Advanced Thermal Interface Materials for Power Electronics

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Project Duration: FY06 to FY09

DOE FreedomCAR and Vehicle Technologies Program
Advanced Power Electronics and
Electric Machines Projects
FY08 Kickoff Meeting

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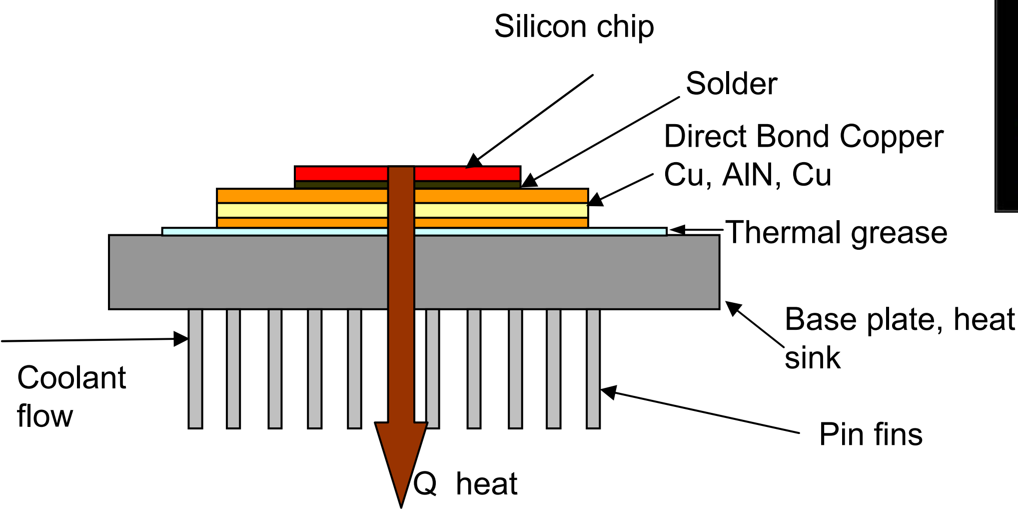
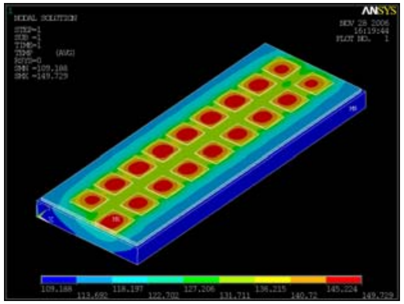
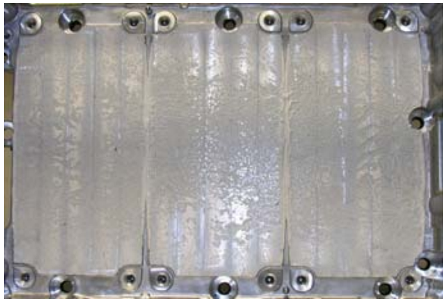
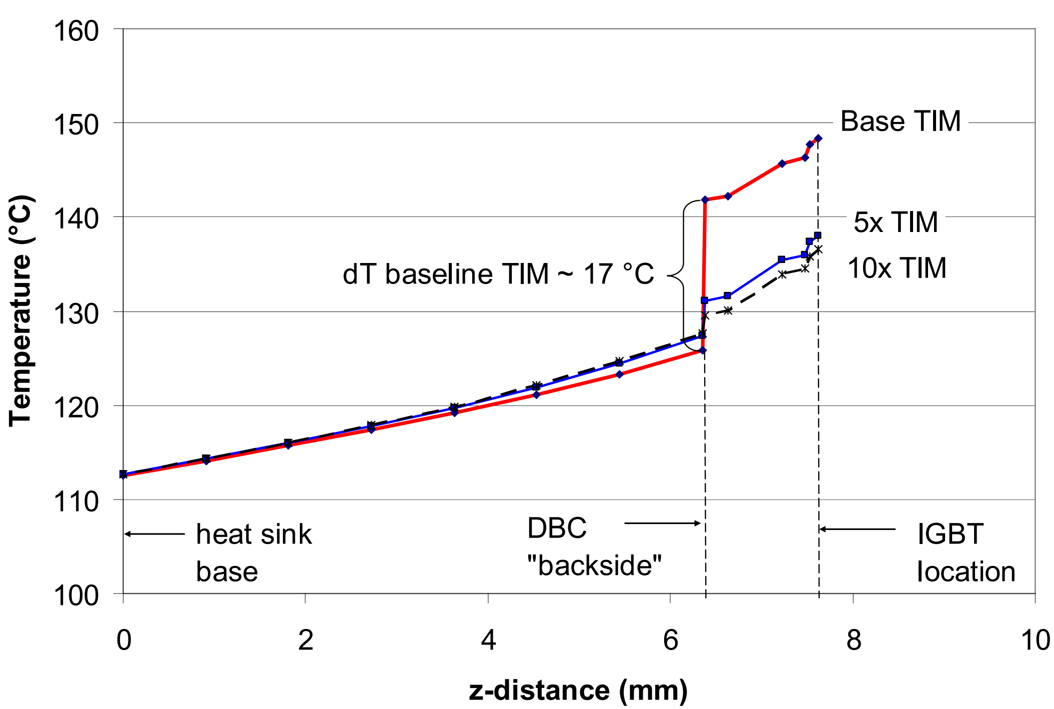
The Problem





