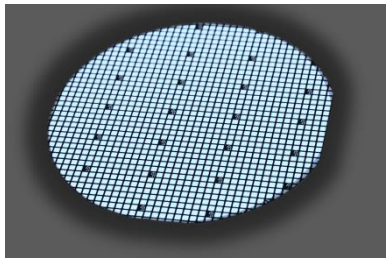



SIC MANUFACTURING IN THE FOUNDRY MODEL

SEPTEMBER 2014

Company History

SiC Research
Launched by
Rutgers University

Prototypes DC-DC Converters, High Frequency Power Switch, SiC Modules for DOD, DOE

Prototypes of SiC
Schottky Diodes, MOSFETs, JFETs

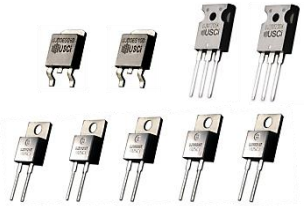
ACQUIRED BY DOLCE MGMT TEAM

Princeton, NJ
"Einstein's Alley"

New HQ Established
Built in-house 4''FAB

Fab-Lite model
On-Line With Foundry Partner To Increase Capacity

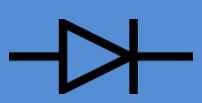
Q1: Production Release xR
1200V & 650V JBS Diode Series
1200V Normally-on JFETs



Q4: Production Release
1200V Cascode Series

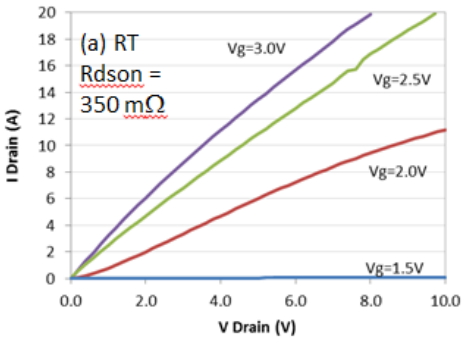
1999 2002 2005 2009 2010 2012 2014

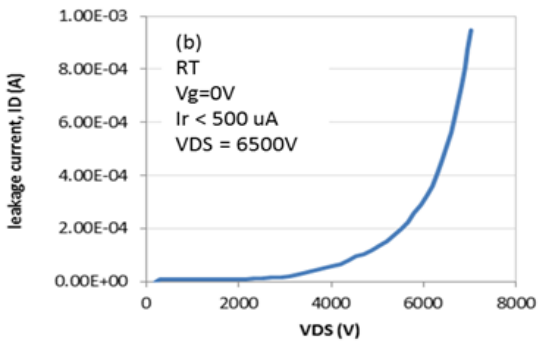
SiC Technology Focus Areas

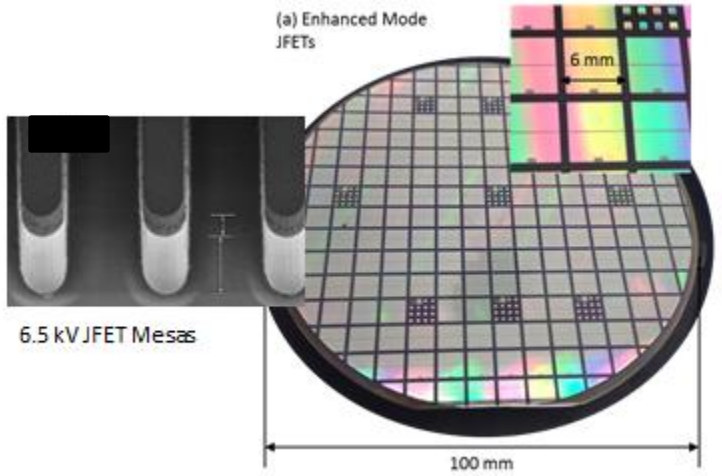
JBS	JFET	MOSFET	IC
			
650V – 16kV	**650V-6.5kV**	**1200V – 10kV**	**50V**
Low V_F Zero Q_{RR}/T_{RR} 175°C package 250°C die	Normally On & Off Ultra low FOM Minimal E_{ON} & E_{OFF} 175°C package 250°C die	Low $R_{DS(ON)}$ Low Q_{GD}, Q_G 150°C	500°C $T_{J(MAX)}$

