“High Performance Interface Materials with Morphing Fillers ”

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OUTLINE

- Interfacial Thermal Impedance
  - Contact and Bulk Contributions
  - Important physical properties of a Thermal Interface Material (TIMS)
- Design of A Typical TIM and Limitations
  - Rheology versus thermal conductivity
  - Filler particle Size
  - Polymer rich filler exclusion zone
- Overcoming Limitations With Morphing Fillers
- Results on a Representative TIM with Morphing Fillers
- Future Directions

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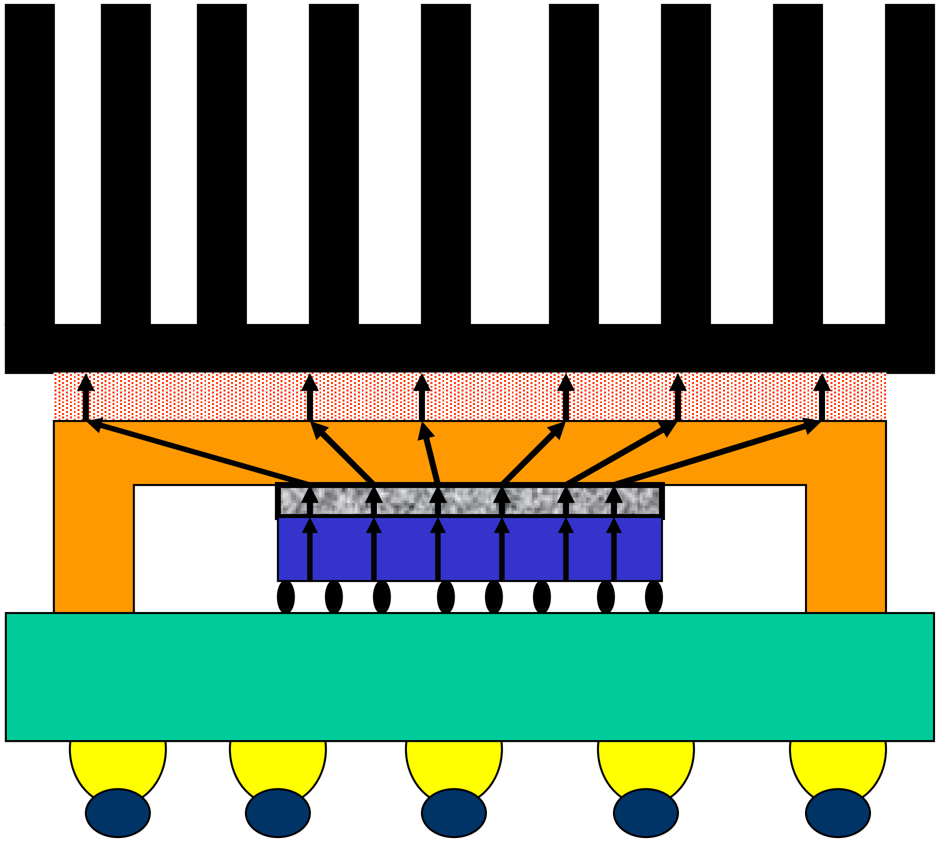
Interfacial Thermal Impedance

MICROPROCESSOR BGA PACKAGE



Thermal Interface Materials

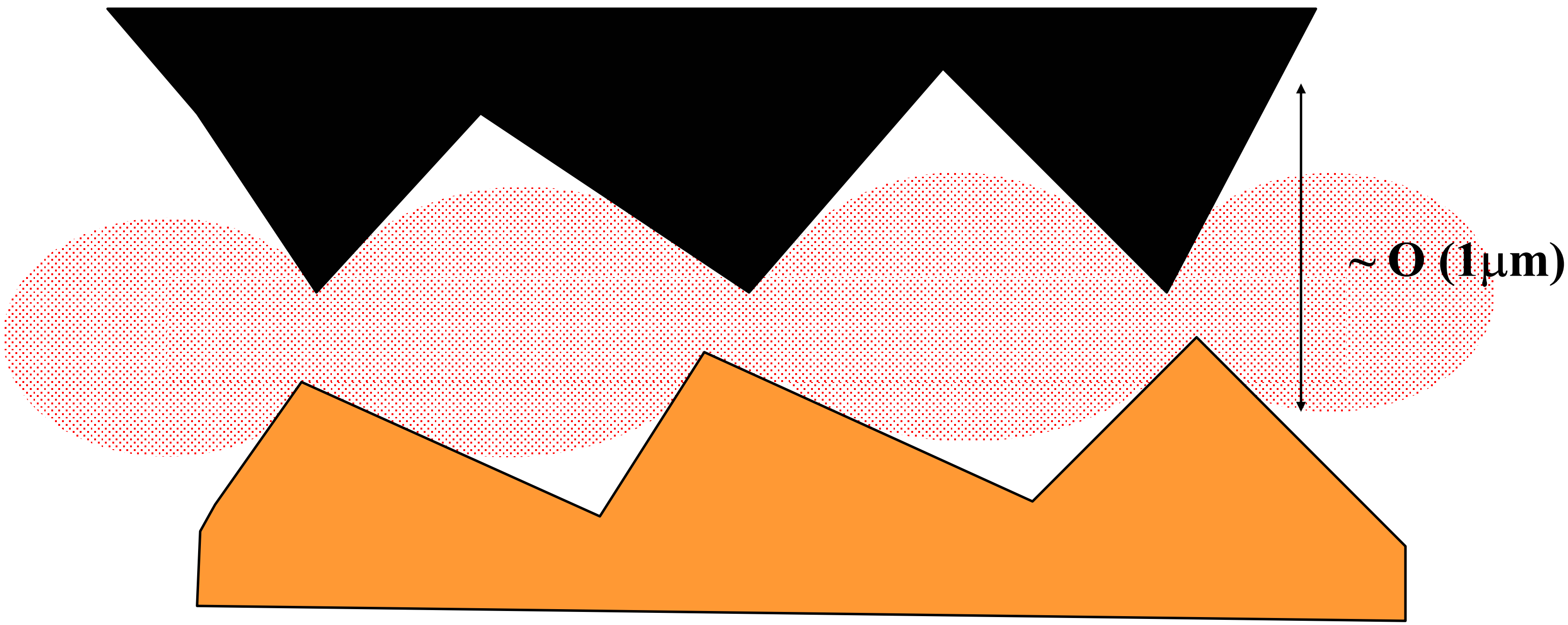
1. Case- Sink

TIM/Case Contact and TIM/Sink Contact

2. Die – Case

TIM/Die Contact, TIM Bulk, TIM/Case Contact

Microscopic Deviation from Flatness



Rheology and Wetting Have Major Impact

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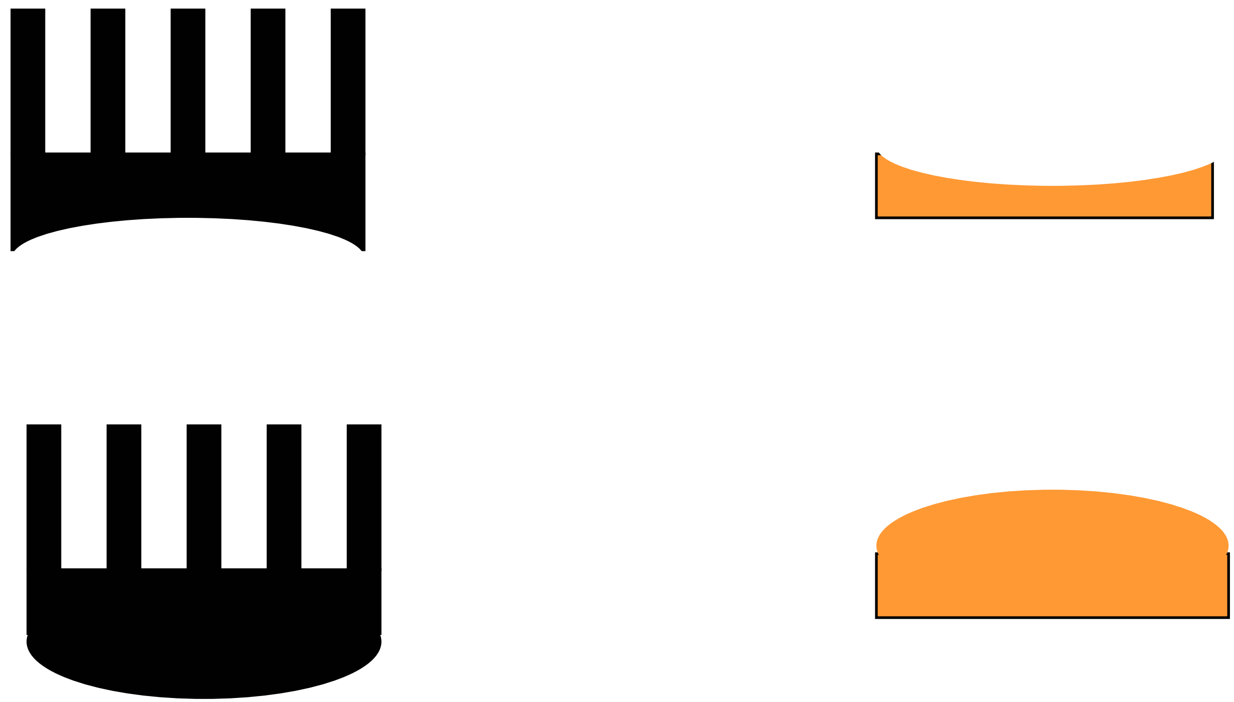
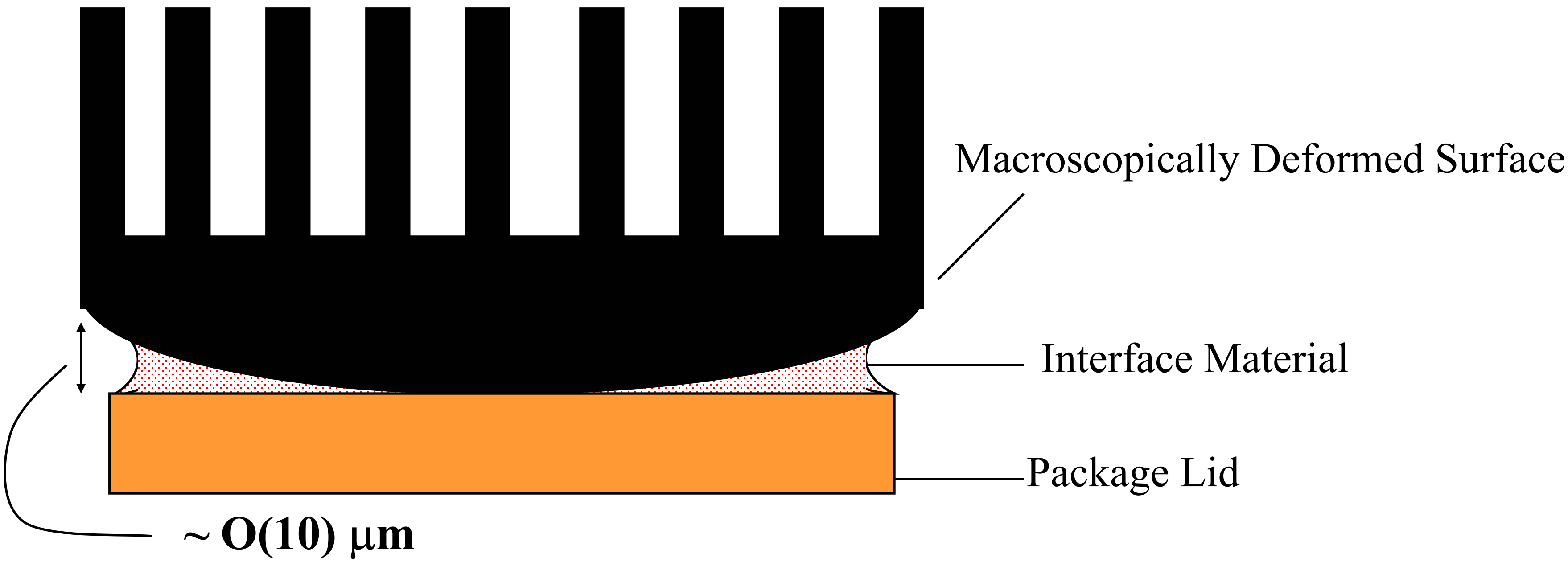
MACROSCOPIC DEVIATIONS FROM FLATNESS