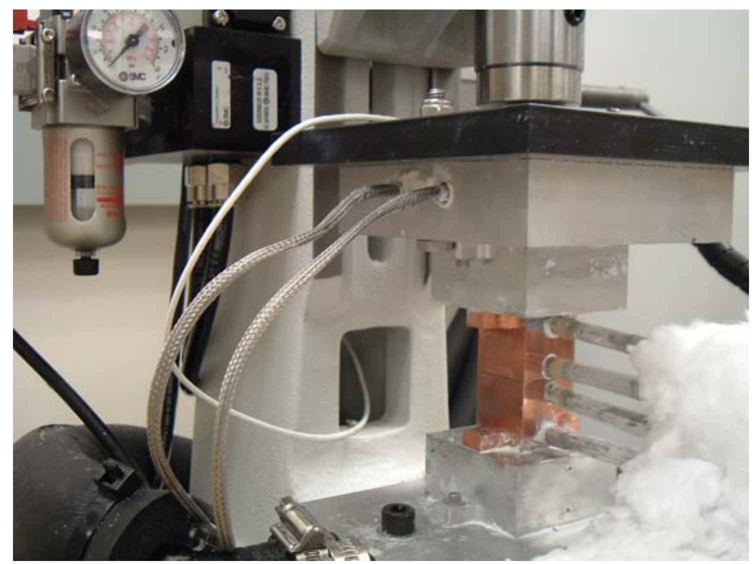




- Conventional grease used in inverters (R > 50 mm^2K/W for 75 um or higher thickness) poses a bottleneck to heat removal
- Problems with greases include: application, pump out, and dry out
- In-situ performance of greases may be substantially worse than material specifications

Description of Technology/Approach

- Objective is to identify low cost, low resistance (~ 5mm^{2}K/W) thermal interface material (TIM)
- NREL TIM apparatus
  - Based on the ASTM D5470 steady state method
  - Capable of measurements from -30°C to 150°C and over a load of up to 500 lbf (2220 N)
- Investigating alternatives for in-situ characterization
- Impact of thermal cycling and aging effects on interface material resistance will be explored

