Parametric Design Study of a Power Electronics Package

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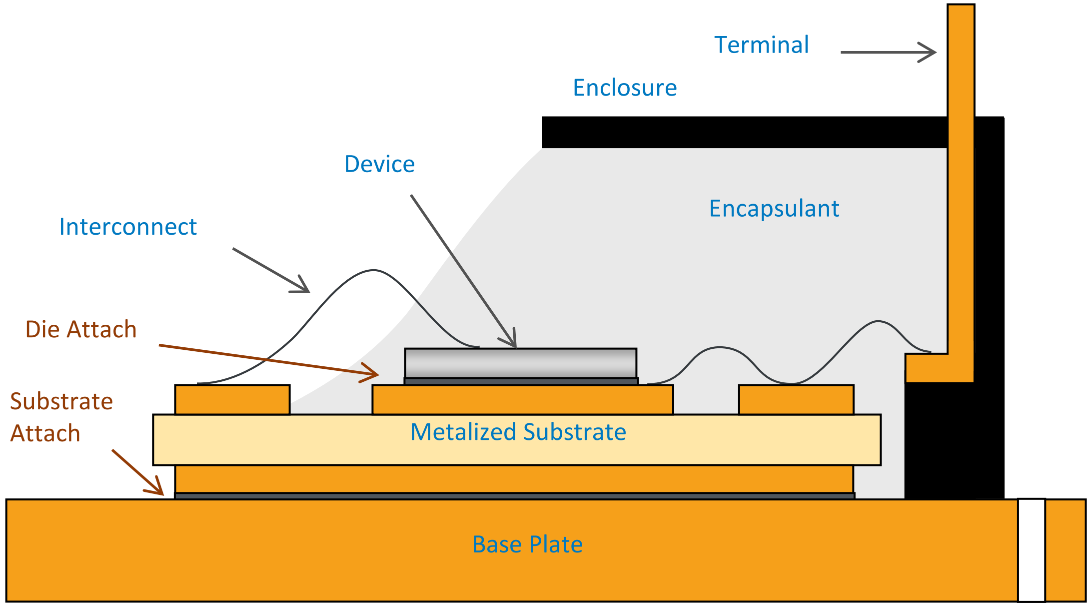
National Renewable Energy Laboratory, Colorado
IEEE ITherm Conference
July 21-23, 2020

