Improved Organics for Power Electronics and Electric Motors

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Project ID #:
PM037

Overview

Timeline

- Project start: October 2010
- Project end: September 2013
- Percent complete: 16%

Budget

- Total project funding
  - DOE 100%
- FY11: $250k
- FY12: $250k
- FY13: $250k

Barriers*

- Barriers Addressed
  - Reliabilty and lifetime of power electronic devices (PEDs) degrade rapidly with temperature increase.
  - PEDs need improved thermal management to operate at higher temperatures.
  - New paradigms in cooling would enable achievement of higher power densities without compromise to device reliability.
- Targets:
  - DOE VTP* 2020 target: 105°C Coolant
  - DOE VTP* 2020 target: 4 kW/liter power density

Partners

- NTRC – ORNL
- Mossey Creek Enterprises

* VTP Multi-Year Program Plan 2011-2015

Objectives

- Identify and develop lower-cost and better-performing organic compounds for dielectric and thermal management applications in power electronics, electric motors, and film capacitors.
- Reduce volume and improve thermal reliability of power electronics, electric motors, and film capacitors through improved thermal management strategies.

Milestones

- **FY11 - 1: Establish baselines by measuring thermal properties of unused and serviced organic molding compounds from power electronic devices, electric motors, and film capacitors.**

- **FY11 - 2: Develop test methods that representatively thermal cycle organics for laboratory tests and subsequent characterization.**

Technical Approach

- Harvest *unused* organic dielectric materials from power electronic devices, electric motors, and film capacitors for thermal property testing (thermal diffusivity, thermal conductivity, and heat capacity).

- Harvest *used* organic dielectric materials from power electronic devices, electric motors, and film capacitors for thermal property testing. Compare with thermal responses of unused materials.

- Develop test fixtures for in-situ thermal property testing.

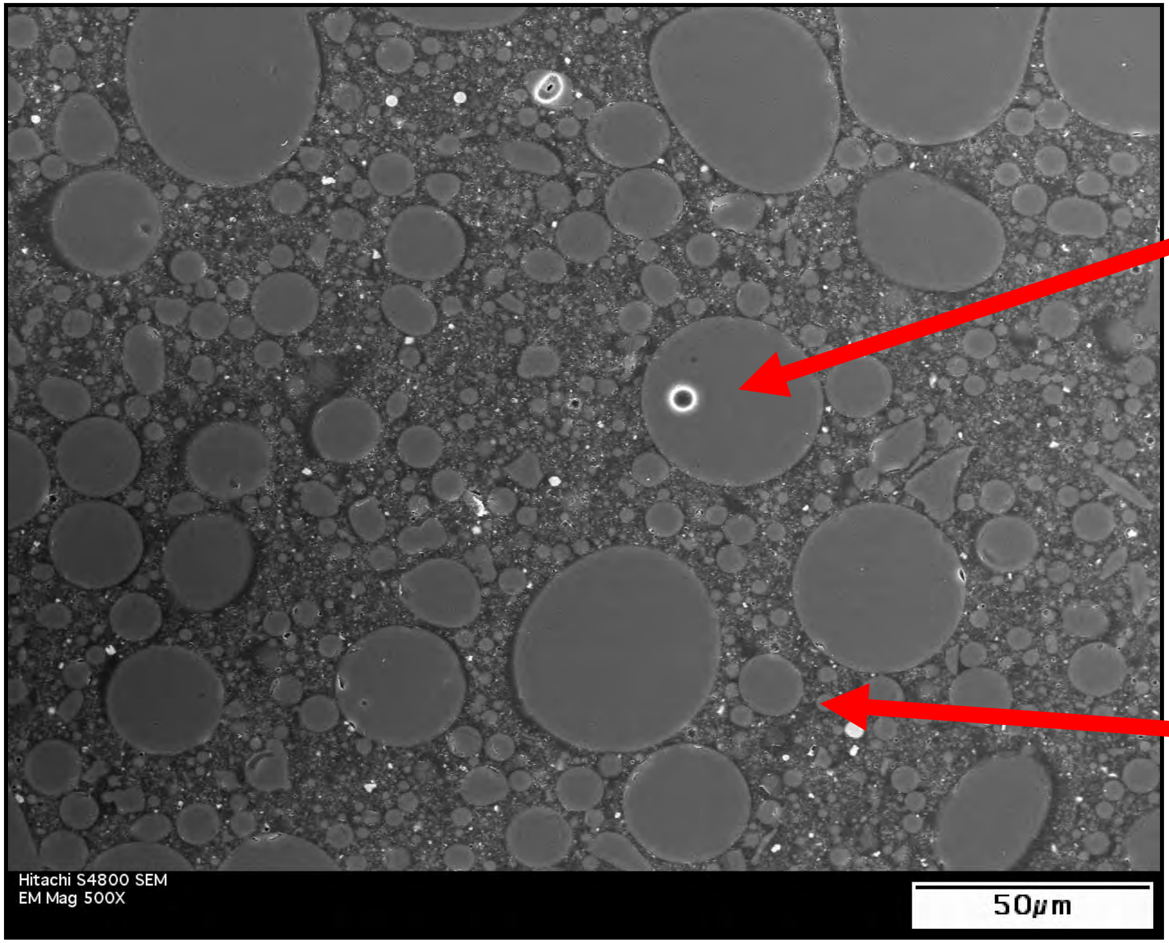
- Develop organic materials (e.g., epoxy molding compounds) with improved thermal properties, ease of processing, and sustained low cost.

