NINETEENTH ANNUAL

BiTS

Burn-in & Test Strategies Workshop

March 4 - 7, 2018

Hilton Phoenix / Mesa Hotel
Mesa, Arizona

Archive

New Possibilities in Composite Materials and How to Simulate Them

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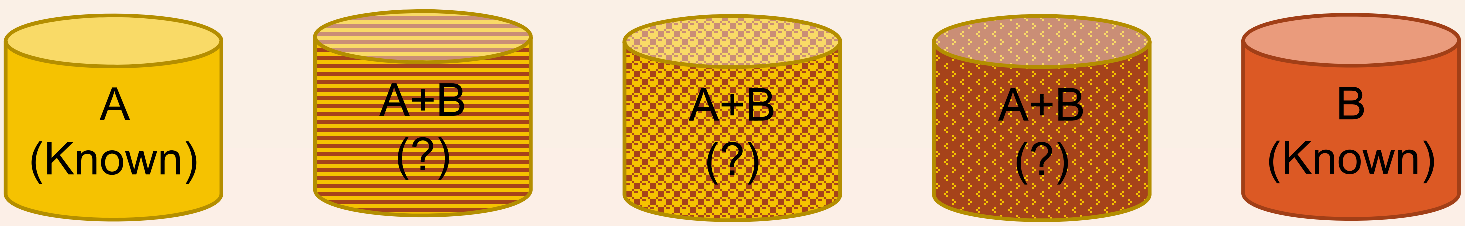
Materion

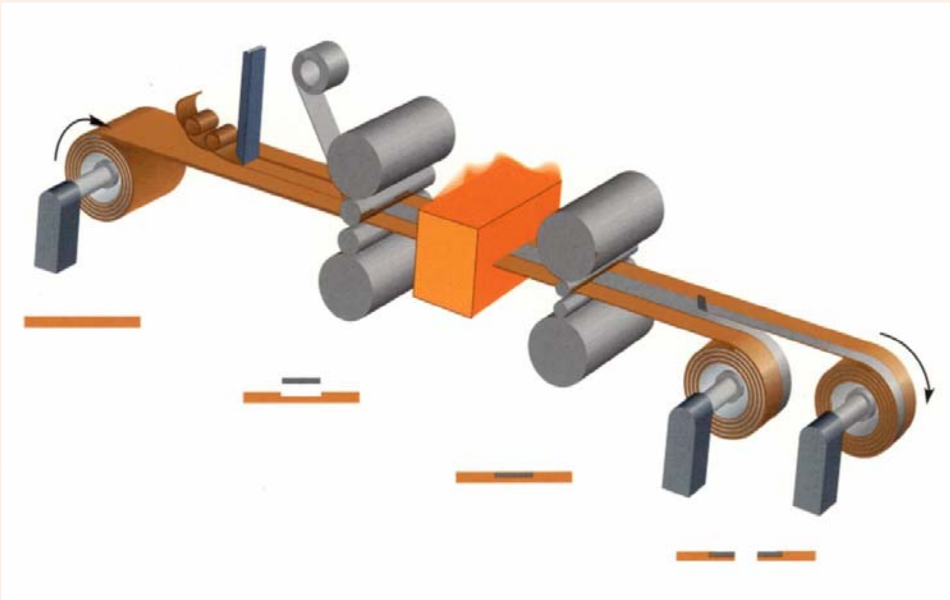
BiTS Workshop
March 4 - 7, 2018

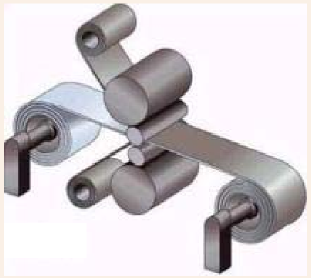
Definitions

- Monolithic – Consisting of one material or alloy
- Composite – Consisting of more than one <u>separate</u> material

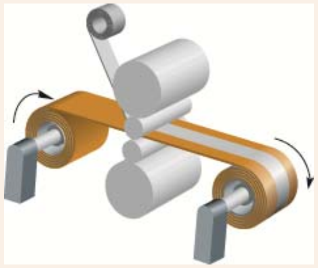


Clad Composite

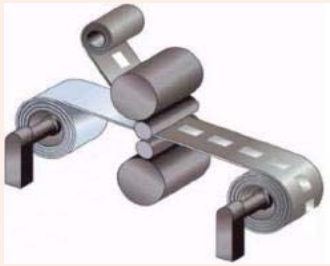




Overlay



Inlay



Patterned

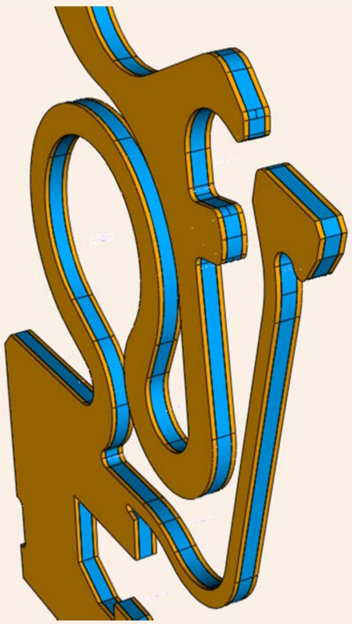
Some History of Clad Metals Combining High Strength and High Conductivity

