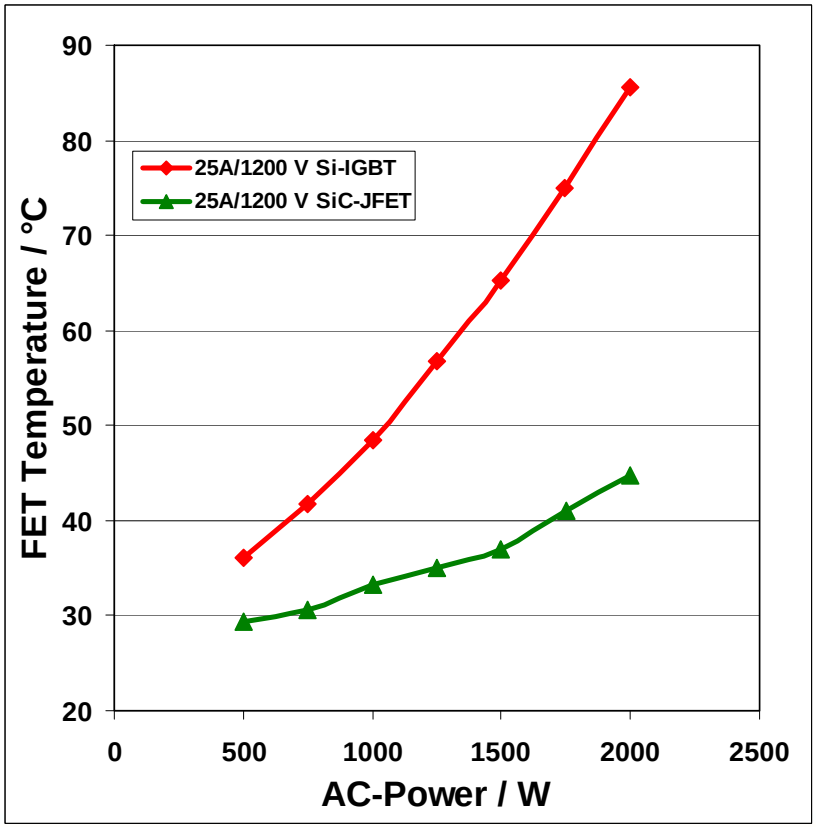
SemiSouth Progress in Solar

SiC OFFET™ in Solar Inverter

Third Party Evaluation of 2 kW Inverter
16 kHz, 350 V DC Input, module
1.6% improvement over Silicon IGBT

Fraunhofer Institut Solare Energiesysteme

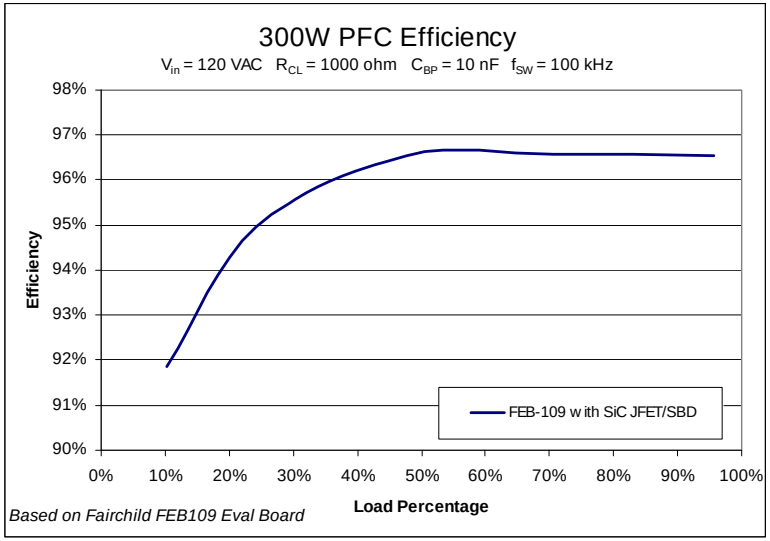


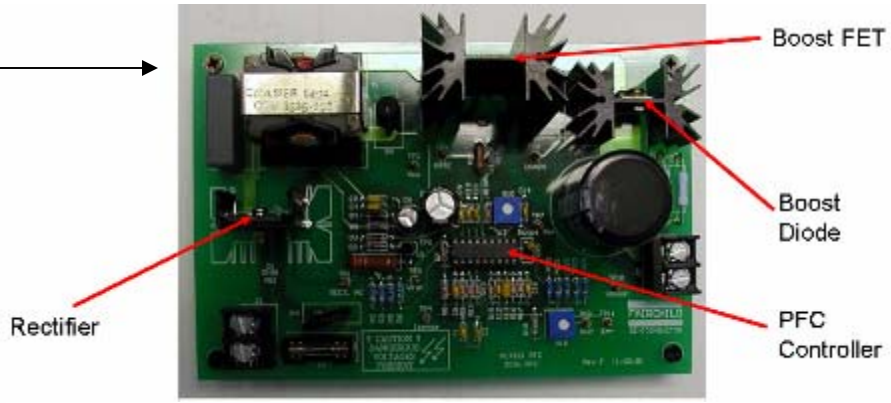


SemiSouth Progress in SMPS

Drop-in OFFET™ demo in Power Supply

- Drop-in Replacement with no topology or control changes!
- Replaced Fairchild IGBT with SemiSouth SiC OFFET™
- Efficiency improvement possible through optimized design
- Fairchild Evaluation Board Detail:
  - 300W Off-line Power Factor Correction (PFC) Switch Mode Power Supply (SMPS)
  - ML4281 PFC controller (average current mode control w/ CVR)
  - 100 kHz

