Materials Compatibility of Power Electronics

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Overview—Technical Work Has Been Ongoing For Approximately One Year

Timeline

- Start – March 2008
- End – Sep 2010
- Percent complete – 40%

Budget

- Total project funding
  - DOE – $330K
- Funding in FY08 -- $225K
- Funding in FY09 -- $105K
- Funding for FY10 -- $200K

Barriers

- Barriers addressed
  - A. Cost of high temperature integrated power electronic (HTIPE) systems
  - D. Abuse tolerance and ruggedness of HTIPE systems
  - E. Weight, volume and thermal control of HTIPE systems

Objectives Addresses Needs Within the Propulsion Materials Program

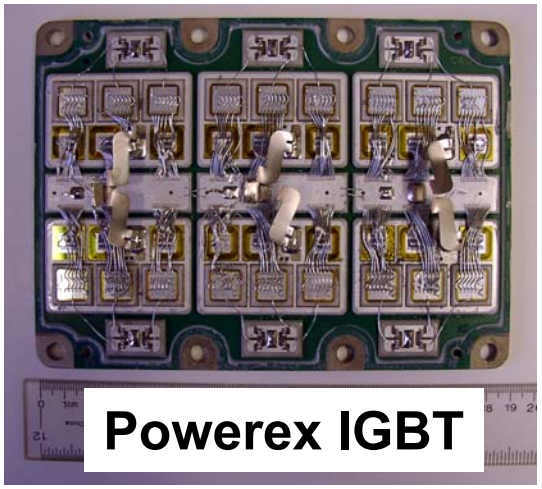
- **Develop and validate a laboratory methodology to evaluate the degradation of power electronics materials/components by evaporative cooling liquids**
  - **Direct cooling of components will allow for reduction of weight and volume of systems**
  - **Methodology will allow for expression of abuse tolerance and ruggedness of HTIPE**

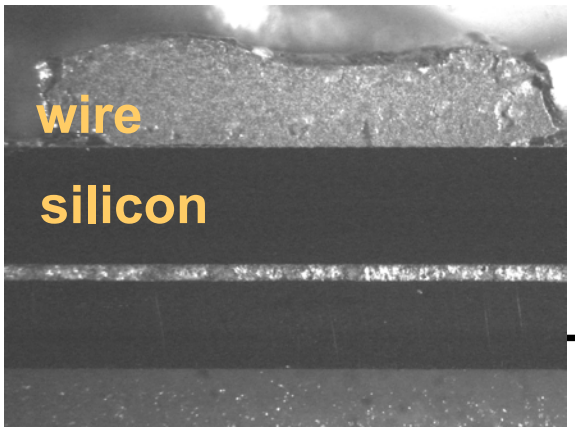
Milestones Are Focused On Addressing Performance

- Develop methodology to evaluate the interaction of the power electronic components with the fluids used in the evaporative cooling systems. Initiate testing of methodology (09/08)
  - Built test system and acquired commercially produced test specimens
  - Initiated testing
- Validate the proposed methodology for examining the interaction of the electrical components with evaporative coolant. (09/09)
  - Collect and evaluate test data
  - Modify test parameter
  - Relate data to material/component performance
  - Define “go/no-go” of failure as related to materials/component performance

Compatibility Addresses Barriers/Design Criteria of Automotive Industry

- Barriers to deployment of power electronics (PEs) are:
  - Weight, size, reliability and cost
- Approach to decrease weight, size, and cost of PEs is to use:
  - Direct cooling of PEs by side-stream cooling from existing air-conditioner (A/C) systems using R134a refrigerant
    - Reduces weight of PEs
    - Eliminates secondary cooling system
- Direct side-stream cooling necessitates evaluation of PEs compatibility with and reliability in the coolant

