AlSiC Replacement for Copper and Aluminum Baseplates

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see also

"Thermal Impedance and Stress in a Power Package Due to Variations in Layer Thickness"

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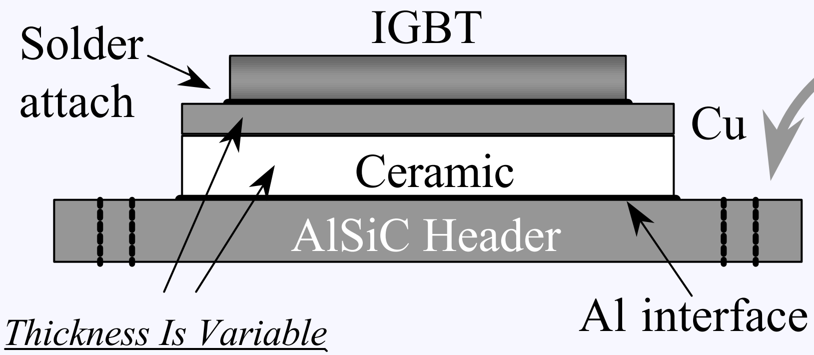
Direct Attached Ceramic on AlSiC

Ceramic on AlSiC

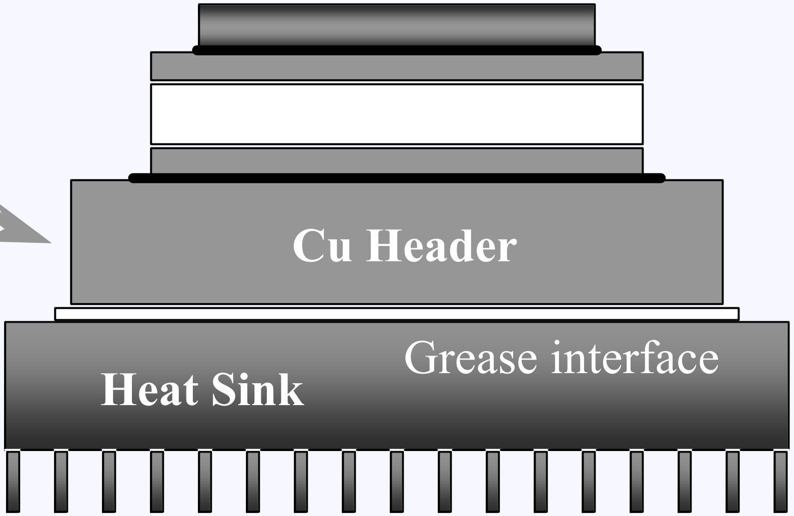


Layer	TCE	Modulus	Density
AlSiC	7.2	226	2.94
Cu	17.3	126	8.96

Process:

1. DBC on ceramic
2. During Al impregnation of SiC (-600°C) the ceramic wets and is attached. Cu anneals.
3. IGBT is attached.

Conventional Package



AlSiC Replacement

Maintain same plate bending rigidity:

Thickness: $\alpha = t_{AlSiC} / t_o$

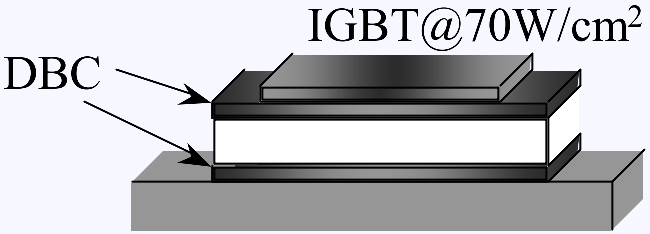
Weight: $\beta = w_{AlSiC} / w_o$

Thermal Resist.: $\gamma = R_{\theta,AlSiC} / R_{\theta,o}$

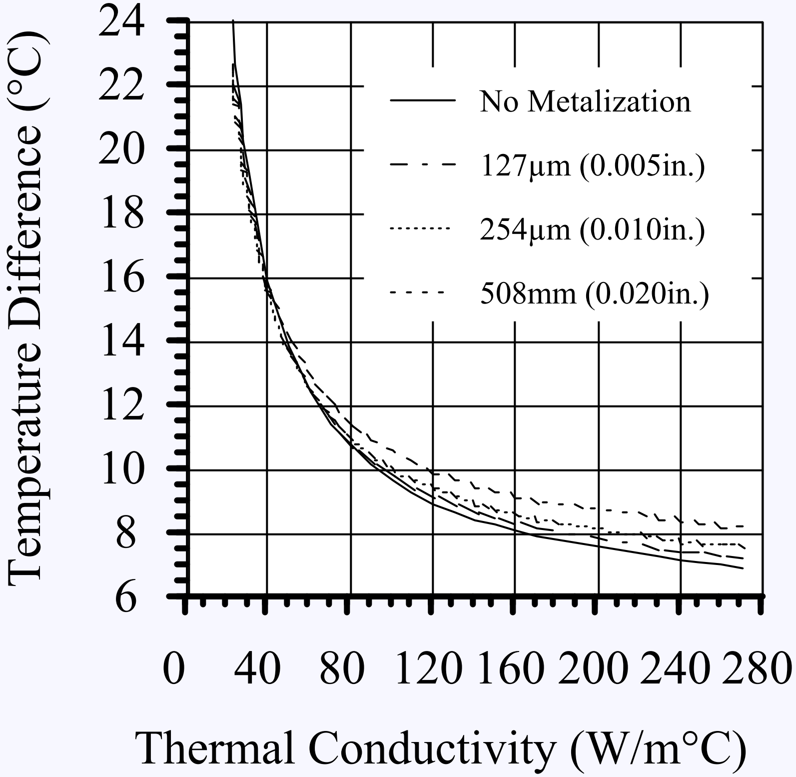
Replacing	α	β	γ
Aluminum	0.69	0.75	0.97
Copper	0.80	0.26	1.85

Thermal Spreading

- Previous Work



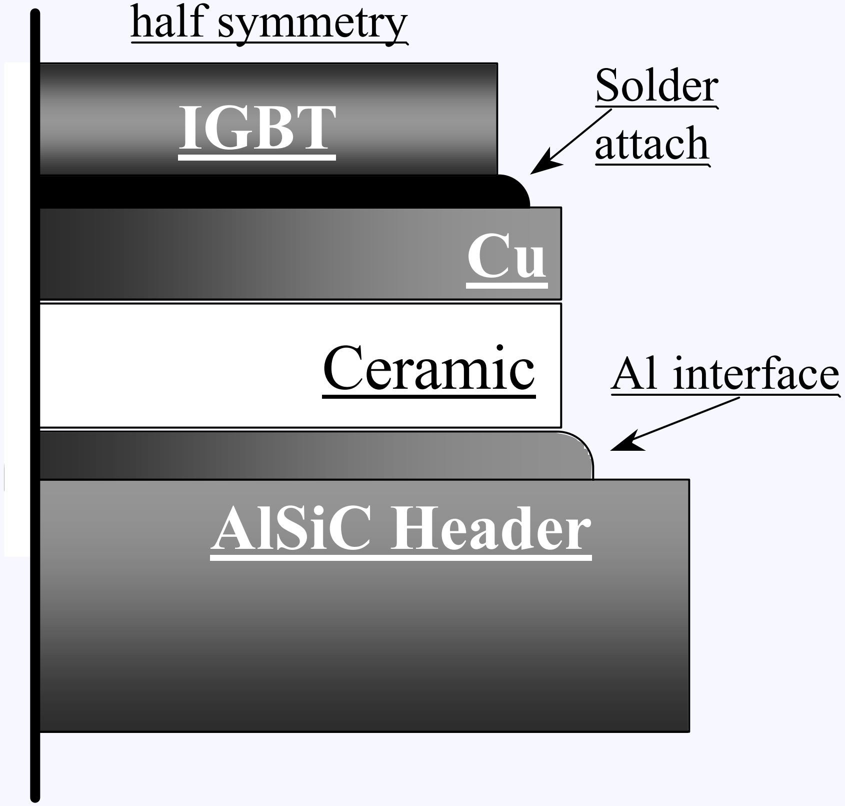
  - 635µm (25mils) Ceramic
  - Vary Cu thickness



