Critical Improvements in Thermal Materials and Characterization Tools for TIMs

Dave Saums
DS&A LLC
Amesbury MA USA
E: dsaums@dsa-thermal.com

Abstract—Considerable focus is placed by industry on development of significantly improved thermal interface materials (TIMs) to replace problematic traditional polymeric materials, to address rapidly increasing heat flux and total power dissipation for AI GPU/APU modules and related processors and other semiconductors.

This presentation will identify critical recent developments as an industry survey, in an era of highly specialized TIMs. This includes materials in different categories, including phase-change metal alloys (PCMAs), phase-change organic, vertically-oriented carbon-based and nanotube arrays, patterned metallic, and graphitic types. Development work is occurring at a rapid pace at universities and industrial manufacturers globally as processor power dissipation has exceeded 1kW per die module.

Identifying critical altered factors that impinge on TIM performance will be part of this assessment, as these factors are driving developments in unusual and specialized types designed to address such factors. Rapid increases in total power, concentrated heat flux, broad area heat flux, semiconductor die warpage, requirements for elimination of silicones, ability to withstand high assembly clamping forces applied, system lifetime reliability, and reworkability. Ability to survive aggressive bubble mechanical action in two-phase dielectric liquid immersion systems is a very recent requirement development; similar factors are important to recognize and understand. Integration of ceramic dielectric layers into copper liquid cold plates is an additional factor, eliminating need for TIM2 materials, solders, and associated thermal resistances in the material stack.

This presentation will also describe continuing development of industry-standard test methodologies for TIMs. Continuing development of standard and custom thermal test vehicles for thermal material characterization is highlighted for SiC and GaN RF and power semiconductors, as well as ICs.

SiC and GaN devices often have higher heat flux values than silicon die replaced, given higher temperature capabilities and smaller die, increasing the importance of TIM resistance and CTE matching through the power packaging stack.

Liquid immersion (single-, two-phase) has selectively been utilized in traction propulsion for power semiconductors for decades. Rapid growth in market demand for two-phase pumped dielectric fluid technologies, single-phase immersion, and two-phase liquid immersion must include evaluation of fluid characteristics, contamination potential from polymeric TIMs, and related concerns

Keywords—coefficient of thermal expansion, stress, warpage, thermal interface material (TIM), AI GPU, IGBT, liquid immersion

Acronyms:

AMB	Active metal brazing
BLT	Bond line thickness
CTE	Coefficient of thermal expansion
DBC	Direct bond copper (also, direct copper bond)
GaN	Gallium Nitride
GPU	Graphics processor unit
HBM	High bandwidth memory
HIR	Heterogeneous integration roadmap
IGBT	Isolated gate bipolar transistor
MMC	Metal matrix composite
SiC	Silicon carbide
TIM	Thermal interface material
TTV	Thermal test vehicle