U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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Power Device Packaging

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Project ID: APE023

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Overview

Timeline

- Start Date: Oct. 2009
- End Date: Sept. 2012
- 10% Complete

Budget

- DOE Share – 100%
- FY10 received: $480K

Barriers

- Existing commercial device packages cannot meet the FreedomCar 2020 targets, with size, temperature and reliability limitations
- Advanced concepts too costly
- Targets:
  - 60% size reduction in package and cooling systems, in line with DOE 2020 targets

Partners

- NREL
- The University of Tennessee

Objective

- Identify the limitations and shortcomings with existing device packaging approaches. Develop new packaging concepts to overcome the issues for improved power density, thermal management, cost, and reliability. Complement other packaging and thermal management research efforts within DOE Vehicle Technologies Program.
- FY10
  - Benchmark and characterize the state-of-the-art commercial device packages
  - Evaluate promising R&D packaging concepts for new packaging development
  - Enhance in-house packaging capabilities to facilitate the future packaging research and development

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Milestone

- **August 2010:** Identify a new feasible packaging concept for further evaluation and development
- *Go/No Go* – Whether feasible candidate packaging technologies have been identified that will potentially meet the target on cost and density without compromising performance and reliability

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Approach

- **Benchmarking the state-of-the-art technologies**
  - IGBT power modules from Toyota Prius and Honda Insight inverters, and solderless IGBT power modules from Semikron
  - Cross-section commercial IGBT power modules, characterize and study their internal architectures and constituents using optical microscopy, scanning electron microscopy, and energy dispersive spectroscopy
  - Literature review
- **Evaluate and select new promising packaging concepts**
  - Evaluating technologies such as sintering through in-house testing and process development
- **Develop new packaging concept**

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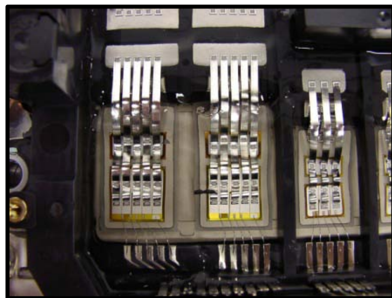
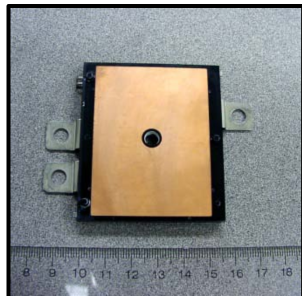
FY10 Technical Accomplishments (1)

- **Sectioned and characterized IGBT modules from 2004 Toyota Prius (End of Life – 160k miles), 2010 Toyota Prius (new), and 2010 Honda Insight (new).**
- **Sectioned and characterized IGBT modules containing sintered die-attachments (Semikron).**

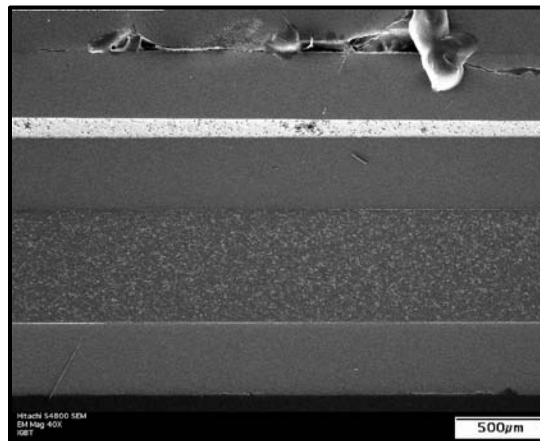
2010 Prius



2010 Insight



2004 Prius (IGBT Cross-Section)



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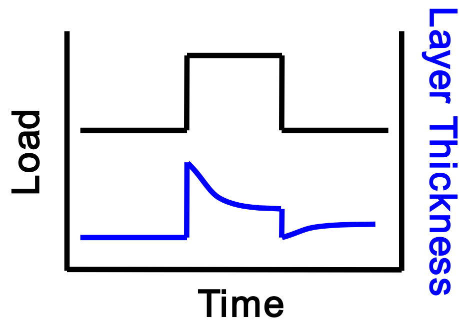
FY10 Technical Accomplishments (2)