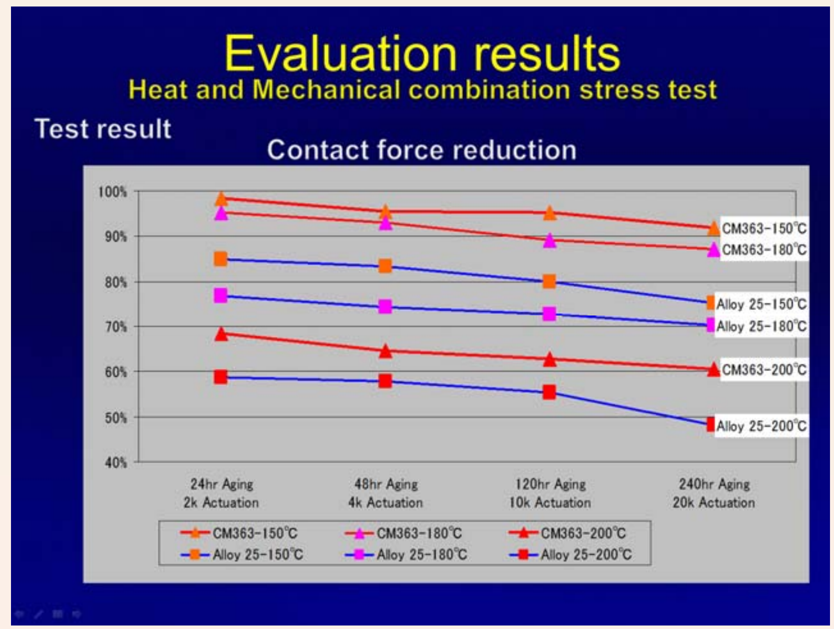
- 1962 – Texas Instruments Conflex Material
  - Cu over 1065 stainless steel
  - Made by many today

COPPER CLAD AUSTENITIC STAINLESS STEEL—A HIGH STRENGTH HIGH CONDUCTIVITY MATERIAL FOR CONNECTOR APPLICATIONS

James Forster
Texas Instruments Incorporated
34 Street
Attleboro, MA 02703

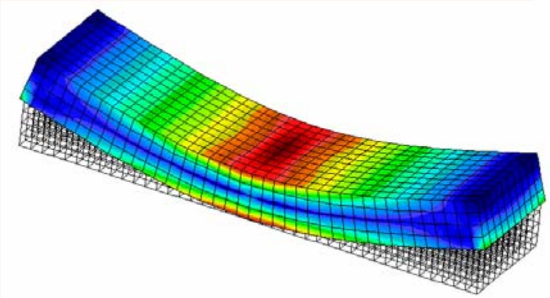
2012 BiTS Workshop

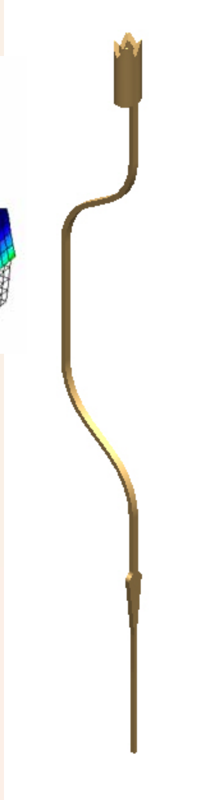




Stress Distribution in Bending

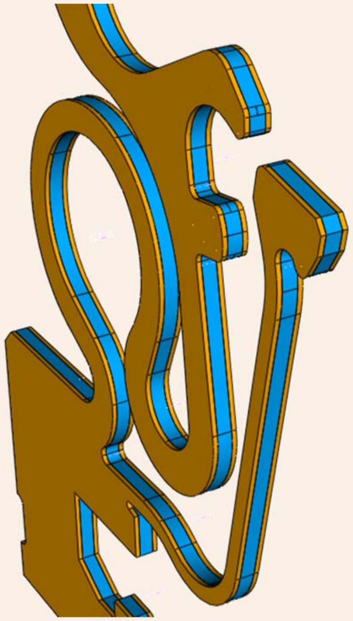
- Outer Surface Stress
  - Highest in the whole structure
  - Dominates fatigue life (# of cycles)
  - Dominates stress relaxation resistance (high temperature capability)
- Center of Beam
  - No to low stress
- Put high strength material on outside and high conductivity material on inside





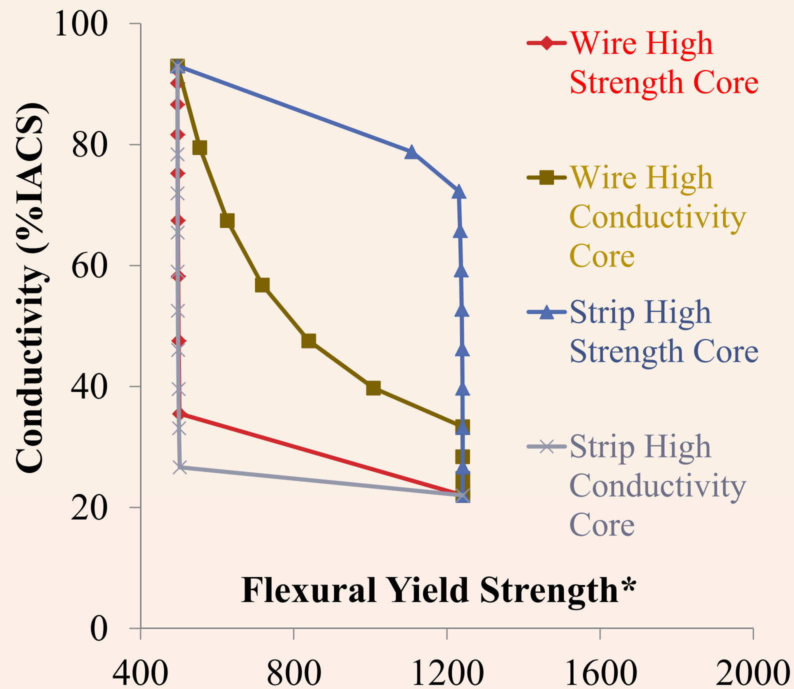
In-Plane Loading (No Out of Plane Bending)

