COMPOSITE METAL HEAT SPREADERS IN HANDHELD ELECTRONICS DESIGN

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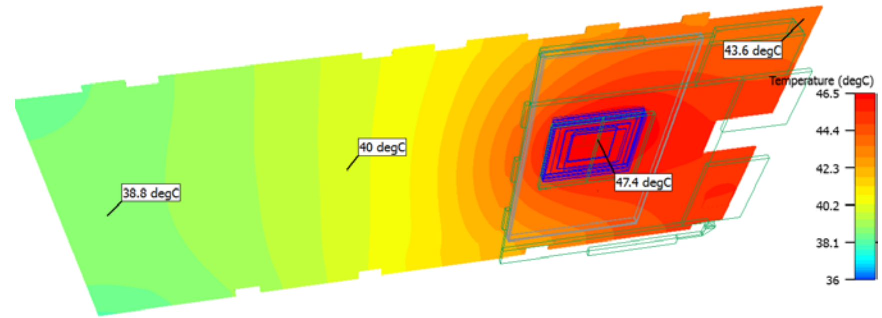
Market Development Manager

Motivation

(1) Handheld Electronics Require Heat Spreaders.

(2) Design criteria often create conflicts.



Design Requirements

Increasing Power Density

Miniaturization

Weight Reduction

Cost Reduction

But…

Thermal Solutions:

- Add Volume
- Add Cost
- Add Weight

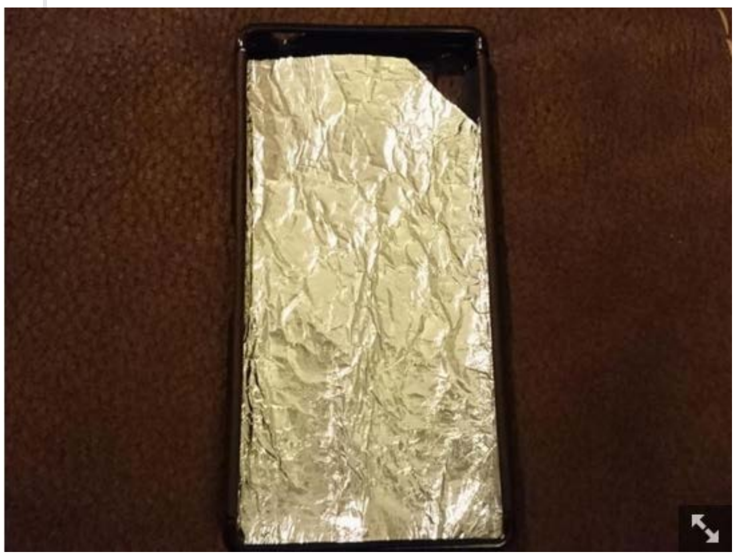
Designers Need to Address This Contradiction

Tue, 07/21/2015 - 16:58

GADGETS

Sony Xperia Z3+ Problems: Fix Your Overheating And Performance Issues By Wrapping Your Phone In Tin Foil

By Ajay Kumar



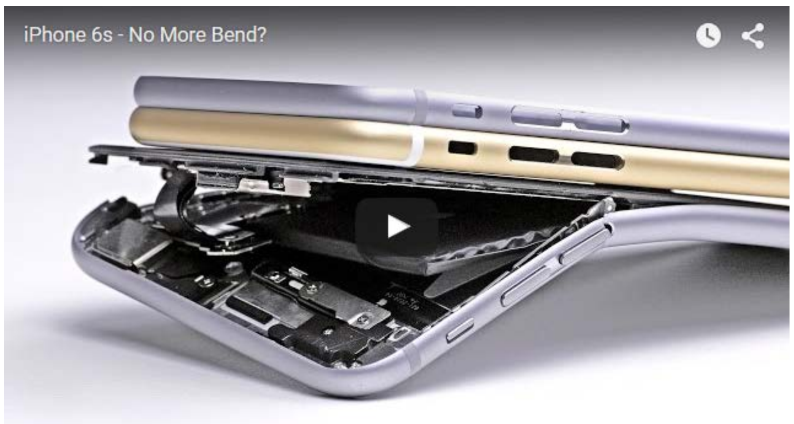
http://www.idigitaltimes.com

This fix mirrors the current state of mobile electronics design, adding conductive films to dissipate heat.

Thermal solutions are an unfortunate necessity, consuming volume and adding cost without directly providing functionality.

iPhone 6S Rumors: Apple Inc. Makes Rear Shell Thicker To Avoid 'Bendgate 2'

By Luke Villapaz @lukeydukey l.villapaz@ibtimes.com on August 10 2015 4:06 PM EDT