- Results
  - Optimum Cu thickness on Al_2O_3 (of 285µm).
  - Increasing Cu thickness increases thermal conductance on BeO, AlN

Physical Performance

- Module Structure



- Variables:

copper thickness: 75–510µm
ceramic thickness: 75–635µm
ceramic type: Al_2O_3, AlN, BeO
AlSiC: 1.3–6.4mm

Layer	Thickness (µm)	Width/2 (mm)
Silicon	350	5.1
63Sn/37Pb	101	5.59
Copper	75-510	6.6
Ceramic	75-635	7.1
Al (356)	51	17.1
AlSiC	1.3-6.4mm	18.4
Adhesive	51	8.4
Baseplate	13.2mm	10.9

Finite Element Analysis

- Dual models:
  thermal and stress,
  with 8-node solid elements
- Meshed for < 5% error
- IGBT with 200W/cm^2
- 25°C thermal ground
- 125°C max at IGBT
- Linear model with no pre-stress.

- Cases Studied

	Layer Thickness		
	Ceramic	Copper	AlSiC
Case I	*varied*	203μm	635μm
Case II	76μm	*varied*	635μm
Case III	254μm	203μm	*varied*

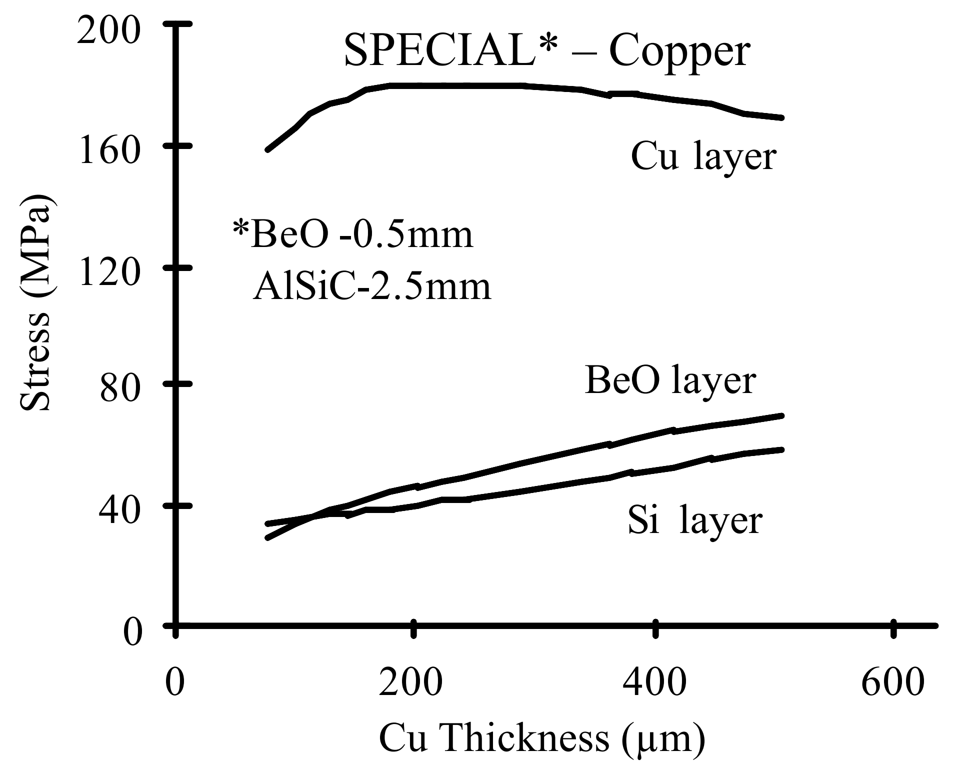
- Stress bounds:
  Copper 192 MPa (equivalent stress)
  Ceramic 264 MPa (tensile principle)
  Silicon 128 MPa (tensile principle)