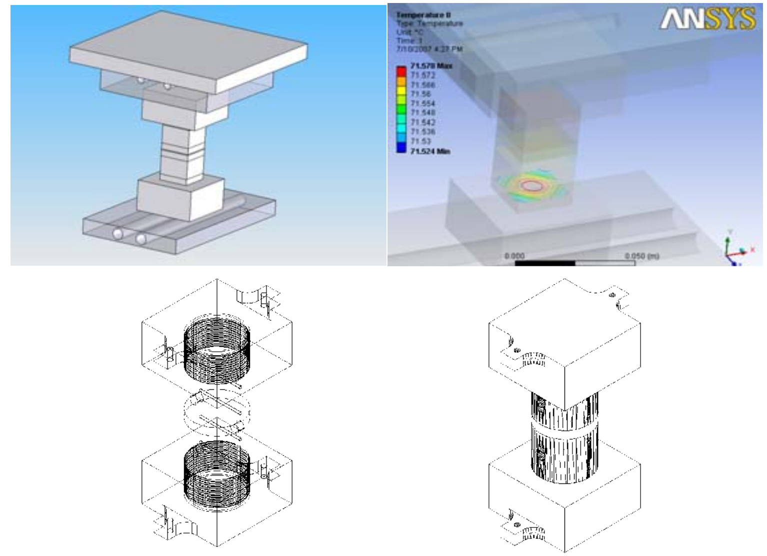


Uniqueness of Project and Impacts

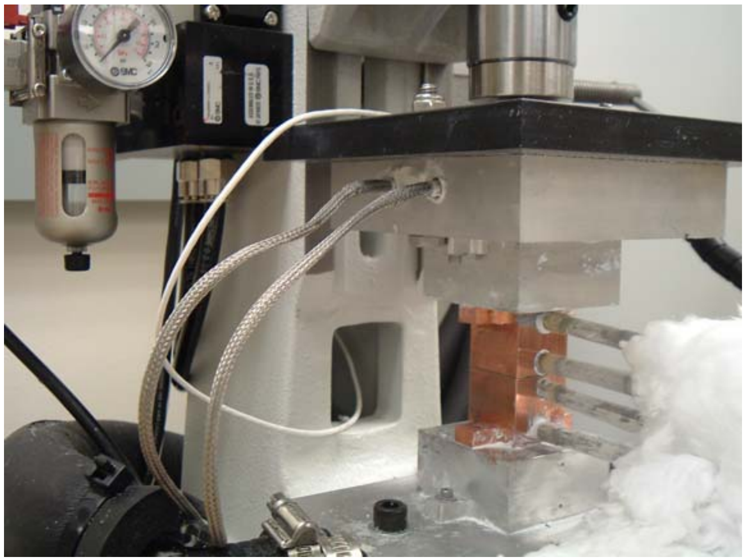
- Enabling technology for 105°C and air cooling
- Objective and consistent database on the performance of interface materials will be established
- In close collaboration with industry, explore interface materials best suited for IGBT package applications
  - Novel materials such as carbon nanotubes (CNTs) are being explored in a realistic IGBT package configuration
- This project will result in identification/fabrication of improved thermal interface materials for automotive applications