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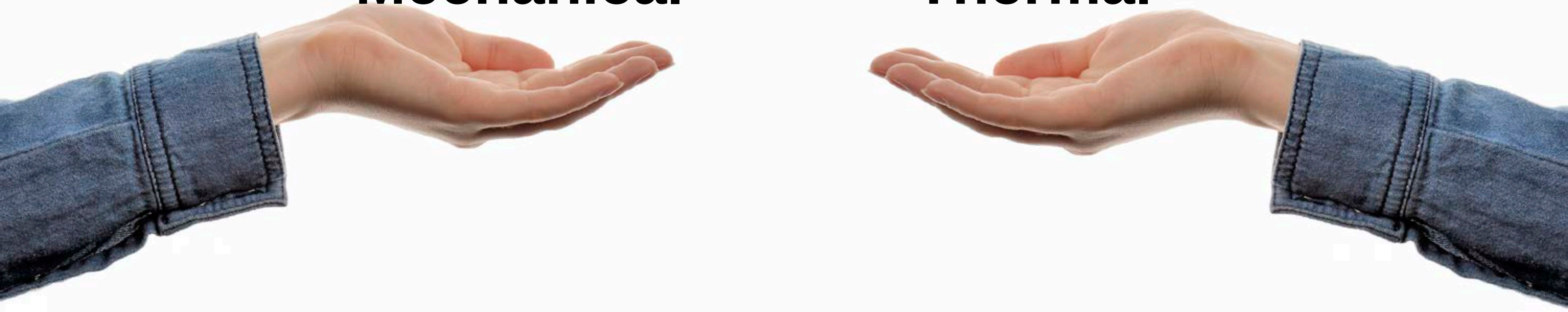
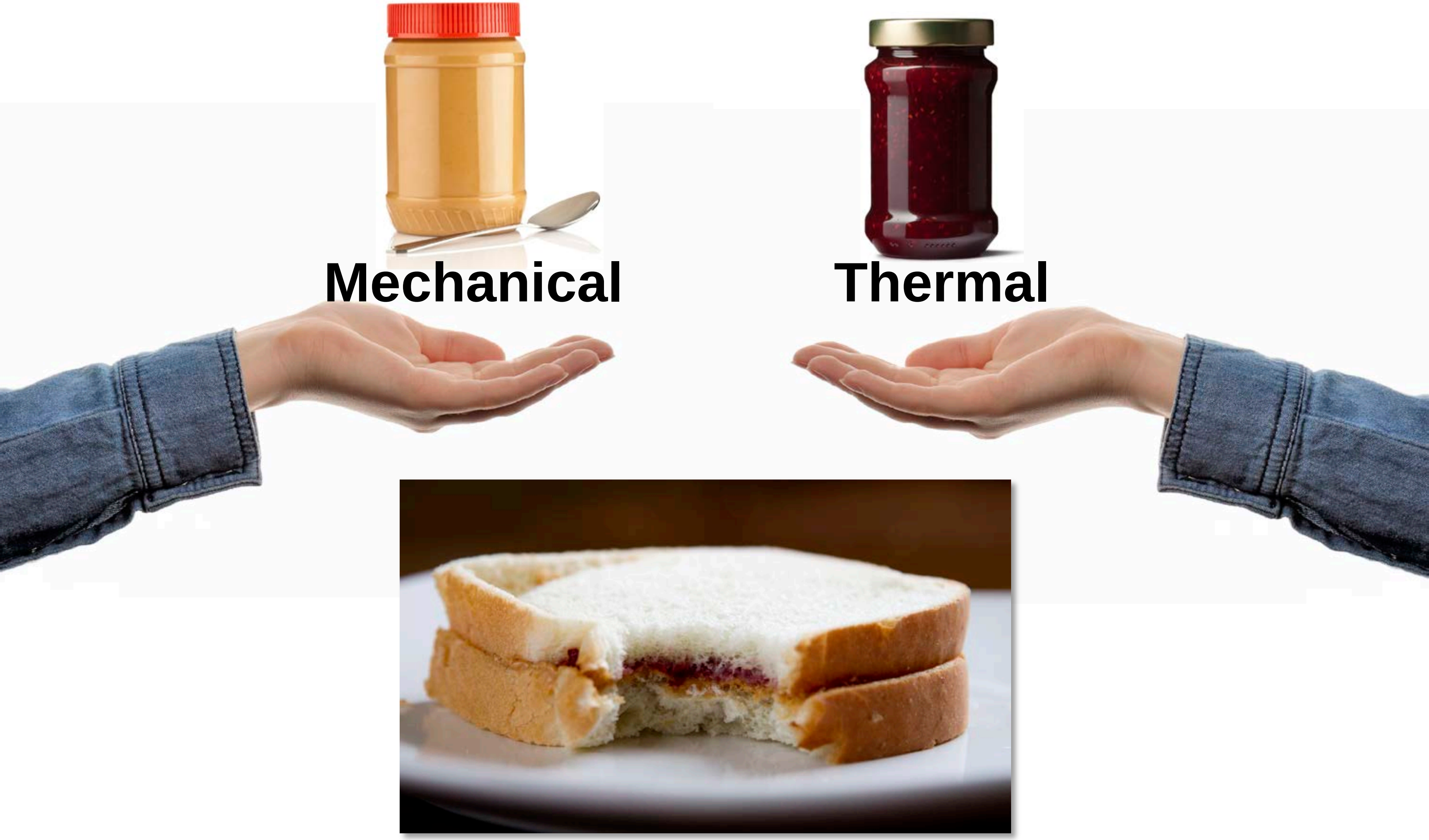
Design trade-offs are unavoidable.

Structural, Thermal and Functional components all fight for the same shrinking footprints.

Mechanical and Thermal designs have historically been considered separately.

Mechanical **Thermal**

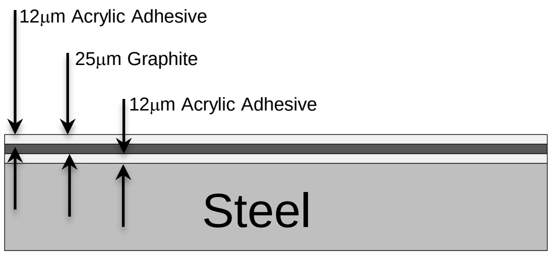


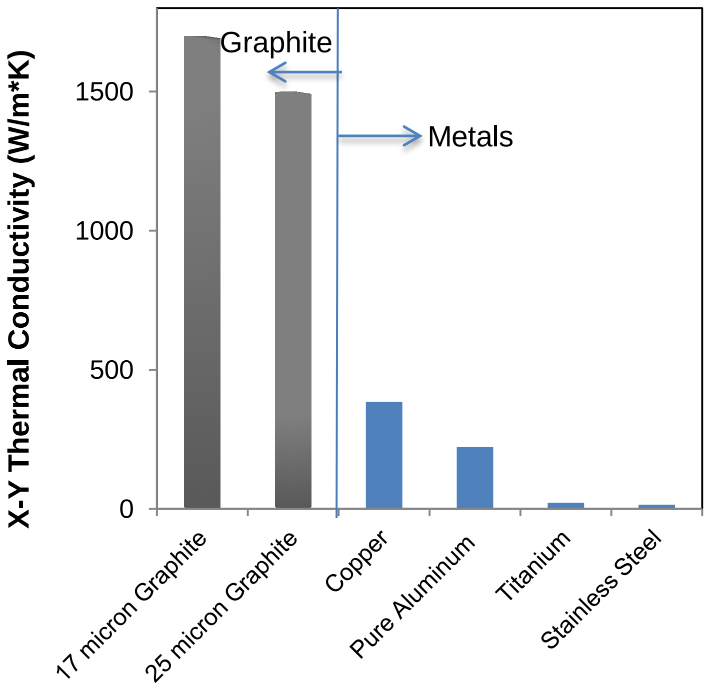

Mechanical
Thermal

Current Designs:

(1) Use enough steel to provide structural rigidity.