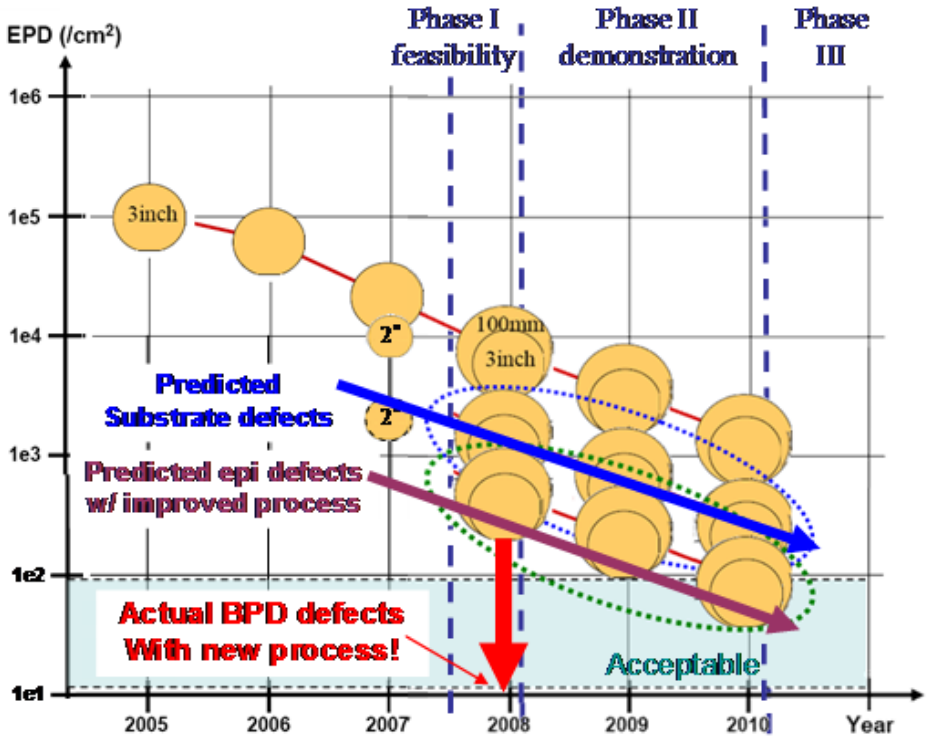




SemiSouth Progress in HV

Material Scaling for High Voltage Devices (> 3 kV) – Funded by DOE Phase I

- Basal Plane Dislocations (BPD)
  - Impact Bipolar SiC devices
  - Bipolar Devices in SiC required above 3 kV
  - BPD's lead to stacking faults
  - Stacking faults lead to device instability
  - SemiSouth eliminated BPD's in Phase I from DOE (2007-08)!