Accomplishments to Date

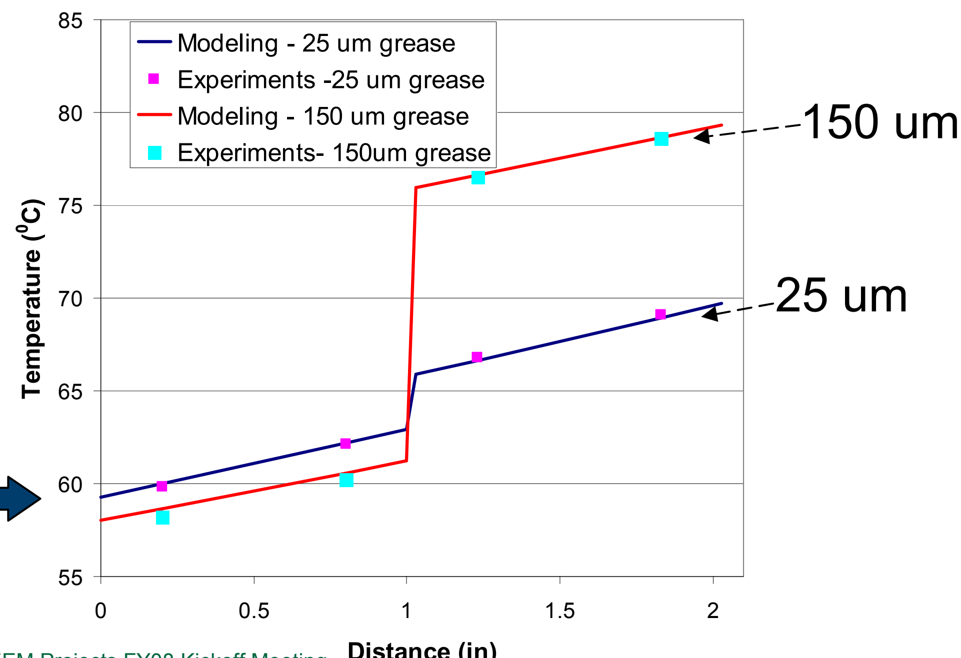
2. Numerical modeling, design changes



1. Experimental setup

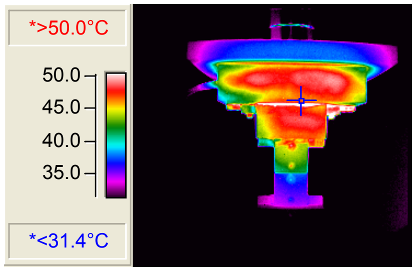


3. Comparison of modeling and experiments

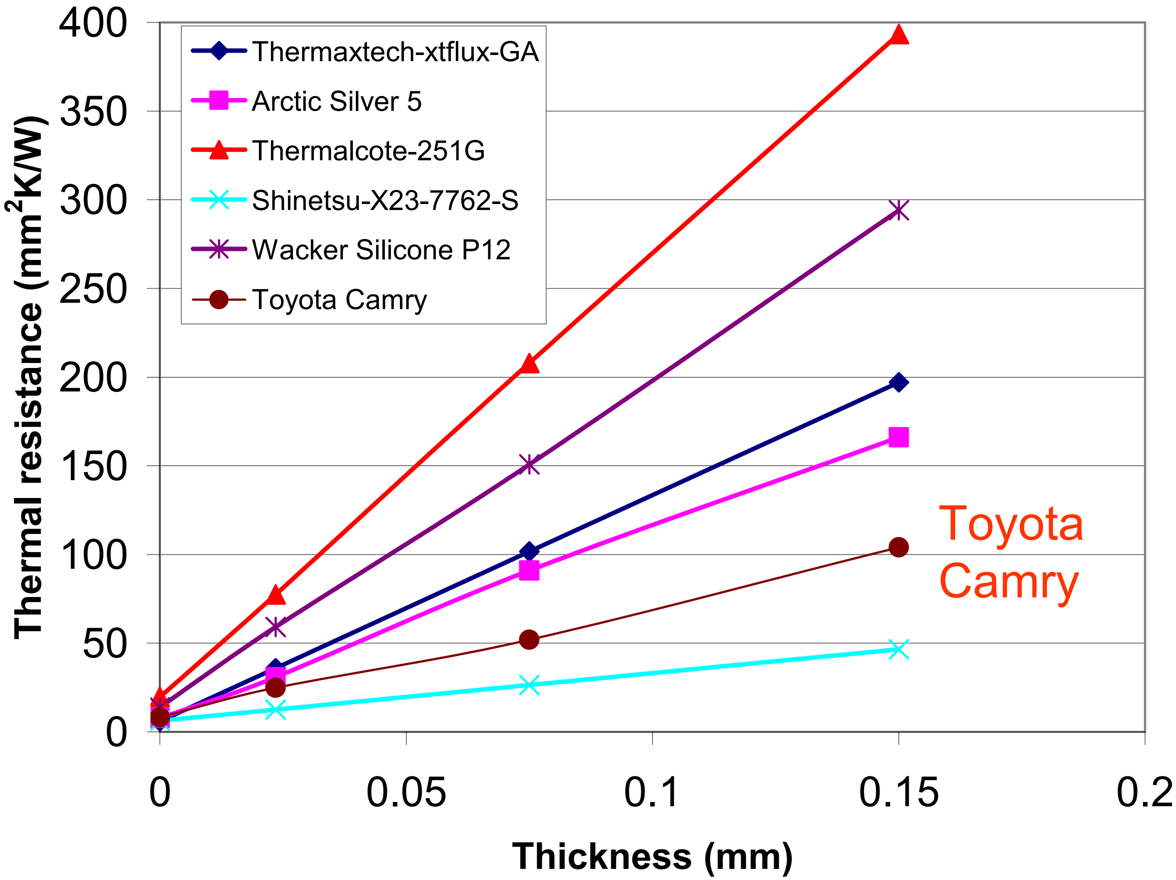