Background



Traditional Power Electronics Package

Maximum operating temperature – 150 ° C


Photo Credit: Gilbert Moreno

Cree Wide Bandgap Device Package

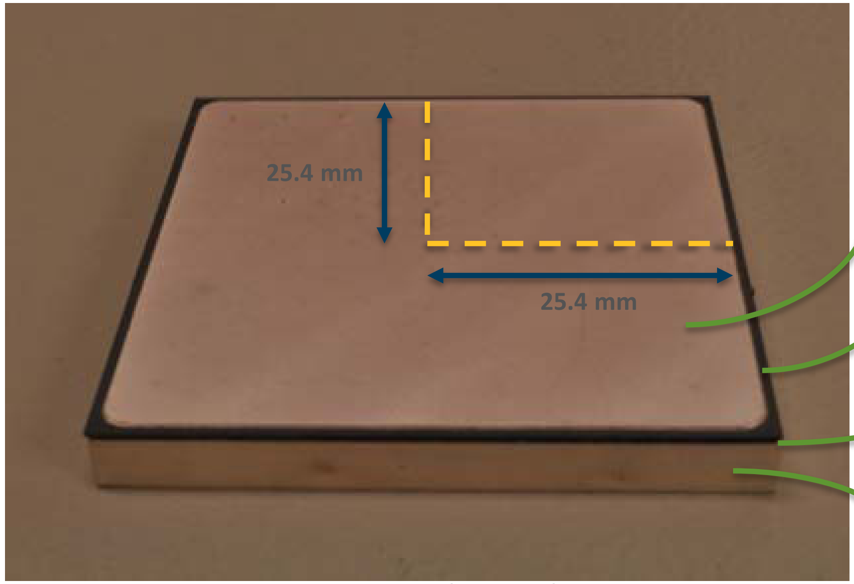
Photo Credit: Paul Paret

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



