Thermal Interface Materials (TIMs) and Challenges Faced by TIM Suppliers

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Outline

- Thermal Interface material (TIM)
  - Description and function
  - Types
  - Applications
- Challenges
  - Performance
  - Supply Chain
  - Testing
  - Capturing value
  - Growth

Courtesy jrgb.com

Courtesy viprecycling.com

What is a Thermal Interface Material?

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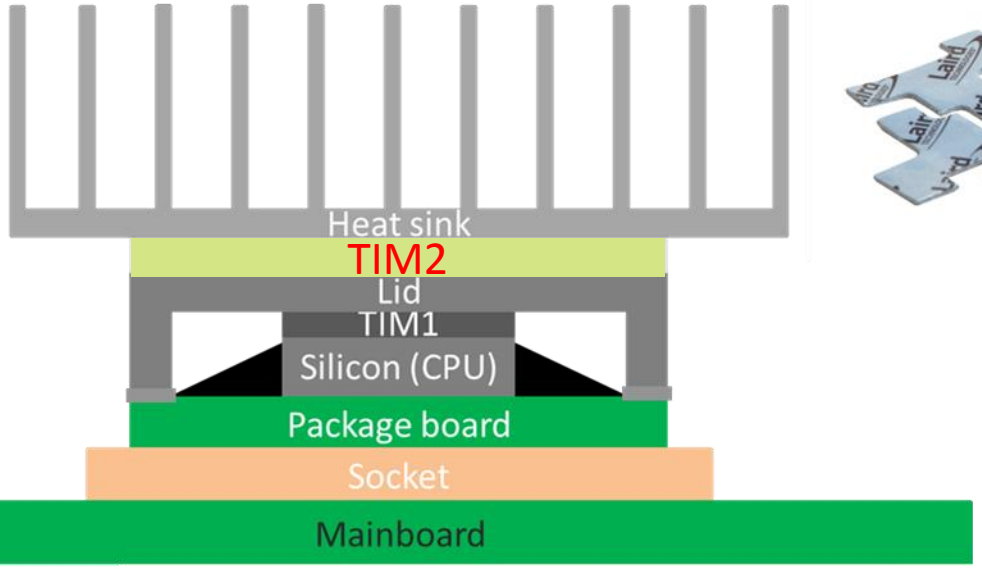
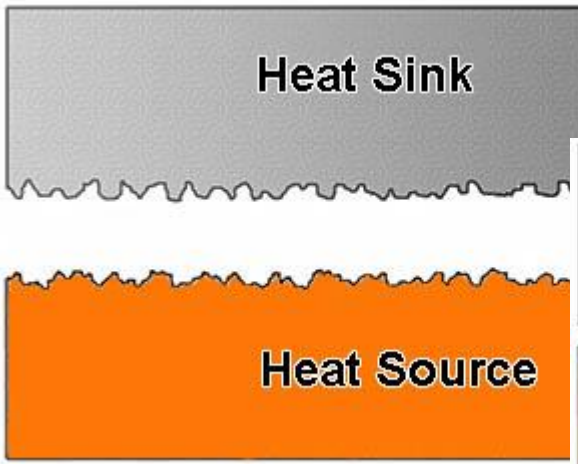
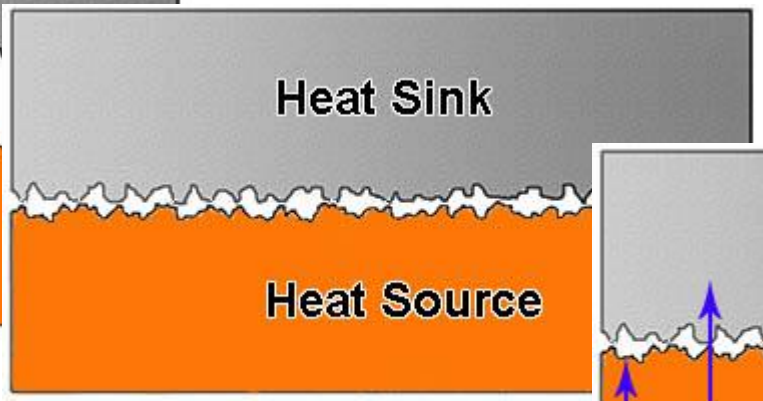


The Problem a TIM Solves

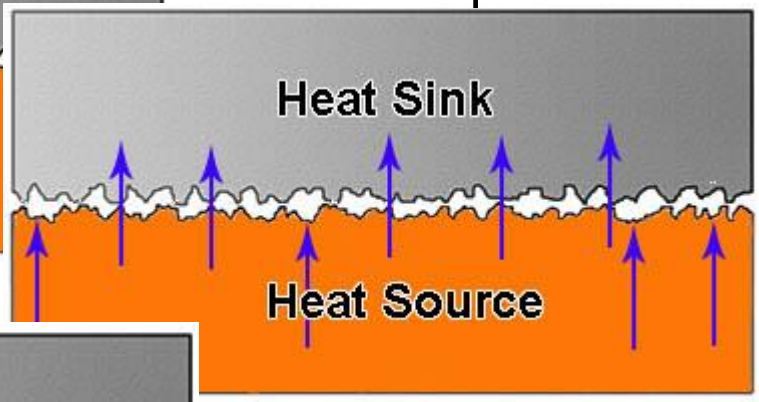
k = thermal conductivity (W/mK)