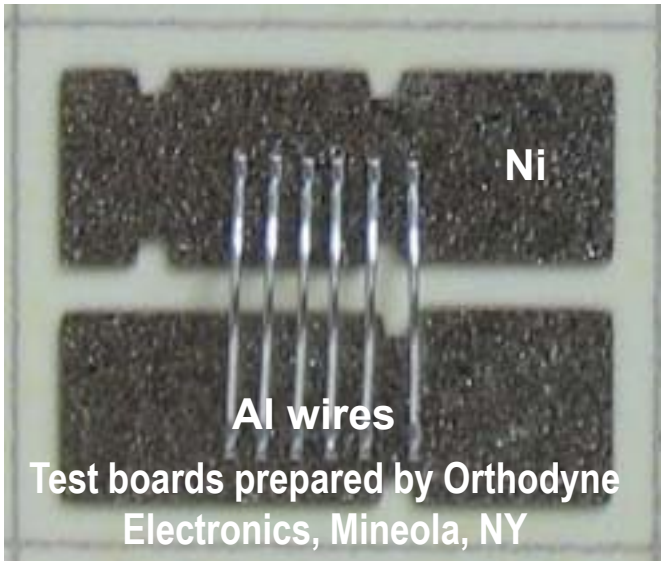




Photos Courtesy of A. Wereszczak/ORNL

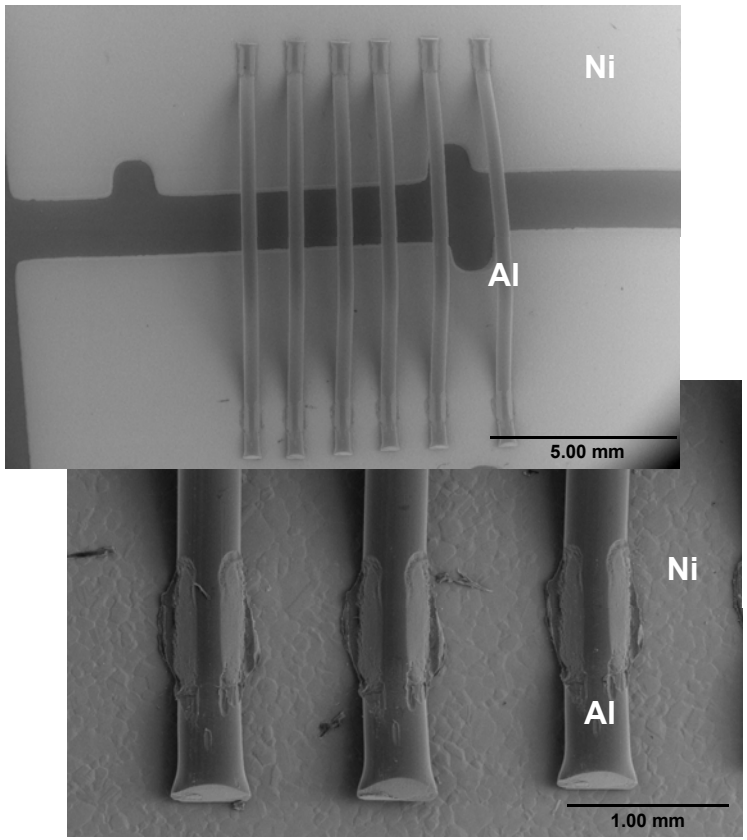
In Addition, Because of the Anticipated Low Reaction Rates in R134a, An Accelerated Test Is Being Sought

- Mimic in service use
- Exacerbate nucleate boiling effects
- Maximize effect of impurities
- Aggravate thermal mechanical stress
- But does not change the in-service failure mechanisms



An Integrated Approach to Compatibility Issues Is Being Developed

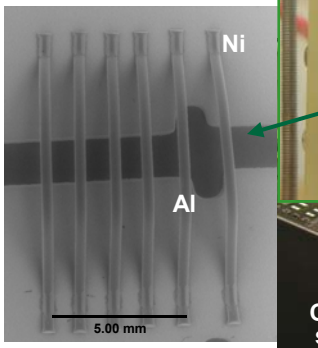
- Effect of coolant on the PEs materials
  - Aluminum, nickel (general corrosion)
  - Bonds of aluminum and nickel (galvanic corrosion)
  - Polymeric materials
- Effect of nucleate boiling on the surface of the metals
- Effect of impurities in the coolant
  - Off-the-shelf or a result of interaction with containment materials
- Effect of thermal stress on the PEs materials
- Evaluation of synergistic effects



