Characteristics of Practical CTE-Matched Composites for Electronics Thermal Management: Newest Materials and Comparative Analysis

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New thermal material developments continue to emerge, including from manufacturers and research laboratories in the EU, Japan, and elsewhere. Specific types of thermal material developments are the focus of certain university and research institutions, as well, including developments with graphene, carbon nanotubes, boron nanotubes, graphite films, and CTE-matched composites. This work is driven by continuing semiconductor industry demand for reductions in thermal resistance through semiconductor packaging materials. Continuing increases in heat flux (power dissipation per unit area, especially critical for point sources of heat on a semiconductor die) and total power dissipation per device have pushed computing and other industry segment engineers to move to two-phase pumped liquid cooling technologies at the system level, with intensified examination of reductions in semiconductor thermal stack resistances.

Principal failure mechanisms for major semiconductor package types include temperature-induced stress, resulting in warpage, ceramic fracturing, solder cracking or separation, edge-seal separation; use of CTE-matched materials addresses these well-characterized failure types. CTE-matched alloys, laminates, and composite materials are used extensively for both hermetic and non-hermetic semiconductor packaging. Continued rapid increase in heat flux per die for power and digital semiconductors requires continued attention to measures to reduce package internal stress. Temperature-induced package stress is a critical determinant of the need for such material selection. Manufacturers continue to develop CTE-matched composite materials with different CTE and bulk thermal conductivity values, yielding a range of such materials to select for a given set of application parameters. CTE-matched rigid package components that must be manufactured with a variety of different features and metallizations are critical to RF, optoelectronic, and IGBT power semiconductor applications such as lids, baseplates, and heat spreaders. CTE-matched rigid materials have been used also for fabrication of sputtering target backplanes, mirrors, wafer fabrication end-effectors for semiconductor equipment, and other applications.

In this presentation, principal characteristics of a range of such CTE-matched packaging materials will be identified and described for a wide range of commercial materials, including very recent material developments. This includes new composites from Spain and Austria and other EU research.

Understanding the distinctions between materials and material properties is important for categorizing and selecting specific materials suitable for specific types of application requirements. Certain material

types are isotropic; a range of CTE-matched and thermal materials is also available that are anisotropic. Differences in these material values are important to understand and so use as an important factor in material selection, for both matching to a specific device CTE value and for understanding how the heat transfer (and in what direction) is to be directed.

Comparative data tables will be included for CTE, bulk thermal conductivity, Young's modulus, relative isotropicity, metallization requirements, machinability and manufacturing processes, and similar. Practical attributes such as ability to incorporate cast or machined features, including internal pedestals, through-holes, surface flatness and roughness attainable, and similar are important characteristics for selection for use. Targeted CTE values necessary and heat spreading characteristics for different categories of applications will be outlined; several new material sets will be included.

References will be included.