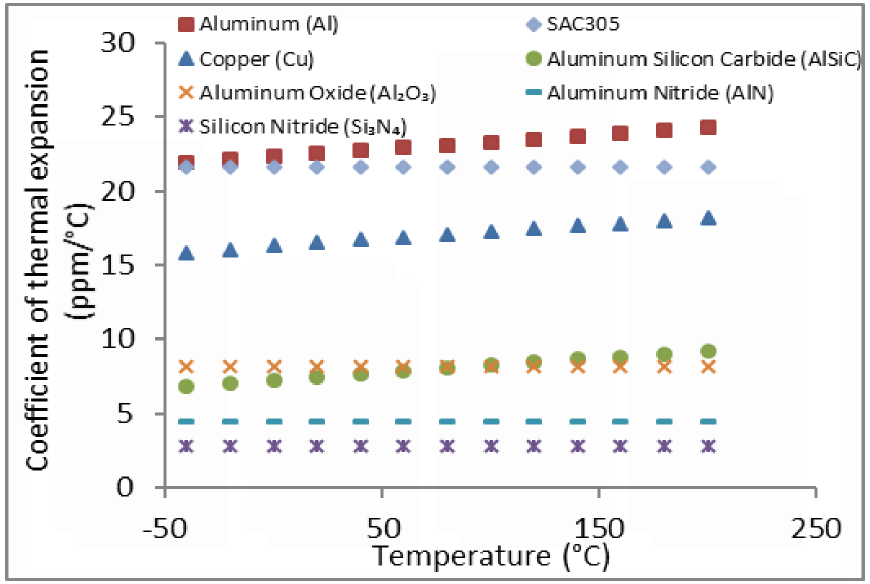
Experimental Sample

Metallization (Cu)

Ceramic (Si_3N_4, Al_2O_3, AlN)

Solder layer (*not visible*) is between the backside Cu metallization (*not visible*) and the baseplate.

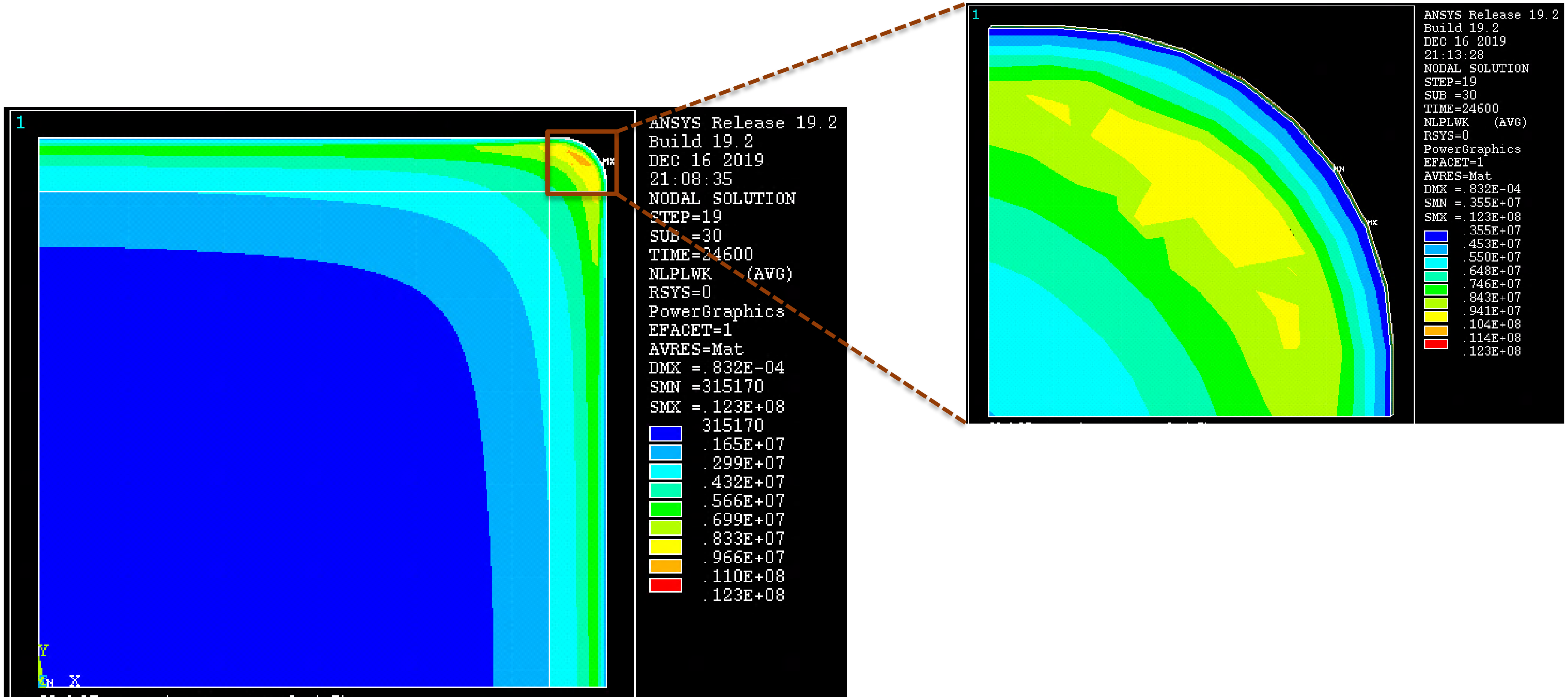
Baseplate (Cu, AlSiC, Al)