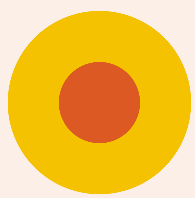
- Either configuration works



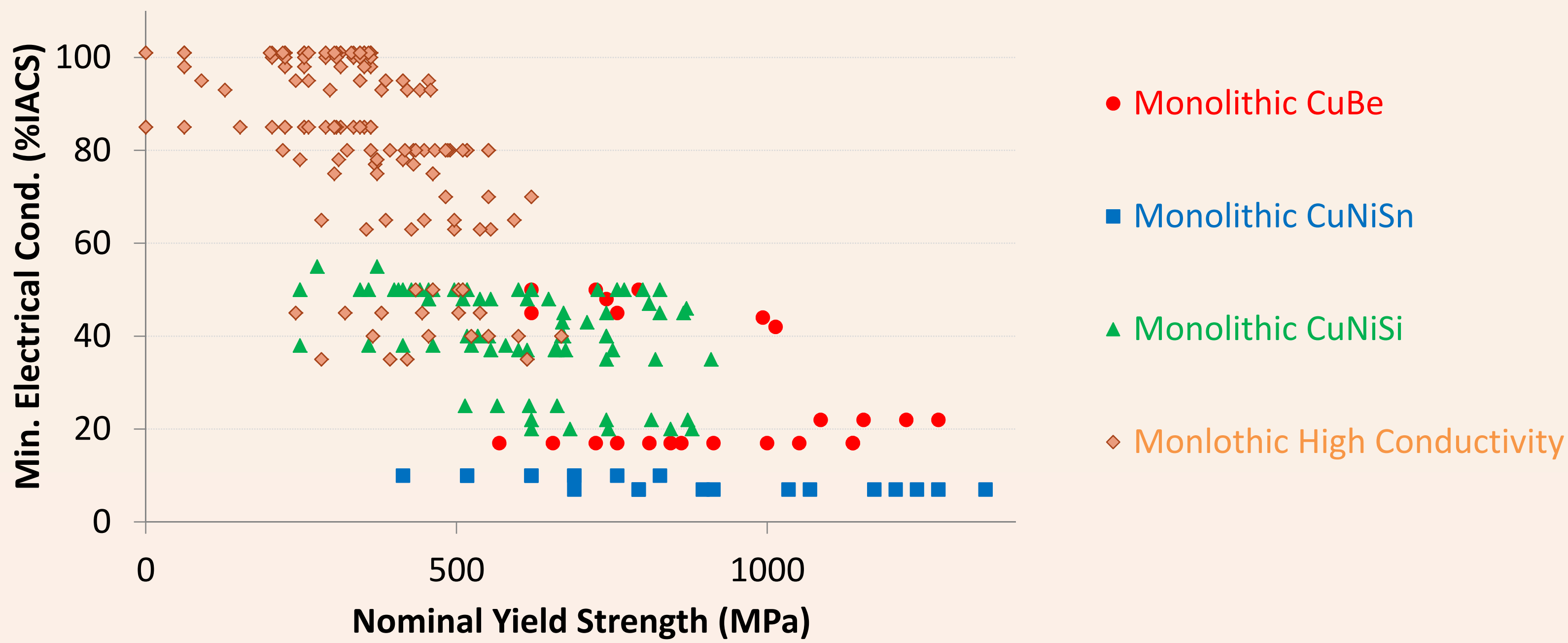
Composite Strength

- In Tension – Soft Metal Dominates
- In Bending – Outer Metal Dominates
- Round Cross Sections Less Effect than Rectangular

