NC STATE UNIVERSITY

PowerAmerica

PowerAmerica

AMO Peer Review
Washington, DC
June 14, 2016

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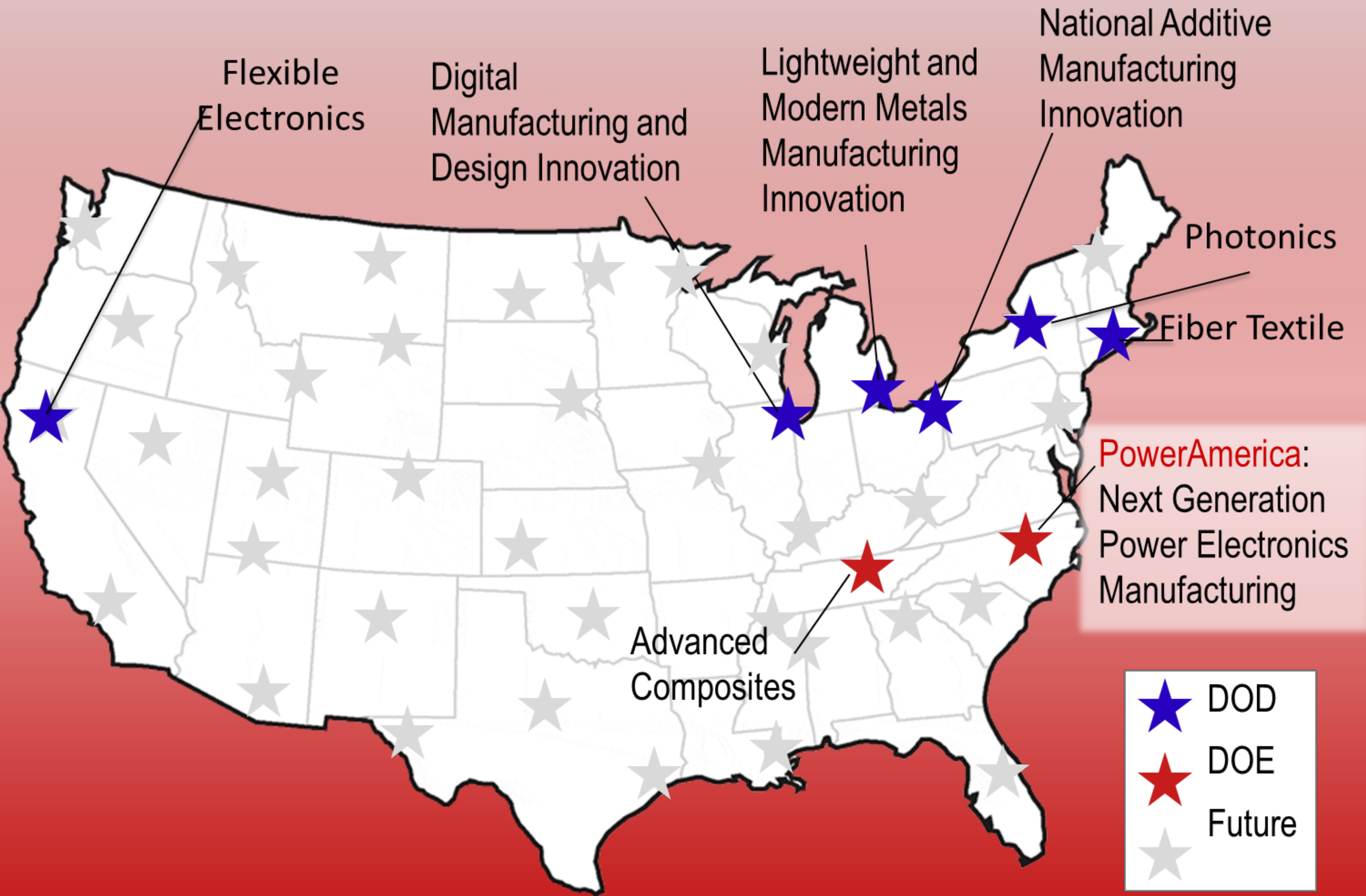
National Network for Manufacturing Innovation



Technology Readiness Levels and Manufacturing Readiness Levels

TRL 1:	Basic principles observed and reported	MRL 1:	Manufacturing feasibility assessed
TRL 2:	Technology concept and/or application formulated	MRL 2:	Manufacturing concepts defined
TRL 3:	Analytical and experimental critical function and/or characteristic proof of concept	MRL 3:	Manufacturing concepts developed
TRL 4:	Component and/or breadboard validation in a laboratory environment	MRL 4:	Capability to produce the technology in a laboratory environment
TRL 5:	Component or breadboard validation in a relevant environment	MRL 5:	Capability to produce prototype components in a production relevant environment
TRL 6:	System/subsystem model or prototype demonstration in a relevant environment	MRL 6:	Capability to produce prototype system or subsystem in a production relevant environment
TRL 7:	System prototype demonstration in an operational environment	MRL 7:	Capability to produce systems, subsystems or components in a production relevant environment
TRL 8:	Actual system completed and qualified through test and demonstrated	MRL 8:	Pilot line capability demonstrated; Ready to begin Low Rate Initial Production
TRL 9:	Actual system proven through successful mission operations	MRL 9:	Low rate production demonstrated; Capability in place to begin Full Rate Production

NNMI Target (TRL 4–7 / MRL 4–7)

Source: NNMI prelim design report.

- Fundamental Principles
  - Cost of devices will be tied to Volume.
  - People have to believe WBG Power electronics are reliable.
  - System Level Value:
    - Size, Weight, Power, Higher Frequency and Efficiency.

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Foundry approach is having an impact for SiC.

GaN foundry approach is less clear.

Reliability needs to be a community effort. Standards!

Demonstration in applications is important, for proof of concept, but also to obtain confidence in technology.

Manufacturing Achievements BP1

- X-Fab Announces First 6-inch SiC foundry offering
  - 5 PowerAmerica Members used X-Fab
  - X-Fab in discussions with several other partners

- USCI: SIC Diodes, MOSFETS
- Genesic: Diodes
- Monolith: Diodes, MOSFETS
- ABB 3.3kV MOSFETS
- Jay Baliga, Integrated Diode
- Future: JFETS, SJTs etc.

- Members anticipating commercialization of some of the above products in 2017 using X-fab.

SiC Foundry at the Scale of Silicon

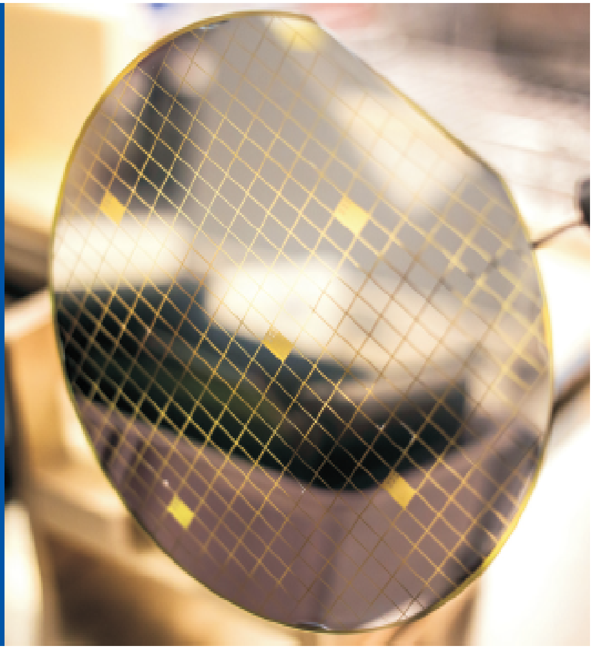
XFAB
MIXED-SIGNAL FOUNDRY EXPERTS

First 6-inch SiC foundry offering

X-FAB has established a 6-inch Silicon Carbide foundry line fully integrated within our 30,000 wafers/month silicon wafer fab located in Lubbock, Texas. With the support of the PowerAmerica Institute, X-FAB's goal is to accelerate the commercialization of SiC power devices by leveraging the economies of scale, automotive quality system and equipment set that have been established in of its silicon wafer fabrication line.

SiC Process Capabilities

- High Temperature Implant
- High Temperature Implant Anneal
- SiC Wafer Thinning
- Backside Metal Deposition (Ti/Ni/Ag)
- Backside Laser Anneal
- Ni Deposition and Etch



Manufacturing Achievements BP1

- CREE Buys APEI - New Company Wolfspeed will IPO
  - Vertical Integration offers increased capability, Increased US competitiveness.
  - 3.3 kV and 10 kV devices being qualified
  - Wolfspeed modules released.

Last March
Last May
This May

CAS325M12HM2

Wolfspeed Sets a New Standard for Power Electronics with All-SiC High Performance Half-Bridge Power Module & Gate Driver Combination

The first commercial product developed and manufactured by Wolfspeed's Fayetteville operation redefines high current power density, efficiency, and performance.