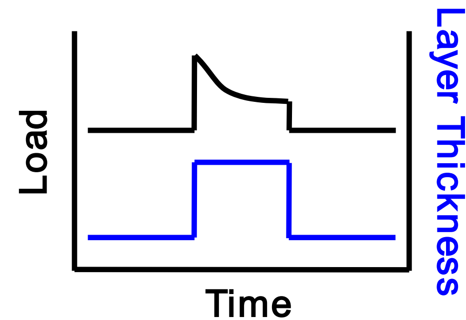
Pressure Assisted Oven

Thermal Shock Oven

Load-Controlled Sintering Profile

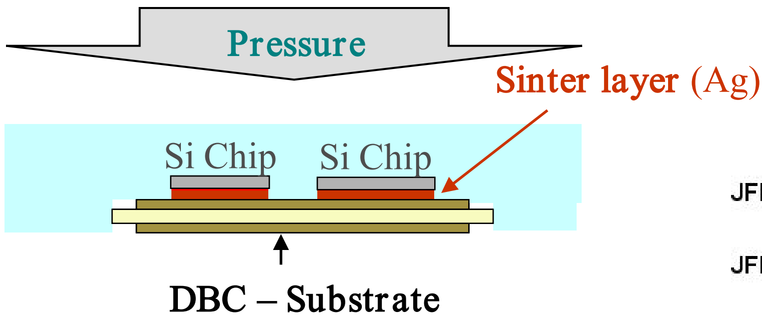


Displacement-Controlled Sintering Profile

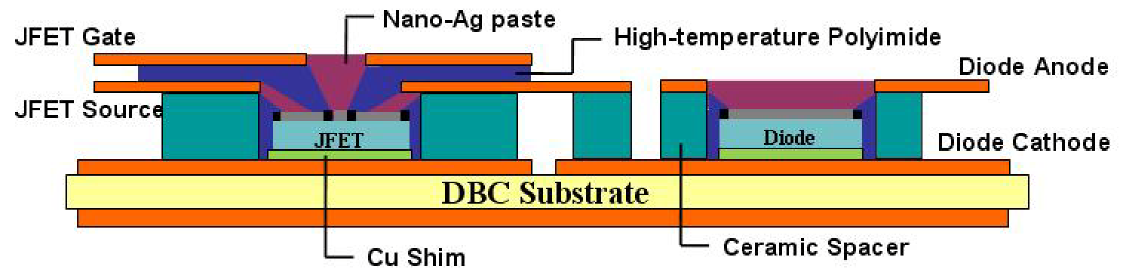


FY10 Technical Accomplishments (3)

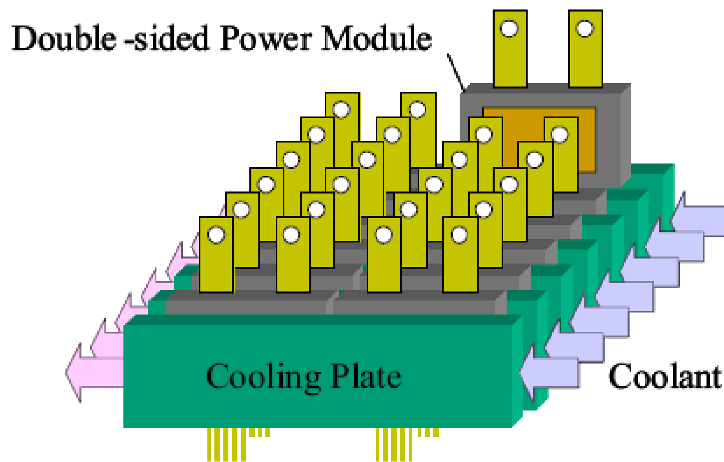
- Assessed the-state-of-art packaging technologies



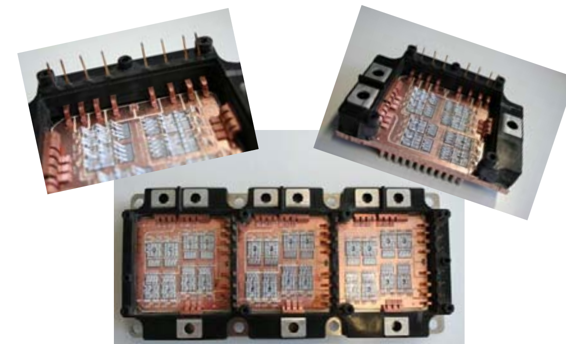
Semikron Sintered Die Attach



A High-Temp Planar Package [Ning, 2009]