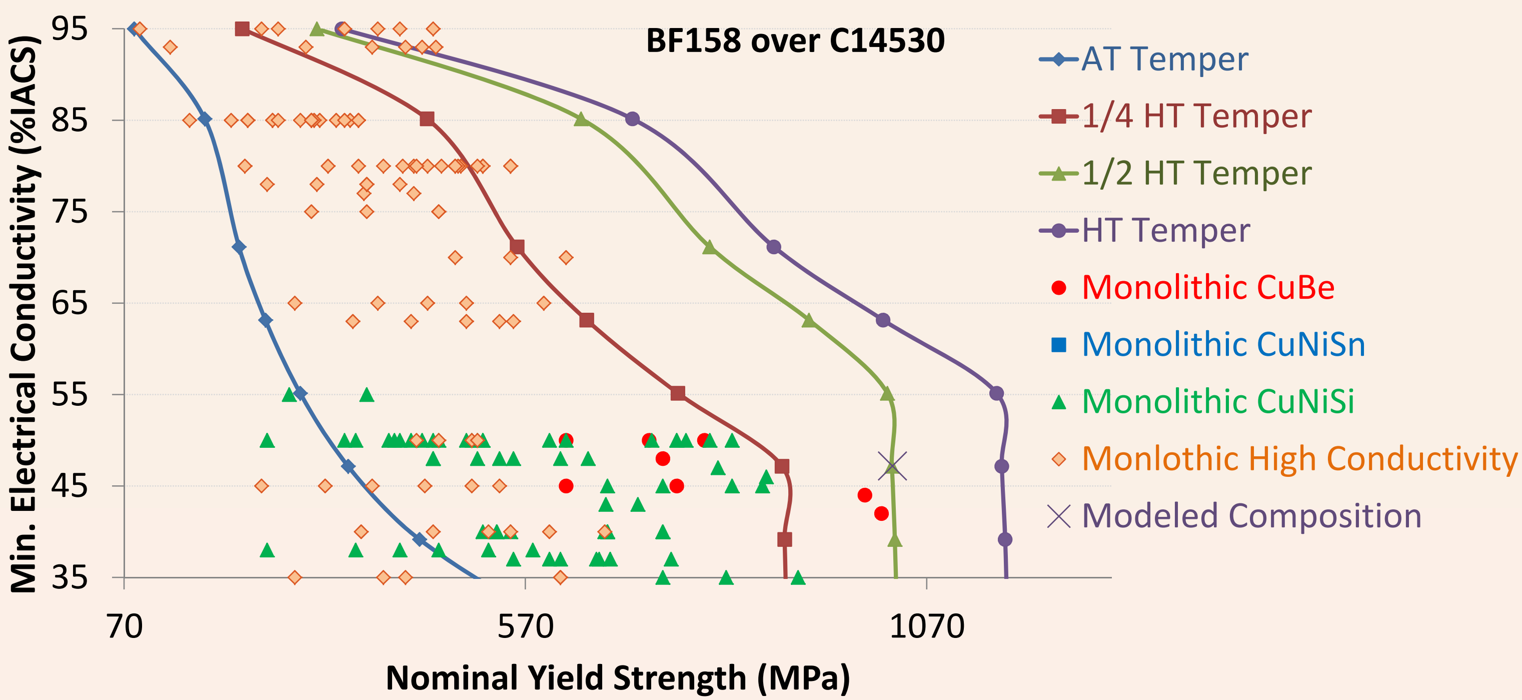




Commercially Available Copper Alloys



Sample Material Made

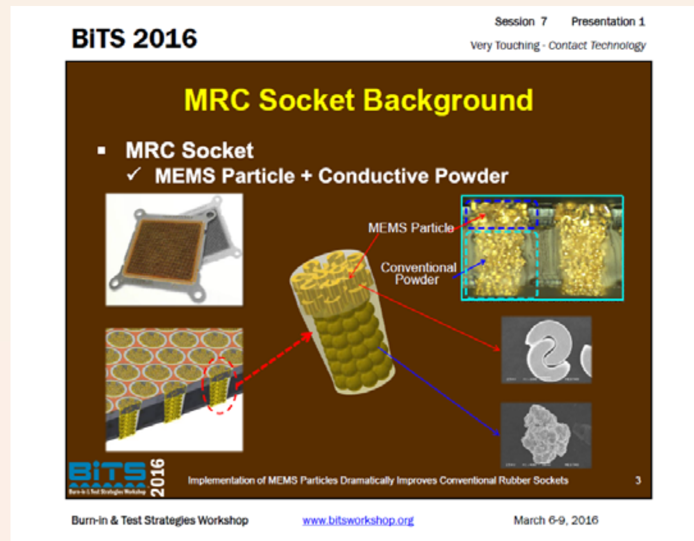


Simulation Tip

- Modelling Complicated composite materials
  - Separate the physics where possible
  - Start simple (fewest properties)
    gradually complicate (most properties)
  - Design <u>simple</u> physical test rig
  - Model as homogenous solid
  - Parametrize properties until simulation matches physical test
  - Combine results for future simulations

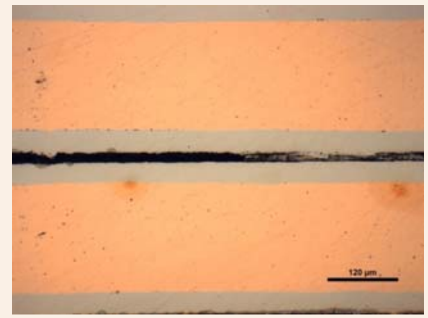
Where Else Can I Use this Strategy?

- Find effective stiffness, conductivity, internal inductance & capacitance as function of strain



Theoretical Spreadsheet Calculations and FEA

- Configuration:
  - Length: 10.0 mm, Width: 1.0 mm
  - Thickness: 0.1 mm
    - 0.025 mm BF158 ½ HT top
    - 0.050 mm C14530 ½ H middle
    - 0.025 mm BF158 ½ HT bottom

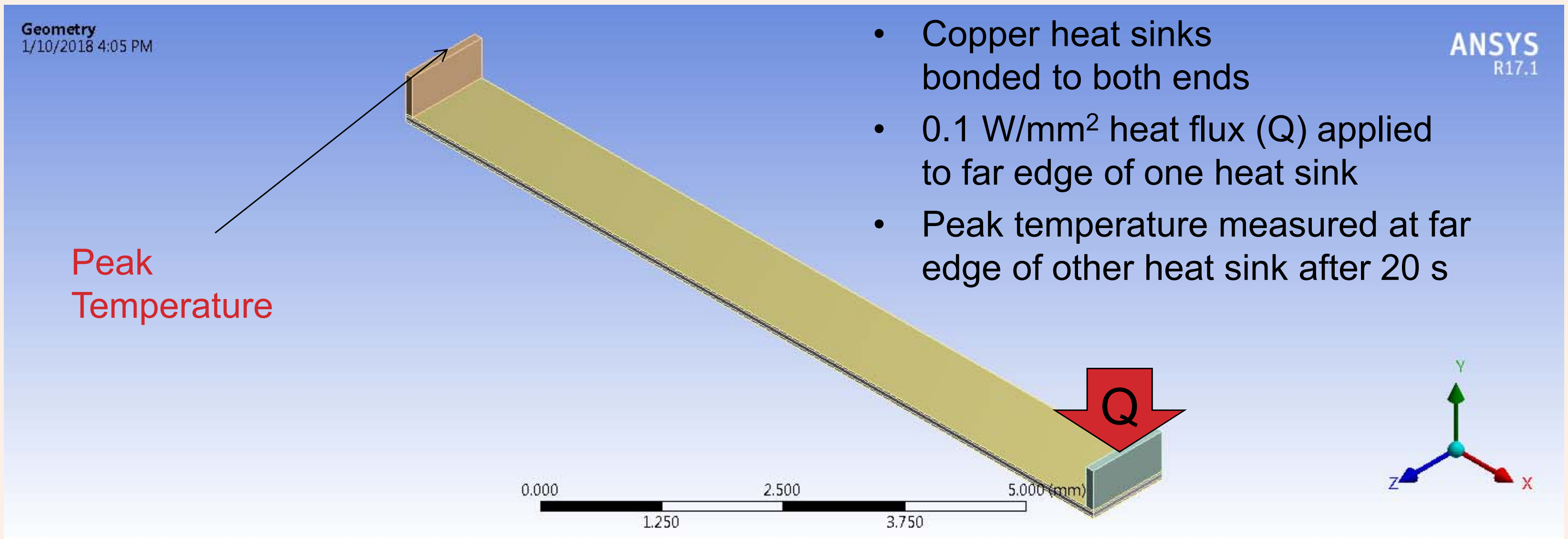


Alloy	Temper	Modulus (GPa)	Thickness (mm)	I (mm^4)	E*I (MN mm^2)	Conductivity (%IACS)	0.2% OYS (MPa)	MBR/t GW	MBR/t BW	CTE (ppm/°C)
BF 158	1/2 HT	127.6	0.025	0.0004	0.0465	7.8	1034	0.0	0.5	16.38
C14530	1/2 H	120.0	0.05	0.0001	0.0125	95	310	1.5	2.0	17.64
BF 158	1/2 HT	127.6	0.025	0.0004	0.0465	7.8	1034	0.0	0.5	16.38
		123.76	0.100	0.0008	126.60	47.2	1027	0.0	0.5	17.0
		Tensile Modulus (Gpa)		Flexural Modulus (GPa)		Conductivity (%IACS)	Flexural Yield Strength (MPa)	Formability		CTE