Manufacturing Achievements BP1

- Agile Switch- Released WBG Product
  - Fast funding allowed project to be completed for APEC.
  - Gave Agile Switch a first to market advantage.
  - ~100 organizations following-up to evaluate system

1200V/300A GATE DRIVER KIT

150kW/25kHz HEAT SINK (Embedded Heat Pipes)

200kW/30kHz HEAT PIPE ASSEMBLY

Manufacturing Achievements BP1

- John Deere- Project acceleration achieved. Proceeding to vehicle deployment of 200 kW 1050 V inverter in BP2 ahead of schedule. Commercialization in 2019.

- Toshiba – Project acceleration achieved. Proceeding to design/build of 50 kW PV inverter product for product release in 2017-18.

- Navitas – Demonstrating a 25W “wired” fast charger (>93% efficiency, >10W/in3) at a lower $/W than existing silicon-based systems, representing a nearly 70% increase over existing best-in-class 15W chargers in their same footprint.

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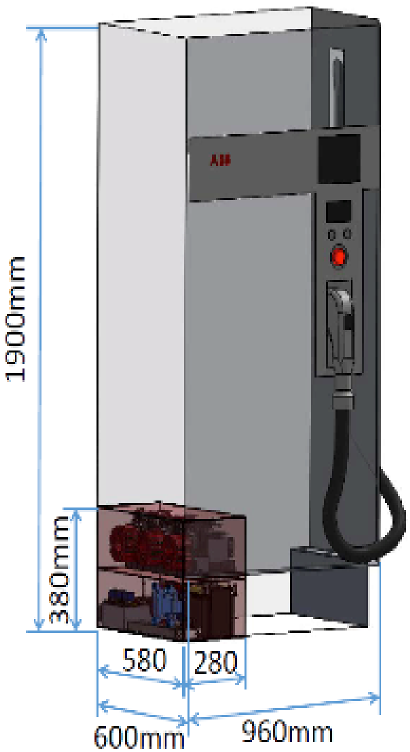
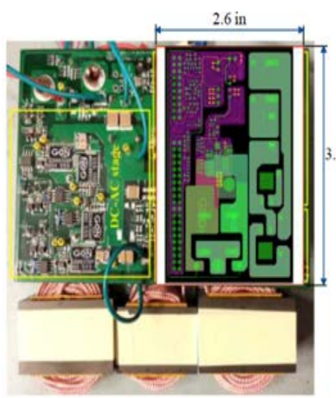
A few of Academic Achievements BP1

- Demonstrations of Volume Reduction and Efficiency Increase

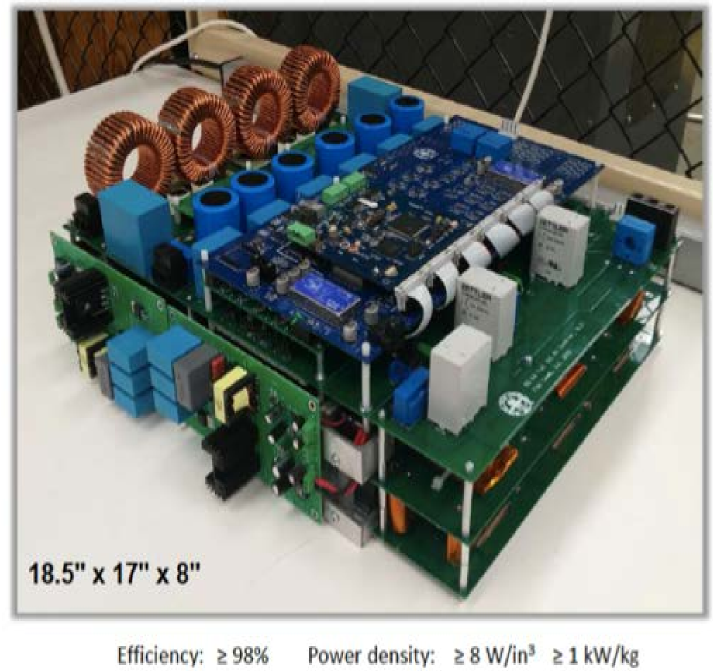


Lukic – MV Fast Charger
10 x size reduction;
4x weight reduction
Cheaper Installation

Husain/Hopkins – 55kW inverter for EV
3X denser than Toyota Prius
12.1 kW/L close to 13.4 kW/L DOE 2020 Goal



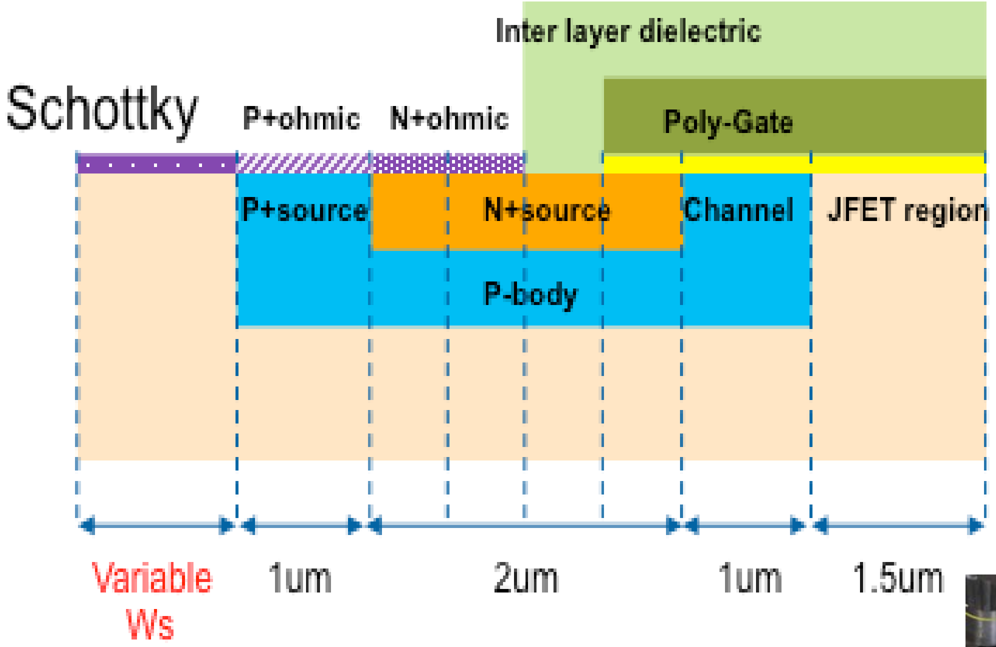
Ayyaner
Transformerless
Micro inverter
12.8 W/in3



Li - Gen-1 50 kW Silicon Carbide Based
Transformerless Photovoltic Converter
98% Efficiency, 8 W/in3
Takes Advantage of Novel Topology

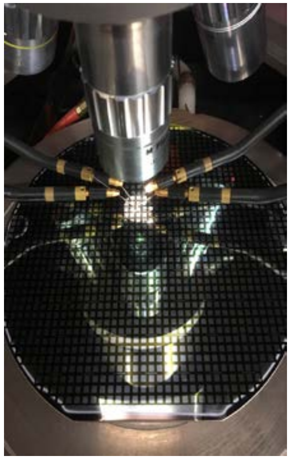
A few of the Academic Achievements BP1

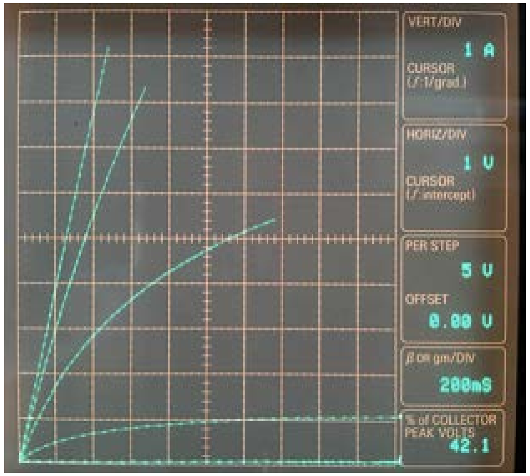
- Wide Band Gap Semiconductor Devices and Education



Baliga/Sung: JBSFET
Reduces Component Count
Higher performance Lower Cost
First Academic SIC Device utilizing Foundry Model.
1st Wafers electrical performance close to predicted.

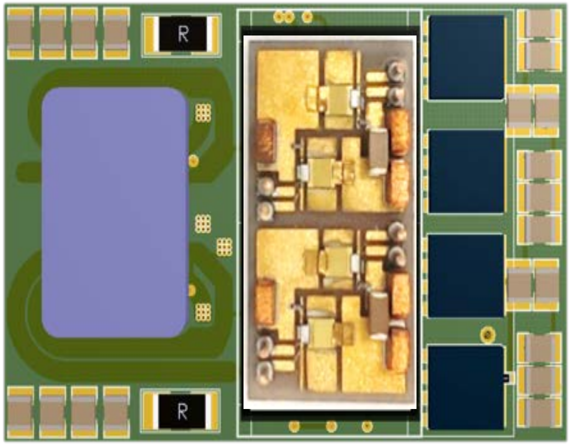
- V. Misra – Improved SiC channel mobility while maintaining low Vt Shift.
- U. Misra – Improved Dielectrics for GaN devices.
- S. Chowdury – 10 mm ~8 Amp HEMT. with > 1000V breakdown.