(2) Laminate with Heat Spreader





Film Strategy:

Pros:

- Graphite can often be added to existing designs.
- High thermal performance for size.

Cons:

- Add Thickness (0.05mm Common)
- Expensive
- Performance Limited by µm thickness.
- Only provides thermal.

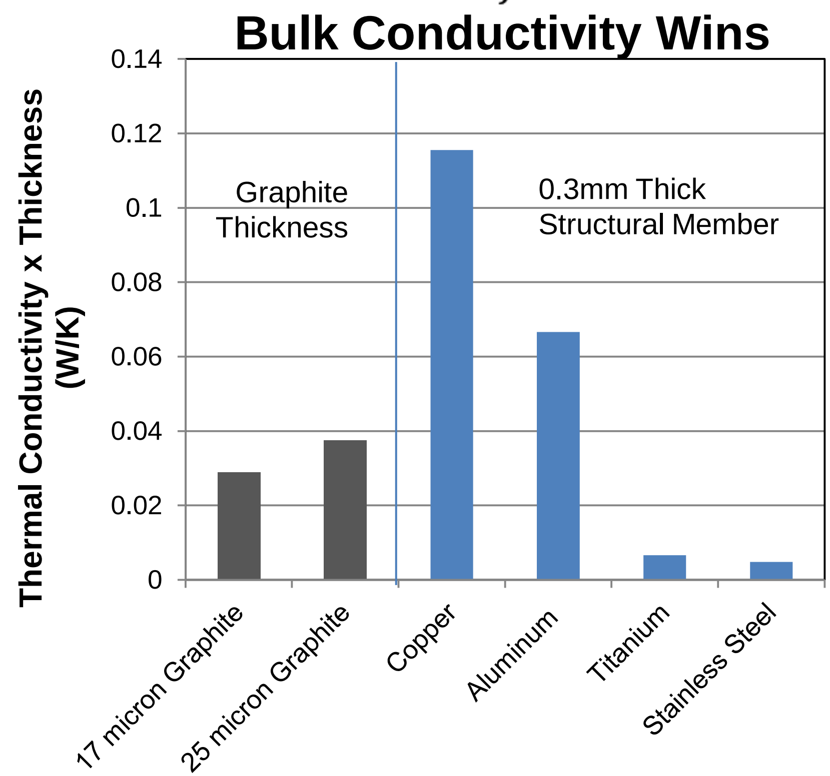
PB&J Strategy:

Meld Mechanical &
Thermal Design

What if a Structural Member was the Heat Spreader?

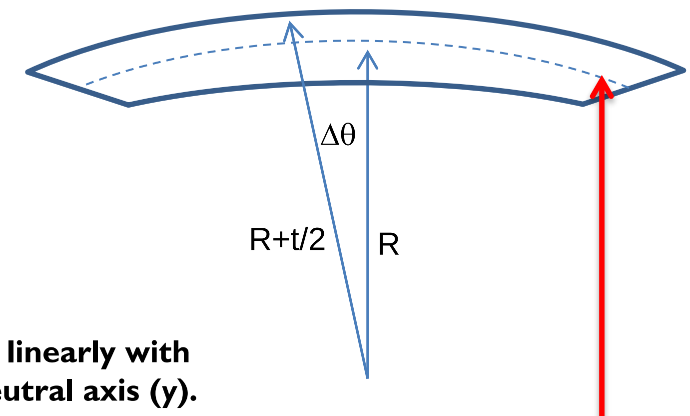
- Eliminate Secondary Films
- Harness Bulk Conductivity
- Utilize Conventional Metals

$$Heat\,Transfer \propto k \cdot t$$



THINK I-BEAMS

- Structural components in mobile devices are loaded in Bending & Torsion.
- With these loadings, stiffness & strength are provided by the outer skins.



Bending strains vary linearly with distance from the neutral axis (y).

$$\varepsilon(y) = \frac{y}{R}$$

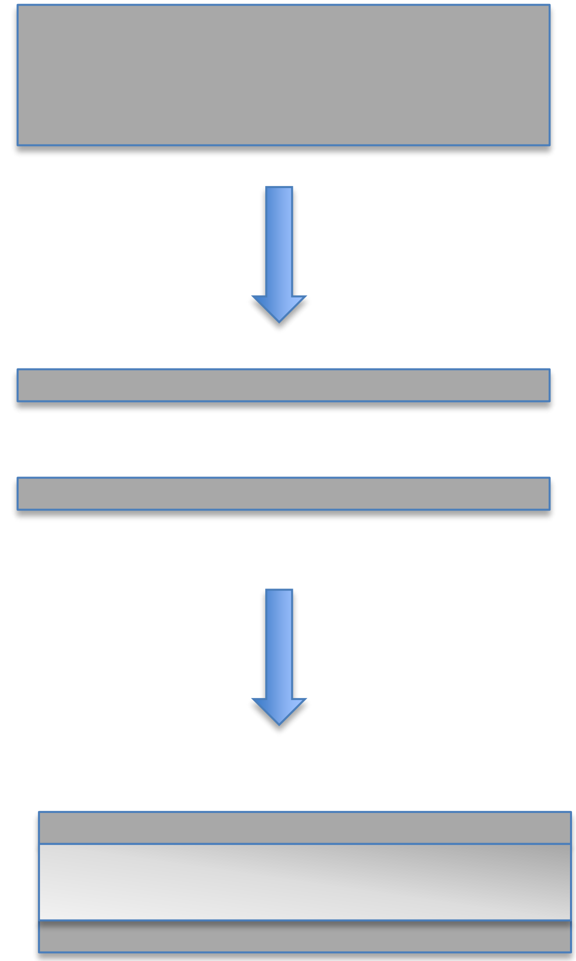
The core is mechanically underutilized.