USCI 6500V DEVICES PROTOTYPES

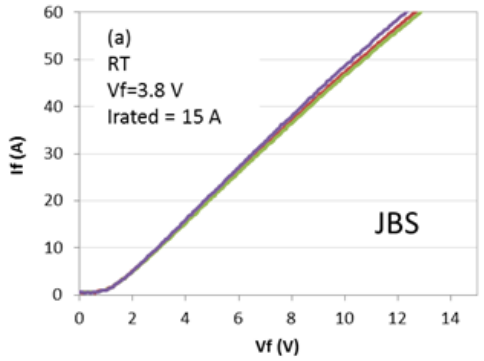
6.5KV N-off JFETs

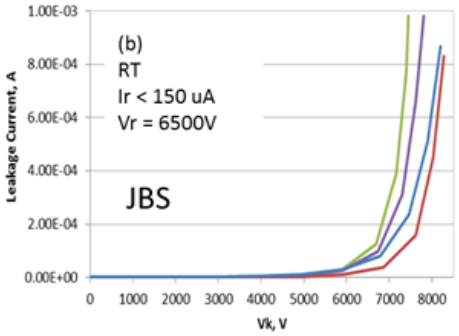


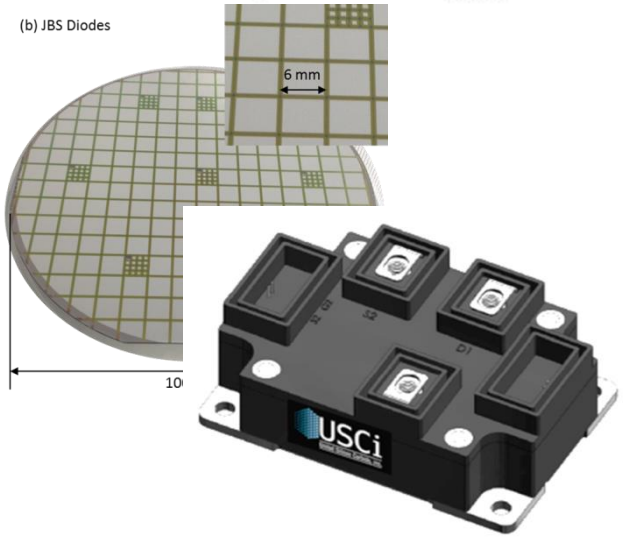




6.5KV JBS Diodes







History of the foundry model in power devices

2008-today
Expansion to 12inch limited. New FAB investments small - most suppliers trying to exploit overcapacity at 8inch. Outsourcing older tech to meet demand.

2005-2008
8inch Foundry model applied to FS-IGBTs and Superjunction technologies. Top suppliers still operate in-house FABs.

Late 90s-2000s
8inch Foundry model appears for low voltage MOSFETs – while most incumbents are still at 6inch

1970s-1990s
Power Discretes use custom processes and architectures. Fabs work with previous generation CMOS equipment. Top suppliers own their FABs (5in-6in)

The foundry model in SiC

PROS

- Silicon foundries bring a lot of established baseline expertise and manufacturing discipline
- High uniformity and high throughput processing equipment
- Foundries of sufficient scale with a solid (non-SiC) base business can offer reduced process costs
- By aggregating the SiC business from multiple companies, they can generate more economies of scale
- Capital efficient for ramping volume production