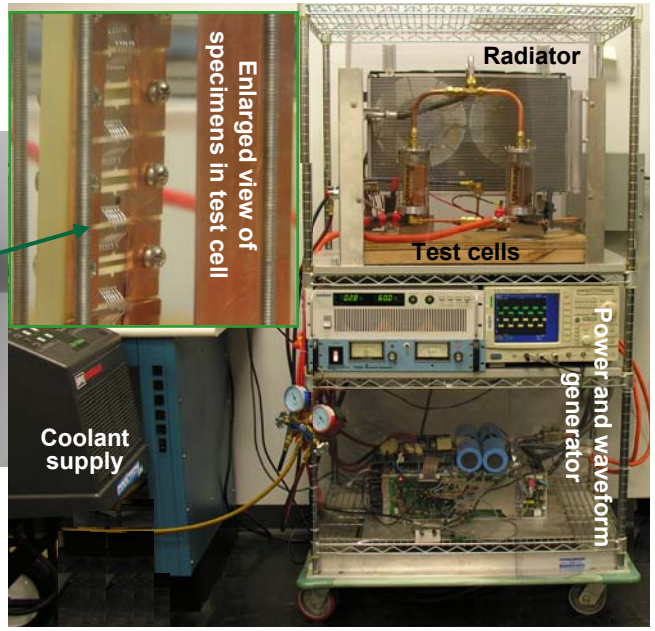
- Bonds all show uniform contact area and deformation associated with the bonding process

A Test System Was Designed and Built for Accelerated Evaluations

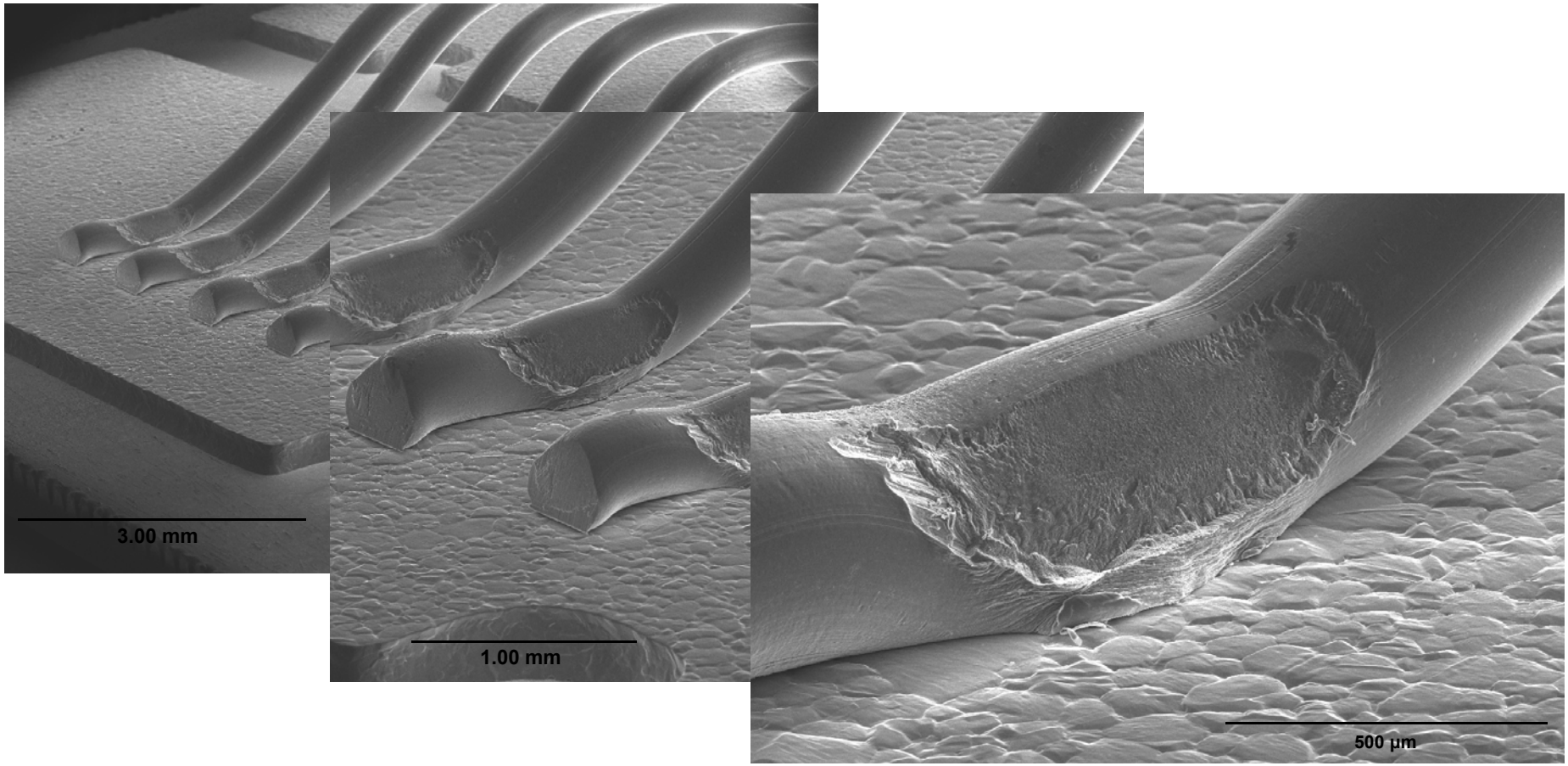
- Allows for high current flow and shaping of the current wave form
  - A square wave of one second on and one second off is driving 10 amperes through each 0.4 mm (400 microns) diameter aluminum wire
- Data recording
- Visual observation of the boards
- Post exposure evaluation of effects of resulting nucleate boiling on the aluminum bonds