Consider a phone's mid-frame:

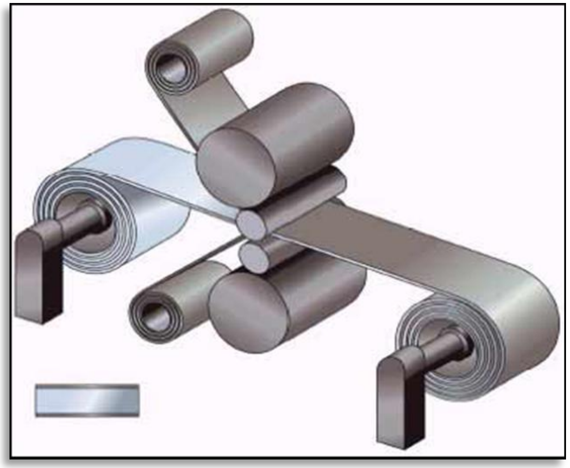
Standard Approach:
Solid Cross Section, typically Steel.

Remove the under-utilized core:
It's not contributing 100% structurally anyway!

Replace the Core with a Bulk Thermally Conductive Material:
Get the best performance from both materials.



CLAD Metals



Metallurgical bonding between metal layers.

- High Volume reel-to-reel process
- Extreme Pressures between Rolls
- Large Plastic Deformations
- Heat treatments to diffuse/stabilize interface.

Common Clad Composites:

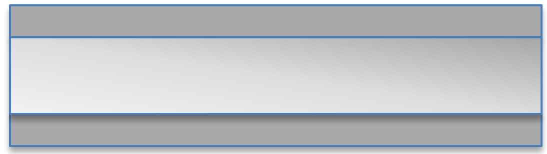
Coinage.

Low CTE Thermal Materials:

- **Cu / Invar / Cu**
- **Cu / Moly / Cu**

Structural+Thermal Materials

Material Selection



Structural

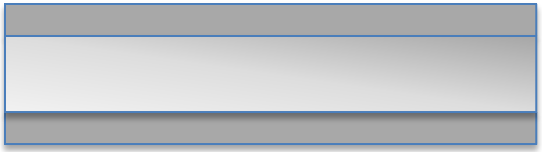
Material	Modulus (GPa)	Cost
Steel	**198**	**$**
Molybdenum	330	$$$$
Aluminum	66	$
Magnesium	45	$$

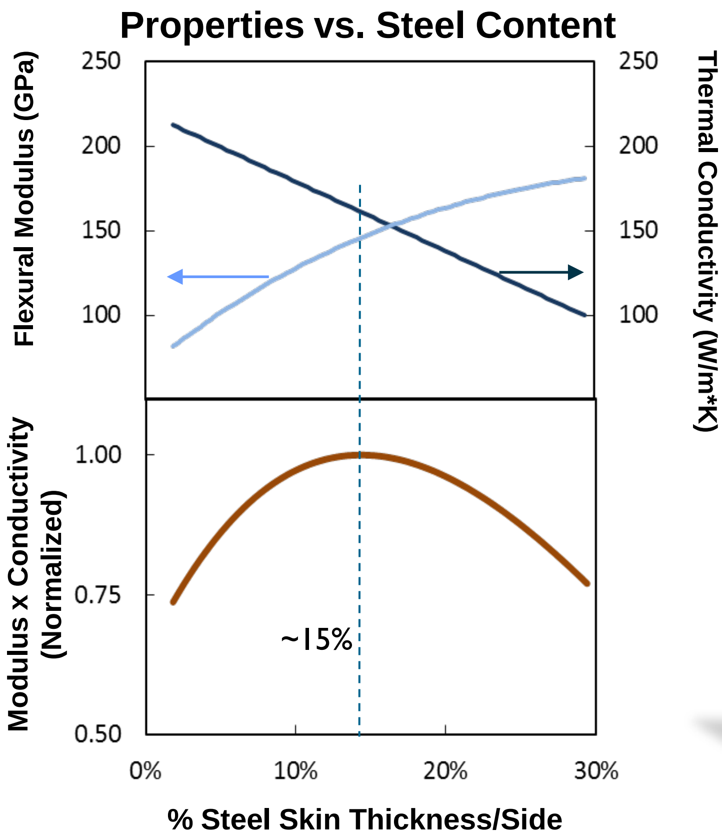
Thermal

Material	Thermal Conductivity (W/m*K)	Cost
Aluminum	**220**	**$**
Copper	400	$$
Magnesium	160	$$
Graphite	150-1500	$$$$

GPa/$ and Watts/$ analyses give
Steel & Aluminum
as the most economical Stiff & Conductive Materials.

Steel+Aluminum Design





Optimal Material has Large Stiffness & High Thermal Conductivity:

At 15-70-15 Ratio:

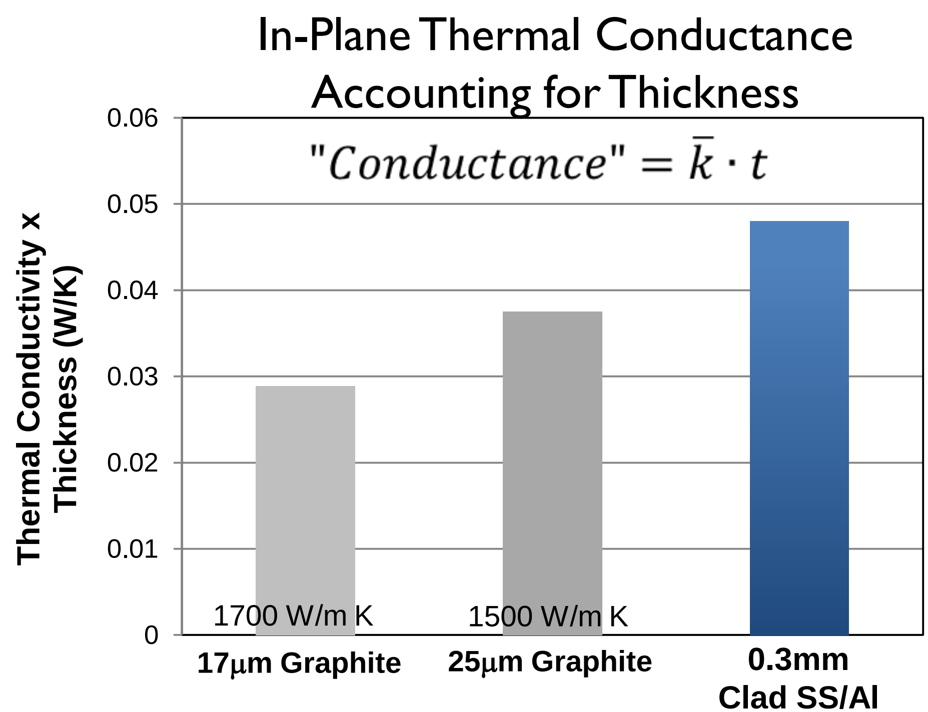
- 80% The Stiffness of Stainless Steel (153 GPa)
- 10x Steel's X-Y Thermal Conductivity (160 W/m*K)
- 53% the Density (4.3 g/cm^3)
- Costs ~2-5x Stainless per Component

*Marketed as Materion **eStainless.**

What does this mean for Electronics Design?