Macroscopic Deviation from Flatness



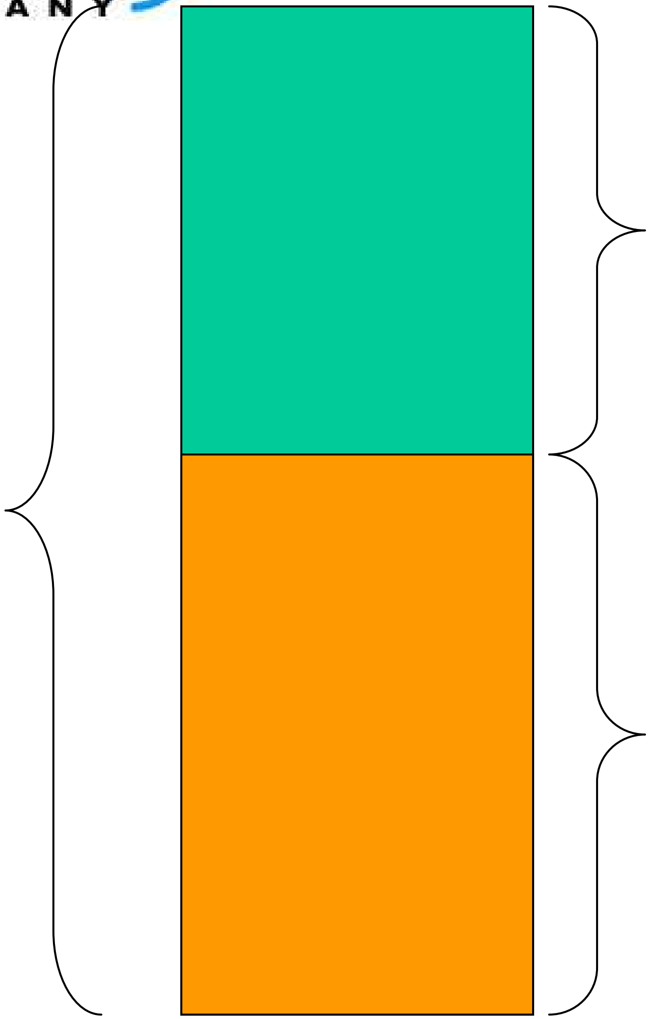
Bulk Thermal Conductivity Has Major Impact

Standoff For Mechanical Reasons

Bulk Thermal Conductivity Has Major Impact

R_T

Total Thermal Impedance Associated with TIM



R_i

Contact Resistance

Complex to define-

- Surface Profile,
- Rheology
- Surface Tension
- Filler Attributes

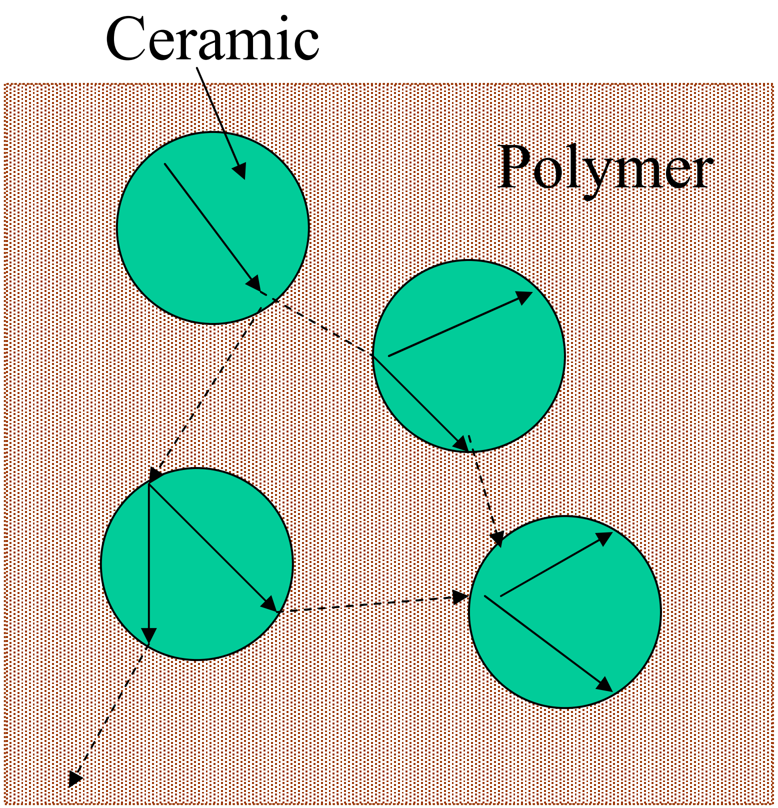
R_B

Bulk Resistance

- L/k
- L is TIM thickness
- k is TIM Thermal Conductivity

Design of A Typical TIM and Limitations

Poor Heat Transfer Through Polymer



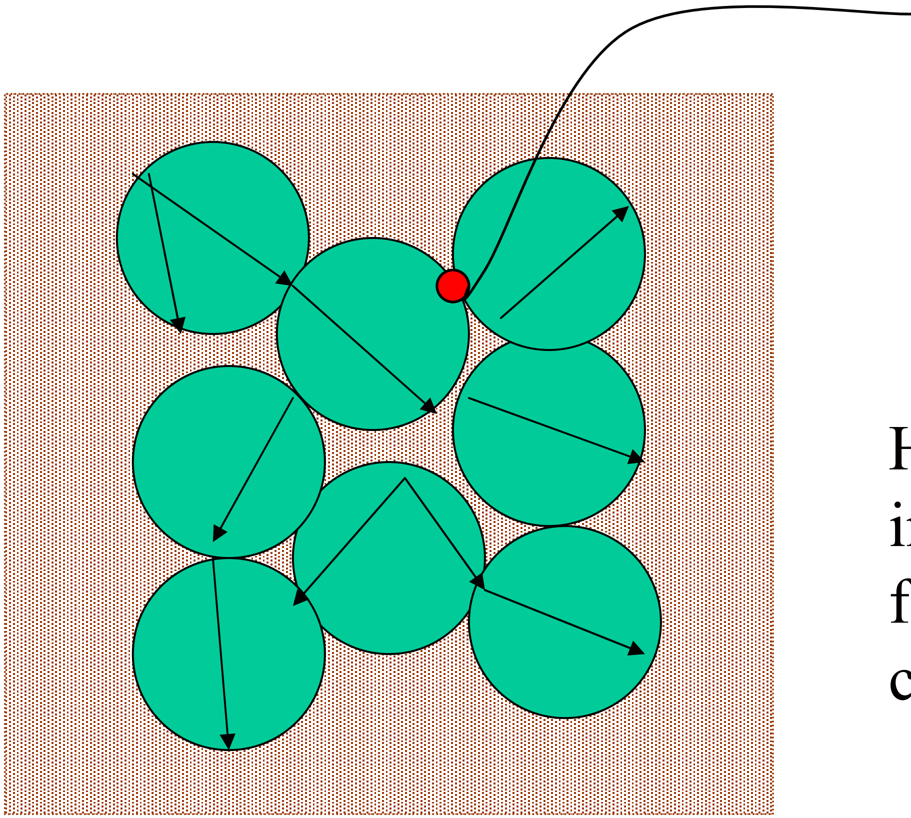
$k_{polymer} \sim O\ (0.1)\ W/m\text{-}K$