Material Properties

- 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



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DEC 16 2019
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SUB =30
TIME=24600
NLPLWK     (AVG)
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PowerGraphics
EFACET=1
AVRES=Mat
DMX =.832E-04
SMN =315170
SMX =.123E+08
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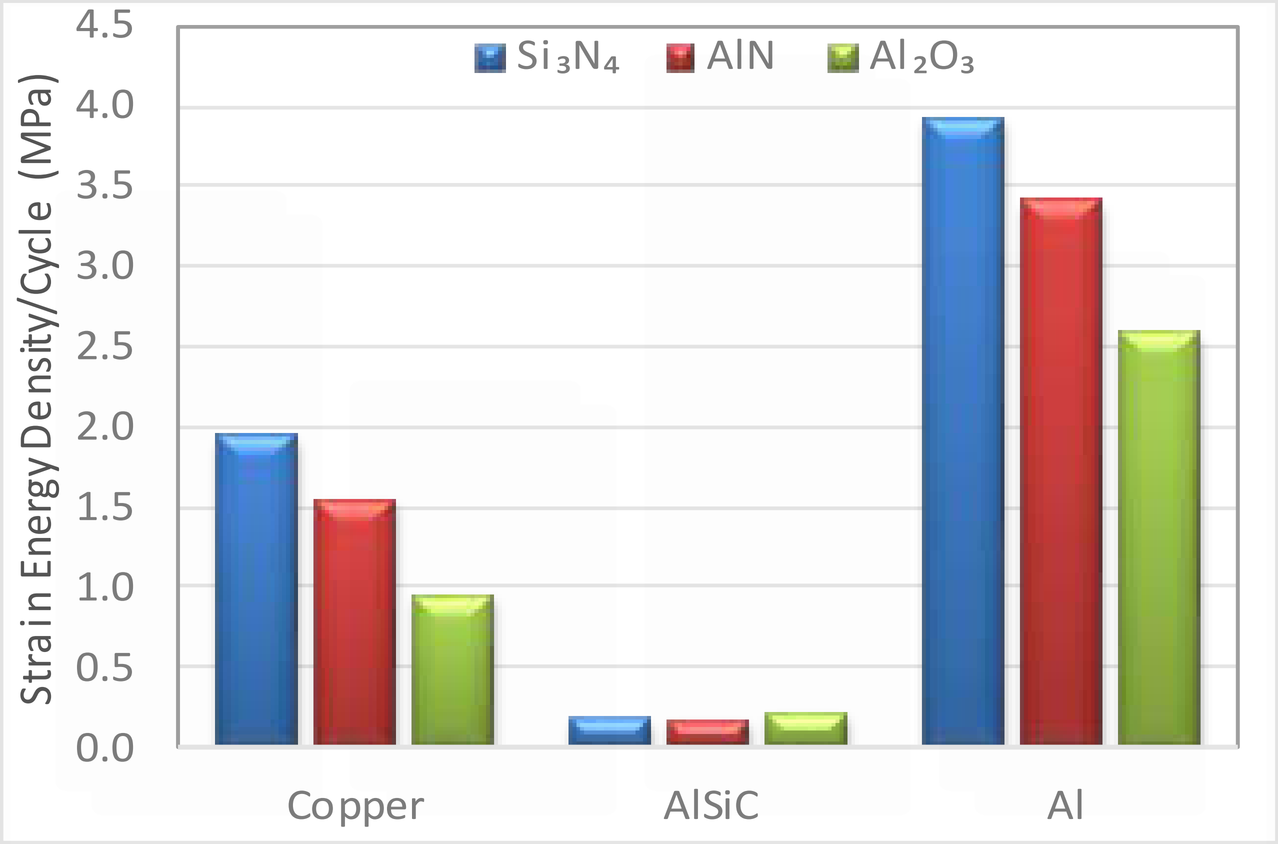
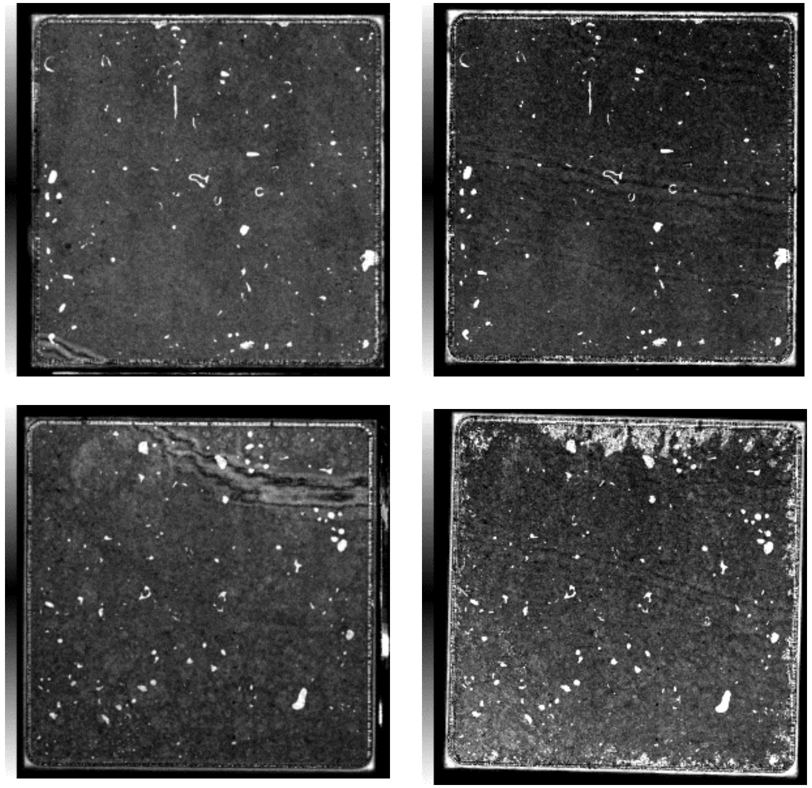
Strain Energy Density Contour Plot

- Strain energy density/cycle (volume-averaged at the corner region) was selected as the metric for comparison.