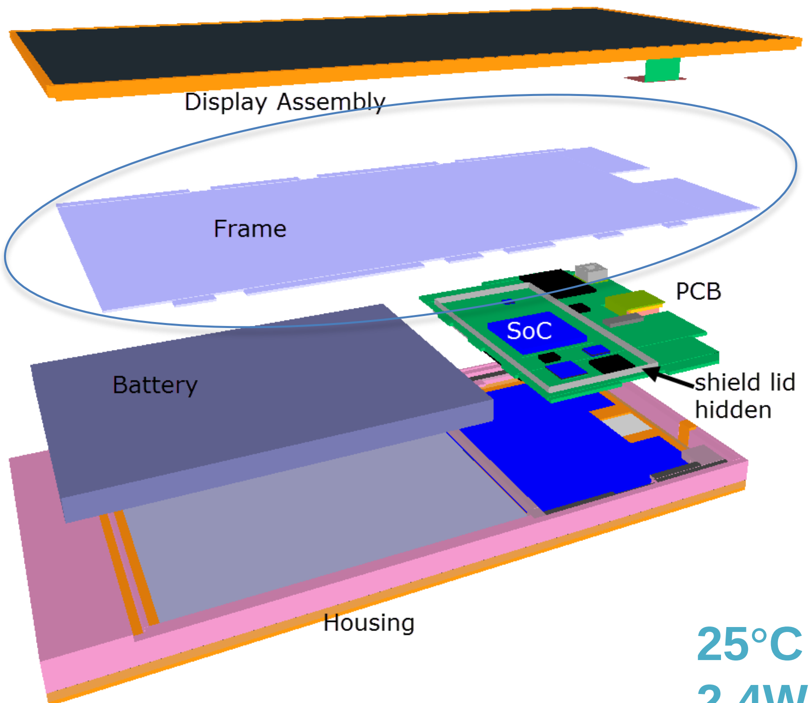
- **Replace Steel + Graphite systems with a Single Low-Cost Material.**
- **Replace Aluminum Alloy Components with smaller structural materials.**

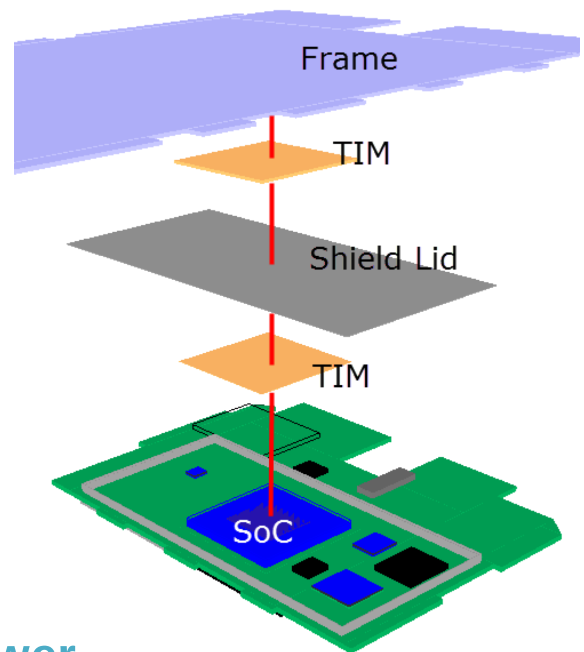
The Bulk Conductivity of Clad Stainless-Aluminum can provide substantially more in-plane conductance than thin Graphite Films.



Smart Phone Thermal Model

- **Direct Substitution of Mid Frame:**
  - **0.36mm Steel + 25μm Graphite System.** (Plus 25μm Acrylic Adhesive)
  - **0.36mm Steel/Aluminum Clad**
- **Each Layer Modeled Individually (SS/Al/SS and SS+Graphite+Adhesive)**