CONS

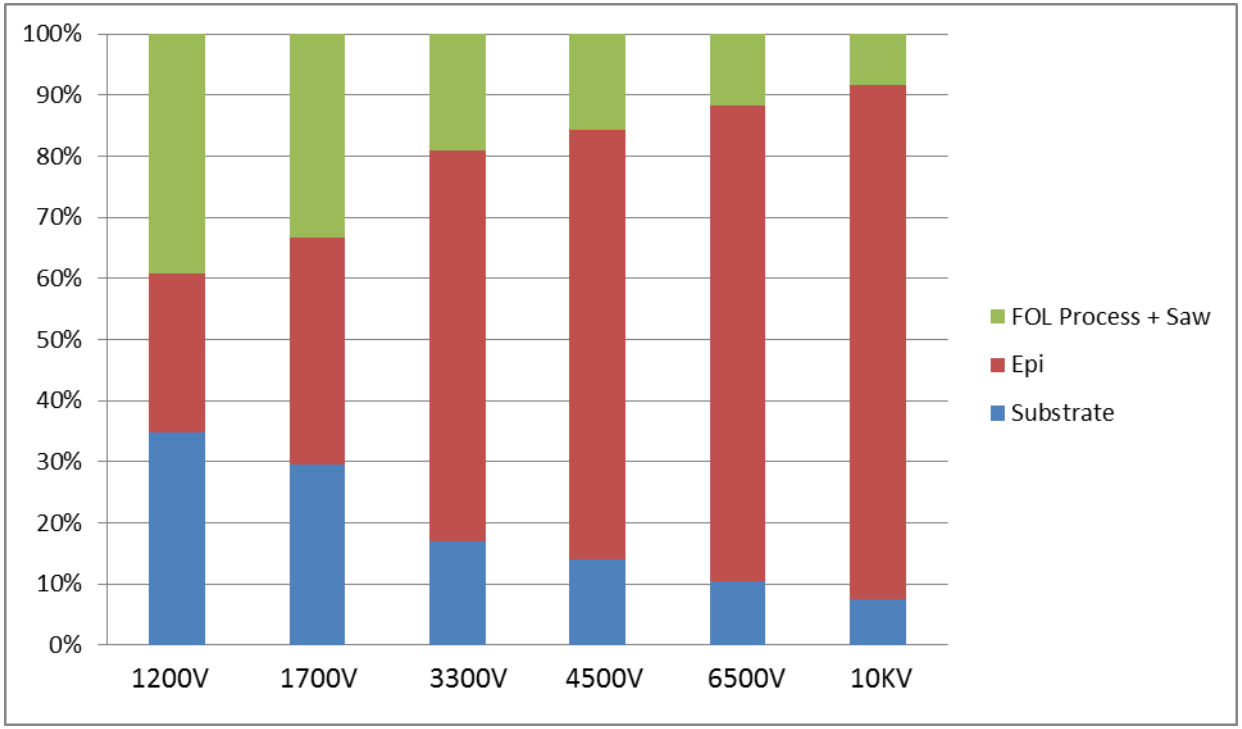
- Most foundries need consigned equipment to enable a SiC process
- Concerns about IP protection – exclusivity can defeat the cost benefit from volume aggregation.
- Speed of technology development
- Volume projections in the near term 2-3 years are still too low to justify large investments
- Capacity and engineering resource allocation

Economics of 6inch foundry process costs

Fab size	Fab Outs/mo	Monthly Running costs	Cost/Wafer at 80% utlization
Small	1000	$1,000,000	$1,250
Small	10000	$2,000,000	$250
Medium	30000	$3,000,000	$125
Large	60000	$4,000,000	$83