Teaming Accomplishments BP1

- Especially strong university / industry relations
- Subhashish Bhattacharya – CREE, Lockheed Martin, Monolith
- Fred Lee – Transphorm, Navitas,
- Transphorm – NC State, Virginia Tech



Lee- 700W/in^3 projected (without cap)

Ecosystem Accomplishments BP1

- Engaged with Numerous Organizations
  - RTCC, NCSEA, IPC, SMTA, PSMA, NCMBC, PEIC, FREEDM, Clean Energy Center, NDU, expanding interactions with additional universities.
- Involved in Economic Development Activities
  - Interfaced with Centennial Development, SBDTC, NC Dept. of Commerce
  - Strengthening Relationships with Critical members through Master Research Agreements. In discussions with companies moving to NC.
- Socialized Device Bank Concept with Industry
- Examining licensing potential of PowerAmerica Process
- Annual Meeting Extremely Successful based on Member and Executive Committee feedback.
- APEC Meeting: 14 papers, Web traffic doubled,
  - 12 new contact leads for membership, Numerous repeat contacts

Papers Published APEC

- “Design, Package, and Hardware Verification of a High Voltage Current Switch” NC State University, Adam Morgan
- “Effective Control & Software Techniques for High Efficiency GaN FET Based Flexible Electrical Power System for Cube-Satellites” NC State University, Subhashish Bhattacharya
- “Effective Control & Software Techniques for High Efficiency GaN FET Based Flexible Electrical Power System for Cube-Satellites” NC State University, Subhashish Bhattacharya
- “Series Injection Enabled Full ZVS Light Load Operation of a 15kV SiC IGBT Based Dual Active Half Bridge Converter”, NC State University Suyash Shah
- “Conducted EMI Analysis and Filter Design for MHz Active Clamp Flyback Front-End Converter” VA Tech, Fred Lee,
- "Power Semiconductors Enabling Next Generation Applications" GeneSiC,
- “Medium Voltage (>= 2.3 kV) High Frequency Three-Phase Two-Level Converter Design and Demonstration Using 10 kV SiC MOSFETs for High Speed Motor Drive Applications”, NC State University, Sachin Madhusoodhanan,
- “Design and Evaluation of Isolated Gate Driver Power Supply for Medium Voltage Converter Applications”, NC State University, Ashish Kumar,
- “A SiC-based Power Converter Module for Medium-Voltage Fast Charger for Plug-in Electric Vehicles” NC State University, Srdjan Lukic,
- “A MV Intelligent Gate Driver for 15kV SiC IGBT and 10kV SiC MOSFET”, NC State University, Ashish Kumar / Subhashish Bhattacharya,
- “Decomposition and Electro-Physical Model Creation of the CREE 1200V, 50A 3-Ph SiC Module”, NC State University, Adam Morgan,
- “Digital-Based Interleaving Control for GaN-Based MHz CRM Totem-Pole PFC”   VA Tech, Fred Lee,
- “A Novel AC-to-DC Adaptor with Ultra-High Power Density and Efficiency” VA Tech, Fred Lee,
- “Design Consideration of MHz Active Clamp Flyback Converter with GaN Devices for Low Power Adapter Application” VA Tech, Fred Lee,

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WBG Semiconductor Material Properties Are Ideal for High Voltage/Temperature Power Applications

Semiconductor Material	Energy Bandgap (eV)	Critical Electric Field (MV/cm)	Thermal Conductivity (W/m·K)	Saturation Velocity (10^7 cm/s)	Mobility ($cm^2/V\ s$)	Dielectric constant (ε_s)	Intrinsic Carrier Conc. (cm^{-3})
GaN	3.44	3.3	195	2.7	1500	9.5	$1.9\ 10^{-10}$
4H-SiC	3.26	2.2	380	2	950	9.7	$3.4\ 10^{-8}$
Si	1.12	0.25	150	1	1350	11.8	$1.5\ 10^{10}$

- **Wide Bandgap**
  - High temperature operation with reduced cooling requirements (lower n_i)
  - Radiation hard operation
- **Large Critical Electric Field**
  - High voltage operation at lower resistance
  - Increased speed, smaller dimensions
- **Large Thermal Conductivity**
  - High power operation with lower ΔT due to self-heating
- **Large Saturation Velocity**
  - High Frequency operation with reduced size of passives (less weight and volume)

SiC wide band-gap results in an intrinsic temperature of over 1000 ºC

WBG power devices offer low-resistance at high voltages and operation at elevated temperatures

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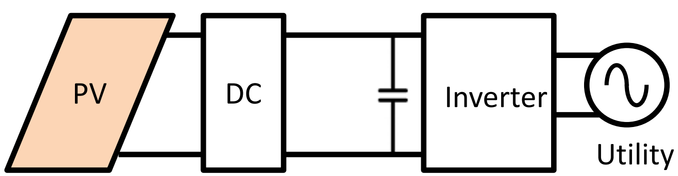
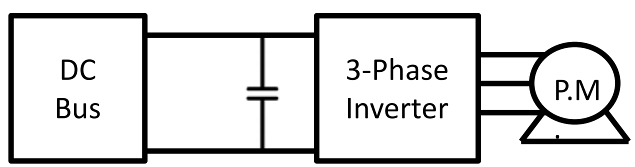
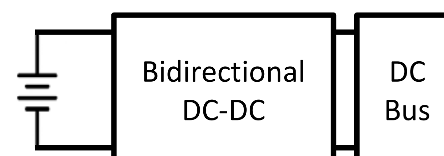
WBG Low-resistance at High Voltage and Elevated Temperature Operation has Commercial Applications

Commercial applications:

- Hybrid/electric, all/electric vehicle systems
- Grid-tie renewable energy inverter systems
- DC-DC converters
- Charge and discharge of energy storage systems
- Regenerative power (brakes, elevators, etc.)
- More electric aircraft and ship (floating microgrid)
- Deep well drilling
- Battery and solid-state converter systems for power distribution network stabilization







*A 27-MW 15-minute NiCd battery bank at Fairbanks Alaska stabilizes voltage at the end of a long transmission line

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WBG Low-resistance at High Voltage and Elevated Temperature Operation has Military Applications

Hybrid Electric/All-Electric Vehicles

• Selective interconnect could enable 100-500kW converters for high temperature environments (improved fuel economy, enhanced stealth capability, auxiliary field power generation, and limp home advantage)

Multi-level Solid State Power Substation (SSPS) (Power distribution, utilities, etc.)

• SiC enables >50% size & weight savings over iron core transformers

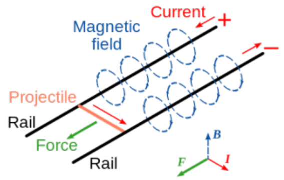
• Mobile lightweight efficient power converters for renewable energy, reduce logistics

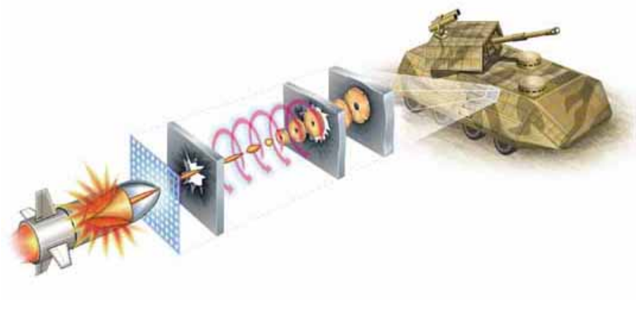
Tallil Airbase, Iraq

Pulsed Power Systems : Increased Action capability for military systems

• Electromagnetic Railgun and

• Electromagnetic Active Armor





More electric aircraft: electric systems replace non-propulsive hydraulics and pneumatics

Electric warship: Power Conditioning for Propulsion and Weapons (EM Railgun, High Energy Laser Shield)