$k_{filler} \sim O\ (1\text{-}1000)\ W/m\text{-}K$

$k_{TIM} \sim O\ (1)\ W/m\text{-}K$

Fig. 1a

Poor Contact Even At Percolation Concentration

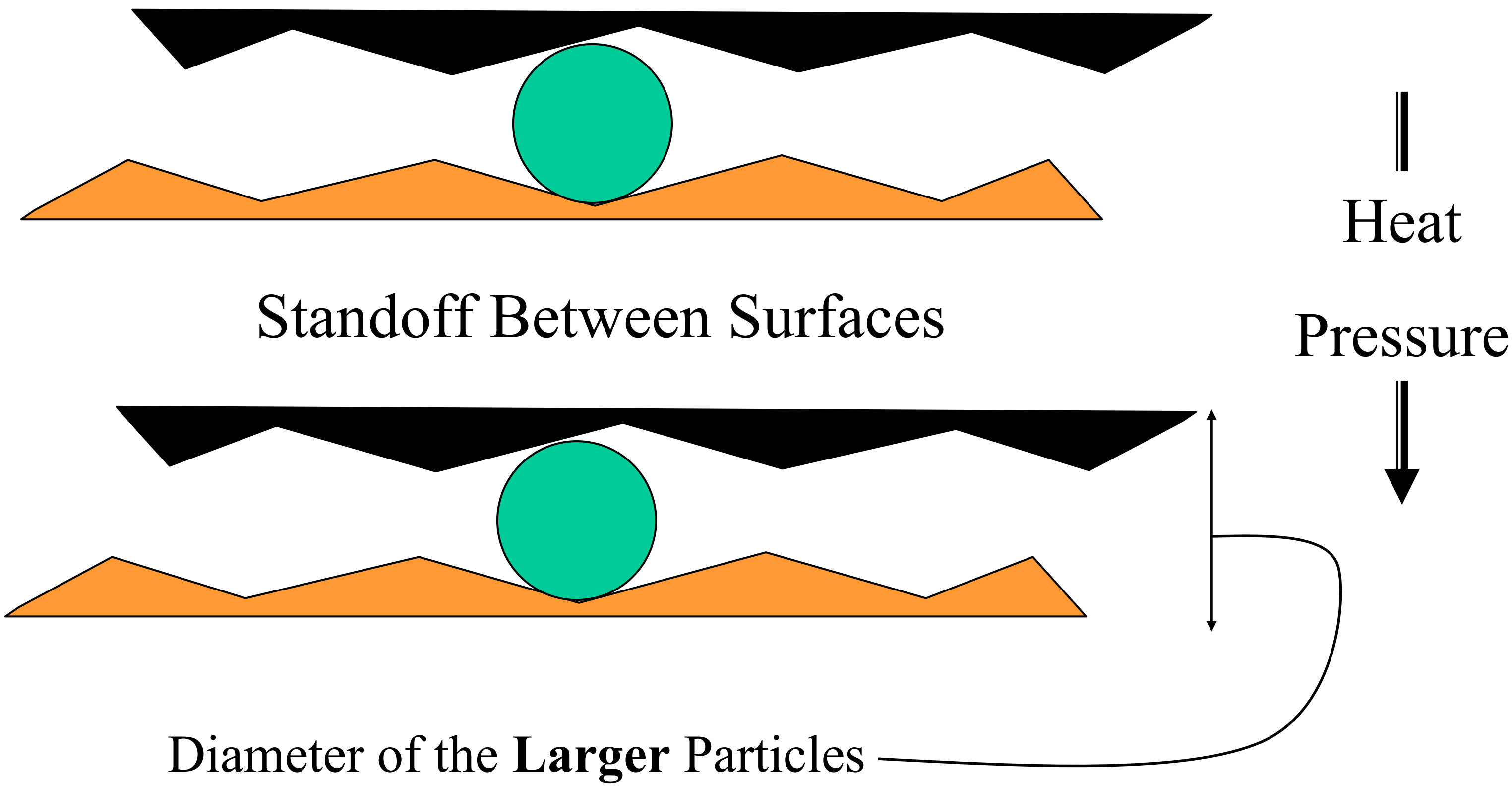


Poor particle-particle contact is a severe bottleneck

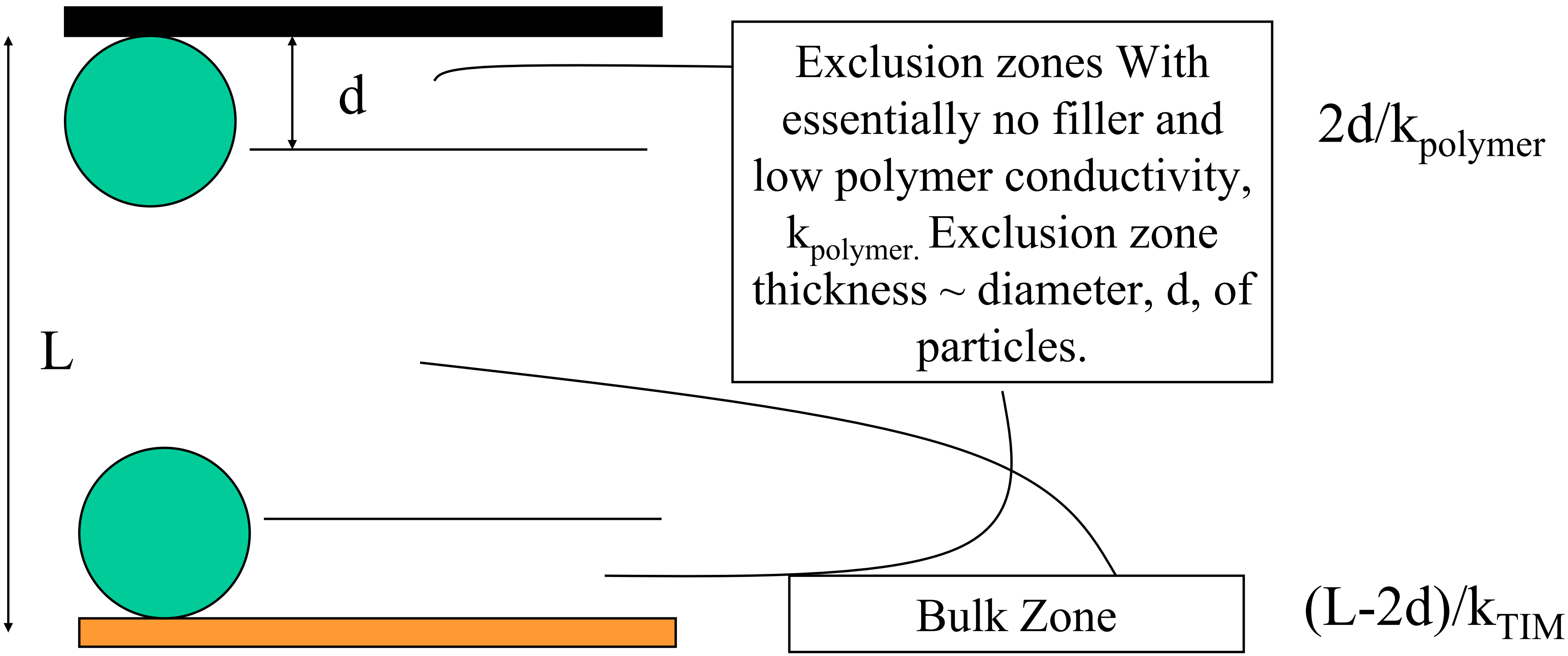
High filler loading increases viscosity much faster than thermal conductivity

Fig 1b

Standoff


Heat
Pressure
Standoff Between Surfaces
Diameter of the **Larger** Particles

Polymer Rich Surface Layer



High Performance Thermal Interface Material

High thermal conductivity (bulk)

Micro-rheology capable of flowing into micro size rough channels (contact).

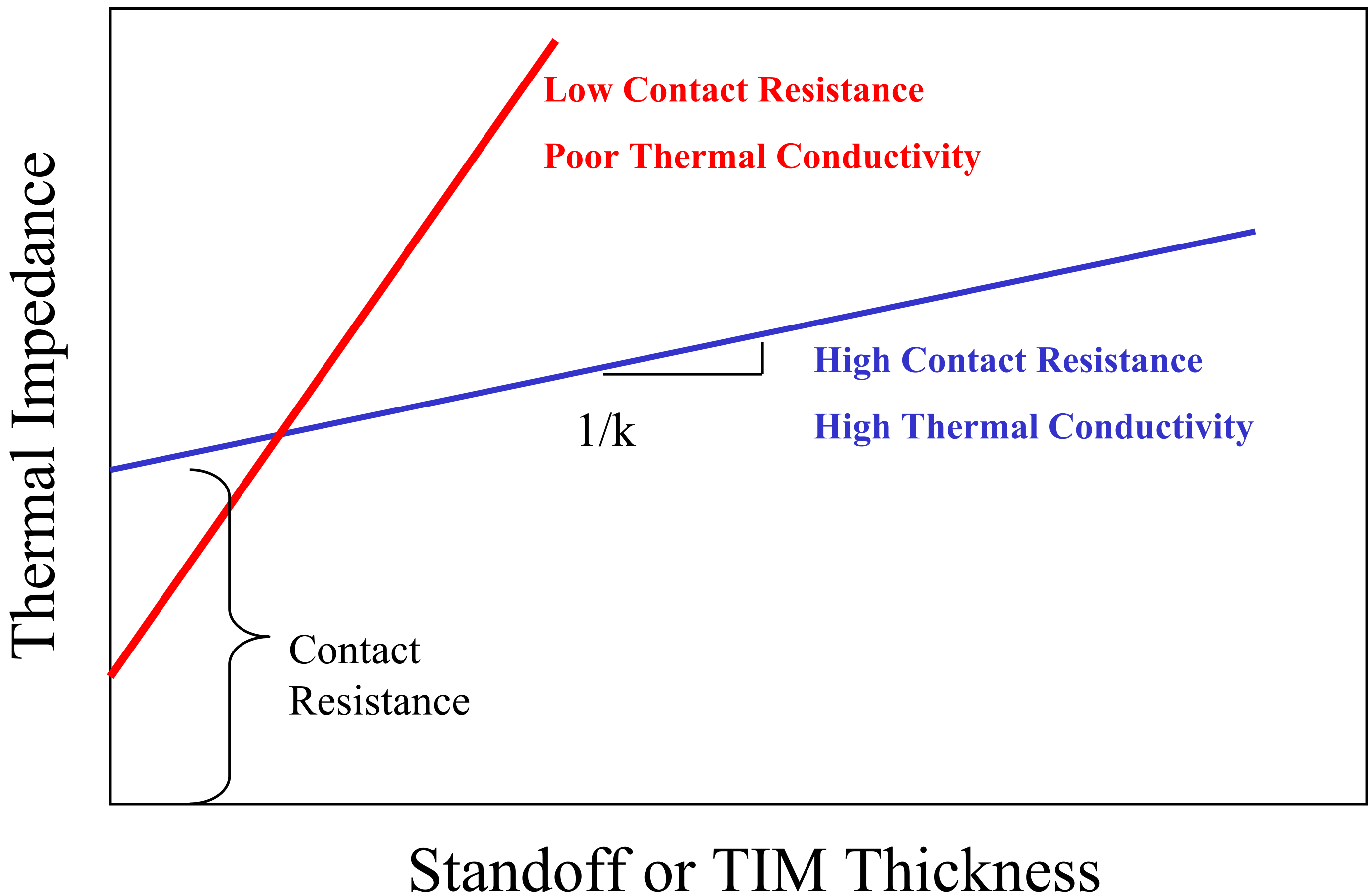
Excellent wetting to displace air (contact)

Complication

High thermal conductivity means higher fill loading (bulk)