k of air = 0.02W/mK

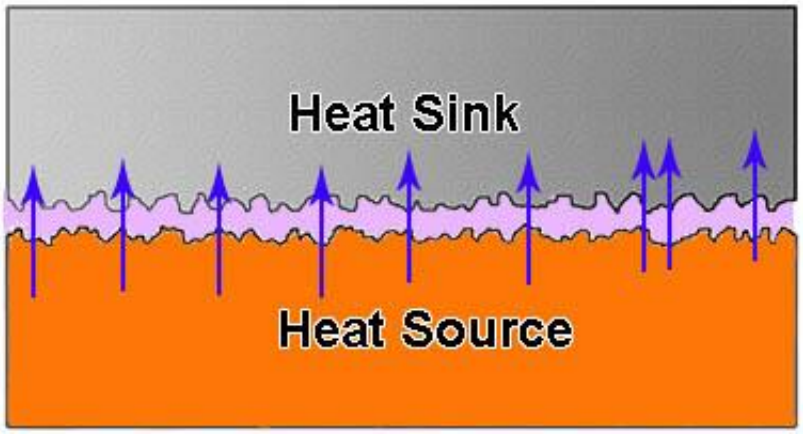


Heat passes through contact points



Contact area <10%

k of TIM = 0.5-10W/mK



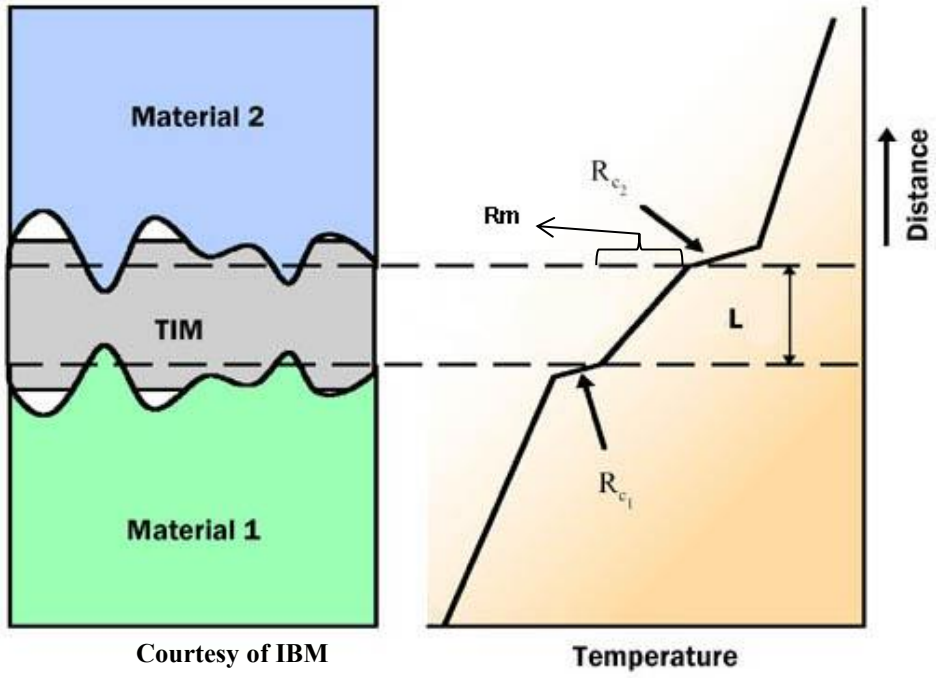
Minimizes resistance of heat flow into, through and out of an interface

The Problem a TIM Solves

Total Thermal Resistance(R_{th}) = Resistance $_{material}$(R_m) + Resistance $_{contact}$ ($R_{c1+}R_{c2}$)

k = Thermal Conductivity (W/mK) L = thickness $R_m = \frac{L}{k}$

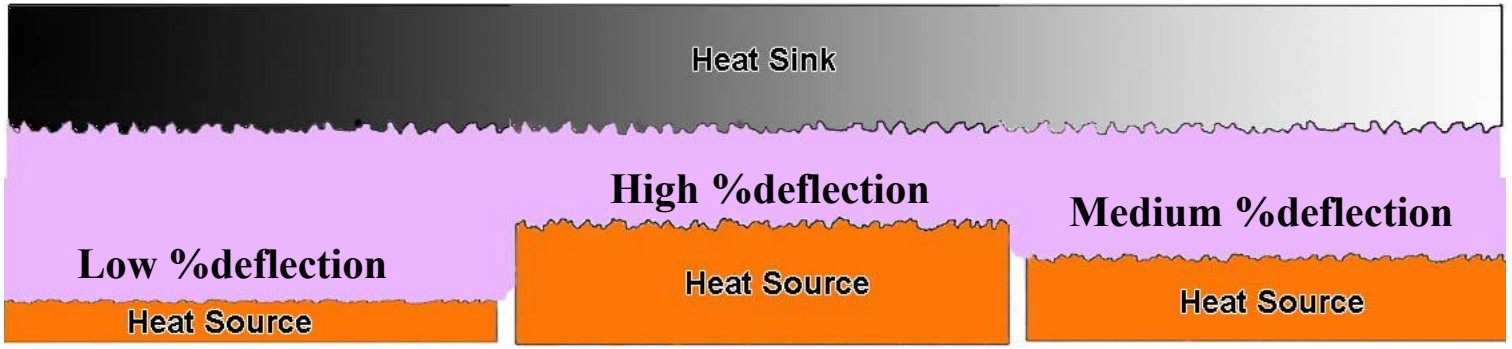
$$R_{th} = \frac{L}{k} + R_{c1+}R_{c2} \ (Kmm^2/W \text{ or } {}^oCin^2/W)$$



