Thermal Materials Developments, Thermal Materials Testing, and Thermal Systems: Key Solutions for Mil/Aerospace Electronics Systems

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COURSE SUMMARY

Electronic design at the system level consists of integration of an array of different individual semiconductor and electrical components. Integration of disparate component types for vehicle electrification includes IGBT power semiconductors, ICs, RF devices, discrete power semiconductors, capacitors, battery cells, and subassemblies such as DC-DC converters. Many of these component types, while highly efficient, also dissipate some amount of heat. Managing heat dissipation becomes the responsibility of mechanical engineers responsible for the system enclosure, internal mechanical and thermal design, and balancing many competing factors – while also meeting overall system design requirements.

A major failure mechanism for electronic systems is inadequate heat dissipation, both from individual components and at the system level. Heat is the single largest cause of failure, with vibration and dust and other environmental factors as examples of other causes.

Thermal interface materials (TIMs) provide a critical intermediary between processors, power transistors, IGBT power modules, battery cells and cold plates, and other components that generate heat and heat sinks and mechanical components – to allow transfer and spreading of a given heat load to larger metallic surfaces and ultimately to the ambient air. Thermal materials, broadly defined, can include materials that act as heat spreaders (i.e., moving heat in-plane) and as interface materials (i.e., through-plane, through a stack of materials from point source to ultimate heat sink). Substrate materials provide another critical piece in the overall system design, and these include polymeric- and ceramic-based solutions. Developments in this area continue to push cost and performance levels, to meet new system design requirements.

Testing of thermal materials (including heat spreaders and thermal interface materials, as well as substrate materials) is a continuing area for improvement in methodologies and equipment, as well as understanding of data output. Primary test methodologies will be discussed, indicating the purposes for which each test methodology is intended, as well as interpretation of data.
Thermal management systems include air cooling and several types of liquid cooling technologies. Liquid cooling technologies include heat pipes and loop heat pipes, single-phase pumped liquid systems, and two-phase liquid cooling systems, with water/glycol, commercial dielectric fluids, or low-cost refrigerants as coolants.

Categorizing and evaluating this range of thermal management technologies is increasingly important as a key component of vehicle electrification, and as the industry moves towards higher temperature operation of power semiconductors (silicon, GaN, and SiC). This tutorial presentation will provide insight across this range of different technologies and will include examples of system implications.

Topics included are:

- Thermal interface materials:
  - Categorization of major material types
  - Testing methodologies
  - Evaluation and selection criteria for implementation
  - Failure mechanisms for specific material types and solutions
- Graphite films and sheets: Distinguishing heat spreader materials from TIMs and why these are important materials
- CTE-matched rigid thermal materials as baseplates, substrates, and module materials
- Testing methodologies for thermal materials; purposes for each methodology and interpretation of test data
- High temperature requirements and material selection
- Categorization of thermal management hardware types
- Advantages and disadvantages by thermal management hardware type
- Examples of implementation for different types of electronic systems
- Liquid coolants available
- Continuing challenges and requirements for thermal management materials and systems
- Opportunities and recent new developments

For thermal systems, hardware components, and materials manufacturers, understanding specific application requirements for industry segments such as electrification for drive systems, battery packs, and control systems are critical in order to address specific industry developing needs.

INSTRUCTOR BIO

Dave Saums has forty years of experience in electronics thermal management, leading development activities for thermal materials, thermal components, and two-phase liquid cooling systems. Work experience included positions with a manufacturer of mil/aerospace grade miniature airmoving devices and a major high-volume manufacturer of liquid cold plates and heat sink assemblies. This was followed by several years of work with the first company to develop phase-change thermal interface materials, then a role as vice president of marketing for a CTE-matched composite materials manufacturer. This work experience included hundreds of visits to OEM engineering groups globally. Saums resigned to found a business development consulting firm and has been leading that business for eighteen years. He has been general chair of a well-known thermal technologies workshop for twenty-one years, has served as general chair for Semi-Therm Symposium, and has been general co-chair for four thermal management workshops for power electronics in the European Union. Saums also proposed and served as the general chair for a power electronic thermal management workshop, held very successfully with Semi-Therm Educational Foundation and Binghamton University (NY) in July 2020. He was named a Fellow of the International Microelectronics, Assembly, and Packaging Society (IMAPS) in 2010.

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