Wirebonds

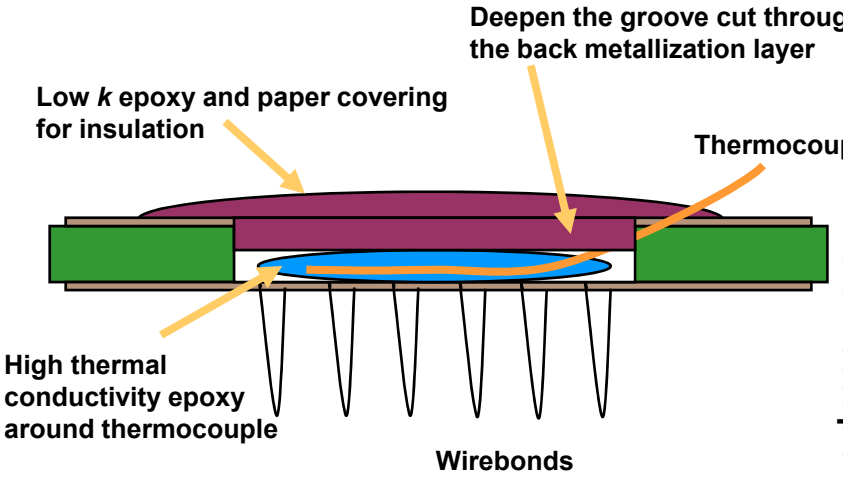


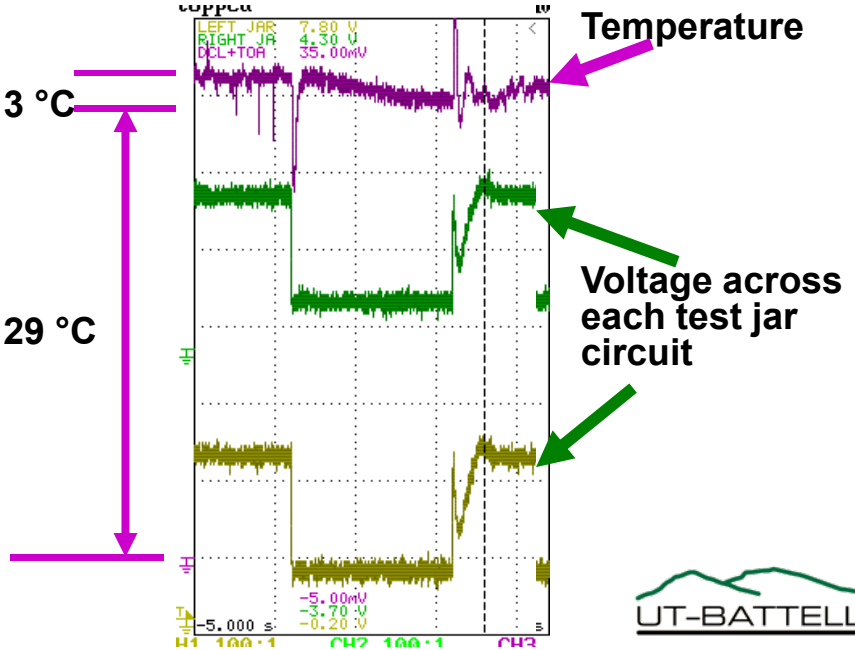
There Were No Observable Environmental Effects On Wires or Board After 690,570 Test Cycles



Enhancements To Test System Are Made As Knowledge Increases

- **Measure temperature change**
  - Actual temperature measurements in evaporative cooling is inherently difficult
- **Increase test current**
  - Running at 50% greater peak current per wire reported for available hybrid auto inverter
- **Increase current on time of waveform**
  - A square wave of two second on and two second off is driving 30 amperes through each 0.4 mm (400 microns) diameter Al wire



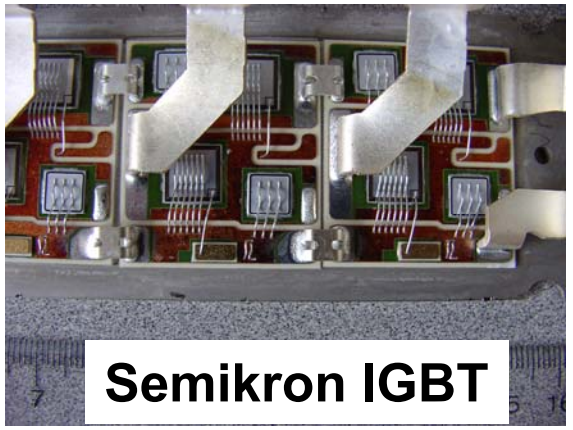


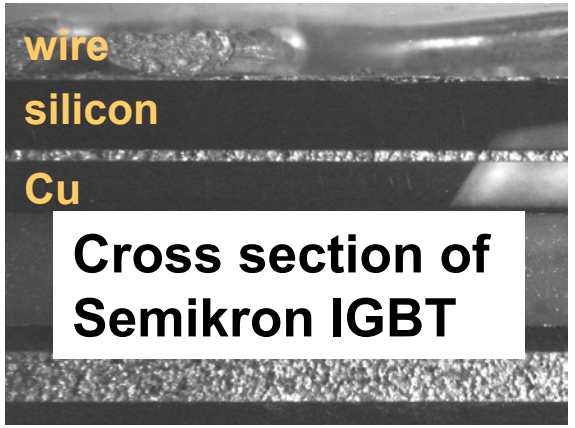
Future Work—Continue As Needed Enhancements and Validate Test Methodology

- Develop "go/no-go" criteria of failure
  - Separate effects due to methodology from that due to coolant
    - Variables include coolant, current, cycle time
- Use more prototypic boards
  - Refine "go/no-go" criteria of failure
- Confirm feasibility of cooling approach and develop minimum test data that allows for a meaningful dialogue with system designers

Successful Demonstration of Compatibility of Direct Side-Stream A/C Cooling With Power Electronics Will Allow:

- PEs concepts that reduce the component count and integrate functionality to decrease size, weight, and cost
- This task achieved milestone (09/08)
  - Develop methodology to evaluate the interaction of the electrical components with the fluids used in the evaporative cooling systems. Initiate testing of methodology.
- In FY09, this task is on track to achieve milestone (09/09)
  - Validate the proposed methodology
  - Define "go/no-go" of failure as related to materials/component performance





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