Courtesy of IBM

- Minimize total thermal resistance:
  - Increase k
  - Decrease L
  - Decrease R_c

Thermally Conductive Gap Filler



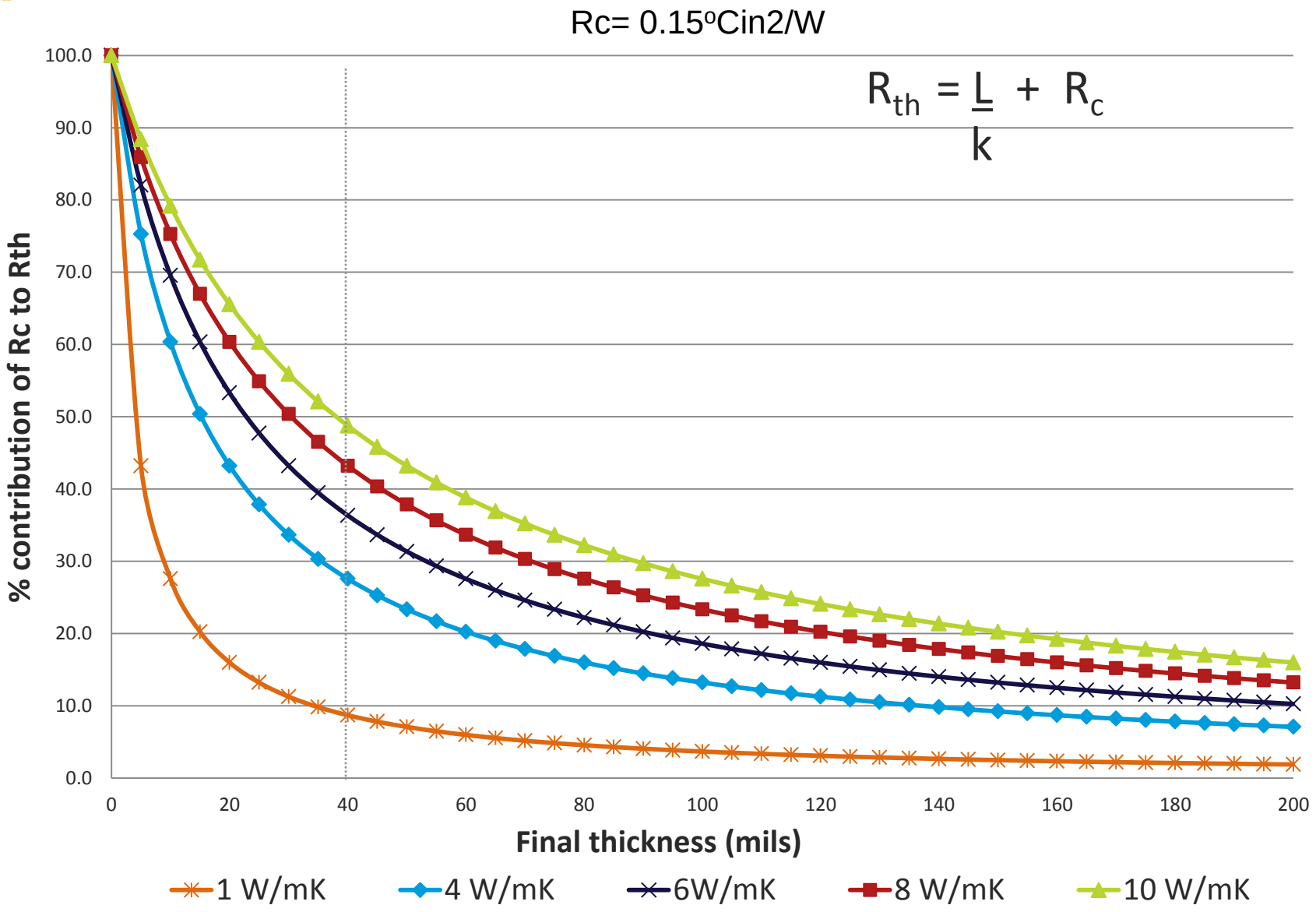
- Is a TIM that fills “a large gap” between heat generating and heat dissipating surfaces
  - Usually silicone based – wets surfaces easily
  - Filled with thermally conductive fillers- BN, ZnO, alumina
  - Gaps of 0.25-5mm (10-200 mils)
  - Thermal Conductivity of 0.5 to 10 W/mK
  - Deflection of 10 to 70% without excessive pressure
  - Delivered between release films on a roll, as sheets or in cartridges for automated dispensing
- Applications
  - Automotive electronic control units (ECUs)
  - Telecommunications
  - Microprocessors
  - LED lighting
  - Memory