Thermoelectrical FEA Procedure

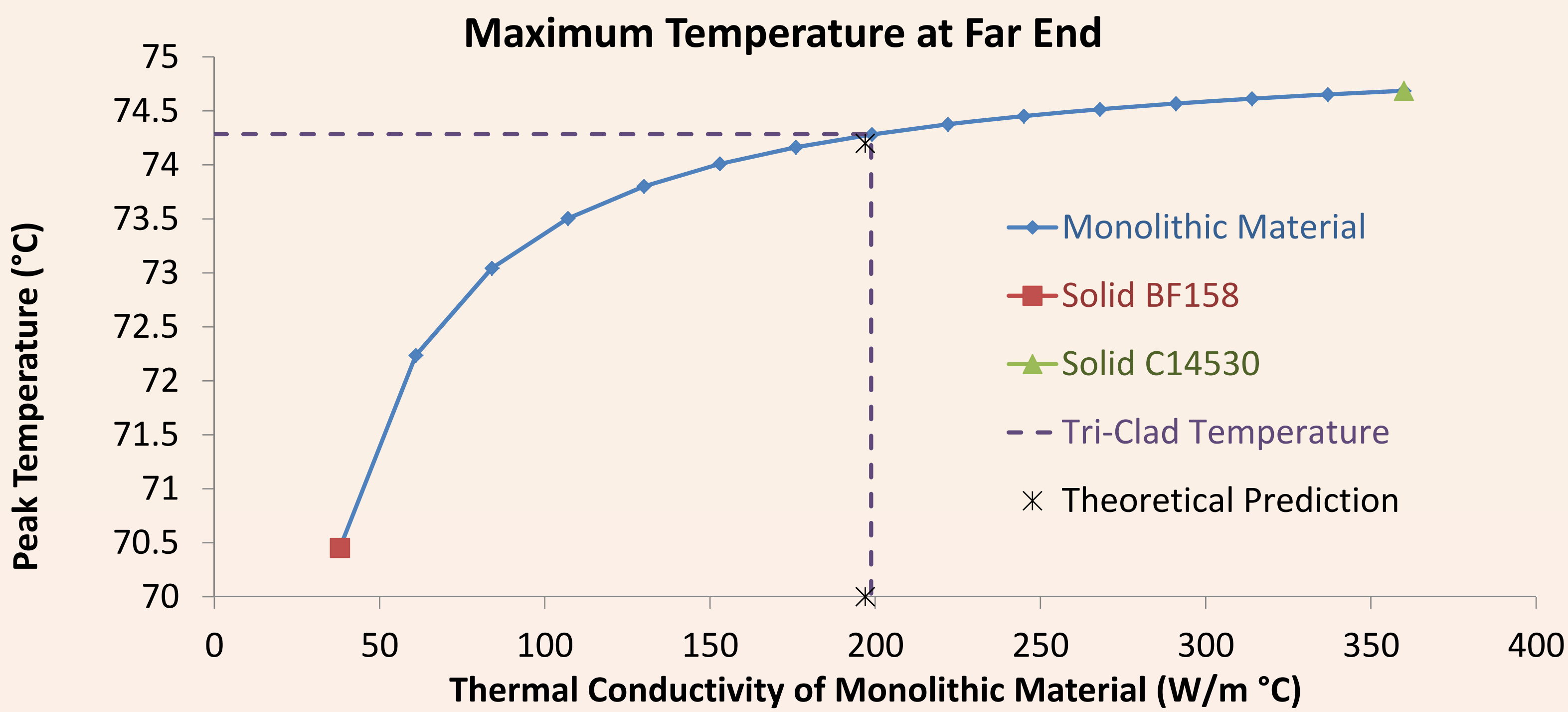
- Thermal Behavior
  - Model composite with heat transfer problem
  - Compare to monolithic material with varying k_x
- Electrical Behavior
  - Model composite with electrical heating problem
  - Compare to monolithic material with k_x determined above and varying σ