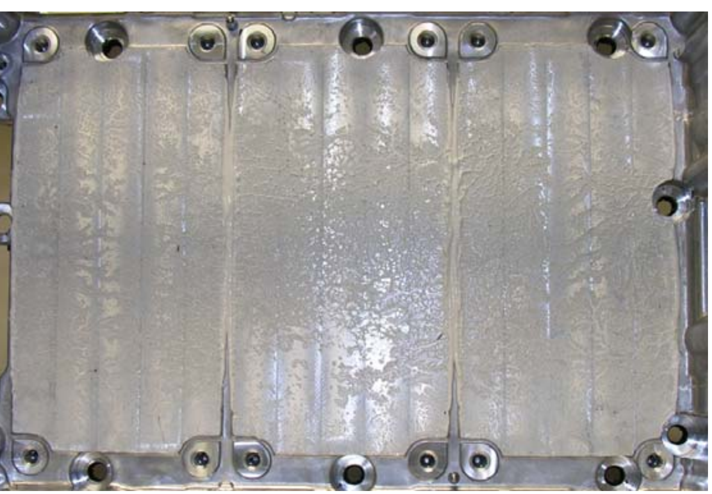
Accomplishments to Date

Brand of grease	Cost ($/g)
Thermaxtech-xtflux-GA	1.2
Arctic Silver 5	2
Thermalcote-251G	0.04
Shinetsu-X23-7762S	0.9
Wacker Silicone P12	0.07
Toyota Camry	?