More filler implies less ability to flow and wet out (contact)

Design Dilemma



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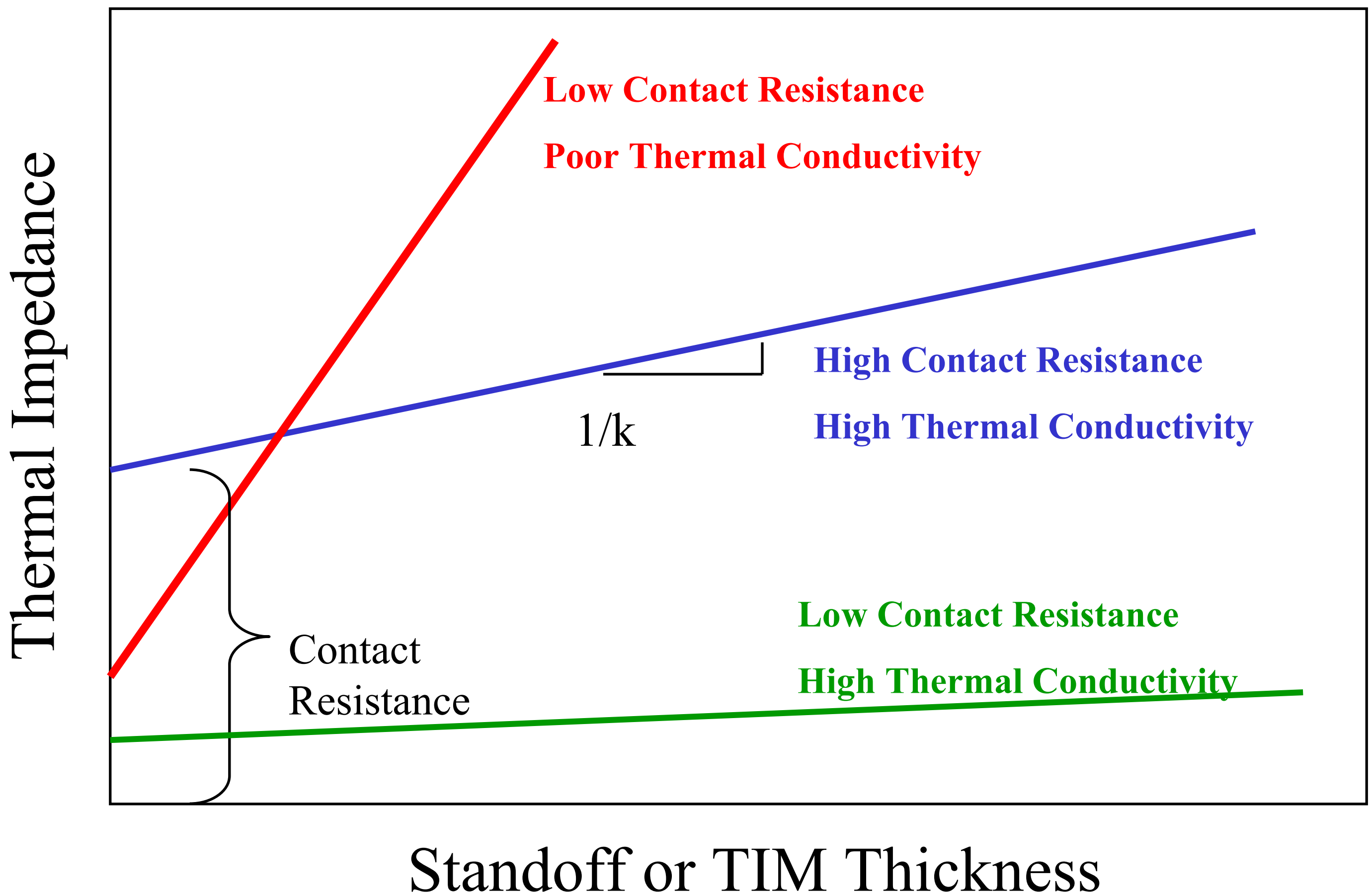
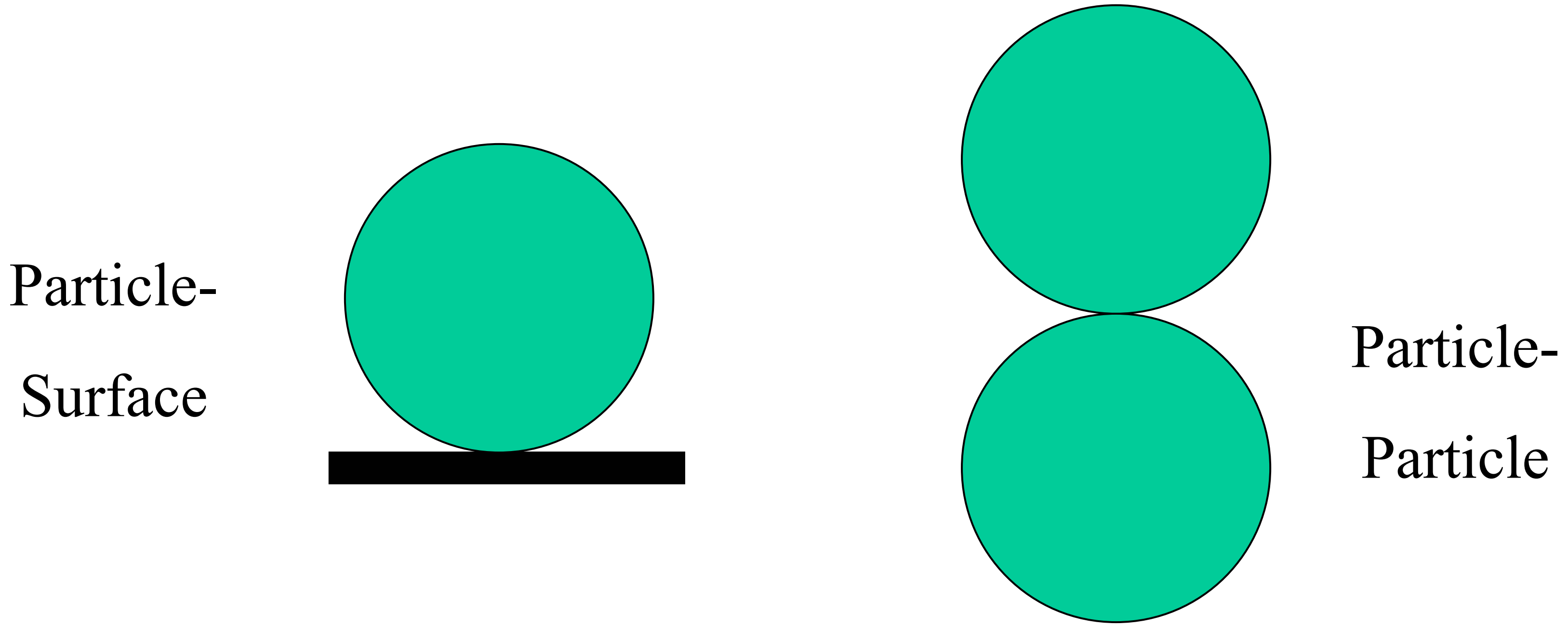
Overcoming Limitations With Morphing Fillers