Thermal Finite Element Model

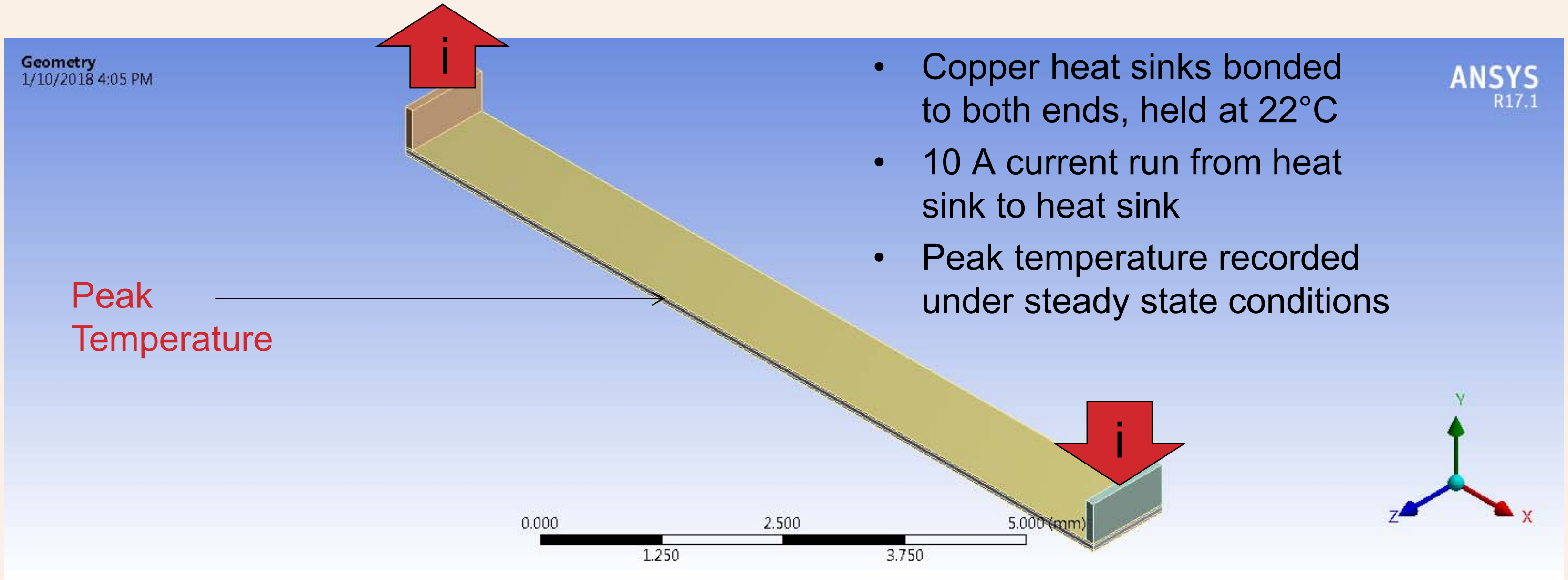


- Copper heat sinks bonded to both ends
- 0.1 W/mm^2 heat flux (Q) applied to far edge of one heat sink
- Peak temperature measured at far edge of other heat sink after 20 s

Thermal FEA Results

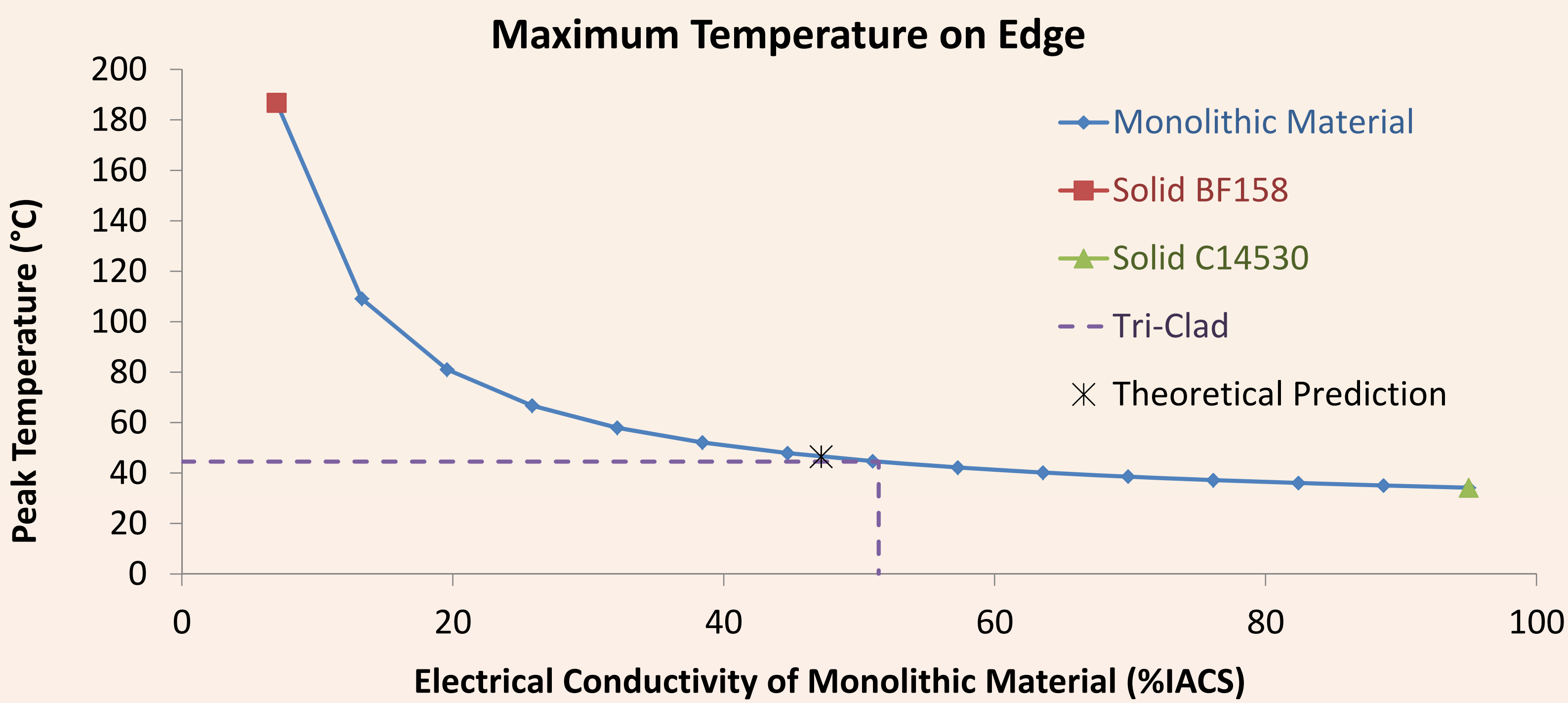


Thermo-electric Model



- Copper heat sinks bonded to both ends, held at 22°C
- 10 A current run from heat sink to heat sink
- Peak temperature recorded under steady state conditions

Thermo-electric FEA Results



Thermoelectrical FEA Results

- 4 Possible Current/Thermal Paths

– 199 W/m K, 51% IACS

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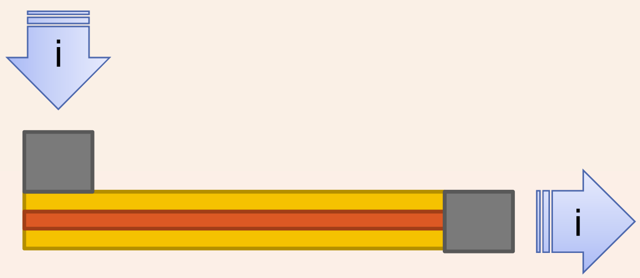
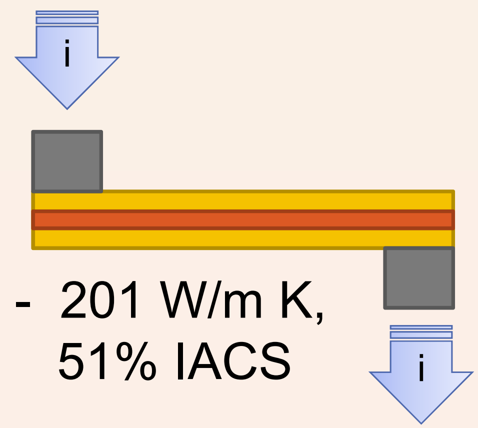