USS Zumwalt DDG 1000 destroyer is US Navy's first "all-electric" ship

USS Zumwalt all electric destroyer

Strategy for Wide Adoption of WBG Semiconductor Devices

Vision

Accelerate Wide Adoption of WBG Semiconductor Devices in PE Systems

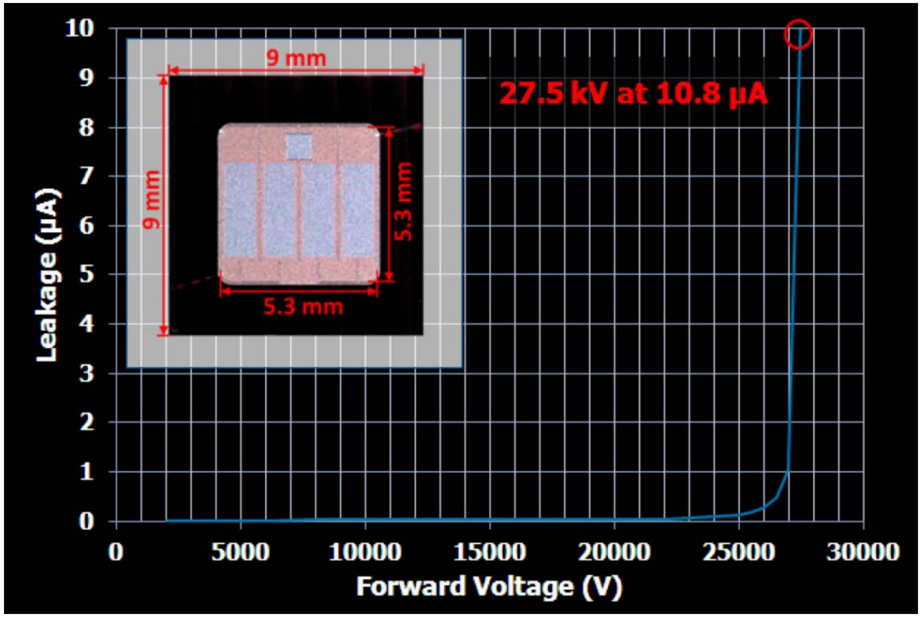
Strategy

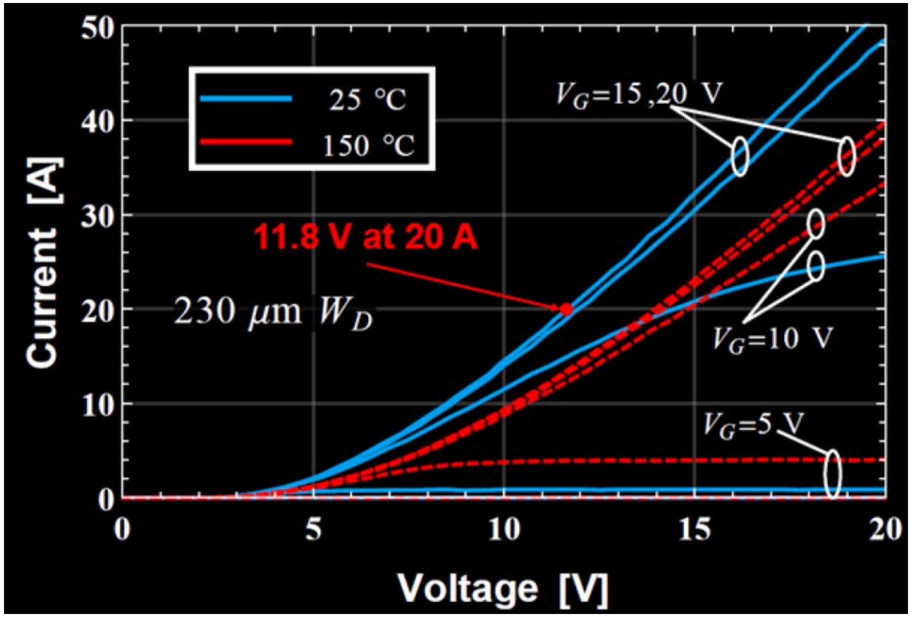
- Highlight Performance Advantages of WBG Devices
  Stress high voltage at low resistance, high temperature, and high frequency WBG device operational advantages over those of *Si* counterparts
- Establish Reliability of WBG Devices
  Leverage *Si* Reliability best practices in developing WBG reliability standards
- Showcase System Insertion Advantages of WBG Devices
  - Develop packaging technology that allows for full WBG performance potential
  - Demonstrate WBG PE system value proposition in terms of higher efficiency, and smaller weight/volume at low overall additional system cost
- Reduce Cost of WBG Devices
  Leverage mature *Si* fabrication practices, and qualify WBG specific processes to enable multiple source high-yield volume production
- Train Workforce in WBG devices/modules/systems

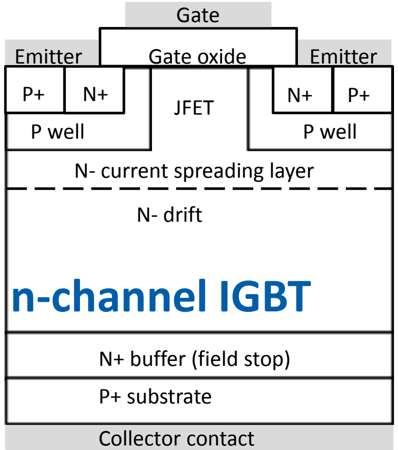
Benefits

Job Creation, Accelerated Technology Innovation, Energy Savings, Smaller Environmental footprint

CREE IGBT Blocks 27 kV with a Low Leakage Current of 1 µA



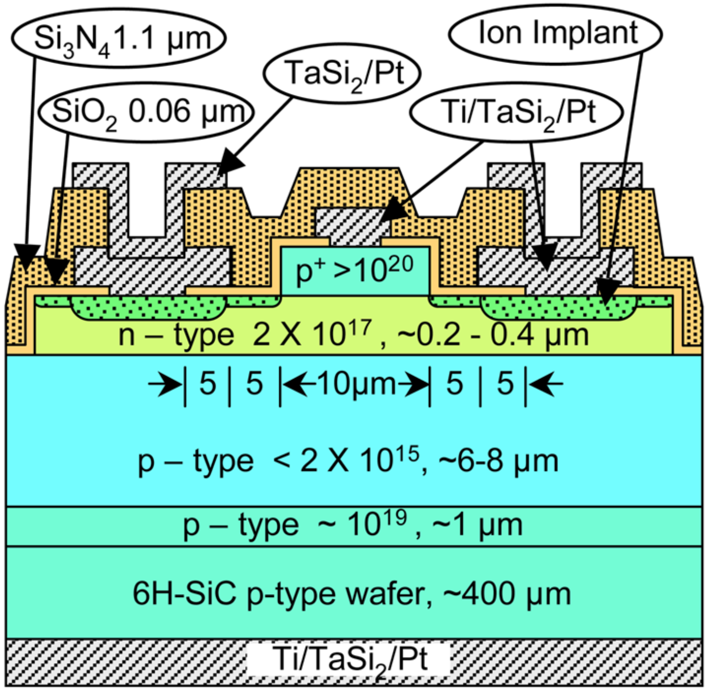


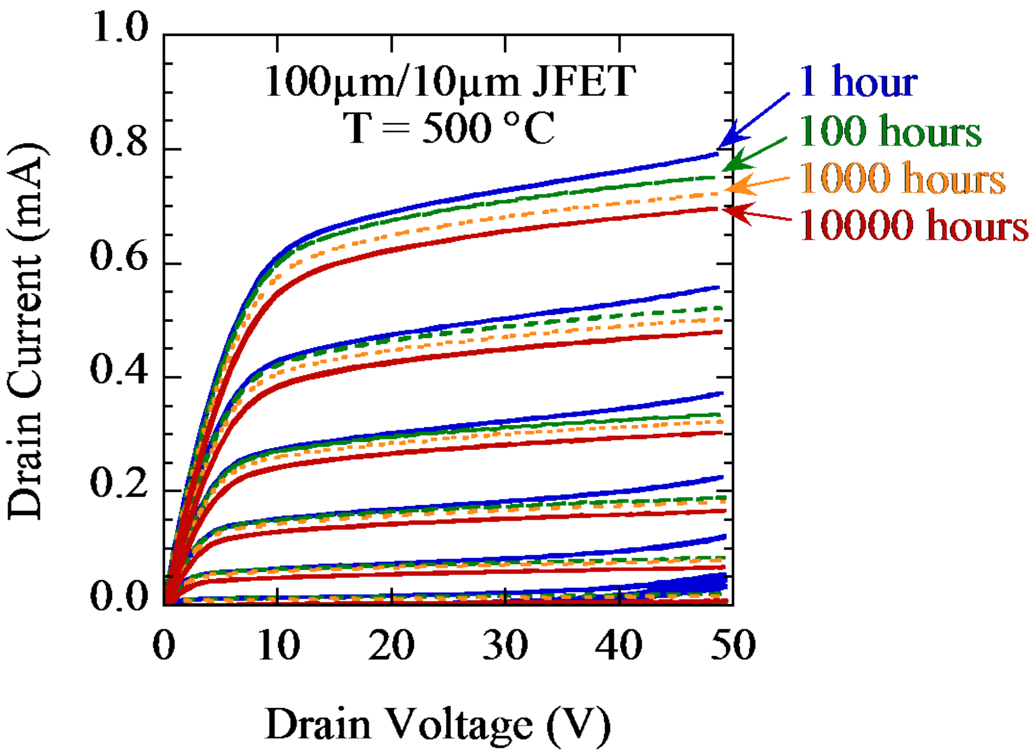


- Thick 230 µm drift layer supports high voltage
- Conductivity modulation reduces on-state resistance

Courtesy of Dr. S.-H. Ryu, CREE Inc.