4. Experimental thermal resistance results for various greases





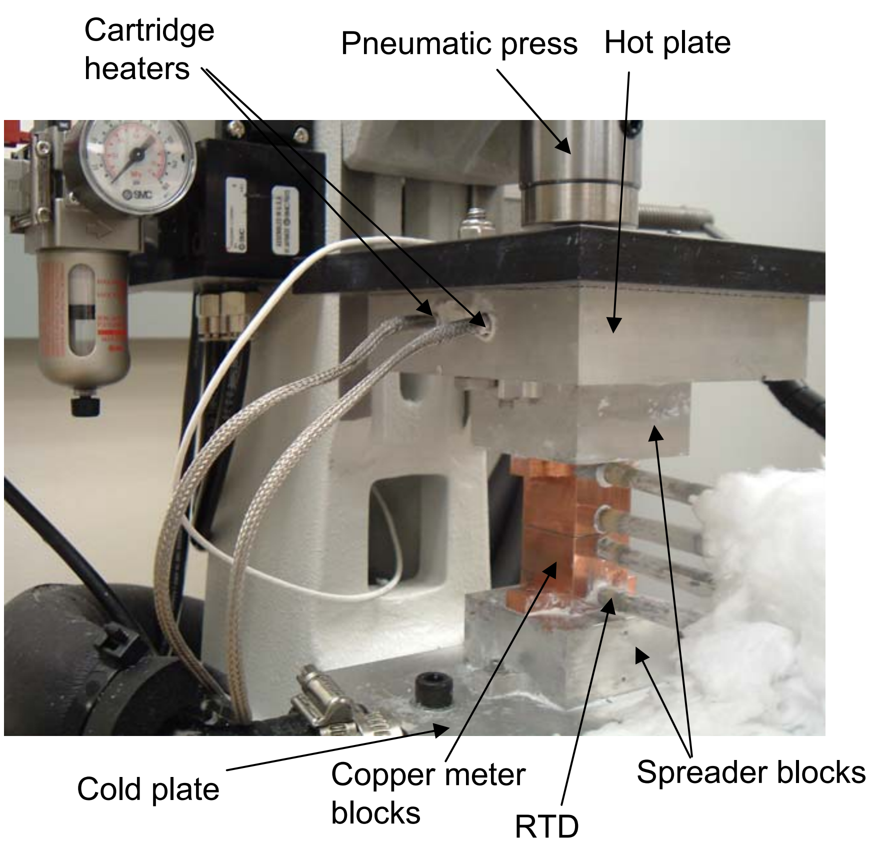
Toyota Camry Inverter

Project Objectives for FY08

- Perform thermal resistance measurements for various state-of-the-art TIMs
  - greases, phase change materials, metallic TIMs, solders, graphite
- Perform thermal resistance measurements for carbon nanotubes (CNTs) grown on realistic package substrates
- Study the impact of thermal cycling (from -40 to 150°C) on the TIM thermal resistance
- Study the effects of “aging” on TIM thermal resistance
- In-situ characterization of thermal resistance

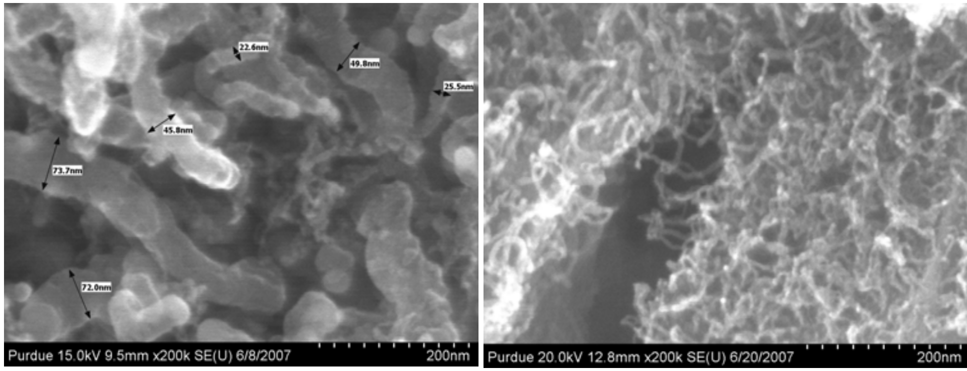
Technical Approach for FY08

- Continue to perform consistent and accurate measurements for characterizing TIM performance
- Measure thermal resistance over automotive temperature (50 ~ 125°C) and pressure ranges (20~ 100 psi)
- Key components and measurements
  - Four temperatures via RTDs
  - Force via a load cell
  - Power supplied to resistor in the hot plate
  - Silicone oil coolant in the cold plate
  - Pneumatic press for applying force
  - $R = \Delta T \, A/Q$



Technical Approach for FY08

- Establish a consistent, objective database of the thermal performance of different TIMs such as:
  - Greases (already commenced)
  - PCMs
  - Pads
  - Solders
  - Metallic TIMs
  - Graphite-based materials
  - CNT-based TIMs (already commenced)
- In conjunction with industry, compare results with alternative techniques (e.g. Laser Flash)