– 199 W/m K, 51 % IACS



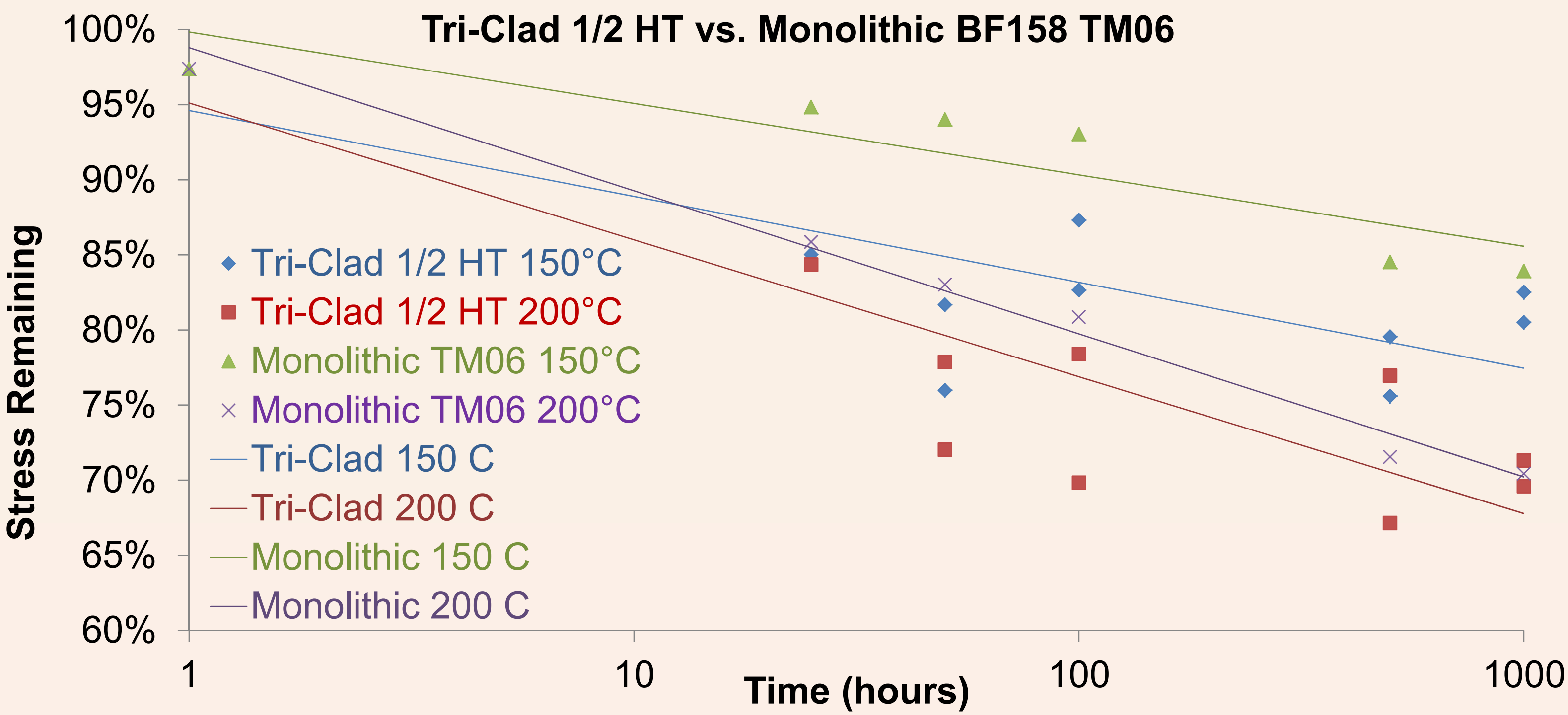
- 201 W/m K, 51% IACS

Discussion

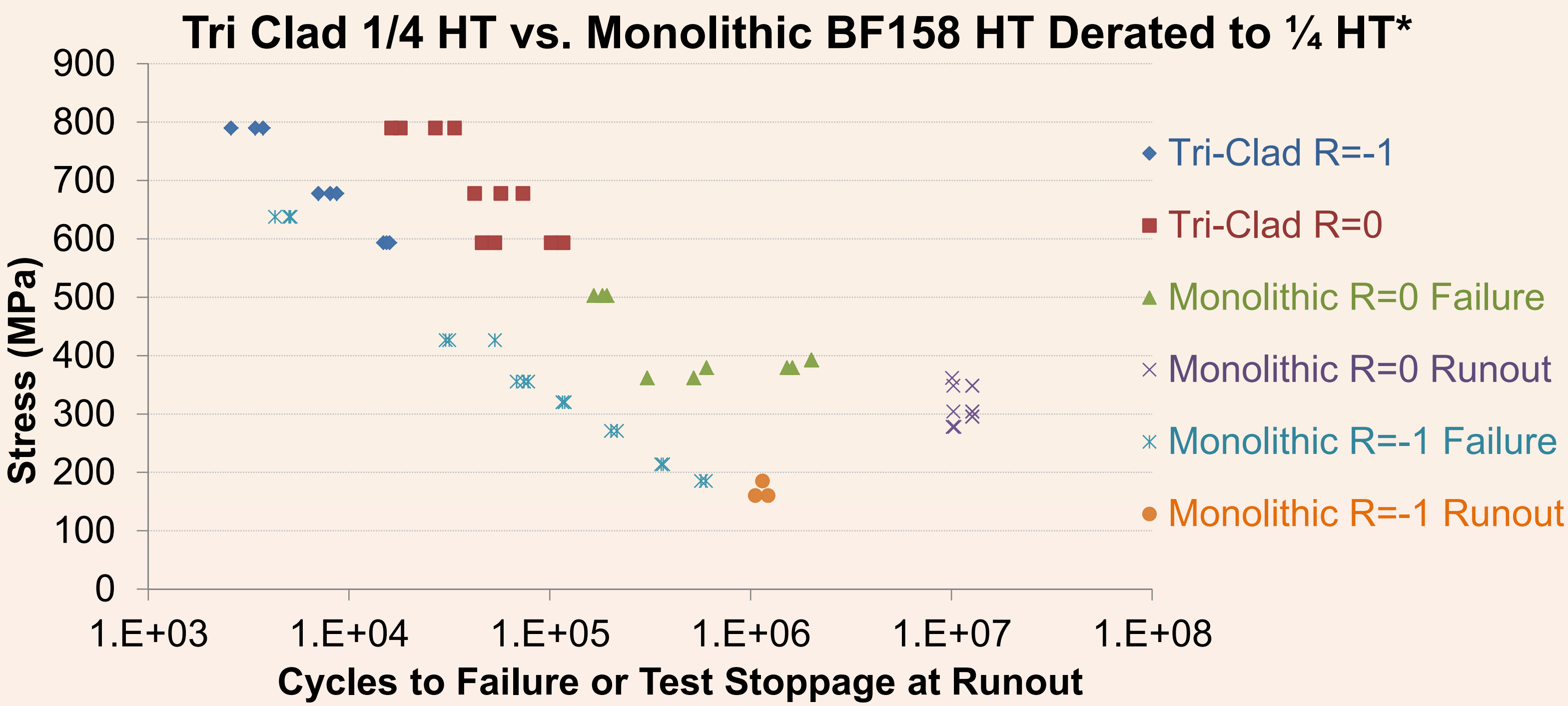
- Fatigue and stress relaxation physical test results in line with theory
- Thermal and electrical conductivity converge to resistors in parallel under all configurations