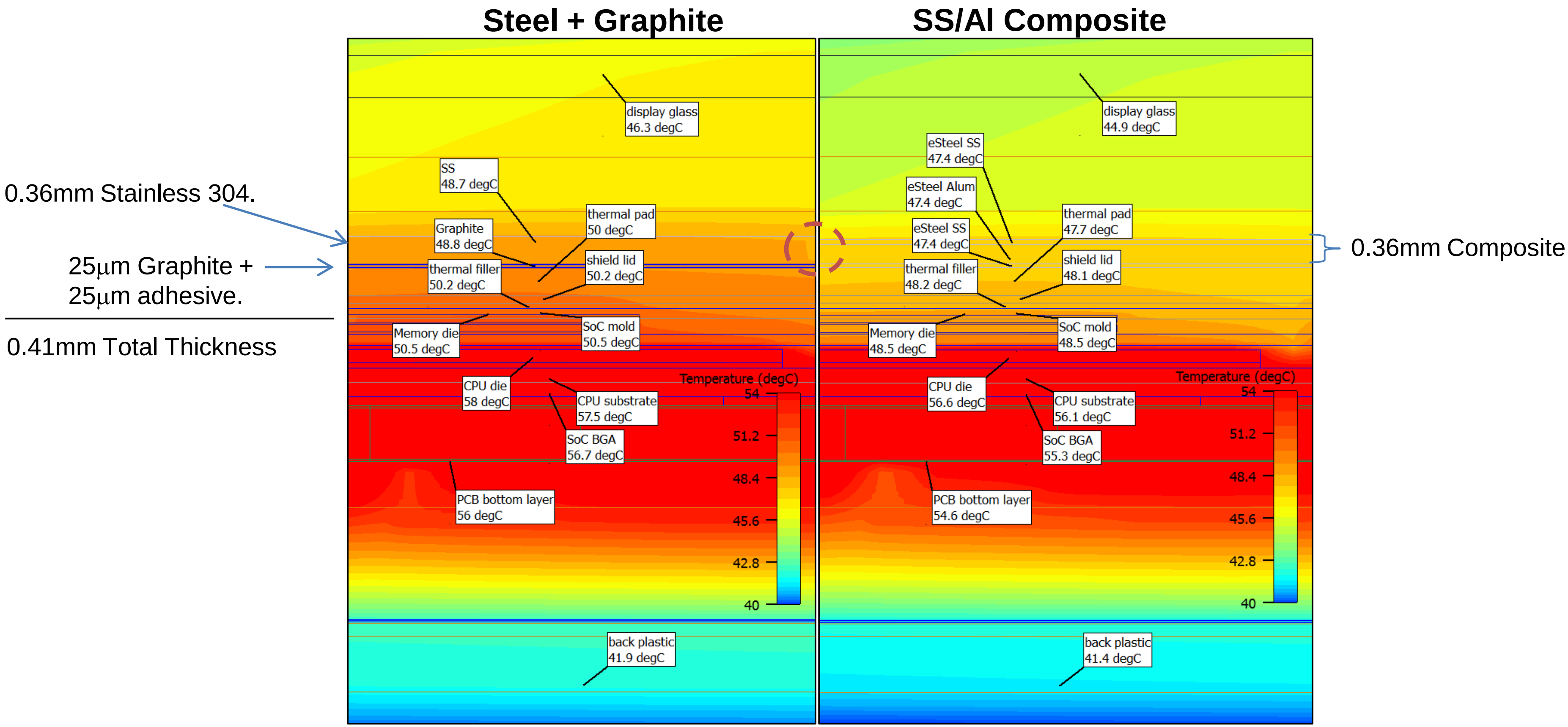
25°C Ambient
2.4W Total Power

Smart Phone Thermal Model

- **SS/Al clad design reduced temperature through thickness**

  (CPU Die Temperature reduced 2.4°C.)

- **Little Heat-Gradient across Graphite Layer**



Smart Phone Thermal Model

Steel + Aluminum:

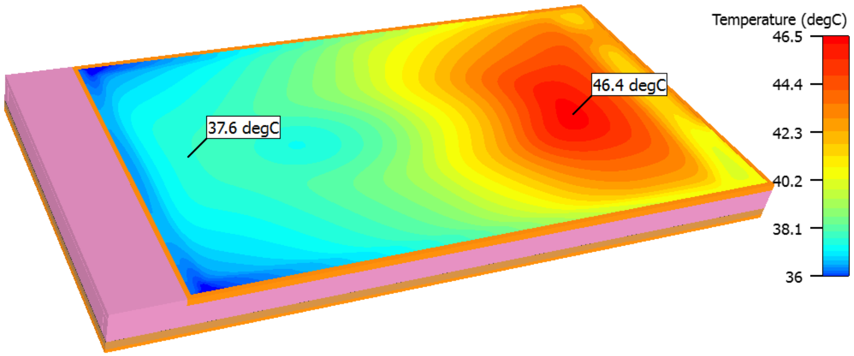
- 1.3°C Reduction in Hot Spot
- 25% Reduction in temperature gradient.

➢ **Promotes improved heat dissipation from surfaces.**

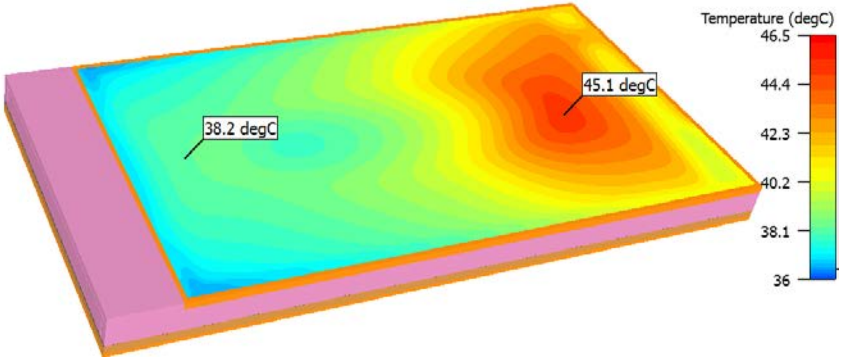
➢ **Enables more power consumption & less throttling.**

➢ **Lower Cost**

Steel+Graphite



Steel+Aluminum Composite



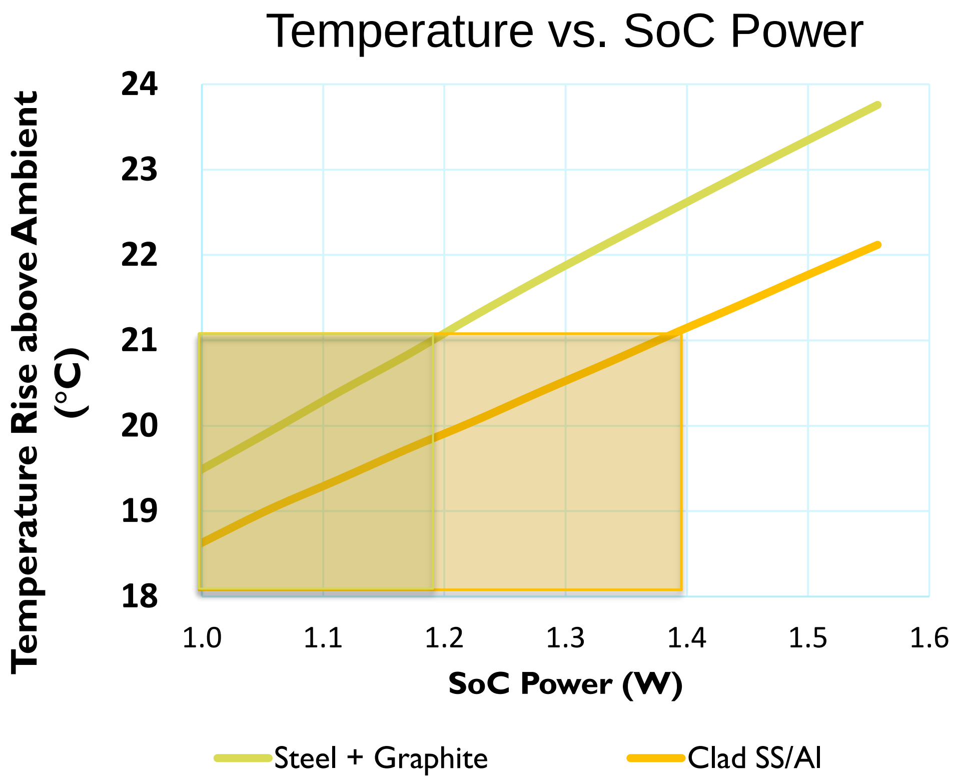
Smart Phone Thermal Model

Enhanced Heat Spreading promotes energy dissipation.