POWERAMERICA NASA Glenn SiC JFET Demonstrates 10,000 Hours of Stable Electrical Operation at 500 °C





< 10% changes during thousands of hours of electrical operation at 500 °C

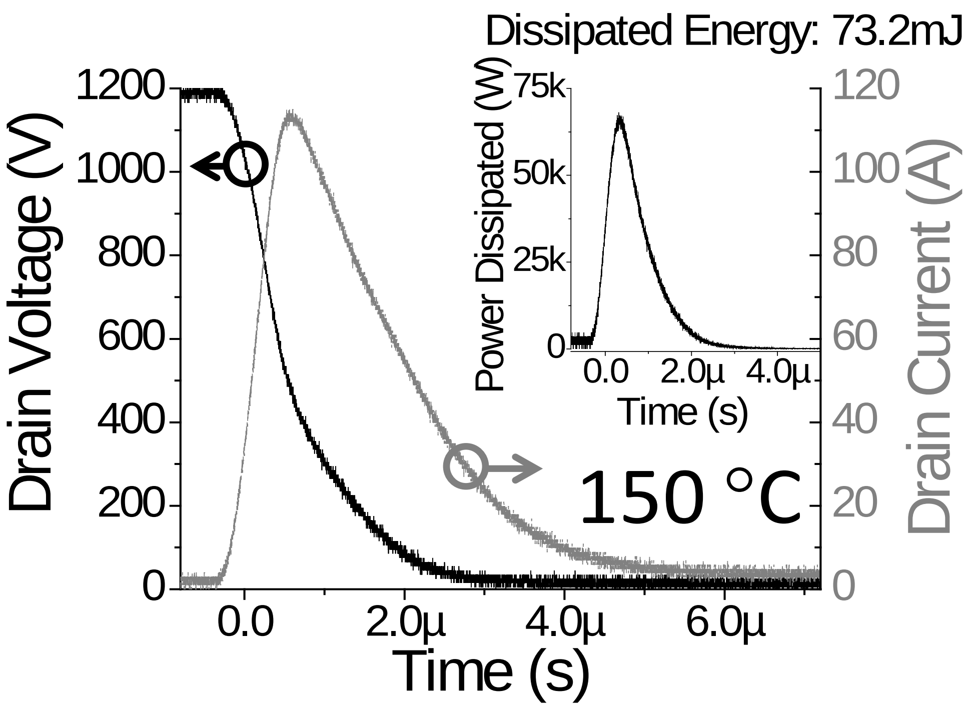
NASA Glenn 6H-SiC JFET Designed for 500 °C durability

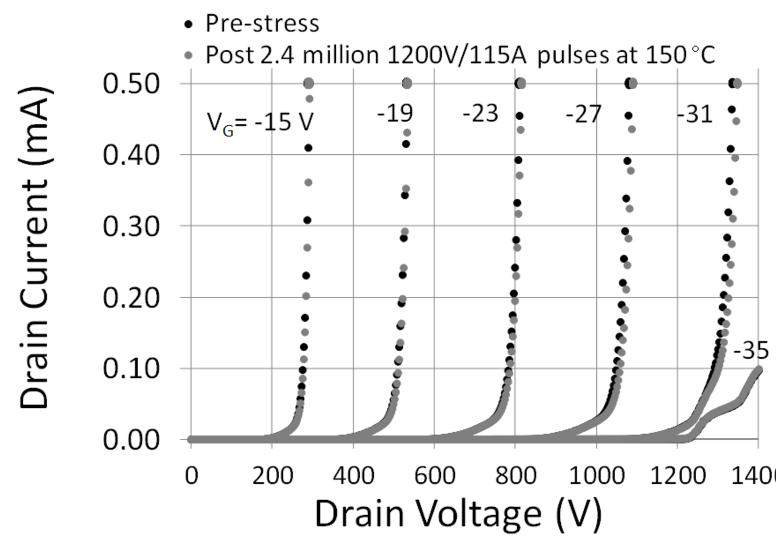
Ti/$TaSi_2$/Pt metallization, Oxide (wet/rewet) and sputtered nitride passivation

Courtesy of Dr. P. Neudeck, NASA Glenn

POWERAMERICA

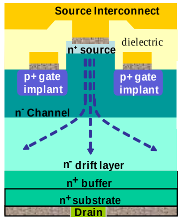
SiC JFET Electrical Characteristics Do Not Degrade after 2.4 million 1200-V Hard-switch Pulses at 150 °C





Blocking voltage JFET curves do not change after 2.4 million 1200-V/115-A hard-switch pulses at 150 ºC

- Peak current is 115 A: 13 times the JFET's 250 W/cm^2 rated current at 150 °C
- Energy dissipated by the JFET during each hard switching event is 73.2 mJ
- Peak dissipated power: 68.2 kW
- Current rise rate was 166 A/µs and the pulse FWHM was 1.8 µs



Standardized accelerated testing of large volumes of WBG devices will establish their reliability

TEXAS TECH UNIVERSITY
Center for Pulsed Power & Power Electronics

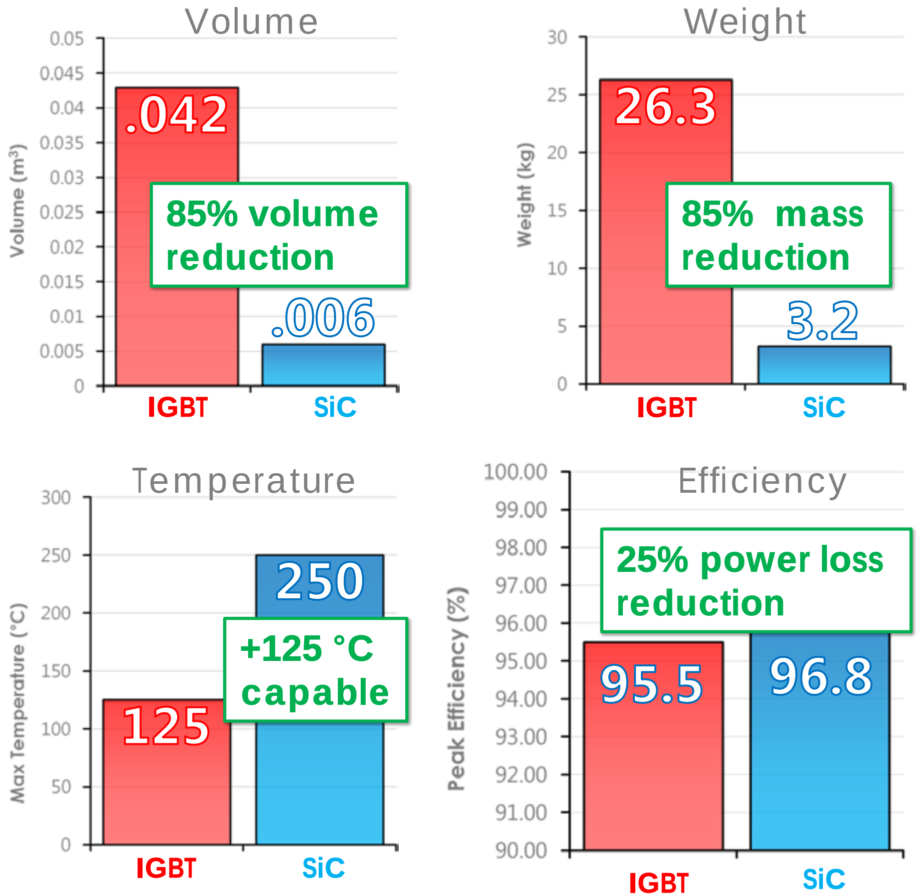
ARL

Replacing Si-based Power Devices with SiC Increases Power Density and Relaxes Cooling Requirements

Commercial Inverter
Si IGBT Based (5kW)

APEI, Inc. XT-1000 SiC Inverter
SiC Based (5kW)