Ideal Candidate





Poor Particle-Particle and Particle-Surface Contact

Fig 2

Improved Contact with Liquid Bridges

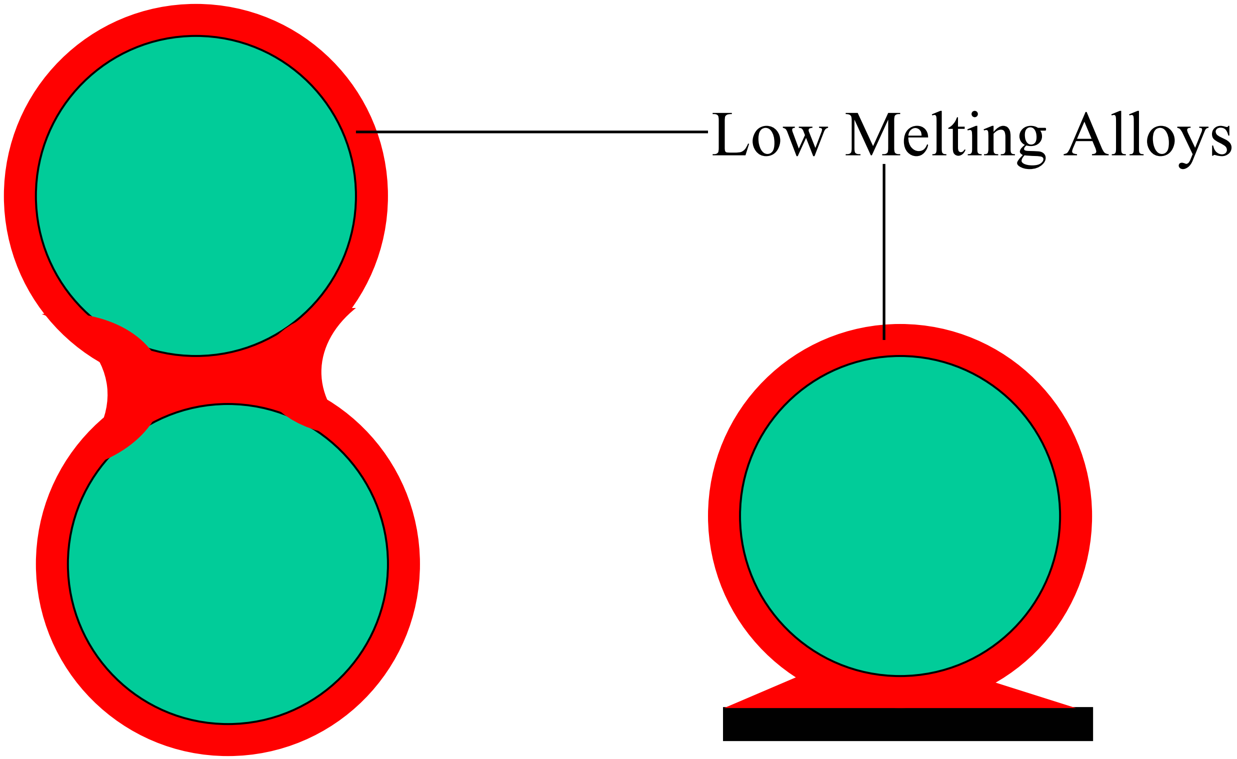
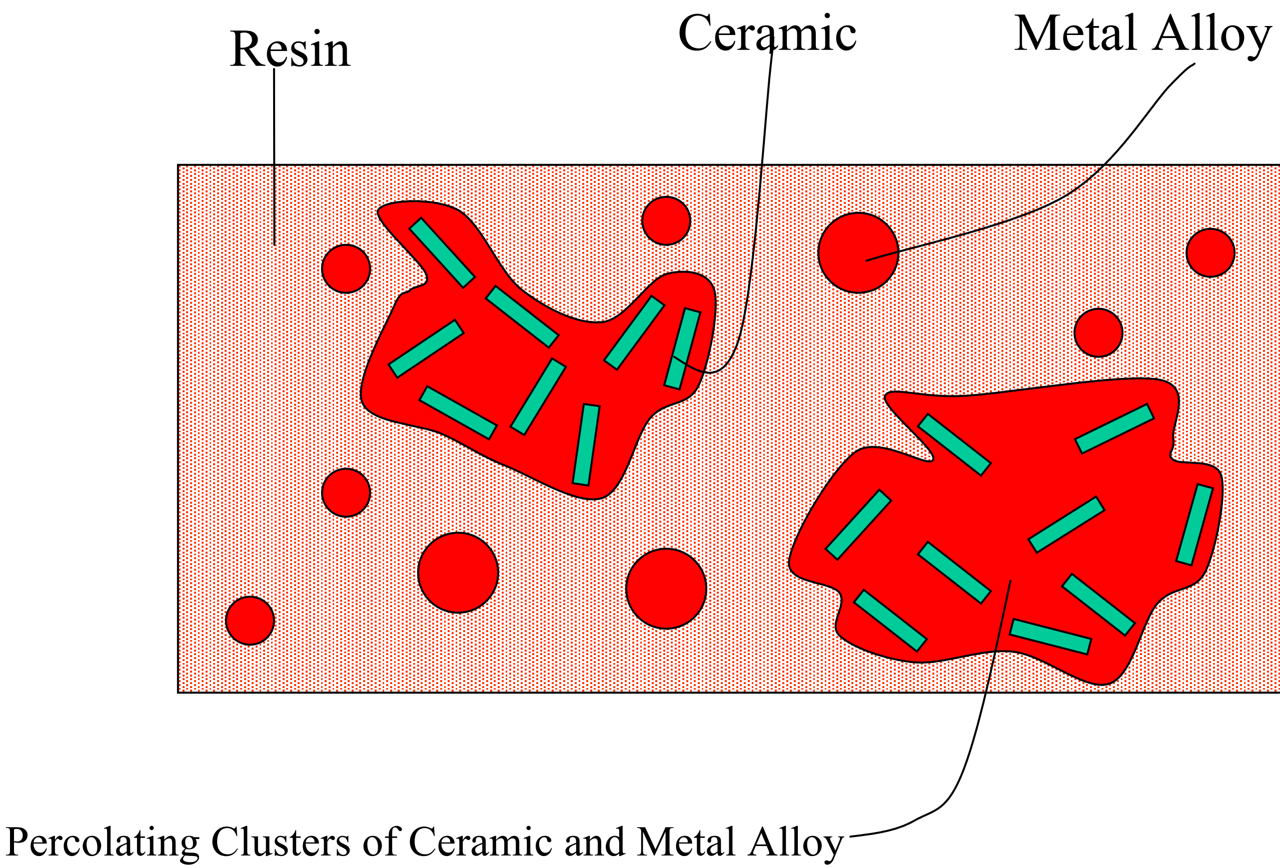
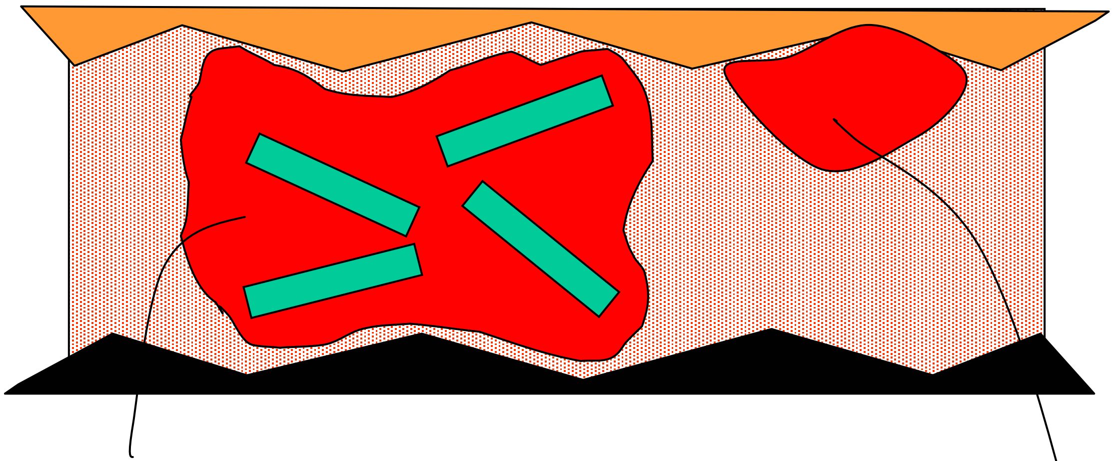


Fig 3

The New Thermal Interface Material



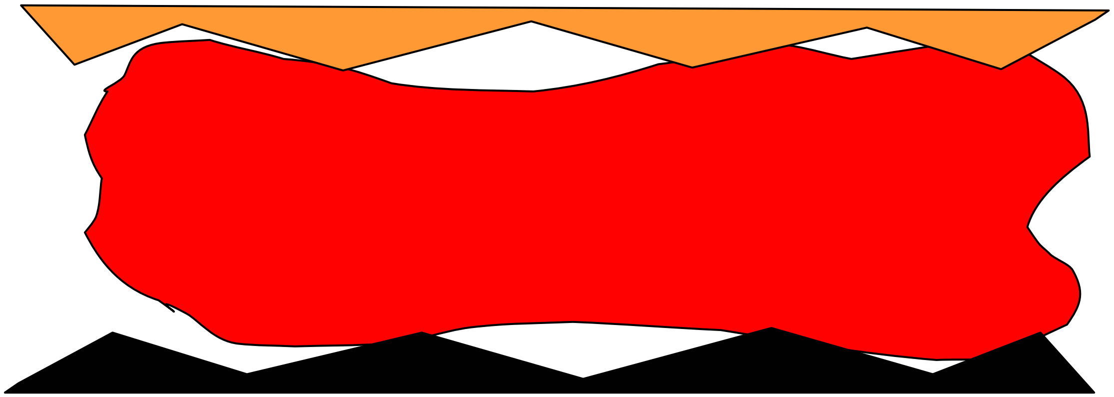
Better Heat Transfer with New Technology



Heat percolating cluster with thermally conductive ceramic dispersed inside large metal domains - improve thermal conductivity.

Metal drops reduce contact resistance

Low Melting Alloy As TIM?



- Good thermal performance
- Less than optimal wetting
- Low viscosity – pump out concerns
- Metal exposed to environmental degradation

A Representative TIM with Morphing Fillers

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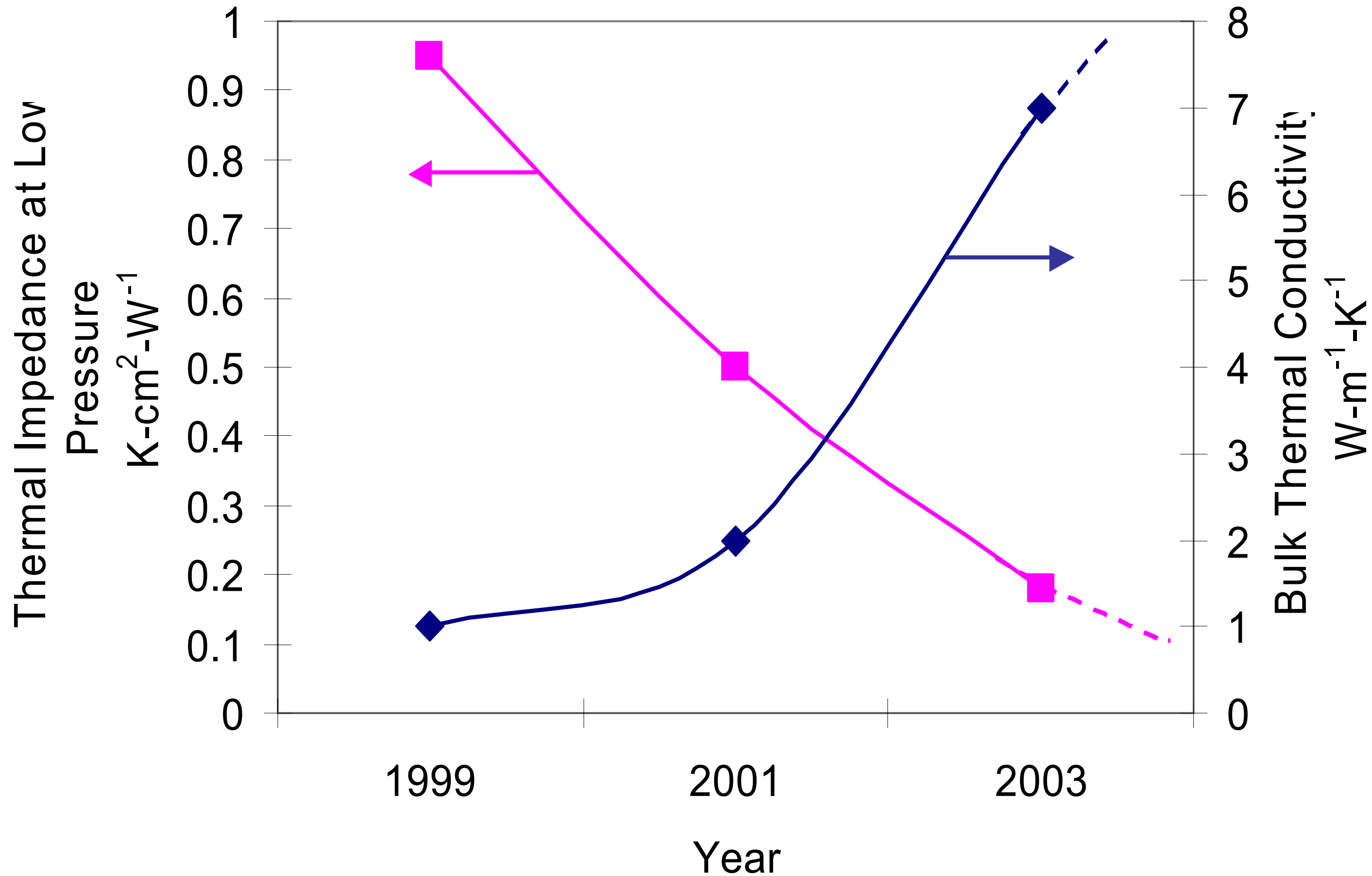
Interface Materials Development at Bergquist