Temp limit set at 46°C in 25°C room.

15% More Power Possible with SS/Al Clad.

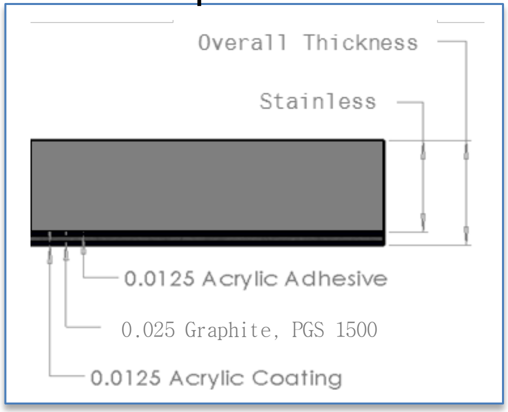
Reduces need for Throttling to reduce temperatures.



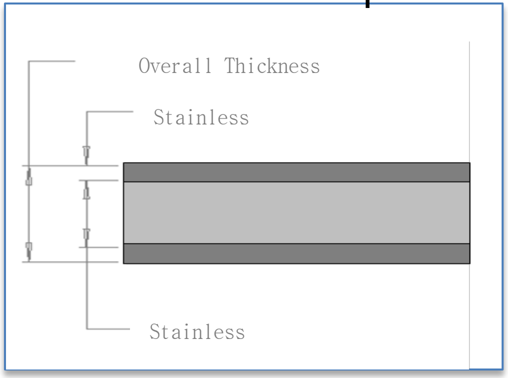
Metal Composite Heat Spreading

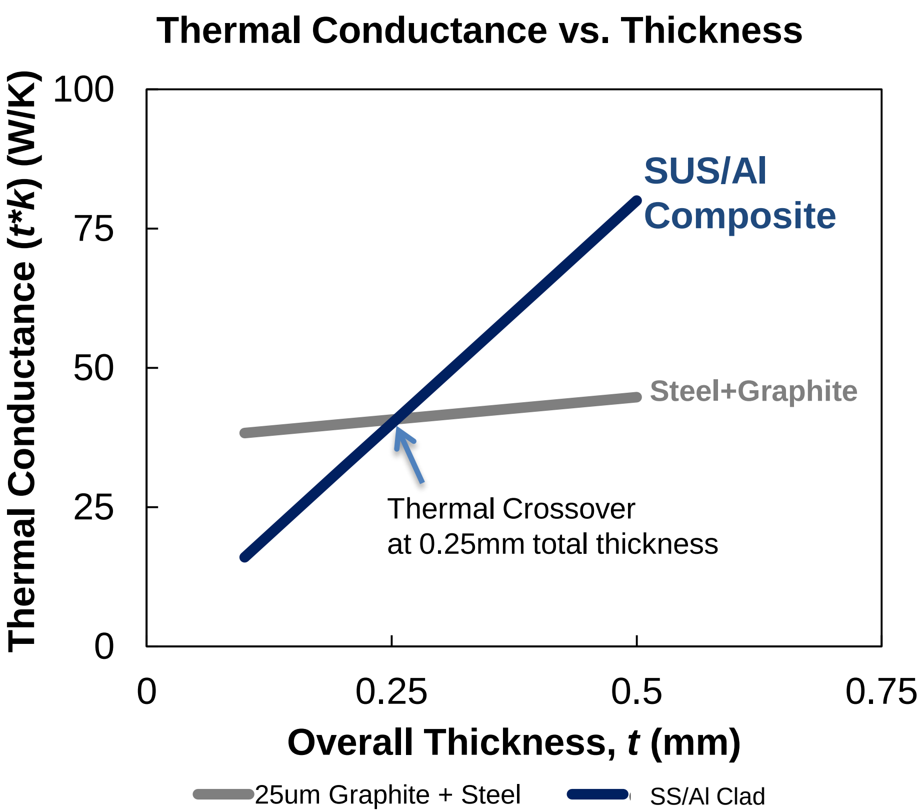
Should Consider Total Component Thickness.

SUS+Graphite



SUS/AL Clad Composite



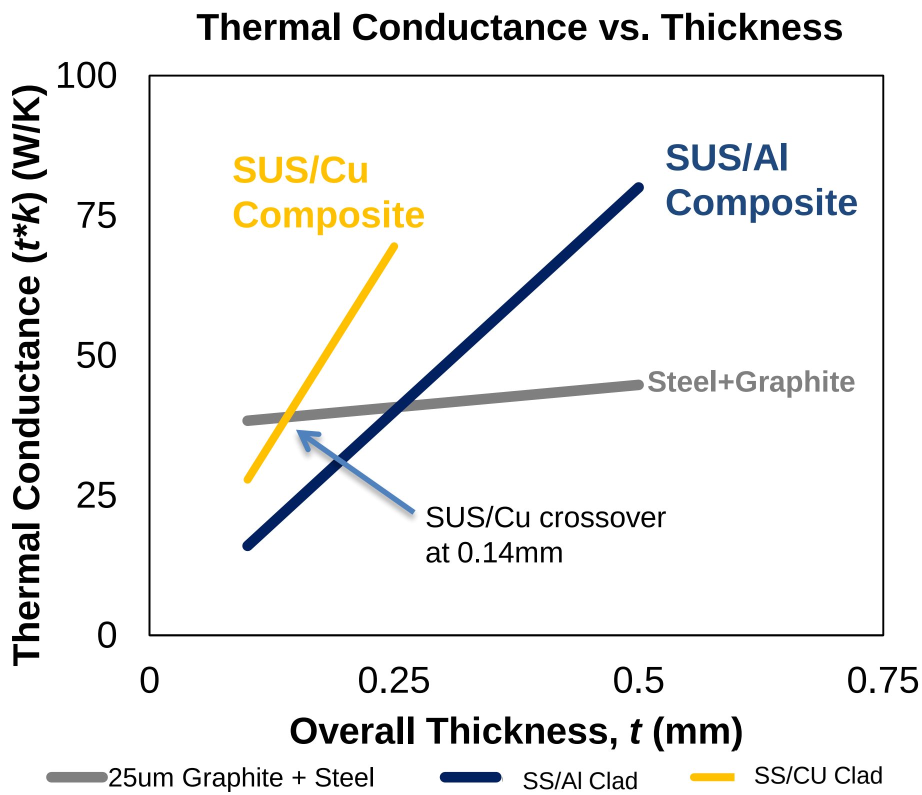


For Components over 0.25mm, the SUS/AL Composite provides enhanced heat spreading.