Impact of Baseplate & Ceramic Material



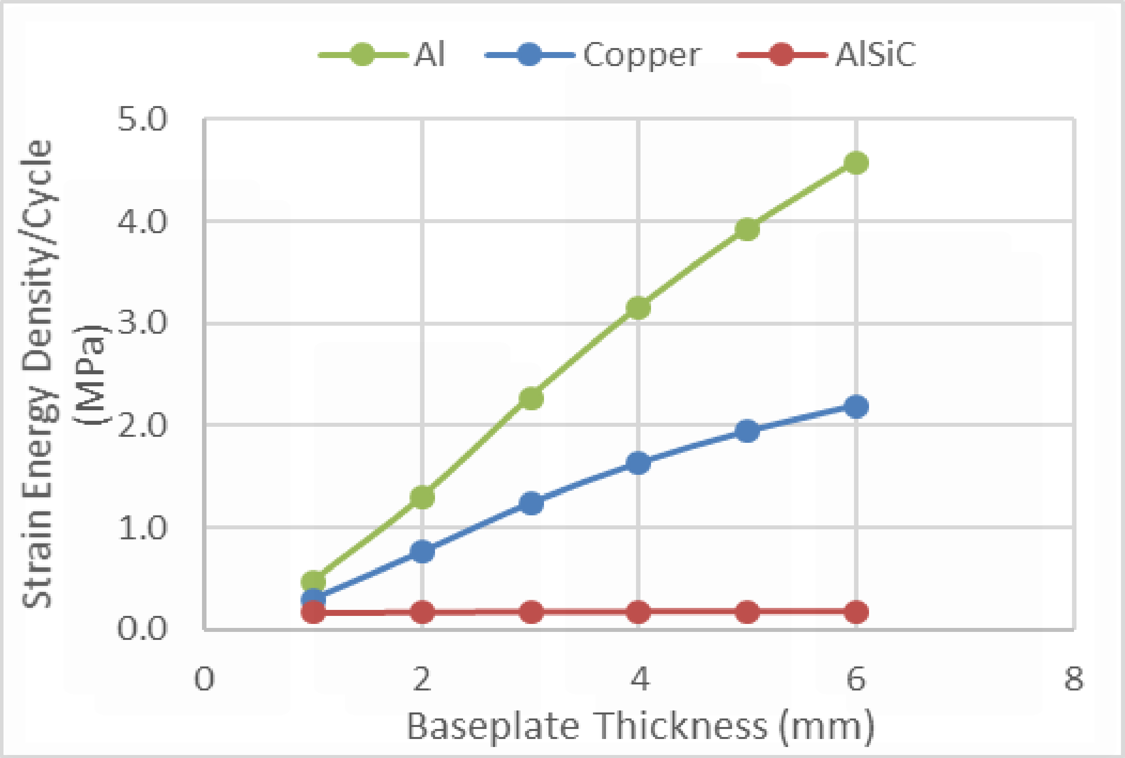
Thickness of baseplate – 5 mm; ceramic – 0.32 mm, metallization – 0.2 mm