Optimum Gap Filler Properties

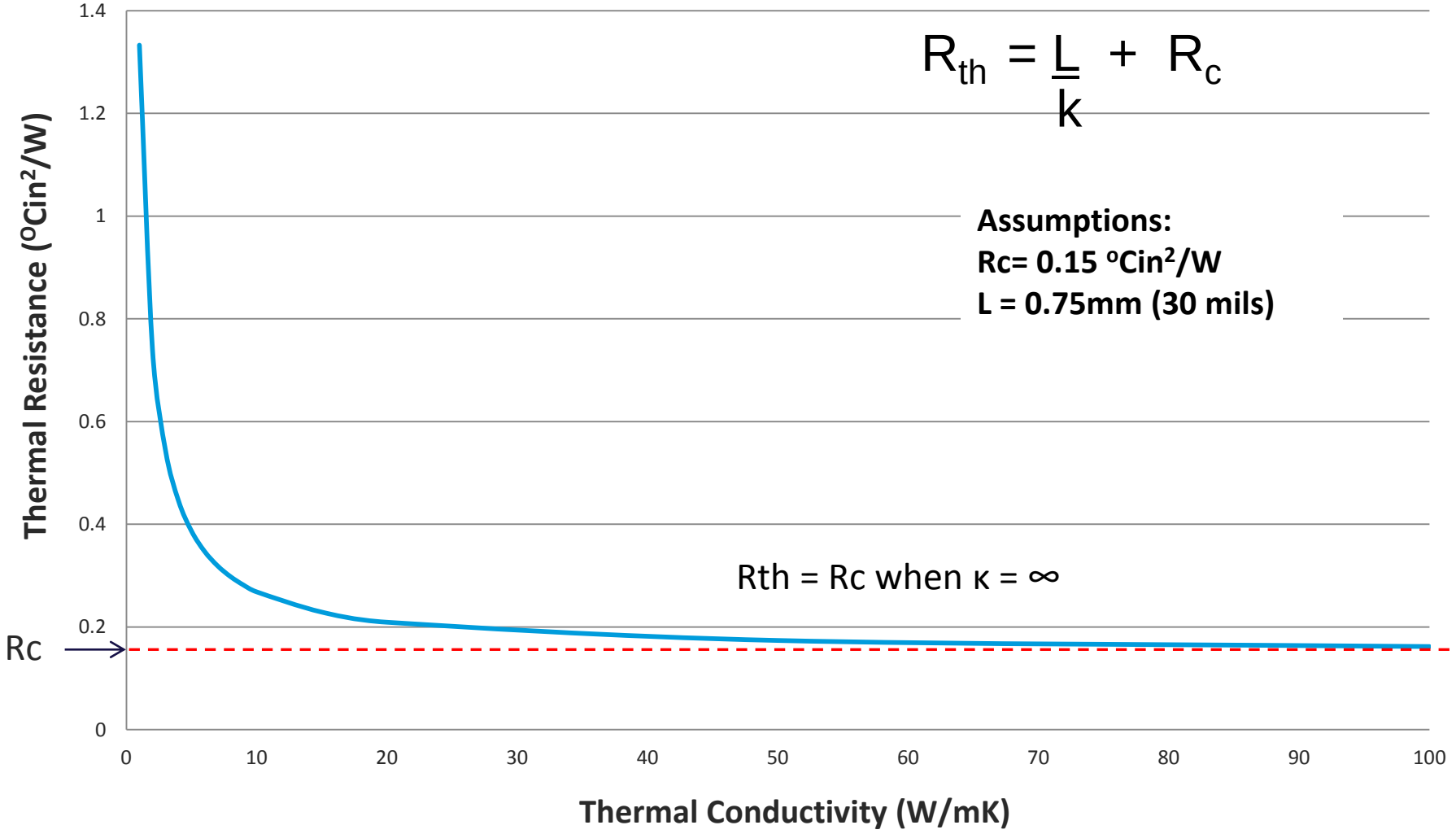
- General
  - Low total thermal resistance
    - High thermal conductivity
    - Low contact resistance (good surface wetting)
  - Easy to use
  - Low outgassing/Low bleeding
  - High volume resistivity
  - Easy to rework
  - Unique colors

- Sheets
  - Low modulus
    - Low stress during deflection
    - Low steady state stress
  - Finishing options: 1 sided tacky, PSA
- Dispensable
  - Multi-application friendly
  - Automated process
  - Highly conformable at low pressures
  - Cured in place option for improved reliability
  - Low abrasion