	Thermal Conductivity	Electrical Conductivity	Flexural Modulus	Flexural Yield Strength	Thermal Expansion Coefficient
Theoretical Prediction	197 W/m °C	47.2% IACS	126.60 GPa	1027 MPa	17.0 µm/m °C
FEA Model	199 W/m °C	51% IACS	126.60 GPa	937 MPa	17.0 µm/m °C

Stress Relaxation Test Data



Fatigue Test Data



Potential Downsides

Recyclability

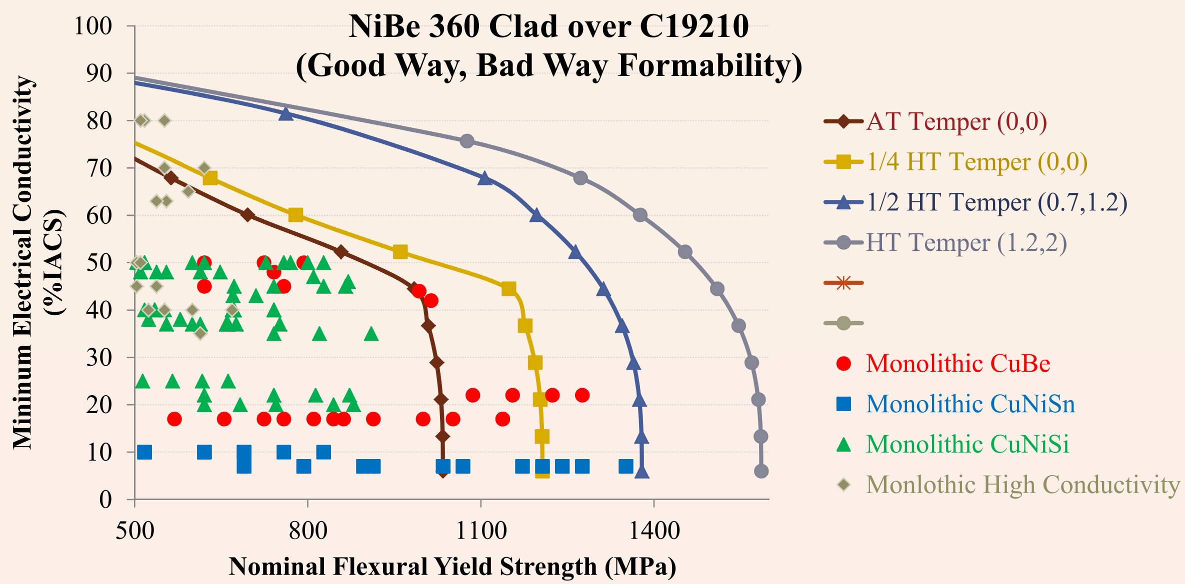
- Composite may not be recyclable
  - Different chemistries
  - No scrap value
- Steel & Cu or Ni & Cu – problem
- Cu alloys – smaller problem

Fabrication Capability

- Different response to stamping clearances
- Different etch rates

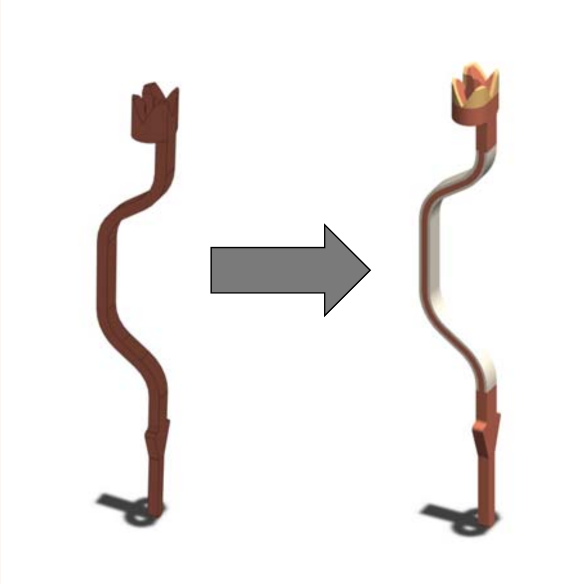
Other Possibilities

- NiBe over high conductivity Cu for high temperature applications



Other Possibilities

- Inlay high strength material in bend area only
- Inlay Paliney or other precious metal in crown area



Conclusions

- Cladding can be used to produce materials with combinations of properties never seen before
- The properties are predictable by simple calculations, confirmed by testing and simulation
- The method used to simulate can be used to estimate properties of composite materials.