Shown to scale

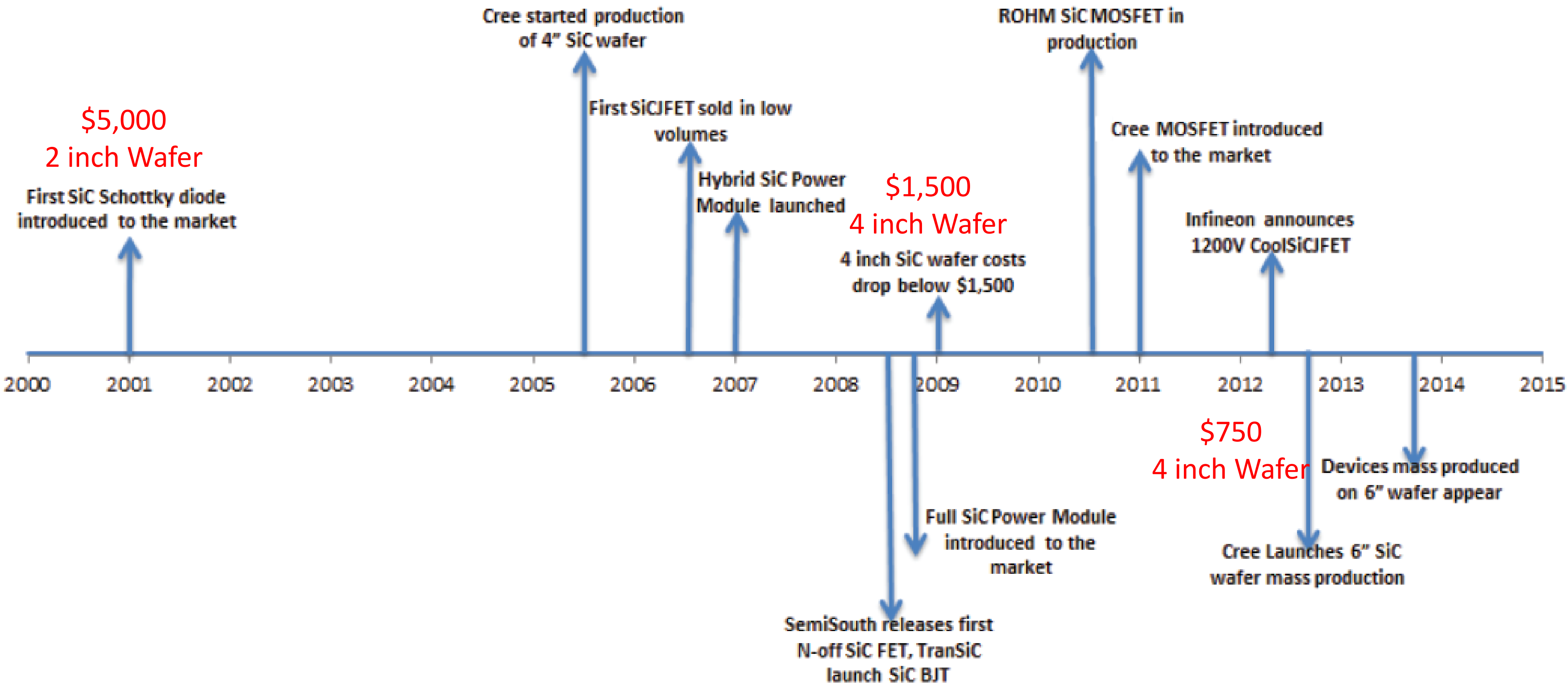


Courtesy of Dr. T. McNutt, CREE

- **Operate w/ Higher Efficiency: translates to fuel savings + less waste-heat to manage**
- **Operate at Higher Temperature: smaller cooling system + "limp-home" margin**
- **Operate at Higher Frequency: reduce the size of passive circuit components**

Wafer Cost Reduced with Volume

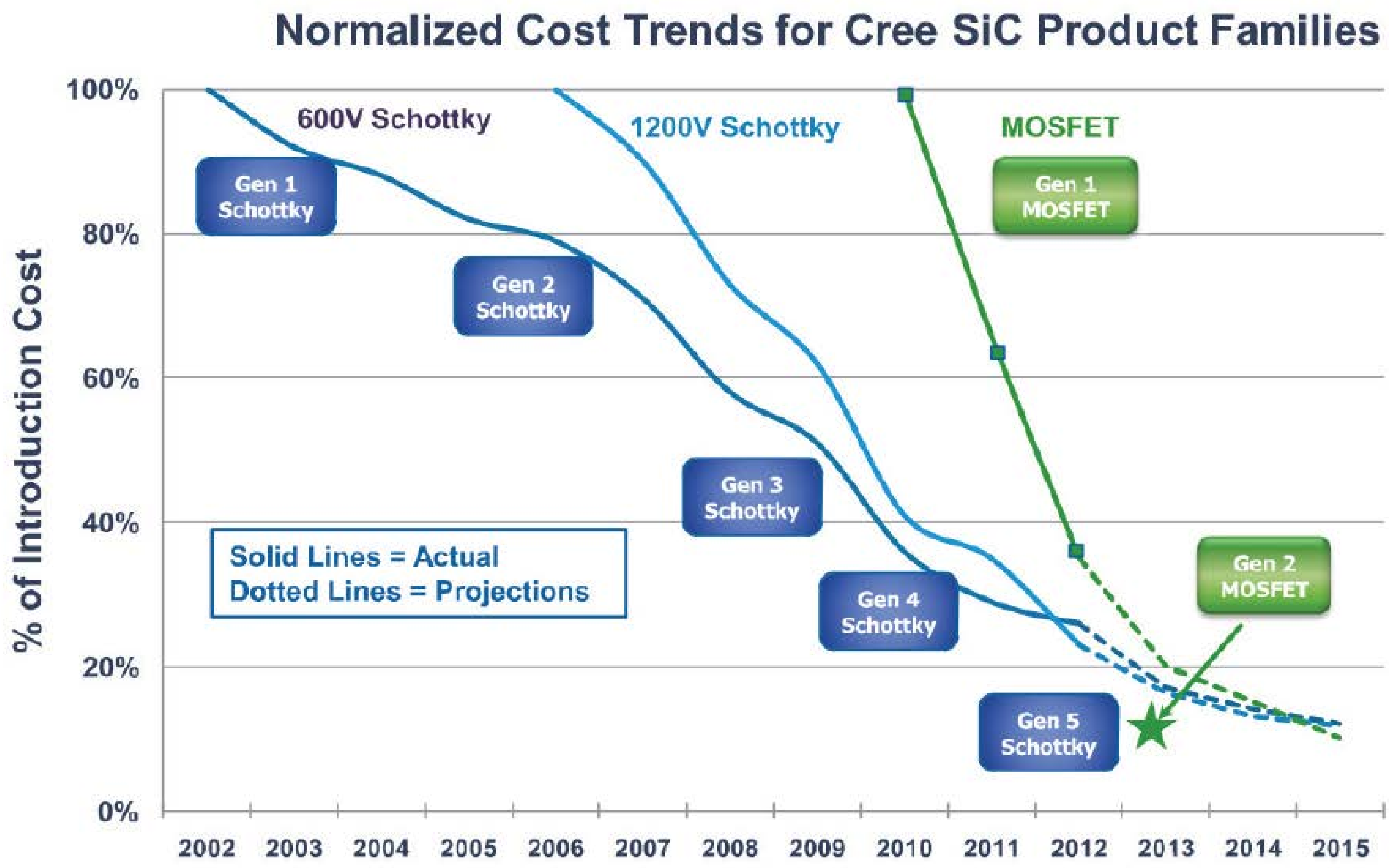
Credit: IHS Technology (http://technology.ihs.com): *The World Market for Silicon Carbide & Gallium Nitride Power Semiconductors* - 2013 Edition



Manufacturing volume lowers wafer costs. Larger area wafer lowers device cost.

PowerAmerica Manufacturing Volume is Critical to Cost Reduction

Credit: Cree, Inc.



Wolfspeed (CREE) is a manufacturer of SiC wafers and power devices

PowerAmerica

WBG Ecosystem Spans Numerous Industries

Wafer Suppliers

Device Design Houses

Wafer Fabs

Reliability and Packaging Fabs

Accelerating WBG adoption requires a clear understanding of industry interplay

OEMs

PowerAmerica WBG Roadmaps Drive Investment and Project Selection

- Government Policy Documents and Market Research Contribute to WBG Roadmap
- PowerAmerica Working Groups Contribute to WBG Roadmap

Silicon Carbide Working Group

Jay Baliga	NCSU	Facilitator
Jeff Casady	Wolfspeed	Lead
Helen Li	FSU	Co-Lead
Greg Romas	LMCO	Member
Iulian Nistor	ABB	Member
Brij Singh	JDES	Member
Fritz Kub	NRL	Member
Akin Akturk	CoolCAD	Member
Aivars Lelis	ARL	Member
S. Anderson	LMCO	Member

Gallium Nitride Working Group

Veena Misra	NCSU	Facilitator
Gene Sheridan	Navitas	Lead
A. Yanguas-Gil	Argonne	Member
J. Dickerson	Sandia	Member
John Wang	ABB	Member
Sandeep Bhalla	ABB	Member
S. Chowdhury	UC Davis	Member
T. Paul Chow	RPI	Member
Aivars Lelis	ARL	Member