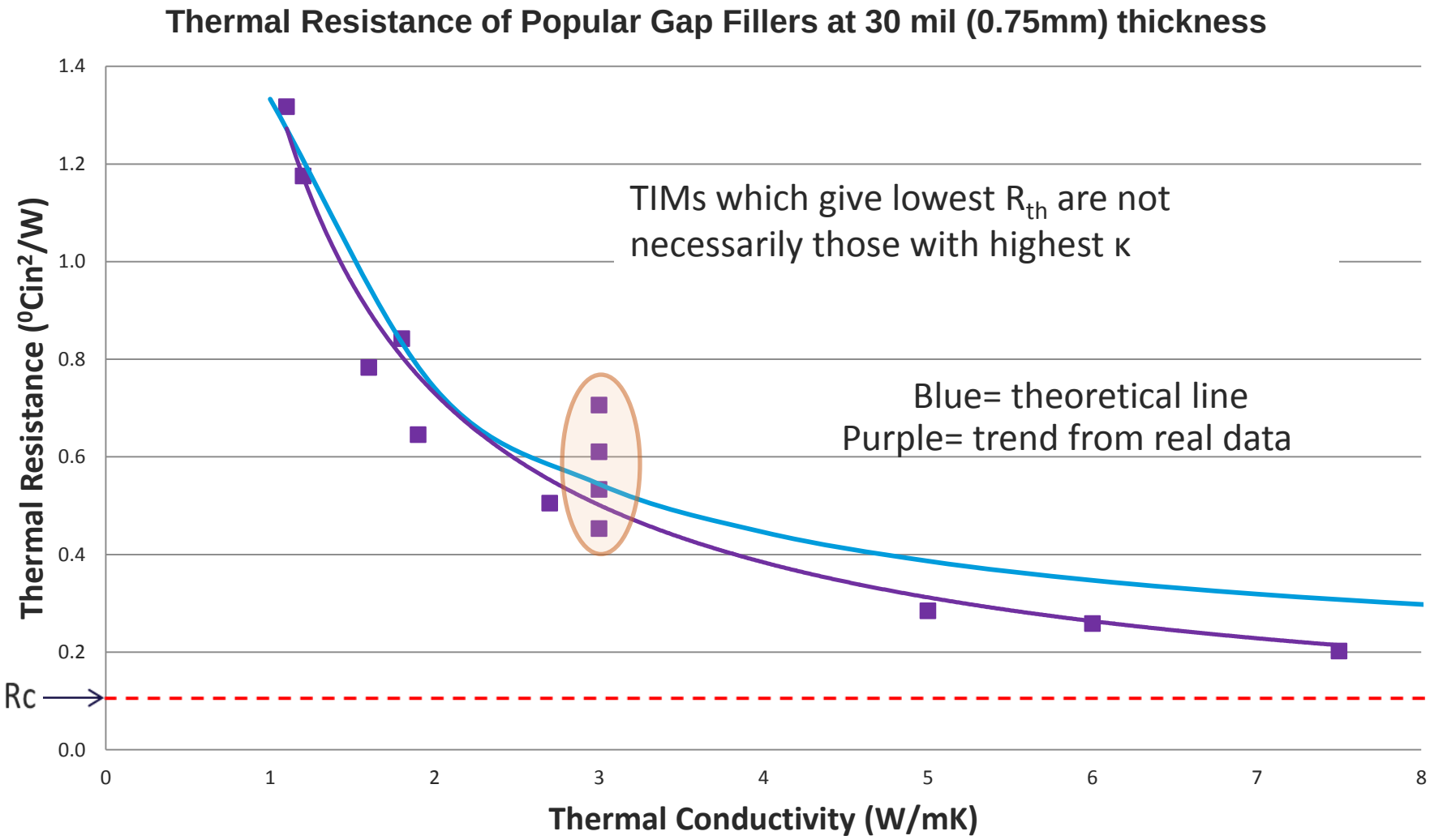
Contact Resistance vs. Thickness



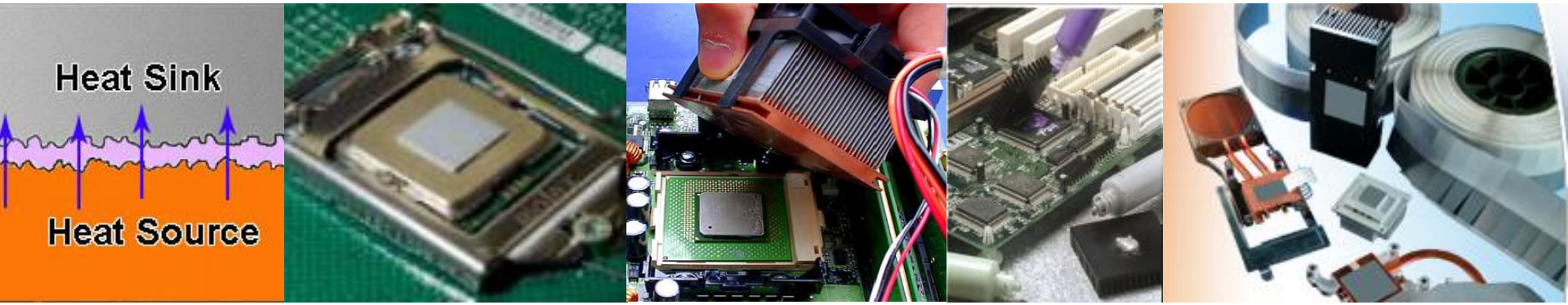
Thermal conductivity Impact on Total Thermal Resistance



