by Victor Veliadis

The Impact of Education in Accelerating Commercialization of Wide-Bandgap Power Electronics

Silicon (Si) power devices have dominated power electronics because of their low-cost volume production, excellent starting material quality, ease of processing, and proven reliability. Although Si power devices continue to make progress, they are approaching their operational limits, primarily because of their relatively low bandgap and critical electric field, which result in high conduction and switching losses and in poor high-temperature performance. Silicon carbide (SiC) and gallium nitride (GaN) devices are revolutionizing power electronics because of their favorable material properties, which allow for highly efficient power devices with a reduced form factor and reduced cooling requirements.

Although wide-bandgap (WBG) power devices have now advanced well past the proof-of-concept stage and are commercially available in a variety of voltage and current ratings, their widespread commercialization has been slow, primarily due to their high cost relative to their Si counterparts and concerns about their reliability. The WBG industry is rigorously investigating the reliability of these devices and producing accelerated aging data that build the confidence that will lead to wide adoption. It has also launched a Wide Bandgap Power Electronic Conversion Semiconductors Committee within the JEDEC Solid State Technology Association to standardize test and characterization methods and formalize reliability and qualification procedures. In this article, I outline the strategic PowerAmerica workforce education effort and its impact in lowering cost and accelerating WBG power electronics commercialization.

The U.S. Department of Energy (DoE) launched the PowerAmerica Manufacturing Institute in 2015 to accelerate commercialization of WBG power electronics. With a US$150 million budget over five years, the organization is undertaking a number of initiatives across the WBG supply chain to catalyze the demand that will lead to mass production, with its cost-lowering benefits. I was named the deputy executive director and chief technology officer of PowerAmerica in 2016, after 21 years in the semiconductor industry, where my technical work included the design, fabrication, and testing of 1–12-kV SiC static induction transistors, JFETs, MOSFETs, thyristors, junction barrier Schottky diodes, and p-i-n diodes as well as GaN radio frequency switches for advanced radar systems fabricated on 150-mm GaN-on-Si wafers. In my role at PowerAmerica, I manage a budget in excess of US$30 million per year that I strategically allocate to more than 35 industrial, university, and national laboratory projects to accelerate WBG power electronics manufacturing, workforce development, job creation, and energy savings. Our organization funds building-block projects that span multiple areas of the supply chain and synergistically culminate in large-scale WBG power electronics adoption. PowerAmerica supports streamlined WBG fabrication in pure-play Si foundries to exploit economies of scale and next-generation device fabrication in vertically integrated foundries that eliminate stacked margins to lower cost. It finances the manufacturing of high-frequency/voltage/temperature modules that allow WBG devices to perform to their full potential. PowerAmerica projects establish WBG ruggedness and reliability through third-party honest broker validation and highlight the compelling advantages of these power electronic systems, which include lower weight and volume, higher efficiency, and a reduced bill of materials. Through these efforts, PowerAmerica has built