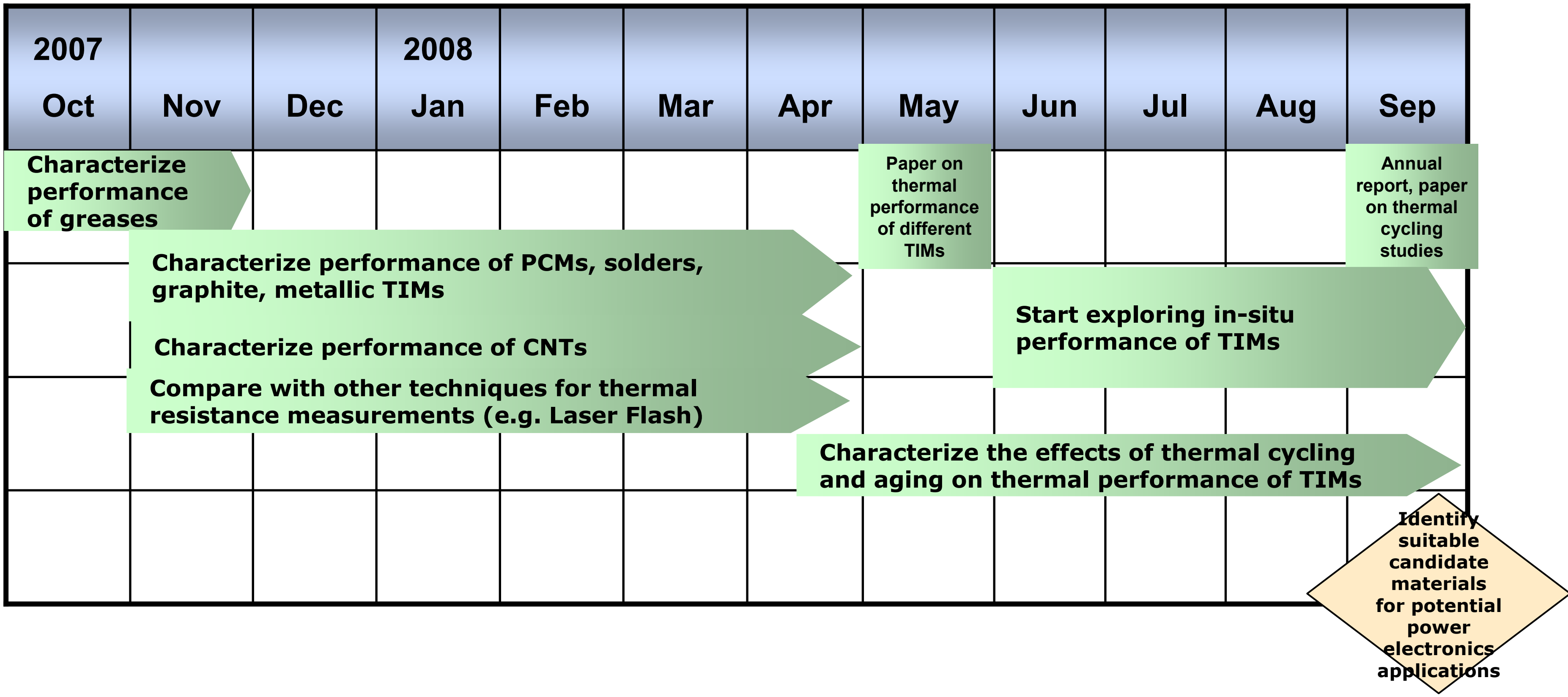
Courtesy: Delphi

Technical Approach for FY08

- Characterize impact of thermal cycling and aging effects on thermal resistance

- Start understanding in-situ TIM behavior – both via steady state (NREL TIM apparatus) as well as transient measurements

Timeline



Decision point discussion: Based on thermal resistance characterization as well as preliminary studies of the impact of thermal cycling, potential candidate materials for power electronics applications will be identified. Detailed in-situ experiments for thermal performance and reliability studies can be performed for some select materials in FY09.

The Challenges/Barriers

- **Technical challenges**
  - Identifying the best (cost, thermal performance, reliability) commercially available materials
  - Accurate, consistent, and repeatable set of experimental data
  - Thorough characterization of reliability (effects of thermal cycling and aging)
  - In-situ performance of TIMs

Beyond FY08

- **FY09**
  - Complete studies related to reliability – including impact of thermal cycling and aging effects
  - Complete in-situ testing both via transient as well as steady-state approaches
  - Explore fabrication of novel interface materials most suited for automotive applications

Questions