Metal Composite Heat Spreading

Copper extends performance range:

- SUS/Al - 0.25mm
- SUS/Cu - 0.14mm



Mechanical Stiffness Cannot Be Ignored:

Composites Provide <u>Thermal+Stiffness</u>

Metal Composite Design

0.2mm x 75mm x 100mm

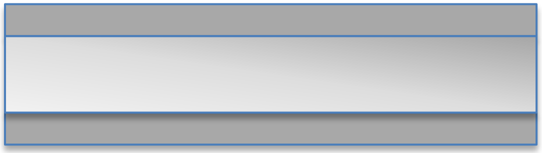
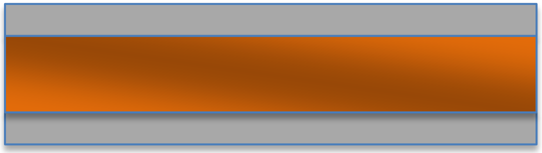
Consider a 0.2mm Steel mid-frame with a 25µm Graphite Heat Spreader(50µm with adhesives): **Total Thickness 0.25mm**

How can Sandwich Composite Designs compare?

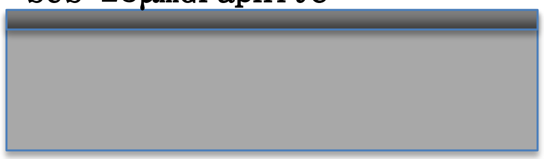
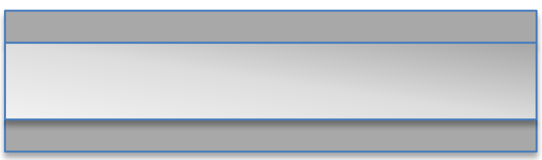
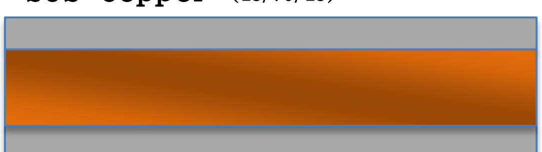
- **Heat Spreading**
- **Bending Stiffness**
- **Weight**

Metal Composite Design

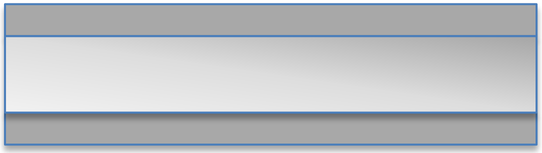
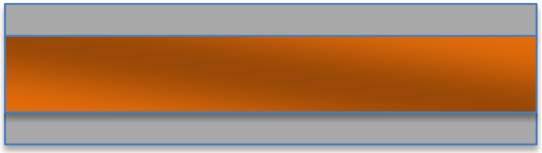
0.25mm Total Thickness

	Composite Bending Modulus (GPa)	Composite X-Y Thermal Conductivity (W/m*K)	Composite Density (g/cm^3)
SUS+25µmGraphite 	101	162	6.6
SUS+Aluminum (15/70/15) 	153	160	4.3
SUS+Copper (15/70/15) 	170	277	8.6

Metal Composite Design

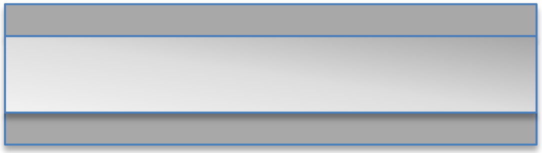
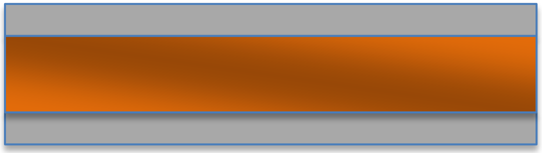
	Total Thickness (mm)	Flexural Rigidity E x I x 10^{10} ($N \cdot m^2$)	Heat Spreading Capacity (W/K)	Weight (g)
SUS+25µmGraphite 	0.25mm	1.3	0.04	12.4
SUS+Aluminum (15/70/15) 	0.25mm	2.0	0.04	8.1
SUS+Copper (15/70/15) 	0.21mm	1.3	0.06	13.5

Metal Composite Design

	Total Thickness (mm)	Flexural Rigidity E x I x 10^{10} (N•m²)	Heat Spreading Capacity (W/K)	Weight (g)
SUS+25μmGraphite 	0.25mm	1.3	0.04	12.4
SUS+Aluminum (15/70/15) 				8.1
SUS+Copper (15/70/15) 	0.21mm	1.3	0.06	13.5

- 54% Increase in Stiffness
- 35% Reduction in Weight
- Same Nominal Heat Spreading

Metal Composite Design

	Total Thickness (mm)	Flexural Rigidity E x I x 10^{10} (N•m²)	Heat Spreading Capacity (W/K)	Weight (g)
SUS+25µmGraphite 	0.25mm	1.3	0.04	12.4
SUS+Aluminum (15/70/15) 				8.1
SUS+Copper (15/70/15) 				.5

- 54% Increase in Stiffness
- 35% Reduction in Weight
- Same Nominal Heat Spreading

- 50% Increase in Heat Spreading
- 40µm Thickness Reduction
- Same Nominal Stiffness

Summary

eStainless Sandwiches can help optimize thermal designs

- Clad Metal Composites provide Thermal & Structural Performance, with high volume cost effective materials.
- Applications may include Cases, Frames, EMI Shields – or anywhere structures aren't contributing thermally.

Thanks for attending!

Don’t miss Thermal Live 2016!
Fall 2016
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