Results - optimum thickness

- Special Case

Ceramic	Copper	AlSiC
0.5mm	*varied*	635µm
BeO		

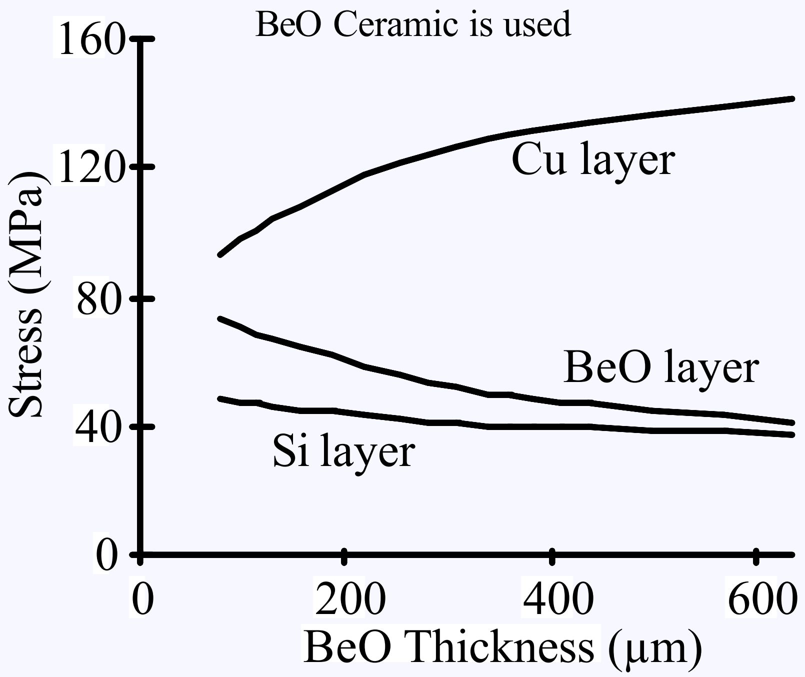
– Example of thickness extremum that maximizes stress. Similar to optimum thickness for thermal conductance.