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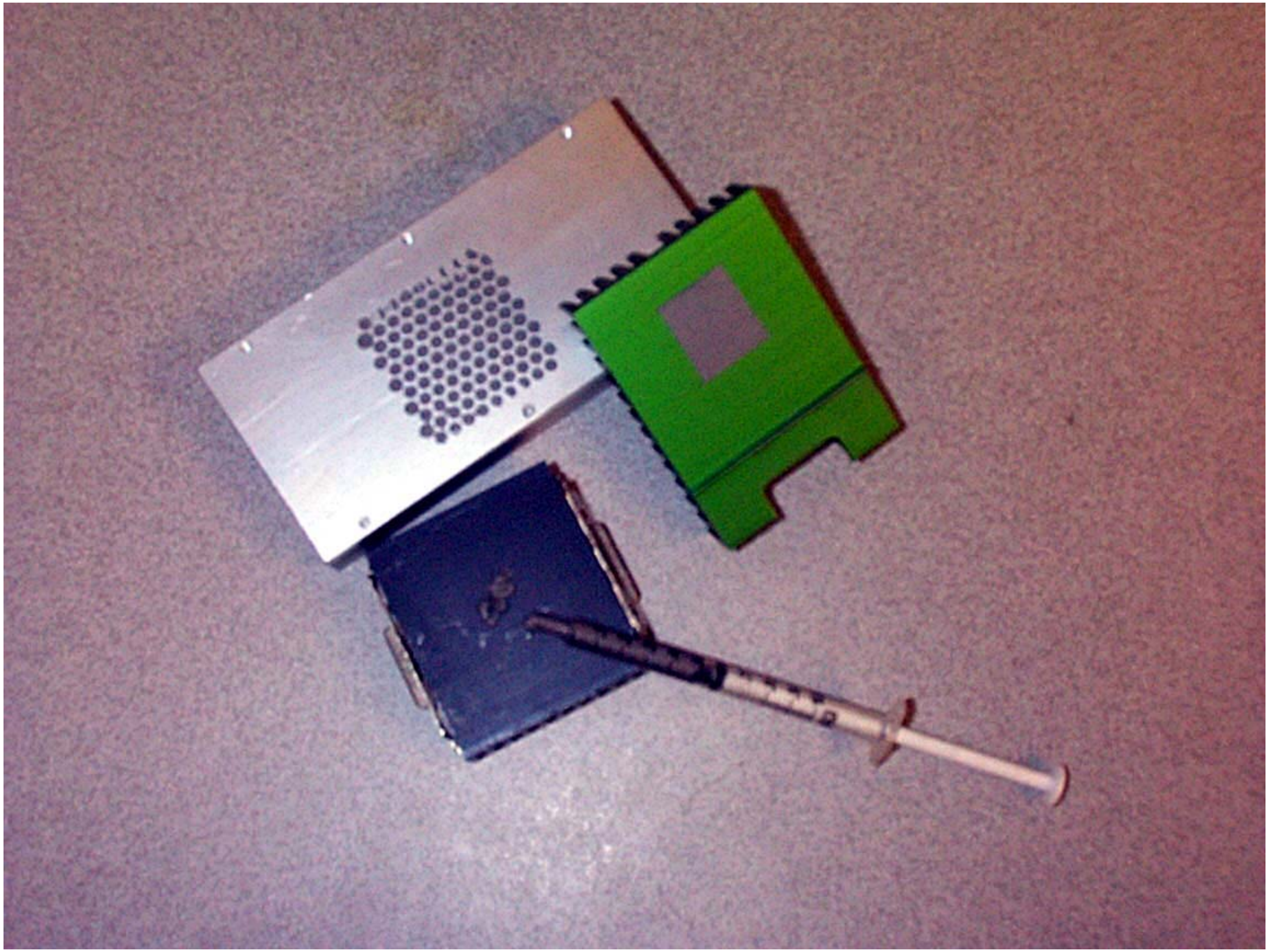
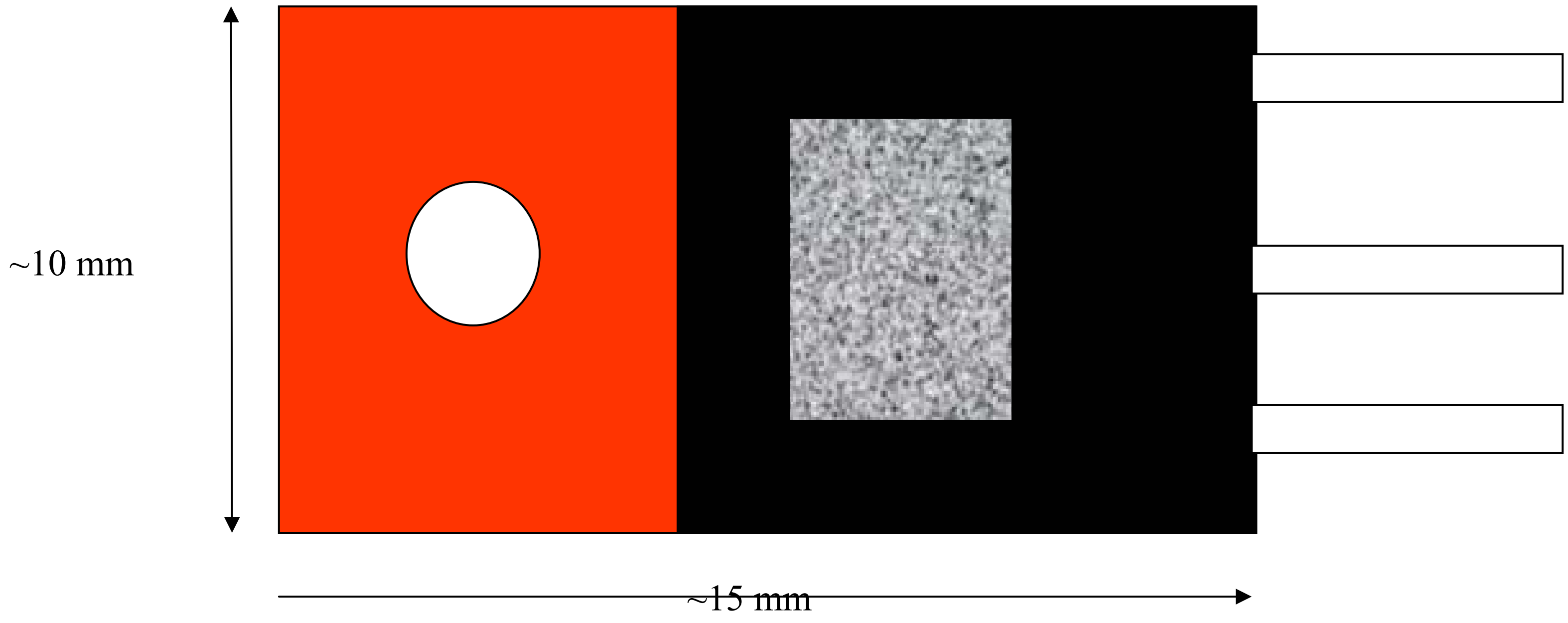
TIC-7500 (US Patent 6,339,120)

Property	Units	Test Method	Value
Thermal Conductivity	$W\text{-}m^{-1}\text{-}K^{-1}$	ASTM D5470	> 7
Viscosity No drip	cp	Brookfield T-F, 2 rpm	> 500 000
Viscosity Microrheology	cp	Brookfield T-F, 20 rpm	150 000
Dielectric Constant at 1kHz		ASTM D150	40
Density	$g\text{-}cm^{-3}$		4.0



The Model Device

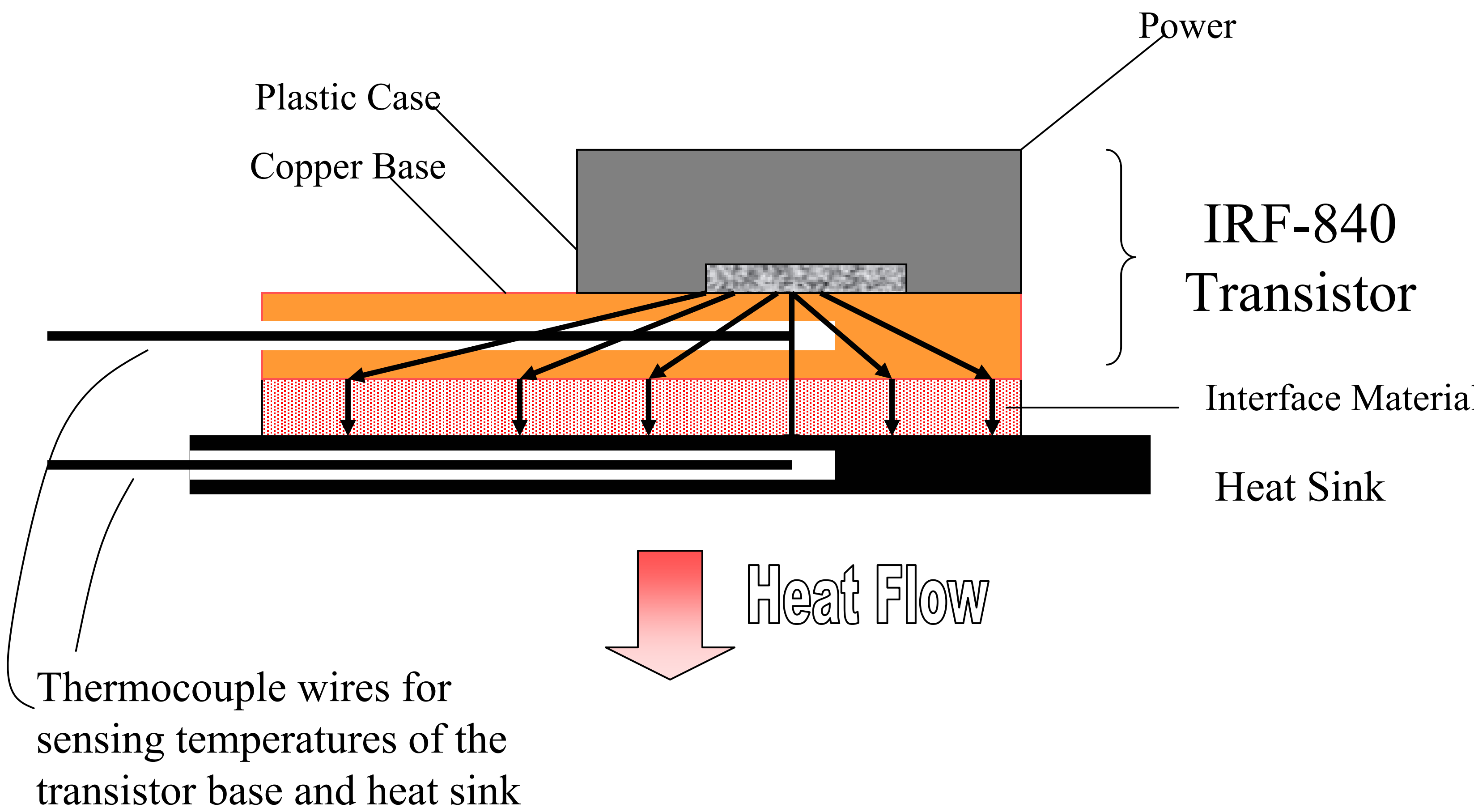


Motorola IRF-840, TO-220 Package, N-Channel MOSFET

Total Footprint ~ 0.2 in^2 (1.3 cm^2)