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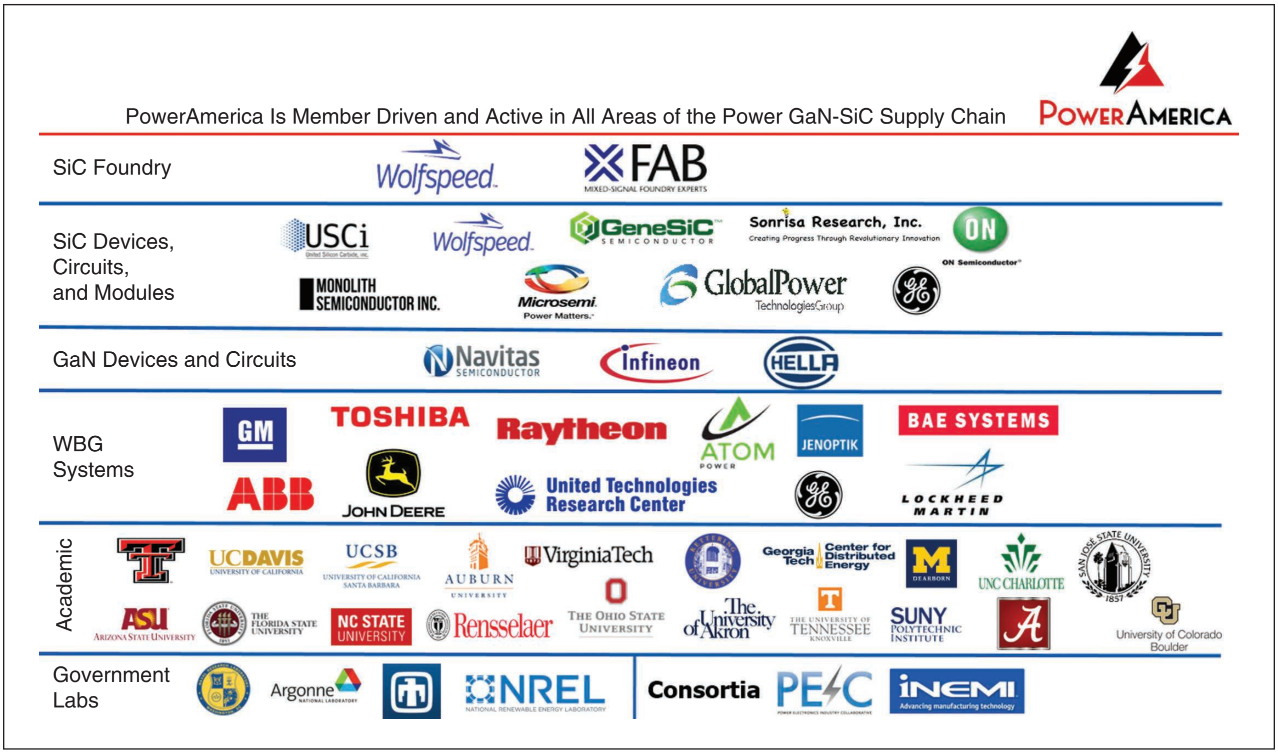
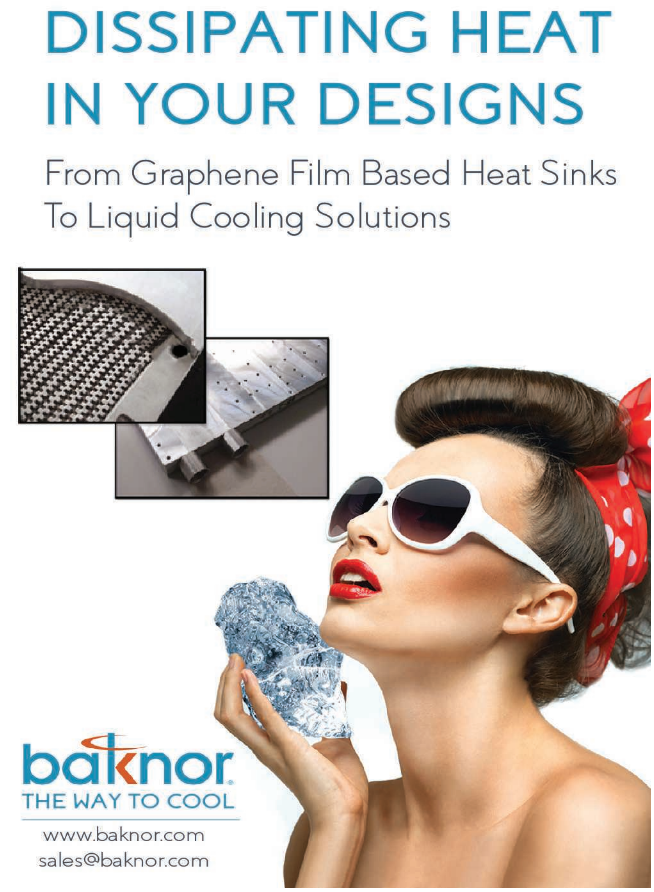
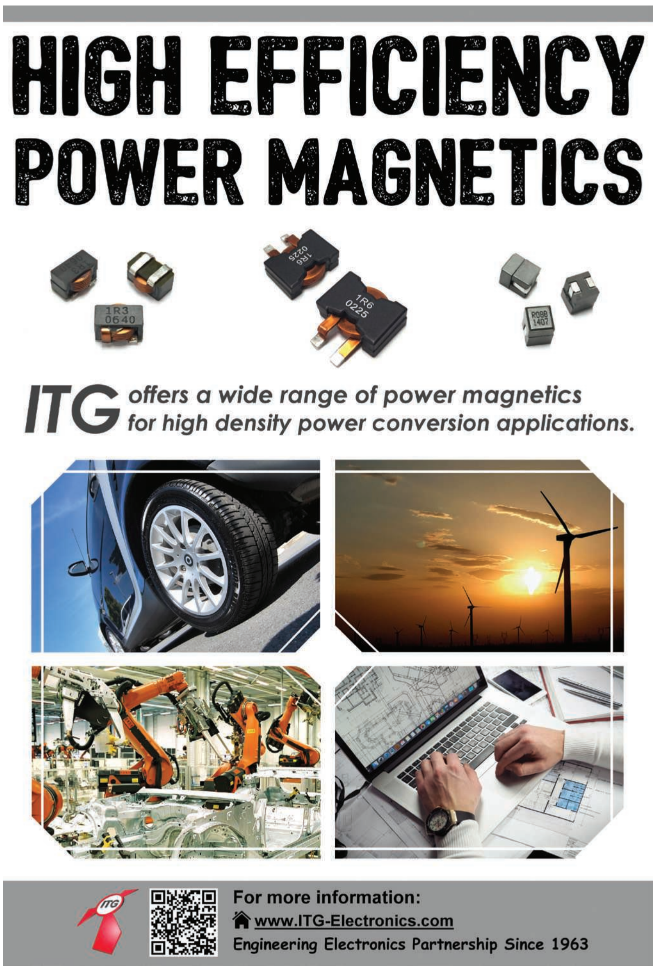