Impact of Contact Resistance on Total Thermal Resistance



Thermally Conductive Grease and PCM



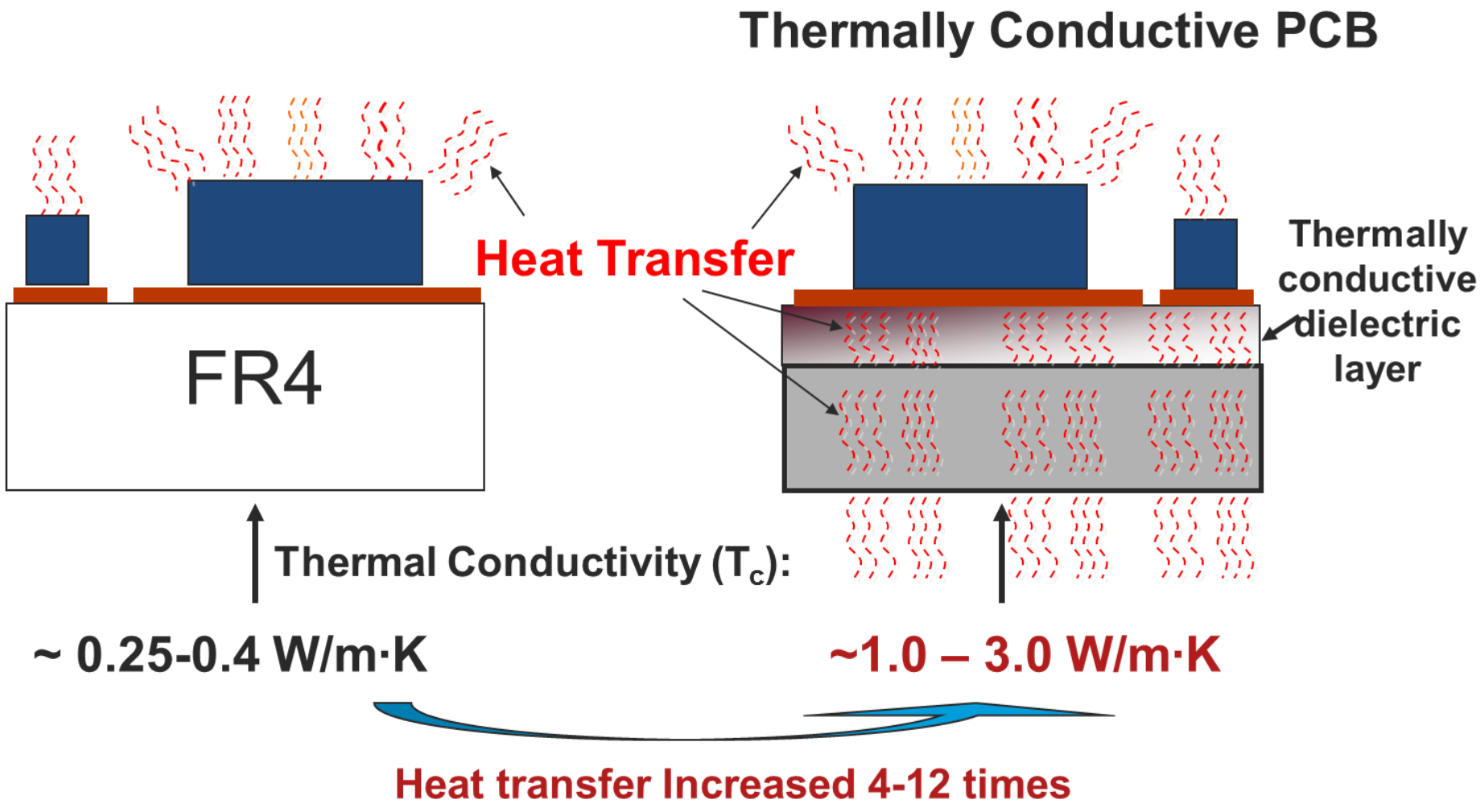
- A TIM with low contact resistance and a thin bond line, typically 50 microns or less, for use in applications having relatively flat surfaces constant applied pressure
  - May be silicone or non silicone based
  - Filled with thermally conductive fillers - BN, ZnO, alumina
  - Dispensable or screen printable
  - Shear thinning, non-slumping, and non-dripping
  - Thermal Conductivity of 0.5 to 7 W/mK
  - Delivered as tabbed parts on rolls, tabbed strips, in bulk cans, syringes or cartridges
  - Flows and wets surfaces at room temperature (greases)
  - Wets surfaces when heated to device operating temperatures (pcm)