PowerAmerica Silicon Carbide Roadmap Drives Long Term Strategy

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
I			650V – 175A chip @ 90C	1.2kV – 150A chip @ 90C	1.7kV – 125A chip @ 90C	2.4kV – 100A chip @ 90C	3.3kV – 50A chip @ 90C	4.5kV – 40A chip @ 90C	6.5kV – 30A chip @ 90C	6.5kV – 60A IGBT chip @ 90C
V	1.2, 1.7 kV SBD/FET	3.3 kV SBD/FET	2.4kV SBD/FET	4.5, 6.5 kV SBD/FET	6.5, 10 kV SBD/FET	6.5kV SBD/IGBT	10 kV PiN Diode/IGBT	15 kV PiN Diode/IGBT	20 kV PiN Diode/IGBT	30 kV PiN Diode/IGBT
$	1.2 kV FET $ 0.40 / A	1.2 kV FET $ 0.30 /A	1.2 kV FET $ 0.25 / A	1.2 kV FET $ 0.20 / A	1.2 kV FET $ 0.15 / A	1.2 kV FET $ 0.10 / A	1.2 kV FET $ 0.08 / A	1.2 kV FET $ 0.05 / A	1.2 kV FET $ 0.04 / A	1.2 kV FET $ 0.03 / A
App	PFC , PV 5-10 kW	Power Supply	UPS/HVAC/ SSCB	PV 50-250kW, 1.5kV bus	EV Traction	MV VSD Automotive Chargers	Central PV 1-10 MW	DC dis. Data Servers	Wind	Grid power Flow

Application Frequency / Technology / Target FOM ($R_{DS}on*Q_{GD}$ for 1.2kV MOS)

2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
40-100kHz DMOS 5mΩ·cm² *41nC	50-500kHz DMOS 3mΩ·cm² *41nC	40-100kHz TMOS 2.5mΩ·cm² *38nC	5-10kHz TMOS TBD	10-30kHz TMOS TBD	5-10kHz TMOS:IGBT TBD	5-10kHz TMOS:IGBT TBD	0.1-1.0MHz IGBT TBD	kHz	5-10kHz IGBT TBD

Estimated SiC Device Market (Yole)

2015	2016	2017	2018	2019	2020
$200 M	$230 M	$275 M	$315 M	$360 M	$440 M

→ **IHS2016 predicts $3B by 2025**

Enablers:

Packaging for low thermal impedance, **200°C**, low stray inductance
Soft Magnetics
Gate drivers
SPICE Models
Open Access Foundry Services
Design Books, Workforce Training

SiC Switch Notes:

SiC MOSFETs are switch of choice for 650V to 6.5kV voltage range
Offered by: Wolfspeed, Rohm, ST Micro, Mitsubishi, Infineon (2016), Monolith, Sumitomo (2017), United SiC (cascodes), …
SiC MOSFETs & SiC IGBTs overlap predicted in 6.5kV-10kV voltage range
Offered by: Only R&D samples from Wolfspeed as of 2016
SiC IGBTs are switch of choice from 10kV to 30kV voltage range
Offered by: Under development at Wolfspeed as of 2016

PowerAmerica Gallium Nitride Roadmap Drives Long Term Strategy

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
100V	Silicon Trench	Lateral GaN on Si	Lateral GaN on Si	Lateral GaN on Si	Lateral GaN on Si	Lateral GaN on Si	Lateral GaN on Si	Lateral GaN on Si	Lateral GaN on Si	Lateral GaN on Si
100V	0.34ohm-nC 1.1c/W	0.2ohm-nC 1.7c/W	0.18ohm-nC 1.2c/W	0.14ohm-nC 1.0c/W	0.12ohm-nC 0.9c/W	0.10ohm-nC 0.75c/W	0.08ohm-nC 0.6c/W	0.07ohm-nC 0.5c/W	0.06ohm-nC 0.4c/W	0.05ohm-nC 0.34c/W
650V	Silicon Superjunctio n	Lateral GaN on Si	Lateral GaN on Si	Lateral GaN on Si	Lateral GaN on Si	Lateral GaN on Si	Lateral GaN on Si	Lateral GaN on Si	Lateral GaN on Si	Lateral GaN on Si
650V	28.2ohm-nC 2.2c/W	3.5ohm-nC 3.5c/W	3.2ohm-nC 2.9c/W	2.6ohm-nC 2.4c/W	2.1ohm-nC 1.9c/W	1.7ohm-nC 1.4c/W	1.4ohm-nC 1.1c/W	1.2ohm-nC 0.9c/W	1.0ohm-nC 0.7c/W	0.8ohm-nC 0.6c/W
Integration		Data Center AC-DC	Mobile Fast Chargers	Wireless Chargers	Consumer SMPS/LED	Solar Inverters	EV Chargers	EV Inverters	Motor Control	Hi-Rel Space
Integration	N/A	Driver	Level-Shift	Bootstrap	Bias Supply	Sensing	Protection	Control	TBD	TBD
Reliability Levels	Consumer	Industrial		Automotive		Hi-Rel				
Estimated GaN Device Market – to be updated	$10M	$25M	$50M	$100M	$200M	$400M	$700M	$1B	$1.3B	$1.6B

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WBG Manufacturing Necessitates Investment in Tools that Perform WBG Specific Processes

Multiple mature Si processes have been successfully transferred to SiC. However, SiC material properties necessitate development of specific processes, whose parameters need to be optimized and qualified:

- **Etch**: SiC hardness allows for only dry etching. Masking materials, etch selectivity, gas mixtures, control of sidewall slope, etch rate, sidewall roughness, etc., are being developed.
- **Doping**: conventional thermal diffusion is not practical in SiC due to high melting point. Evaluate implantation dose, species, energy, temperature, masking material, etc. Post implantation SiC recrystallization and implant activation anneal method (furnace, RTA, etc.), temperature, duration, gas flow, etc. Anneal protective cap layer to minimize wafer surface degradation.
- **Metallization**: evaluate metals, sputter and evaporation, CTE match, resist types and lift-off profiles, metal etches etc.
- **Ohmic contact formation**: high value of metal/SiC Schottky barrier results in rectifying contacts. Post deposition anneal is required for Ohmic contacts. Evaluate metals, CTE match, anneal temperature, gas flow, surface quality.
- **Gate oxides**: Poor quality SiC/SiO_2 interface reduces MOS inversion layer mobility. Develop passivation techniques to improve SiC/SiO_2 interface quality.
- **Insulation dielectrics**: thick dielectrics are deposited in SiC. Evaluate deposited dielectric defects that can affect edge termination and device reliability.

Develop SiC Manufacturing PDKs

POWERAMERICA

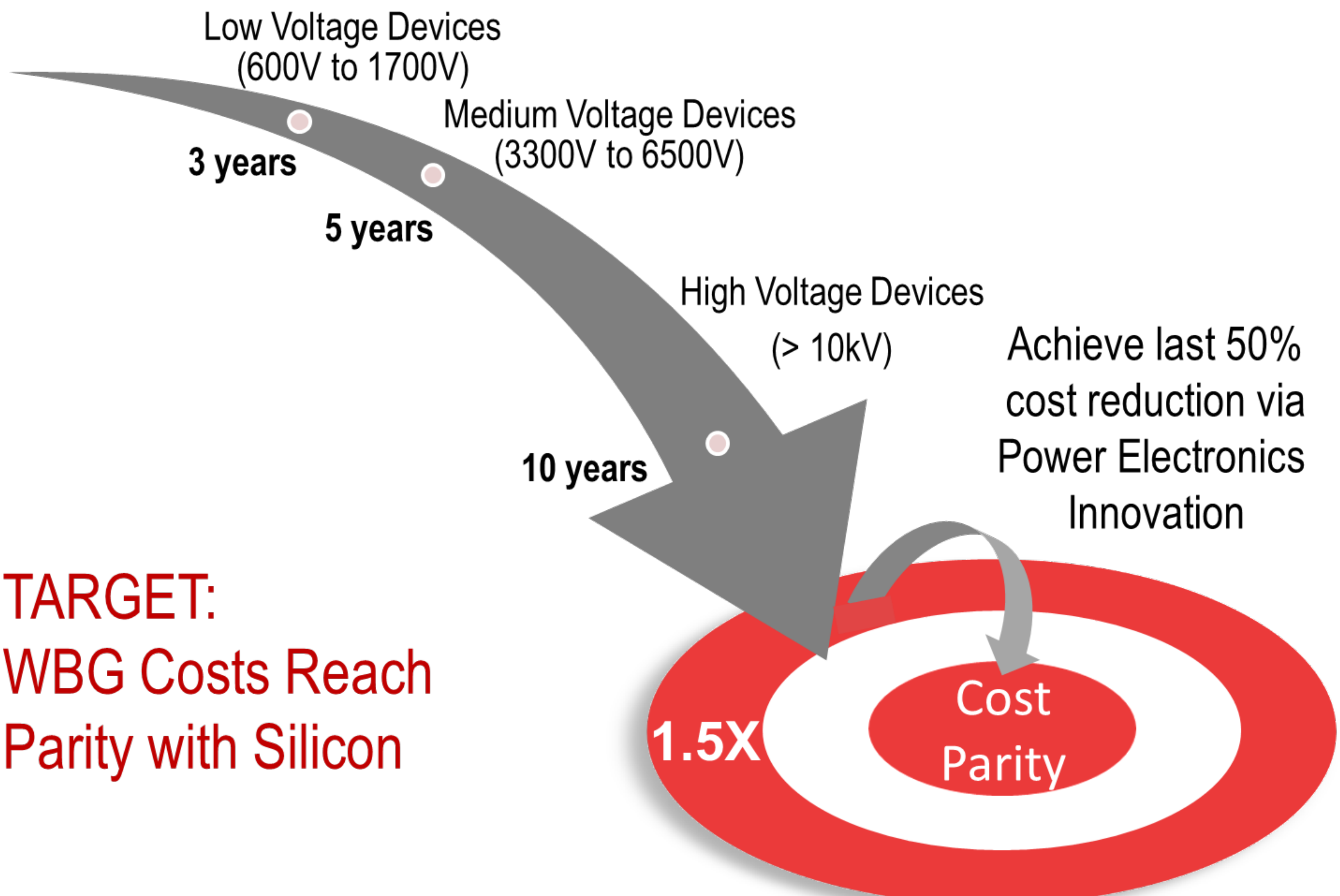
X-FAB Leverages Si Infrastructure and PA Tool Investment to Offer SiC Manufacturing Services

