Parametric Design Study of a Power Electronics Package

Paul Paret
National Renewable Energy Laboratory, Colorado
IEEE ITherm Conference
July 21-23, 2020

This presentation does not contain any proprietary, confidential, or otherwise restricted information.
Background

Traditional Power Electronics Package

Cree Wide Bandgap Device Package

Maximum operating temperature – 150 °C

Crack Propagation in Pressure-Assisted Sintered Silver
Objective

• Investigate the impact of power electronics packaging materials and geometric design on the substrate attach
  – Large-area attach
  – Prone to thermal cycling.
• Typical substrate attach materials are
  – Solders such as 63Sn37Pb, SAC305, 95Pb5Sn
  – Sintered silver
  – Transient liquid phase alloys.
• Automotive power electronics package design
  – Reduce cost, weight and volume
  – Improve thermal performance and reliability.
Modeling Setup

Material Properties

- **Metallization (Cu)**
- **Ceramic (Si$_3$N$_4$, Al$_2$O$_3$, AlN)**
- **Solder layer (not visible) is between the backside Cu metallization (not visible) and the baseplate.**
- **Baseplate (Cu, AlSiC, Al)**

- Quarter-symmetry model *(yellow dashed lines in top-left figure)* used in simulations.
- Anand viscoplasticity constitutive model used to simulate deformation of the solder region.
- Thermal cycling profile:
  - -40°C to 150°C
  - 5°C/min ramp rate
  - 10 min dwell at extreme temperatures.
Strain Energy Density

• Strain energy density/cycle (volume-averaged at the corner region) was selected as the metric for comparison.
Impact of Baseplate & Ceramic Material

![Strain Energy Density/Cycle (MPa)](chart)

- Thickness of baseplate – 5 mm; ceramic – 0.32 mm, metallization – 0.2 mm

C-SAM Images of SAC305 solder with AlSiC (top) and Cu (bottom) baseplates. Images on the left and right were taken at 0 cycles and 500 cycles, respectively.

• AlSiC baseplate offers superior reliability than its Cu or Al counterparts, mainly due to the low coefficient of thermal expansion mismatch with the ceramic material.
Impact of Baseplate Thickness & Footprint

Ceramic \((\text{Si}_3\text{N}_4)\) thickness – 0.32 mm; metallization – 0.2 mm

Baseplate thickness – 5mm; ceramic \((\text{Si}_3\text{N}_4)\) – 0.32 mm; metallization – 0.2 mm.

Thermal cycling profile - -40°C - 200°C

• Thickness variation has a larger impact on solder joint reliability than footprint/size variation.
Impact of Ceramic and Metallization Thickness

- Baseplate (Cu) thickness – 5 mm; ceramic – 0.63 mm
- Baseplate (Cu) thickness – 5 mm; metallization – 0.2 mm

Higher the coefficient of thermal expansion mismatch, higher the impact of stiffness variation is.
Reliability of a power electronics package is mainly determined by the CTE mismatch between the component layers.

AlSiC baseplate offers superior reliability than Cu or Al baseplates.

In addition to the CTE mismatch, stiffness mismatch also plays a role, but its impact is dependent on the inherent CTE mismatch.

Thicker ceramic materials are not preferred, however thicker metallization layers can improve the package reliability.
Thank You

www.nrel.gov

NREL/PR-5400-77235