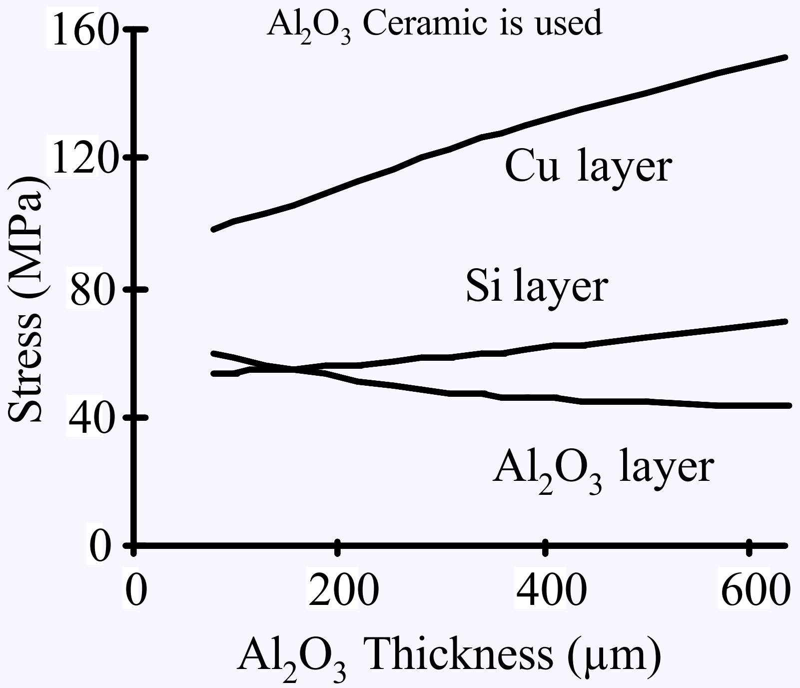


Results - variable ceramic thickness

- Case I – Stress

Ceramic	Copper	AlSiC
varied	203µm	635µm



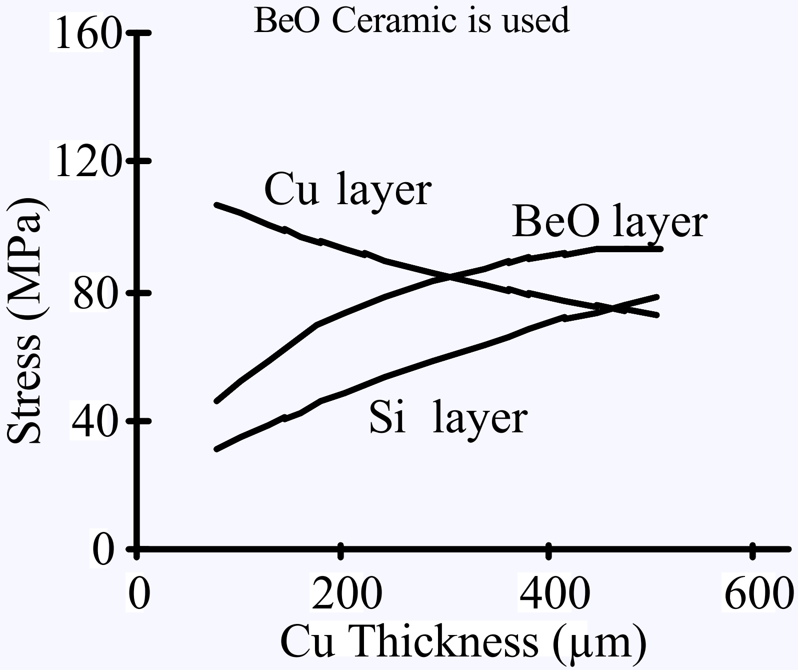


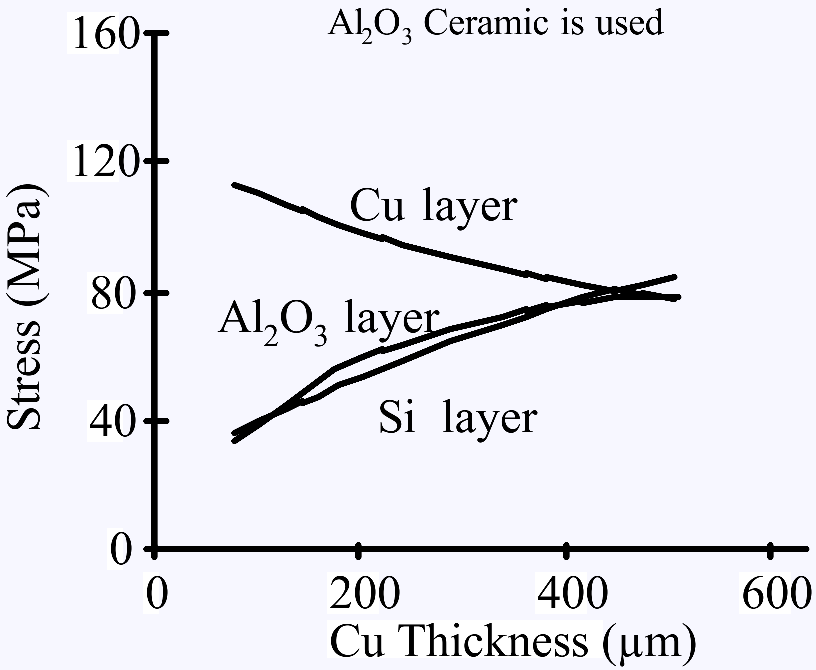
- Si on BeO has lower stress due to lower δT°.
- Thinner ceramic has higher stress for this Cu thickness.