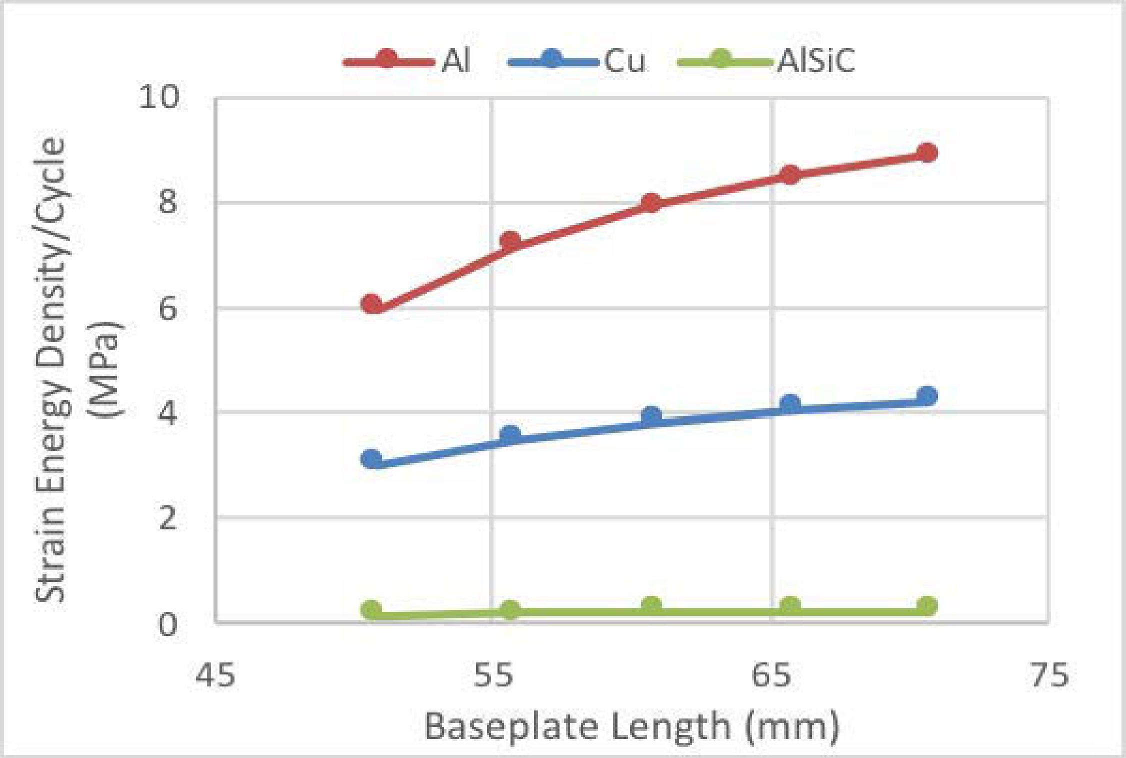
C-SAM Images of SAC305 solder with AlSiC (top) and Cu (bottom) baseplates. Images on the left and right were taken at 0 cycles and 500 cycles, respectively.

- 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



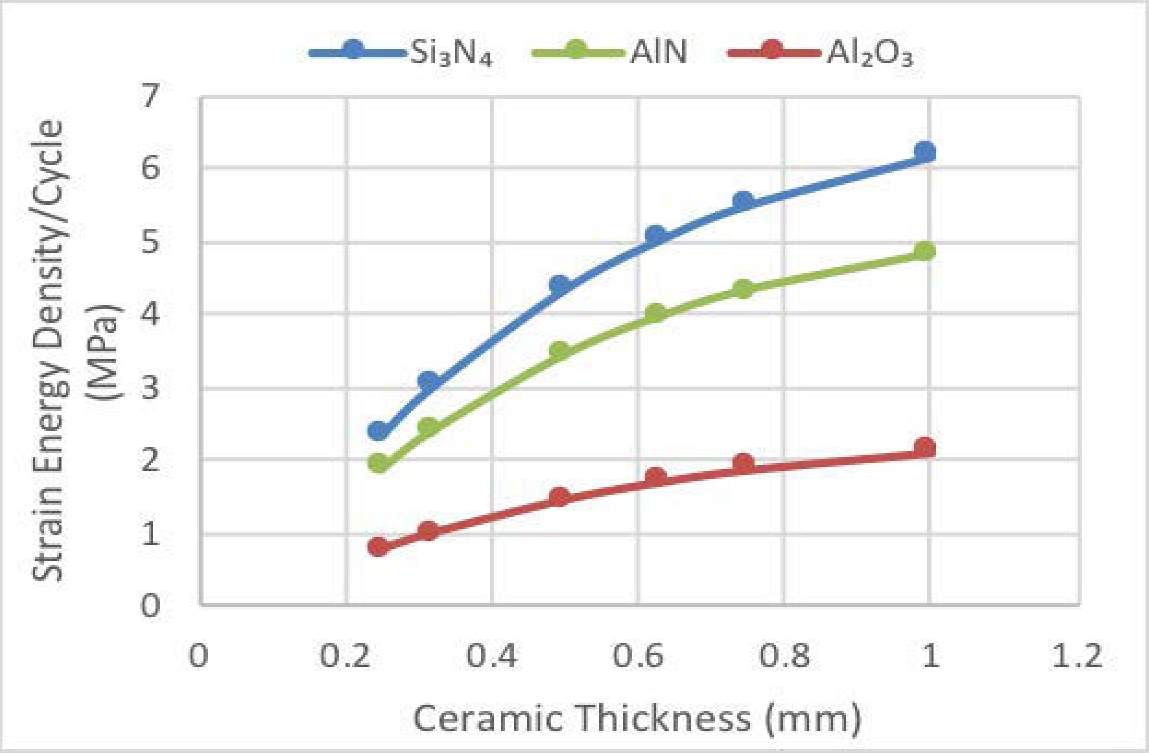
Ceramic (Si_3N_4) thickness – 0.32 mm; metallization – 0.2 mm