Grease and PCM Optimal Properties, Applications

- Optimal Properties
  - Low total thermal resistance
    - High thermal conductivity
    - Low contact resistance (good surface wetting)
  - Low outgassing/Low bleeding
  - High volume resistivity
  - East to apply
    - Naturally tacky tabbed parts
    - Screen print and dispense
  - Easy to rework
  - Resistant to pump out
  - Long term reliability
  - Soften and flow at or below operating temperature of device (pcm)

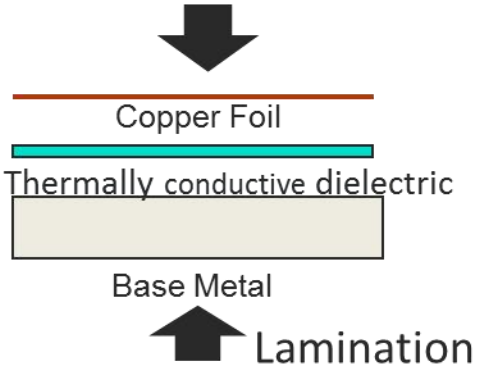
- Applications
  - Notebook and desktop computers: CPU, GPU, APU, memory
  - Miscellaneous electronic devices that generate heat
    - Arcade games, game consoles, power supplies, LEDs, braking systems, set top boxes and more…

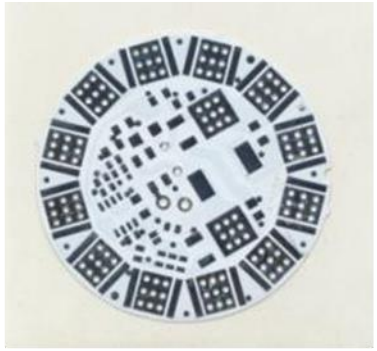
Thermally Conductive Printed Circuit Board Material (TcPCB)



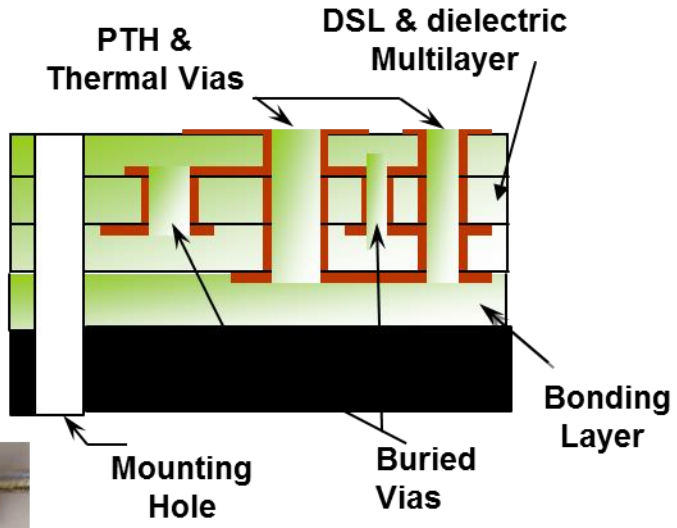
TcPCB Structure and Application

- Epoxy based composites with thermally conductive filler
- Typically 4 - 8 mil, thicker for multilayer applications
- Free-standing dielectric sheets, flexible design construction
- Uncured (vs B-staged), good flow during lamination
- High RTI rating

