U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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Wide Bandgap Power Electronics

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Project ID:
apep_04_chinthavali

Overview

Timeline

- Project start – Oct. 2001
- Project end – Ongoing

Budget

- Total project funding
  - DOE 100%
- FY08 - $432K
- FY09 - $367K
- FY10 - $486K

Barriers

- Barriers
  - Acquiring new prototype devices.
  - Building new gate drivers and test set-ups for power switches with fast switching times
- Vehicle Technology Program Targets
  - DOE 2020 targets: 105°C
  - DOE 2020 target: 13.4 kW/l

Partners

- University of Tennessee, Knoxville
- Industrial suppliers of SiC and GaN devices

Objectives

- To assess the system level impact of wide bandgap (WBG) semiconductor devices on hybrid electric vehicles and to keep up to date with state-of-the-art WBG power devices.

- To study conceptual changes to inverters/ converters and packaging issues to take advantage of WBG device attributes.

  - The objective of the study is to enable cooling with air thereby eliminating the existing liquid cooling system.
  - Increase the power density and decrease the volume and weight for electric-base vehicle traction-drive inverters.

Technical Approach

- **Evaluate new WBG power devices:**
  Acquire, test, and characterize new WBG power devices.
  - Static characteristic tests
  - Dynamic characteristic tests
  - Behavioral modeling

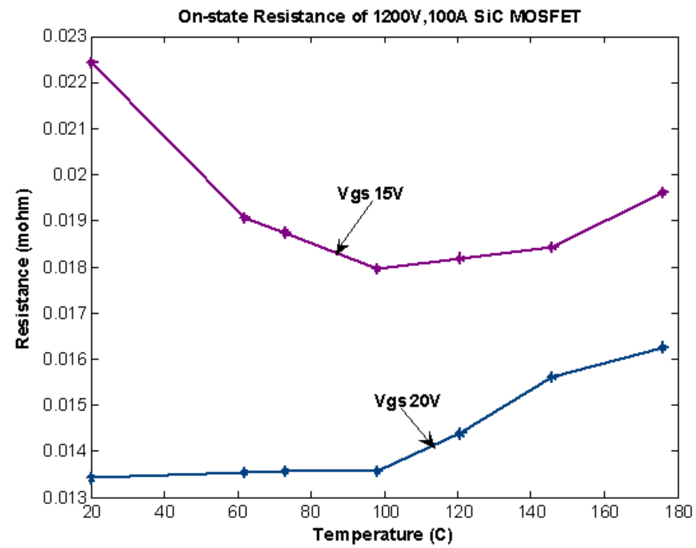
- **Perform a feasibility study on an air-cooled integrated traction drive inverter design:**
  - Conduct thermal simulations on inverter designs to predict performance.
  - Perform design iterations and optimization of the packaging to increase heat transfer and minimize parasitic inductance.
  - Develop an optimal design geometry to serve as the basis for future work.

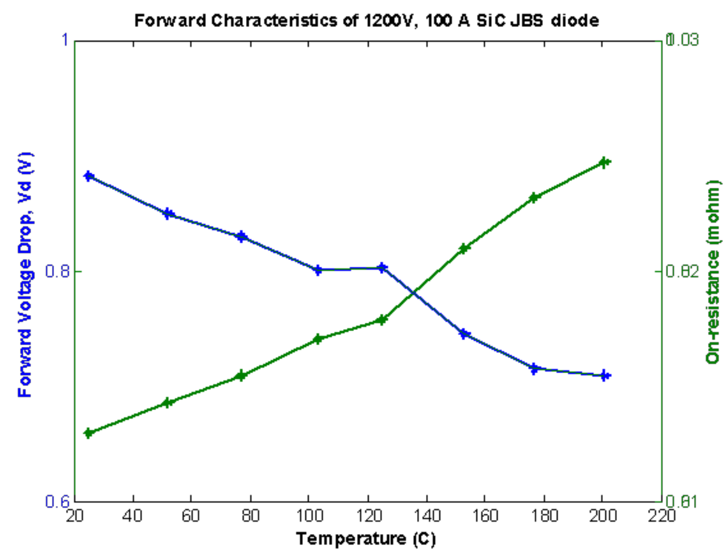
Technical Accomplishments

- Tested and characterized SiC MOSFET and SiC diode in a SiC module.
- At 15 V of gate voltage the on-resistance initially decreased from 0.0194 Ω at 20 C to 0.0161 Ω at 100 C and then started to increase up to 0.0183 Ω at175 C. This behavior was noticed in the MOSFETs tested earlier at ORNL in 2005.
- However at 20 V of gate voltage the on-resistance increased from 0.0134 Ω at 20 C to 0.0162 Ω at 175C. There is a significant change in the forward characteristics of the device at different gate voltages. This will affect the paralleling of the devices for high power modules.
- The static characteristics of a 1200 V 100 A SiC Schottky diode in the SiC MOSFET module were obtained across a wide temperature range (25C-200C). The forward voltage drop at 100 A current increased from 2.1 V at 25C to 2.95 V at 200C.

SiC MOSFET switching losses at 300 V, 50 A

Temp	Eon	Eoff	Etot
25C	1.0544 mJ	1.0304 mJ	2.0848 mJ
100C	1.1138 mJ	1.0344 mJ	2.1482 mJ
150C	1.1318 mJ	1.0694 mJ	2.2012 mJ





Technical Accomplishments

- **Three new air–cooled traction drive inverter designs were completed.**
  - Models were generated using COMSOL FEA software.
  - A preliminary steady state conduction analysis was performed and a single design showing the potential to meet the VTP 2015 targets was selected for optimization.
  - Air flow modeling is underway to ascertain thermal performance.
  - Modifications on the design are in progress to optimize the parasitic inductances.

- **New automated test facility for device characterization is being built.**
  - Will enable device characterization at temperatures up to 600°C.
  - Labview software will be used for automated data acquisition system and control.
  - The facility will have the capability to test diodes and switches up to 1,200 V, 100 A.
  - Test hardware and interface circuitry for static characteristic testing has been completed.
  - The dynamic characterization test hardware and interface circuitry is being fabricated.

Future Work

- Continue to acquire, test, and characterize new devices.
- Complete the Automated Device Test Facility and test for functionality.
- Complete FEA analysis on the air-cooled inverter design to finalize design requirements for a complete inverter.

Summary

- Tested and characterized MOSFET and diode in a 1200 V, 100 A half bridge SiC module.
- Two new SiC JFET modules, one normally-on high temperature package and one normally-off have been acquired for future testing.
- Three different designs of air-cooled inverter have been generated using COMSOL for analysis.
- Steady-state conduction analysis on air-cooled inverter designs has been completed. The designs show that it is feasible to achieve air cooling with WBG devices and meet the VTP 2015 targets.
- The downselected design has been optimized for reductions in parasitic inductance.
- Automated Device Test Facility:
  - Test and interface hardware for static characteristic of devices have been completed.
  - The dynamic characterization test and interface hardware is under development.