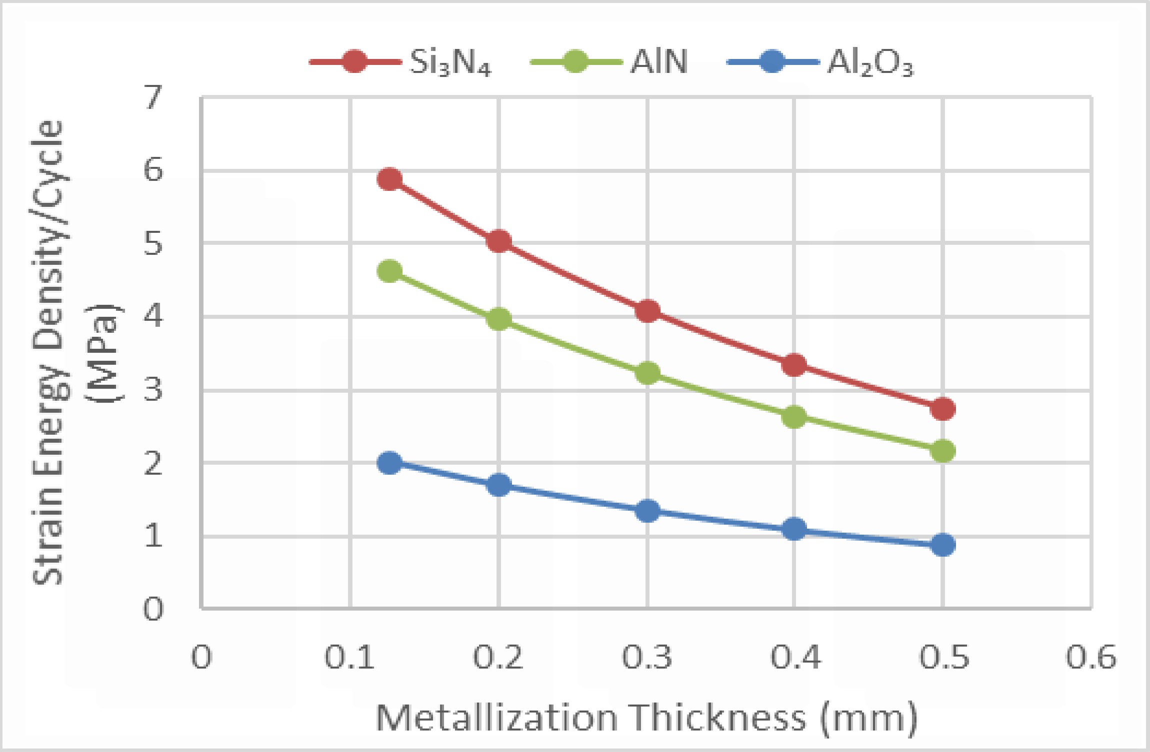
Baseplate thickness – 5mm; ceramic (Si_3N_4) – 0.32 mm; metallization – 0.2 mm.
Thermal cycling profile - -40°C - 200°C

- 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; metallization – 0.2 mm



Baseplate (Cu) thickness – 5 mm; ceramic – 0.63 mm

- Higher the coefficient of thermal expansion mismatch, higher the impact of stiffness variation is.

Summary

- 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.

Acknowledgments

Susan Rogers, U.S. Department of Energy

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Thank You

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