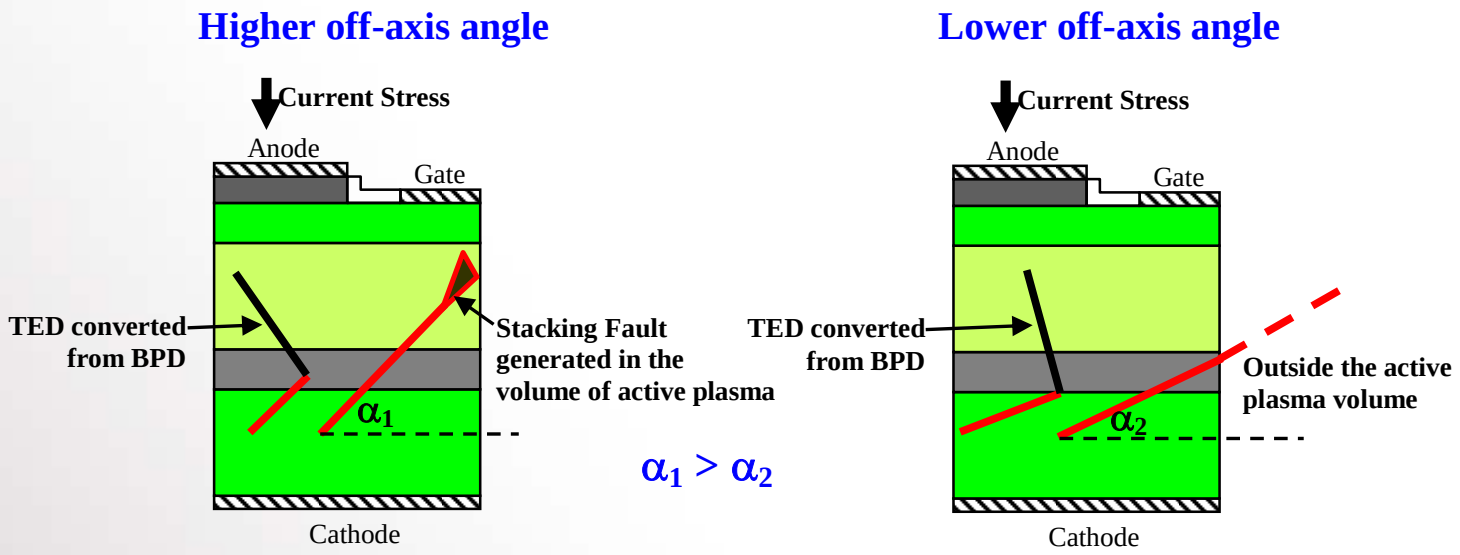


DOE Phase I – Grant # DE-FG02-07ER84693;
Thanks to Dr. Imre Gyuk, DOE Energy Storage Program and Dr. Stan Atcitty, Sandia National Laboratories for support.

SemiSouth Progress in HV

How the BPD propagates into the SiC Bipolar device structure

- BPD's generated in SiC Bipolar Device Active Area Leads to Voltage Drift
- Growing Epitaxy at lower off-axis angle allows us to eliminate defects by converting BPD to Threading Edge Dislocation (TED)



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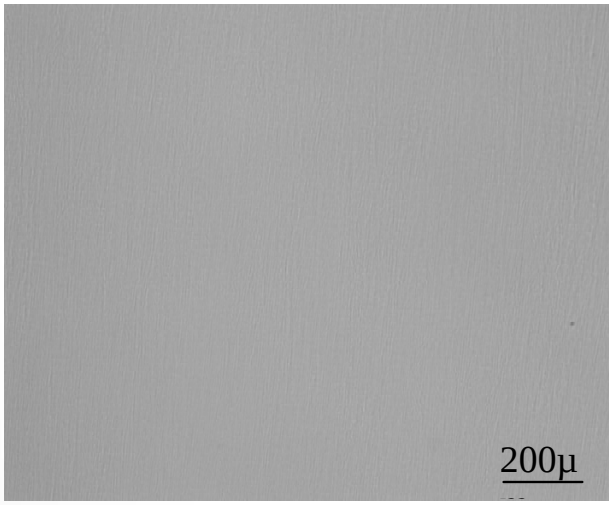
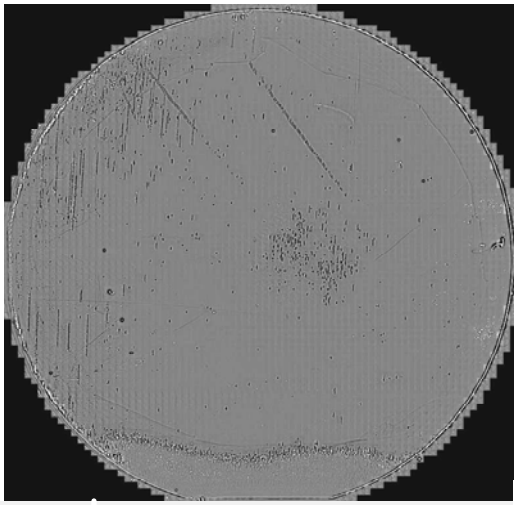
SemiSouth Progress in HV

SemiSouth's SiC epitaxy structure with ZERO BPD! (DOE Phase I Result!)

- Nomarski image (left) and UVPL image (right) of an 11 um thick epitaxy layer (1.5 kV epitaxy structure) with no BPD's
- SemiSouth has demonstrated 100 um thick epitaxy layers (20 kV epi structure) in other funded efforts

Measurement results courtesy of Naval Research Lab (UVPL), SiCrystal (KOH etch), and Mississippi State University (KOH &PL)





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2° off-axis	Etch Pit Density (EPD) Avg / Min / Max (cm-2)	Basal Plane Defects Avg / Min / Max (cm-2)
Virgin Substrate	4.61e4 / 2.15e3 / 1.72e5	1.27e3 / 0 / 7.15e3
Post SemiSouth Epi	6.66e4 / 3.58e3 / 3.12e5	**None**

Summary

- SemiSouth is only company offering normally-off (OFFET™) or normally-on JFET
- Third party measurement of 98.8% peak efficiency in solar inverter (Fraunhofer) using SemiSouth OFFET™
- Strong SiC Epitaxy Materials Development (funded by DOE & others) is allowing SemiSouth to scale up device structures above 3 kV through elimination of BPD
- Further Development needed to push into higher power class for Wind Energy (MW) and other classes requiring high-power, reliable bipolar structures