SiC JBS diodes, SJTs, and MOSFETs presently fabricated at XFAB

- Leverage Existing investment In Capital Equipment.
- Leverage an existing highly trained workforce
- Benefit from existing experience in building qualified products
- Increase yield from better implementation of quality control.

X-FAB Users: ABB, GeneSiC, Monolith, NCSU, USCI

POWERAMERICA Reducing Cost of WBG Power Devices through Manufacturing Volume and Technological Innovation



TARGET:
WBG Costs Reach Parity with Silicon

POWERAMERICA

PA Sustainability through " Accelerated WBG Concept to Prototype" Member Offering

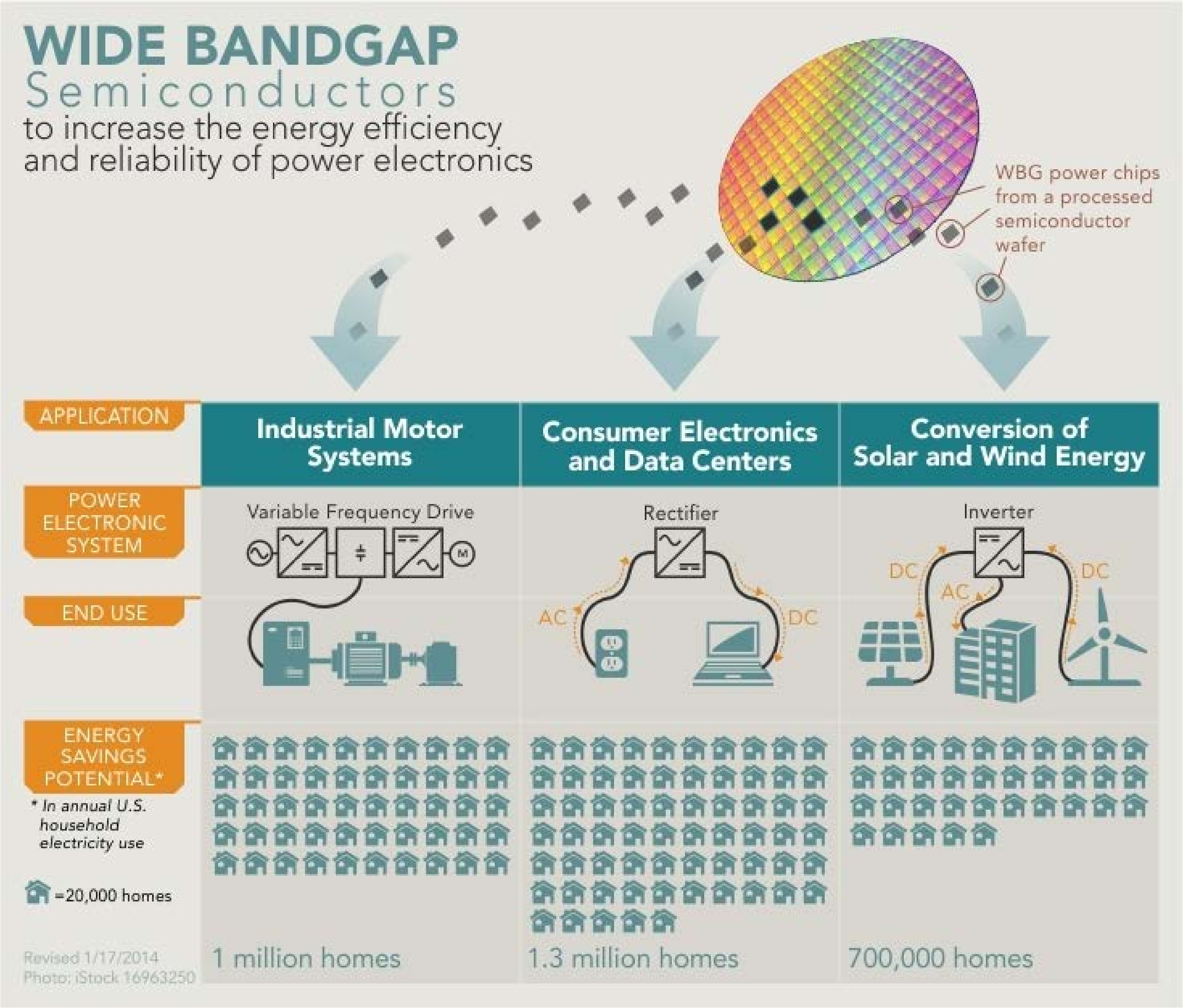
PA assists members with:

- Device design to member's specifications and applications.
- PA fabrication processes that can be tailored to member's devices.
- Access to fab PDK.
- Fabrication at X-fab and/or other WBG manufacturing centers.
- Testing/reliability, and custom reliability development.
- Packaging solutions and custom package design to member's temperature and voltage ratings.
- Circuit and module design to member's device and specifications.
- Module assembly and reliability testing.
- Failure analysis to drive device/circuit/module/system optimization.
- Workforce training (design, fab, test, reliability, packaging, circuit design, module, system) to accelerate member's product introduction to market.
- Consulting by WBG experts.
- Access to WBG ecosystem for market direction, industry perspectives, networking opportunities, problem solving, and gaining confidence in a new technology.
- Ability to influence shared project undertakings within PA.
- Highly WBG trained personnel (graduate students/post-docs) to strengthen member's workforce.
- The overall benefit of accelerated WBG product introduction to market.

PA accelerates industry members' WBG product introduction to market

PA provides University members with industry collaboration opportunities

Wide Adoption of WBG Technology Brings Significant Energy Savings



EWD: Our Vision and Mission …

VISION – The EWD's pipeline strategy and implementation is the global de facto standard of excellence in education, training, and career development for the WBG power electronics workforce

MISSION – Budget Period 2

Establish EWD as a significant catalyst in providing the needed skill sets for workforce career development in WBG power electronics product development and manufacturing

A Strong Workforce and Education Program

Academia

- Pipeline to MS and PhD
- WBG MS Concentration
- Web Portal Distance Education
- Train the Trainer Community College
- Short Courses
- K-12

Government

- DOE/DOD National Labs Internships

NIST

- Manufacturing Extension Partnerships

NSF

- Advanced Technology Education

Industry

- Internships
- Scholarships
- Sponsor Capstone Projects
- Contribute to Short Courses, STEM Outreach
- Jobs
- Professional Development
- Executive Workshops

EWD Partners

K12

College of Education — Lead & Serve — Connecting to the Future

the engineering place

The William & Ida Friday Institute for Educational Innovation

FRC FIRST Robotics Competition

Kenan Institute — Engineering, Technology & Science

Community College

ATE Centers

American Association of Community Colleges

Florida FLATE Advanced Technological Education Center

NC Community Colleges — Creating Success

RTI International

University

Florida State University

Rensselaer

FREEDM Systems Center

Naval Research Laboratory

UCSB University of California Santa Barbara

UC Davis University of California

Argonne National Laboratory

NC State Engineering

Arizona State University

Virginia Tech

NC State University Electrical & Computer Engineering

NC State Poole College of Management

ise Edward P. Fitts Department of Industrial and Systems Engineering

NC State University College of Design

Industrial Workforce

NC State Industry Expansion Solutions

Find your Local MEP

PowerAmerica Industry Membership

NCMEP North Carolina Manufacturing Extension Partnership

Executive Workshops

Manufacturing Industry

PowerAmerica

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