Heat Spreader Area ~ 0.12 in^2 (0.8 cm^2)

Die Size ~ 5.4 mm x 3.8 mm


Power
Plastic Case
Copper Base
IRF-840
Transistor
Interface Material
Heat Sink
Heat Flow
Thermocouple wires for
sensing temperatures of the
transistor base and heat sink

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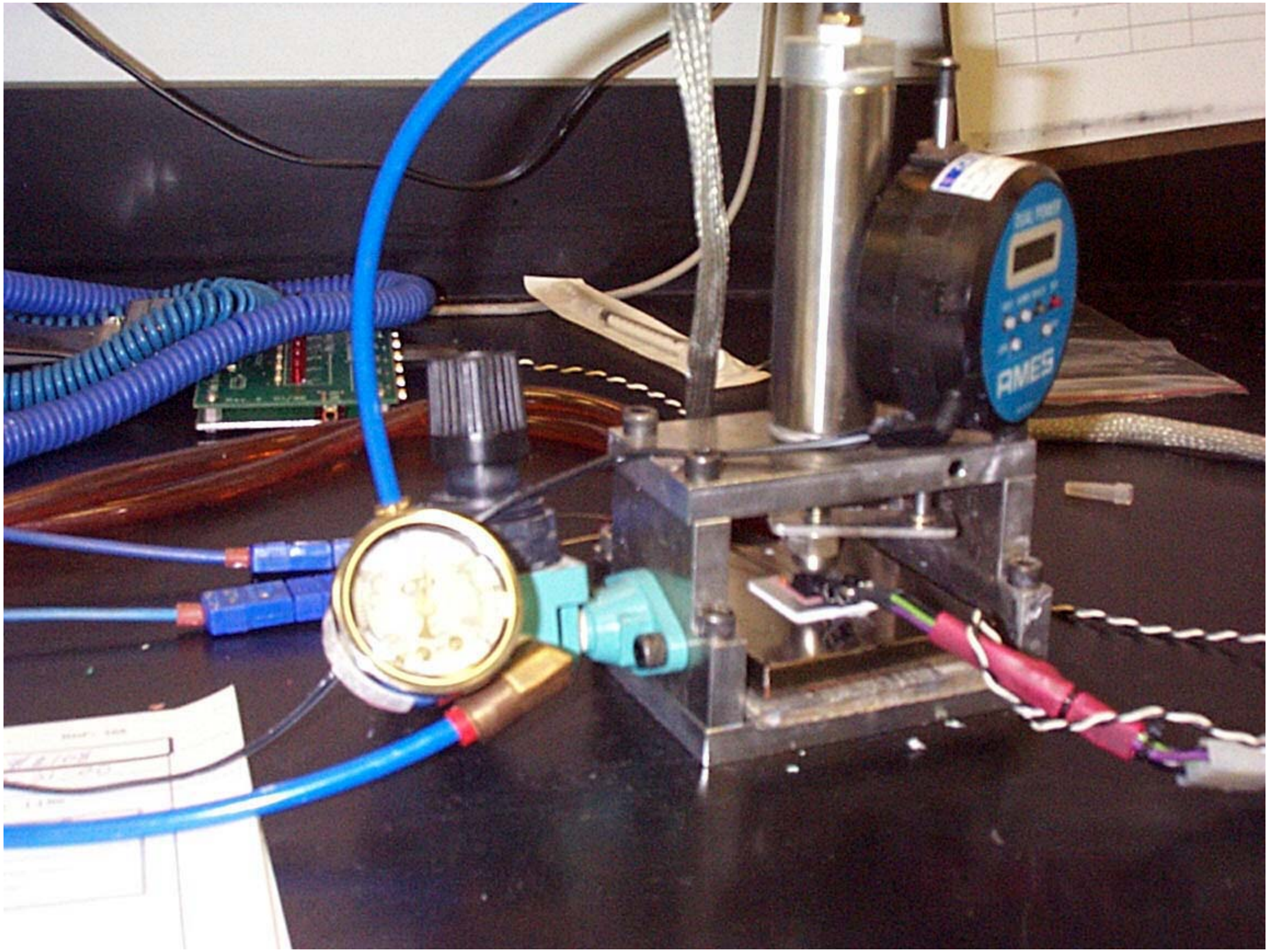

Controlled Variables:

- Voltage and Current to Package (Power)
- Pressure Applied to Package (25-200 psi)

Measured Variable:

- Case Temperature (T_c)
- Sink Temperature (T_s)

Calculated:

- Thermal Impedance $\theta_{c\text{-}s} = (T_c - T_s) / \text{Power}$ ($^{o}C\text{-}W^{-1}$)

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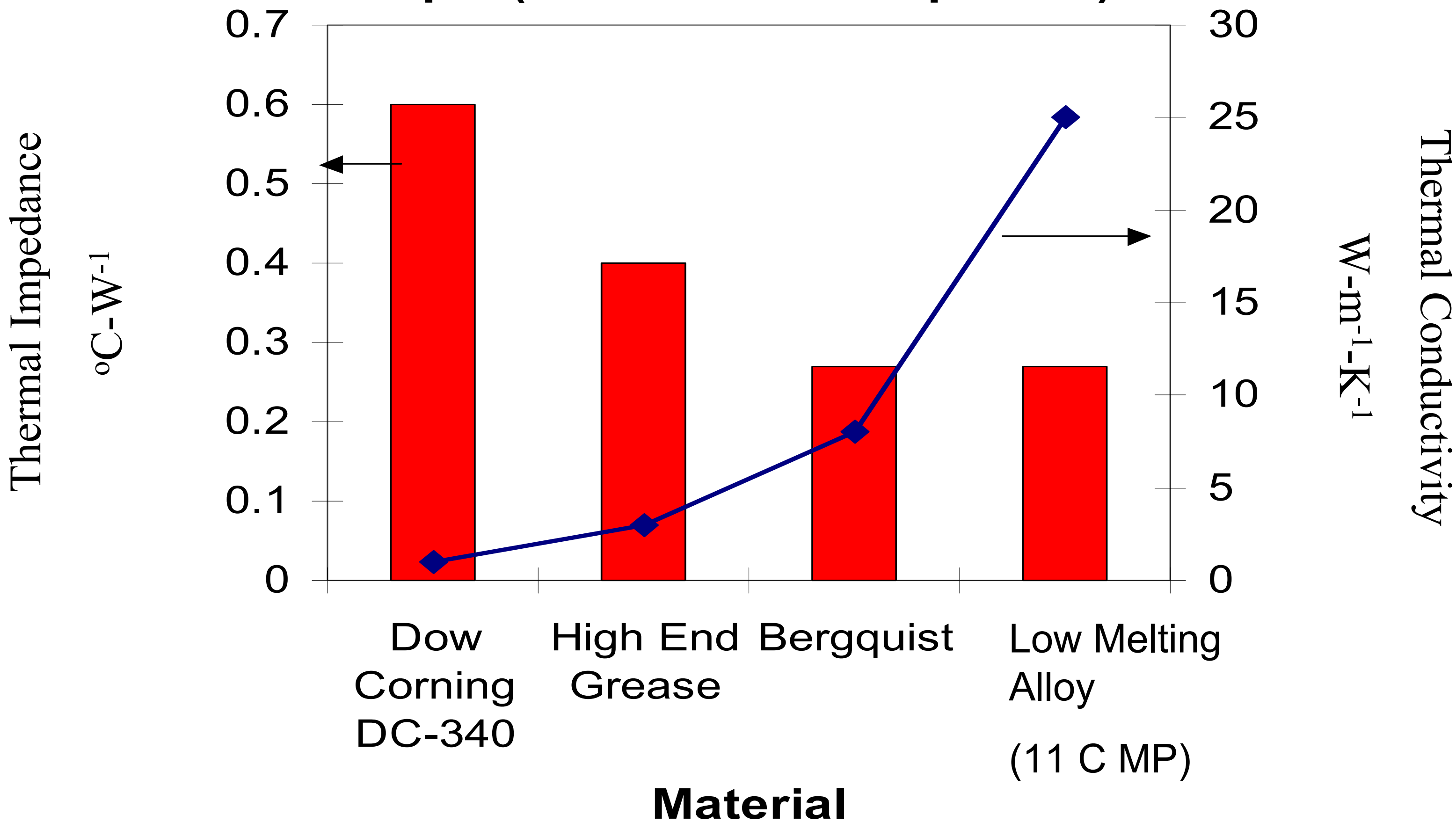
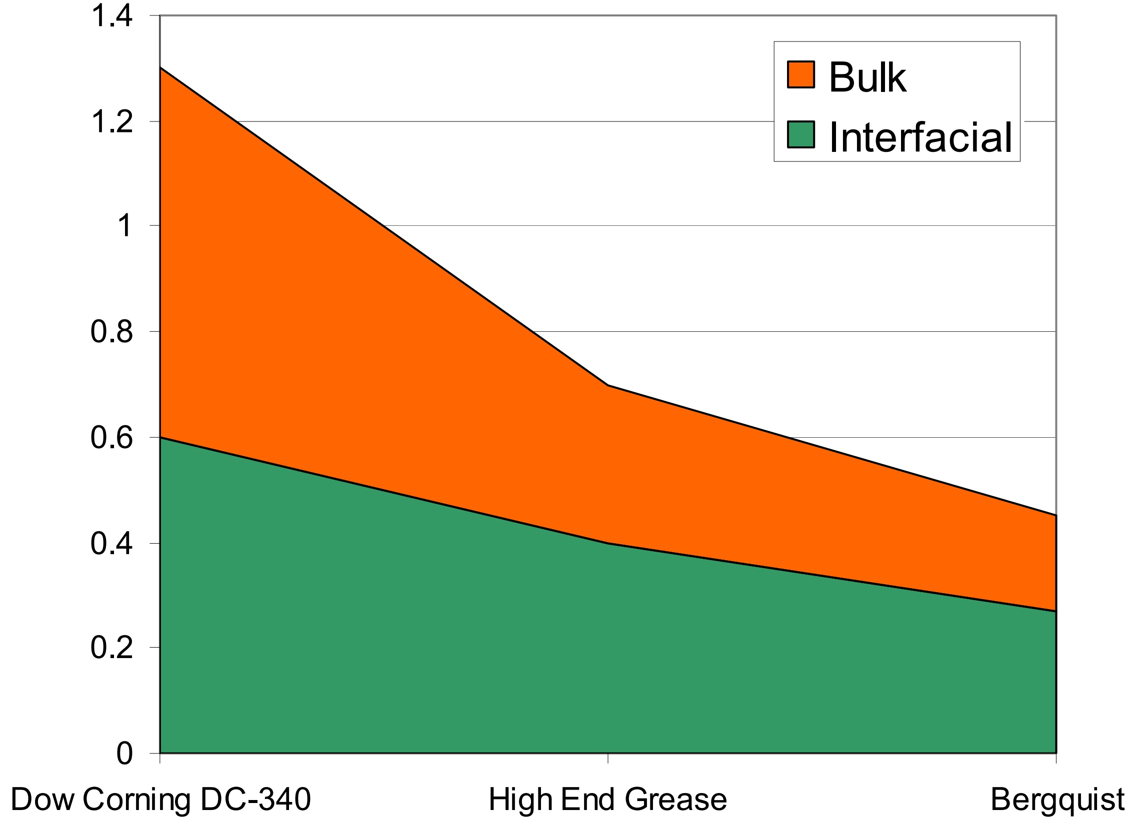
Thermal Impedance
IRF-840, TO-220 Package, Case to Sink
100 psi (~Interfacial Component)