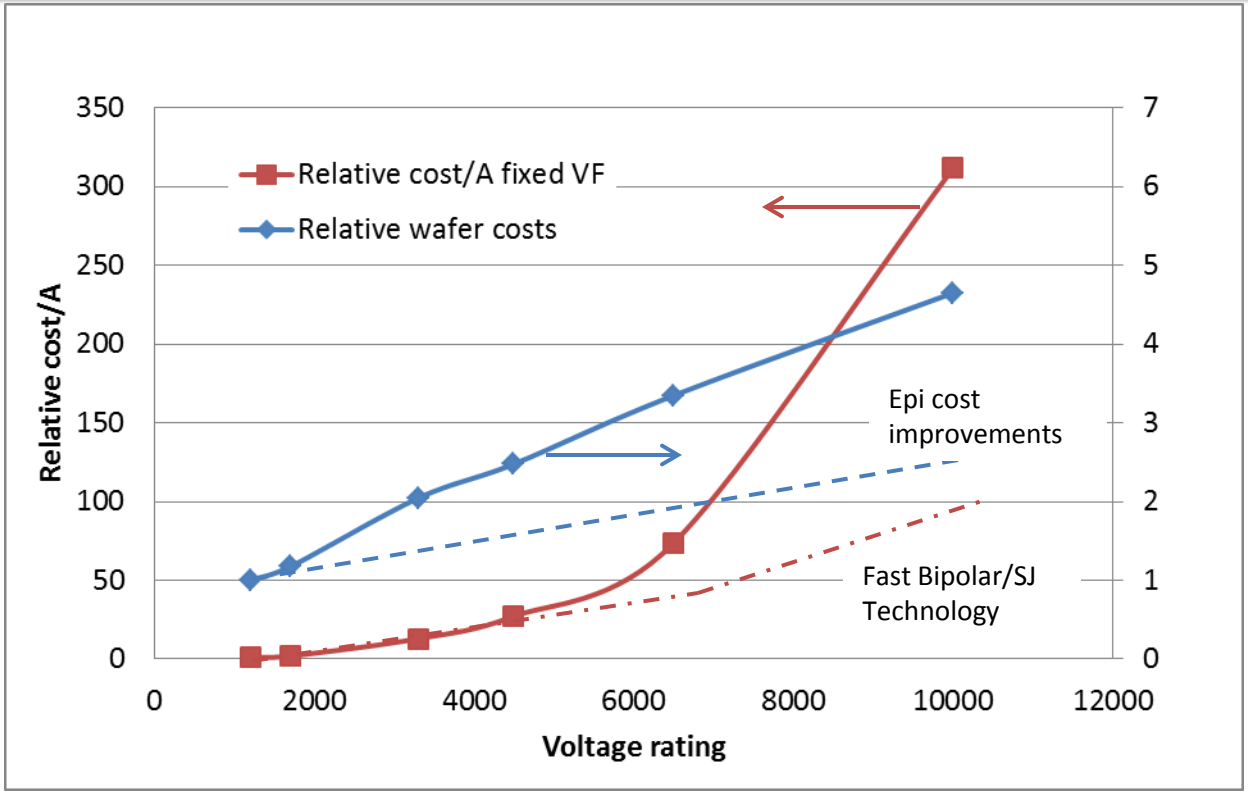
- Total fab volume and utilization drive costs – must find SiC volume drivers, or share the factory with other volume contributors
- High cost tools with limited throughput drive up costs – SiC has several such bottlenecks in epi, implant, backgrind, saw. These are being rapidly improved.

High voltage devices and their cost drivers



- Epi cost dominates present day SiC high voltage costs – area needing rapid improvement in throughput without worsening quality
- For pure unipolar devices (JBS Schottky, MOSFET, JFET), several large chips needed for meet the current requirements.

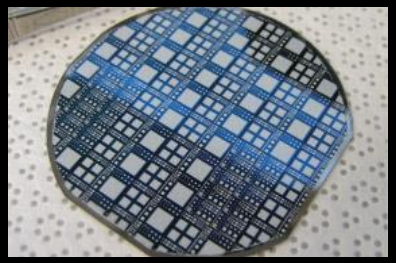
Transistor/diode costs



- Unipolar device costs always increase with voltage rating since RdsA α $BV^{2.5}$
- Flattening the epi cost curve can drive down costs substantially
- Long term: need to get bipolar options to flatten the RdsA – BV relationship

Summary

- The foundry model brings down wafer FAB costs, allow volume ramp with targeted capital expenditures, and brings Si high volume manufacturing capability to SiC.
- This translates both to stable high yields, as well as the ability to quickly deliver large volumes.
- Technological progress is needed and ongoing to drive down epitaxy costs for >3300V devices.
- Insertion of medium voltage diodes into IGBT modules can bring benefits in efficiency and improved operating lifetimes from lower operating temperatures.
- HV transistor solutions have a lot of promise, and initial products must be seeded to allow engineers to work on all the system issues with fast switching at 5-10KV.




Thank You!

USCi Welcomes Your Questions

United Silicon Carbide

732-355-0550