Lexus Inverter Package



Infineon – Hybrid Pack II

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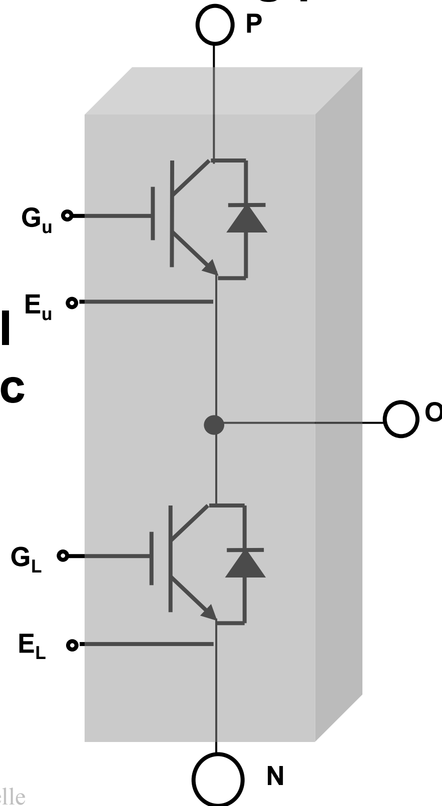
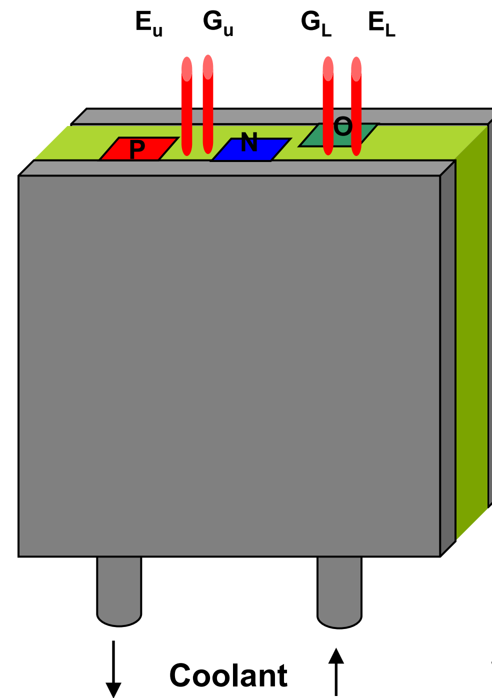
FY10 Technical Accomplishments (3)

- **New package concept assessed**
  - IGB/FWD phase-leg unit for easy integration
  - Double-sided integrated cooling: low thermal resistance
  - Electrical interconnection: low parasitics
  - Planar stacking process: modular, low-cost manufacturing

Electrical Schematic





Module Structure

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Collaboration and Coordination

- **NREL (Federal)**
  - **Collaborated within the Vehicle Technologies Program on thermal management**
- **ORNL Materials Science and Technology Division (Federal)**
  - **Funded by DOE Materials Program**
  - **Coordinated their research activities to serve the materials need of power electronics packaging**
- **University of Tennessee (Academic)**
  - **Subcontractor, to help benchmark commercial packages**

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Future Work – FY10

- Continue to evaluate and down select packaging technologies (materials and processes)
  - Die attach
  - Substrate
  - Encapsulant
- Continue to enhance the in-house packaging capability
  - Complete the installation of pressure-assisted sintering processing facility and thermal shock test facility
  - Conduct preliminary sintering trials with test/model components
- Continue to develop the new package concept

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Future Work – FY11 and Beyond

- Packaging structure optimization
  - Electrical and thermo-mechanical performance evaluation and characterization
- Sample module fabrication
  - Substrate patterning, die attach, interconnect, and encapsulation
- Testing and analysis
  - Electrical, thermal, and thermal-mechanical properties
- Continue to benchmark SOA technologies
- Continue on materials evaluation and process development
- Inverter-level packaging study and new concept development
- Provide packaging support for other projects

Summary

- **The state-of-the-art commercial packaging technologies are being benchmarked**
- **Advanced packaging approaches are being assessed with the objective to develop new packaging concepts meeting DOE 2020 cost and power density targets**