Results - variable copper thickness

- Case II – Stress

Ceramic	Copper	AlSiC
76µm	*varied*	635µm



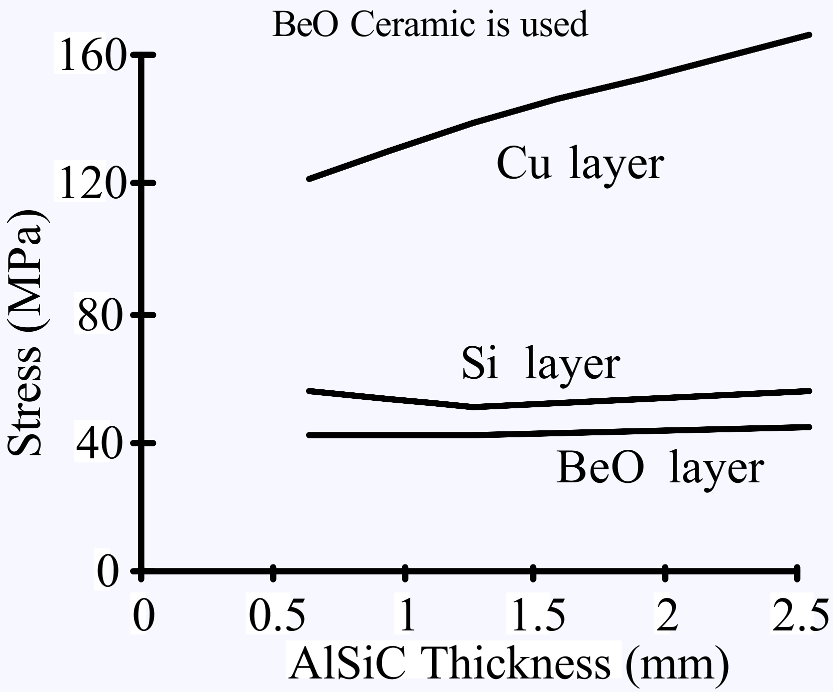


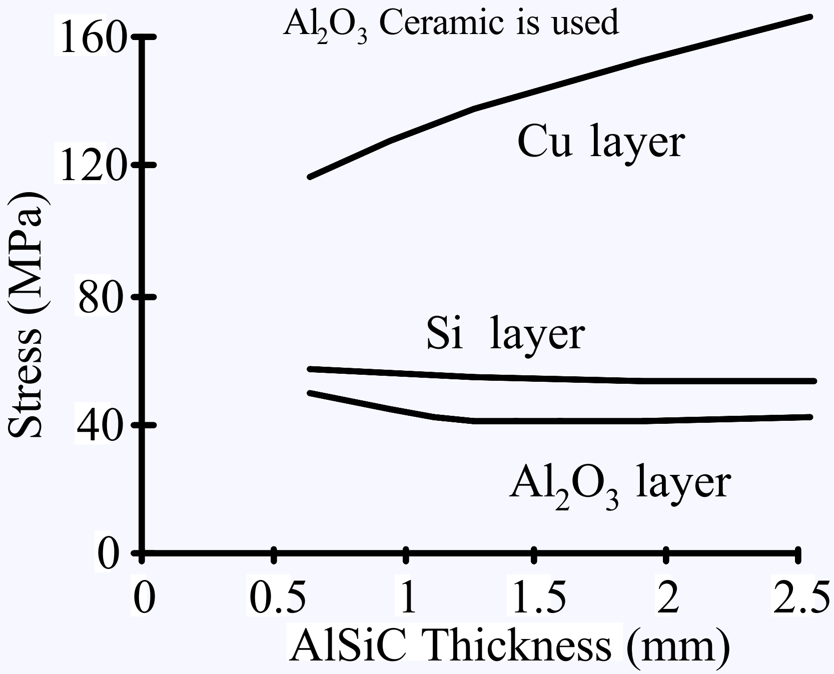
- Thinner copper relieves the stress in the ceramic and Si.
- Thinner Cu has higher stress.

Results - variable AlSiC thickness

- Case III – Stress

Ceramic	Copper	AlSiC
254µm	203µm	*varied*





- Extremums in both Si and Al_2O_3 are observed.
- The matched TCE of AlSiC and ceramic minimizes the ceramic and Si stress.
- Cu reacts to TCE mismatch.

Summary

- Direct–attached–ceramic on AlSiC reduces the number of package layers – reducing the thermal impedance and stress. The TCE of AlSiC is 7.2 and ceramic is 5.8 to 7.4.
- FEM analysis used to evaluate thermal conductance and thermally induced stress for various Cu, *ceramic* and AlSiC layer thicknesses.
- Generally, thinner layers provide less stress due to lower thermal gradients.