FIG 1 The 50 PowerAmerica members span all areas of the power GaN/SiC supply chain and synergistically accelerate large-scale adoption of WBG power electronics.





> ***PowerAmerica projects establish WBG ruggedness and reliability through third-party honest broker validation and highlight the compelling advantages of these power electronic systems.***

a strong WBG ecosystem and is a 50-member driven manufacturing institute (Figure 1).

In addition to fabrication, modules, reliability/ruggedness, and system insertion initiatives, which are comprehensively represented in the PowerAmerica portfolio of projects, a prerequisite to realizing low-cost mass WBG power electronics manufacturing is a well-trained workforce that drives demand. The power electronics industry is traditionally slow to change and adapt to new technologies, and a workforce lacking expertise in WBG will be reluctant to adopt it and unable to exploit its full performance potential. To address this challenge, PowerAmerica has implemented a strategic educational effort that seeks to train the existing workforce, educate students to form the next generation of WBG professionals, and facilitate internships and highly specialized talent recruitment.

PowerAmerica hands-on projects, carried out by universities and their industry collaborators, provide upper-level undergraduate and graduate students with real-world WBG power electronics experience (Figure 2). In the next few years, some of these students will enter the workforce and accelerate the insertion of these devices in industrial products. Other students will become faculty members at universities and train a new generation of students, creating a WBG education snowball effect.

In its four years in operation, PowerAmerica has funded 63 university-applied projects at a total investment of US$24 million providing real-world WBG power electronics experience to more than 300 students. In line with previous years, PowerAmerica is funding 18 university projects in 2019 involving 21 undergraduate, 55 graduate, and nine postdoctoral full-time trainees at a funding level of US$6.8 million. The university–industry collaborative nature of these projects creates ample internship opportunities and a steady flow of qualified personnel into highly specialized WBG employment positions. PowerAmerica university affiliated students have held internships at companies including ABB, John Deere, GE, Lockheed Martin, Raytheon, Eaton, Schneider Electric, XFAB, UnitedSiC, and GeneSiC. Talent recruitment is further boosted through the industry-requested LinkedIn student portal, which PowerAmerica implemented to connect graduating students to industry. A similar approach to connect interns to prospective employers, via a career portal, is undertaken by the Power Electronics Industry Collaborative, a membership-based consortium working to advance and strengthen the U.S. power electronics ecosystem.

To train the existing workforce, PowerAmerica organizes an annual industry-driven 2.5-day WBG short course taught by world-renowned experts from across the United States. The short course aims to provide diverse applied training that fills industry knowledge gaps. Its content was formulated by evaluating data from our industry-wide polls that asked the question: "What training is needed to catalyze your WBG growth and is not available in present educational settings?" The PowerAmerica short course offering is continuously optimized through attendee feedback and is typically offered to sold-out audiences in the fall of each year.