Thermal Impedance Components at 2.5 mil Standoff
IRF-840, TO-220 Package ($^{o}C\text{-}W^{-1}$)



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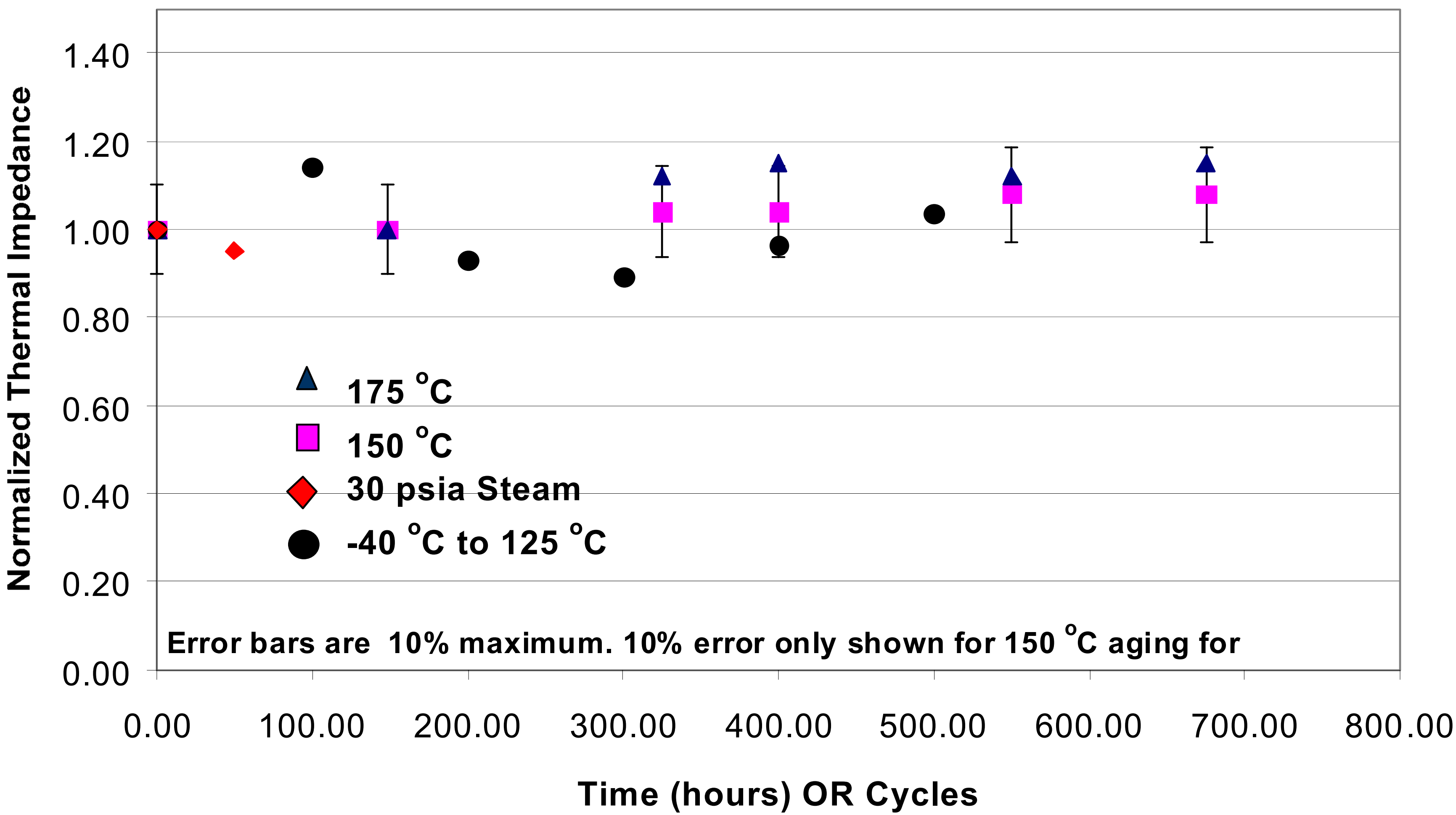
Thermal Impedance After Aging



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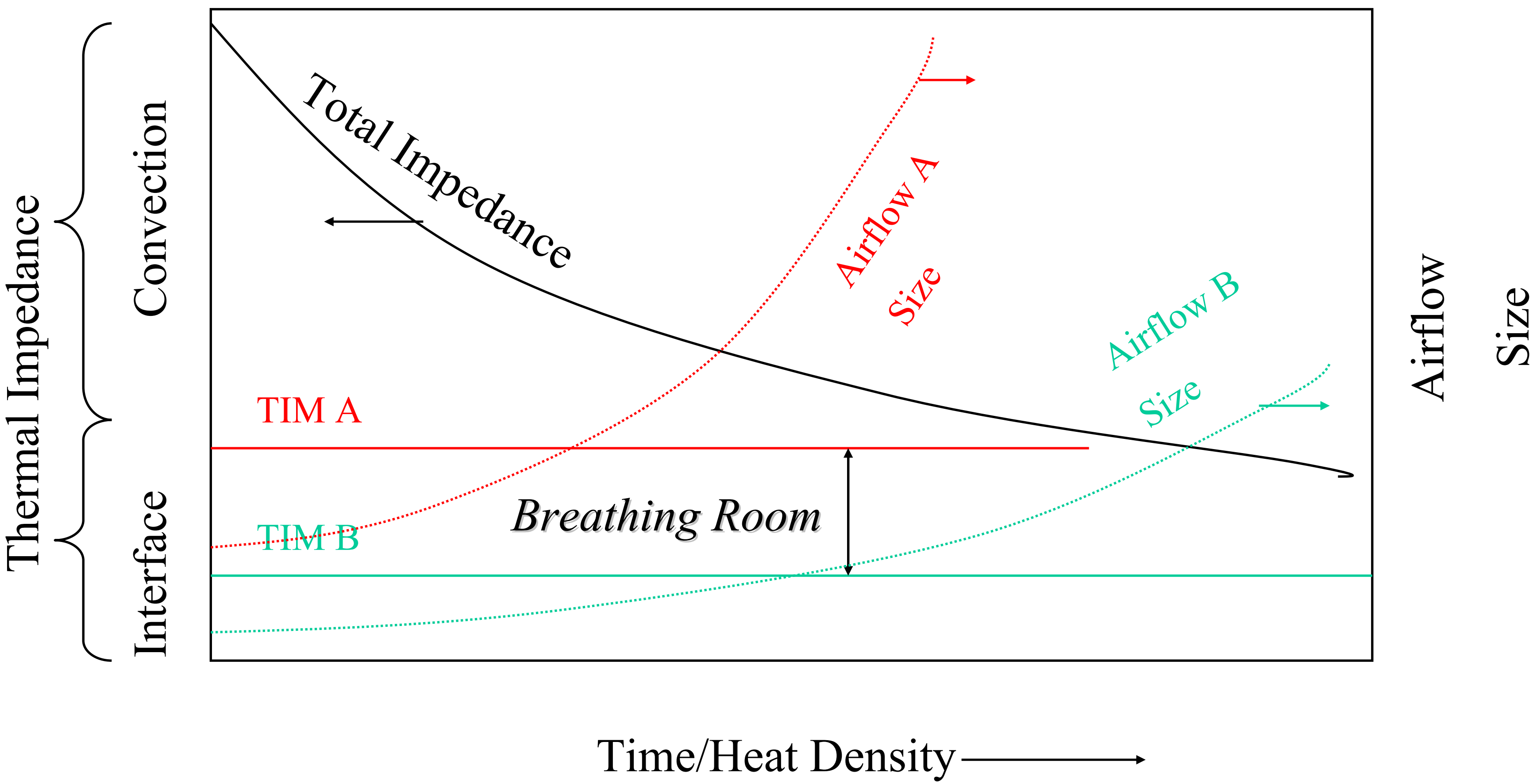
Thermal Impedance
Convection
Interface
Total Impedance
Airflow A
Size
Airflow B
Size
TIM A
TIM B
Breathing Room
Airflow
Size
Time/Heat Density

Further Directions

- Phase Change Compound – for screen printing, stenciling.
- Phase Change Thermal Pads