Technical Accomplishments (1 of 3)

- **Literature survey (particle size distribution, percolation limit)**
- **Surveyed candidate ceramic fillers (electrical insulators) having high thermal conductivities.**
- **Attrition mill undergoing refurbishment**
- **Molds procured for casting organic or epoxy molded compounds (EMCs)**
- **Particle size distribution measurement system procured**
- **Transient finite element model developed for use analyzing thermal conductivity of EMCs**
- **Electrical resistivity and dielectric breakdown test systems undergoing development**

Technical Accomplishments (2 of 3)

Epoxy molding compound with a ceramic filler used in a power electronic module from a hybrid vehicle's inverter



Traditional fillers are electrically insulative, have a low thermal conductivity, and are cheap

Particle size distribution and volume fraction solids must be controlled

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Technical Accomplishments (3 of 3)

Potential ceramic fillers for EMCs

Material	Electrical Resistivity at 25°C (Ω•cm)	Thermal Conductivity at 25°C - κ - (W/m•K)	Heat Capacity - Cp - (J/kg•K)	Density - ρ - (kg/m^3)	Coefficient of Thermal Expansion - CTE - (x 10^{-6}/°C)	Estimated Cost ($/kg)
Silica silicon dioxide (SiO_2)	> 10^{14}	2	700	2600	0.5	2
Alumina aluminum oxide (Al_2O_3)	> 10^{14}	30	900	3900	8	5
Magnesia magnesium oxide (MgO)	> 10^{14}	40	900	3600	10	5
Silicon carbide (SiC)	> 10^{14}	120	800	3100	4	40
Aluminum nitride (AlN)	> 10^{14}	250	700	3200	5	400
Beryllia berylium oxide (BeO)	> 10^{14}	280	600	2900	9	800
Epoxy	> 10^{12}	0.05 - 0.1	1500	1200	30-60	5

Future Work

- Thermally and microstructurally characterize unused and used molding compounds from power electronic devices, electric motors, and film capacitors.
- Model thermal conductivity of EMCs with fillers as a function of volume fraction, particle size distribution, and percolation limit.
- Relate attrition milling conditions to produced particle size distribution.
- Complete electrical resistivity and dielectric breakdown test setups.

Summary

- Identifying and developing lower-cost and better-performing organic compounds for dielectric and thermal management applications in power electronics, electric motors, and film capacitors.

- Comparing epoxy molding compounds (EMCs) of unused and used components through thermal and microstructural characterization.

- Developing new EMCs with high thermal conductivity, that have predictable and simple processing characteristics, and are inexpensive.