Our additional educational initiatives include monthly technical webinars by member experts that are open to all. WBG lectures are also being added to power electronics courses across all 18 of our member universities, and tutorials are organized at the winter and summer PowerAmerica

2 Foundry and Device Development

- 2.1 SiC Power Device Commercial Foundry Development (X-FAB)
- 2.3 Development of Manufacturable Gen 3, 3.3-kV/50-mOhm MOSFET Fabricated on 150-mm 4HN-SiC Wafers Along With HTRB, HTGB, BDOL, TS, ESD, and TDDB (Cree/Wolfspeed)
- 2.14 6.5-kV SiC DMOSFET Development on 150-mm Platform (GeneSiC)
- 2.20 Commercialization of 3.3-kV and Technology Development of 6.5-kV SiC Devices (Microsemi)
- 2.23 SiC Planar DMOSFETs and Power ICs With Enhanced Short-Circuit Withstand Time (Sonrisa)

3 Module Development and Manufacturing

- 3.1 Industry-Driven MV SiC Power Module Manufacturing (Cree/Fayetteville)
- 3.6 Developing Processes for BPD-Free Room-Temperature Al Implantation/Annealing for MOSFETs and Lifetime Control for Bipolar Devices (NRL)
- 3.9 Design and Manufacturing of Advanced, Reliable WBG Power Modules (GE)

4 Commercialization Applications

- 4.1 Power-Dense Engine Coolant 200-kW 2,050-V dc Bus SiC Inverter for Heavy-Duty Vehicles (John Deere Electronic Solutions)
- 4.2 Modular SiC-Based Three-Phase ac/dc Front-End Rectifier With 99% Efficiency (ABB)
- 4.3 Development, Demonstration, and Commercialization of SiC-Based 1-MW Medium-Voltage Motor Drive System (Toshiba)
- 4.7 Direct-to-Line Central Inverter for Utility-Scale PV Plants Using 10-kV SiC MOSFET Devices (VA Tech/Burgos)
- 4.8 MV ac to Low-Voltage dc Power Conversion for Data Center (VA Tech/Li+Infineon)
- 4.10 Transformerless Medium-Voltage Central PV Inverter (FSU/Li+GE)
- 4.11 Asynchronous Microgrid Power Conditioning System (NCU/Bhattacharya)
- 4.23 High-Speed Energy-Efficient HVAC Drive (UTRC)
- 4.15 Isolated, Soft-Switching SEPIC With Active Clamp for 480 V ac to 400 V dc Rectifier for Data Centers (ASU/Ayyanar)
- 4.28 Multifunctional High-Efficiency High-Density MV SiC-Based Asynchronous Microgrid Power Conditioning System Module (UTK/Wang)
- 4.32 GaN-based High-Efficiency Multiload Wireless Power Supply (UTK/Costinett)
- 4.33 Dual-Inductor Hybrid Converter for Direct 48 V to sub-1 V PoL dc–dc Module (U-CO/Maksimovic)
- 4.34 Introduction of WBG Devices for Solid-State Circuit Breaking at MV (UNCC/Manjrekar)
- 4.36 600-V GaN Bi-directional Switch (Infineon)

5 Education and Workforce Development

- 5.1 Education and Workforce Pipeline
- 5.4 Undergraduate Research Scholars
- 5.5 Pre-College Education
- 5.6 WBG Short Courses
- 5.13 Documentation of Design and Process of GaN Power HEMTs (RPI/Chow)
- 5.14 WBG Power Converter Design Space Exploration (NCSU/Lukic)
- 5.16 Universal Platform of Education, Research, and Industrial Rapid Prototyping of High-Power WBG Applications (NCSU/Husain)
- 5.17 Graduate WBG Semiconductor Power Device Lab (NCSU/Pavlidis)
- 5.18 Power Electronics Teaching Lab Incorporating WBG Switches and Circuits (UNCC/Parkideh)

FIG 2 The 2019 annual PowerAmerica project portfolio. New member projects are shown in blue. US$6.8 million is allocated to 18 university projects that provide specialized hands-on training to 85 students.

member meetings, which provide an informal setting for learning and networking. Finally, to educate participants and promote the PowerAmerica WBG ecosystem, I have delivered numerous well-attended tutorials at mainstream trade conferences such as the Applied Power Electronics Conference and Exposition, the International Symposium on Power Semiconductor Devices, the International Conference on Silicon Carbide and Related Materials, the European Conference on Silicon Carbide and Related Materials, the Workshop on Wide Bandgap Power Devices and Applications, and the Energy Conversion Congress and Exposition, which have all experienced a recent surge in WBG-related subject matter.

PowerAmerica has launched numerous WBG power electronic initiatives to educate the next generation of professionals in universities, train the existing workforce, and facilitate internships and highly specialized talent recruitment. A skilled workforce is key in creating the large WBG demand that will spur mass manufacturing with its cost-lowering benefits.

About the Author

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