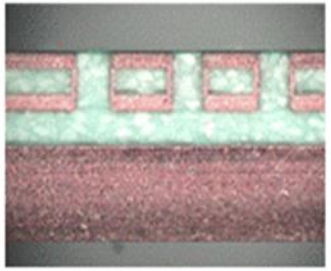




LED board



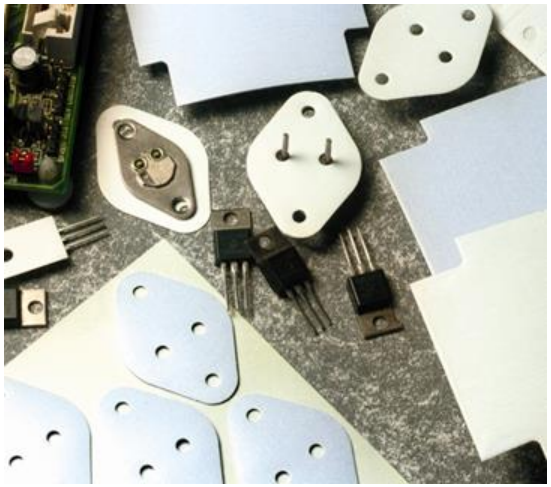
Multi-layer

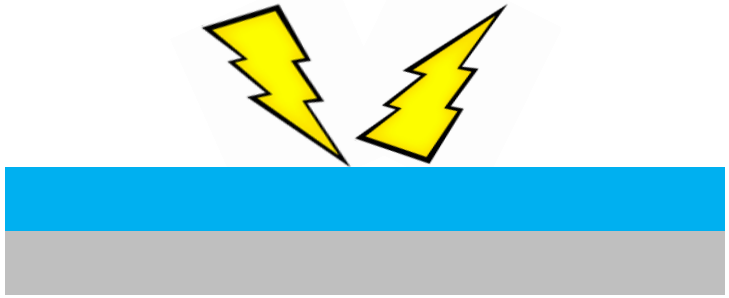


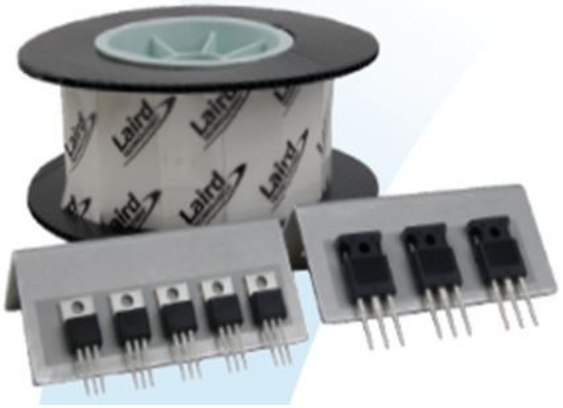
Two-layer cross-section

TcPCB based TE module

Thermally Conductive Electrical Insulator

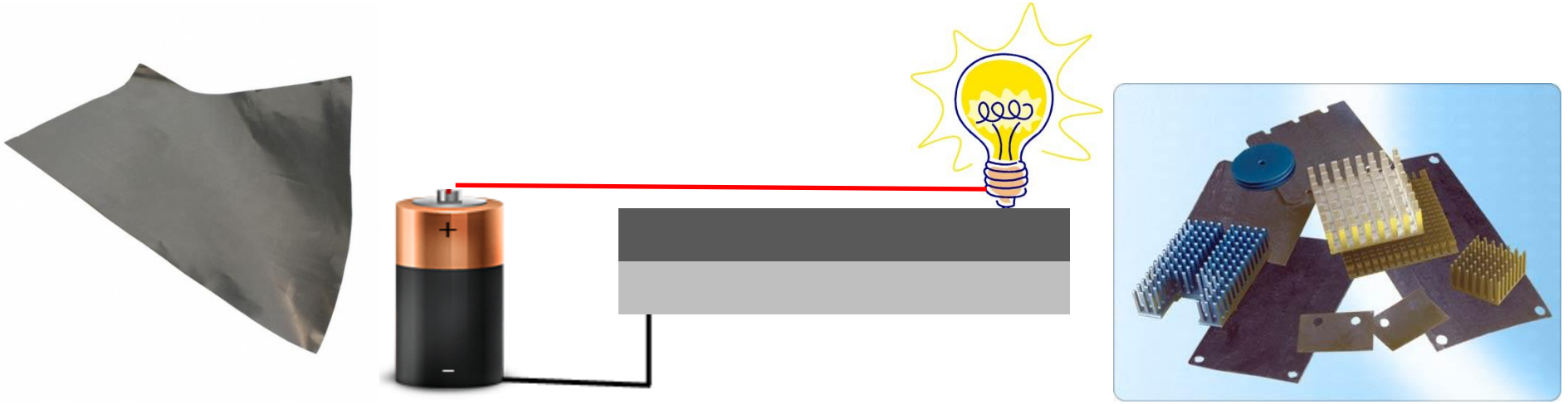






- Thermal transfer with high electrical isolation
  - Typically silicone based material, coated on insulating plastic films or fiberglass
  - Epoxy based adhesive materials
    - Require cure
- Applications
  - TO-220/240
  - Amplifier components
  - Anywhere both heat transfer and high electrical isolation are needed

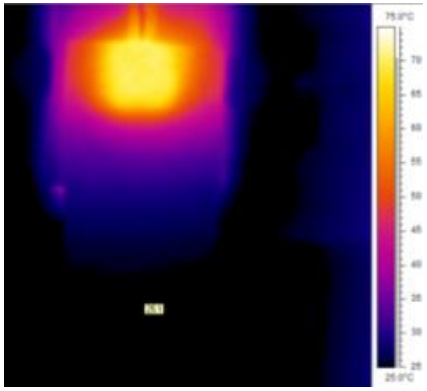
Electrically and Thermally Conductive



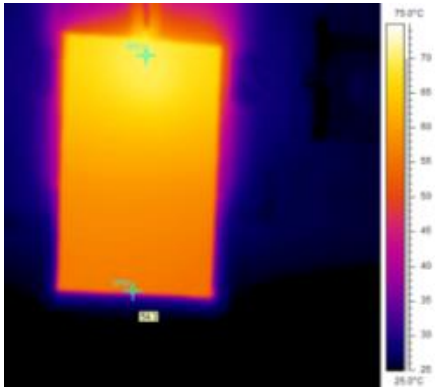
- Thermal transfer with high electrical conductivity
  - Flexible graphite sheets
  - Anisotropic thermal conductivity
  - Adhesive options
    - Electrically conductive
    - Patterned
- Applications
  - High end processors requiring a ground plane
  - Power conversion
  - Telecommunication switching hardware

Heat Spreading

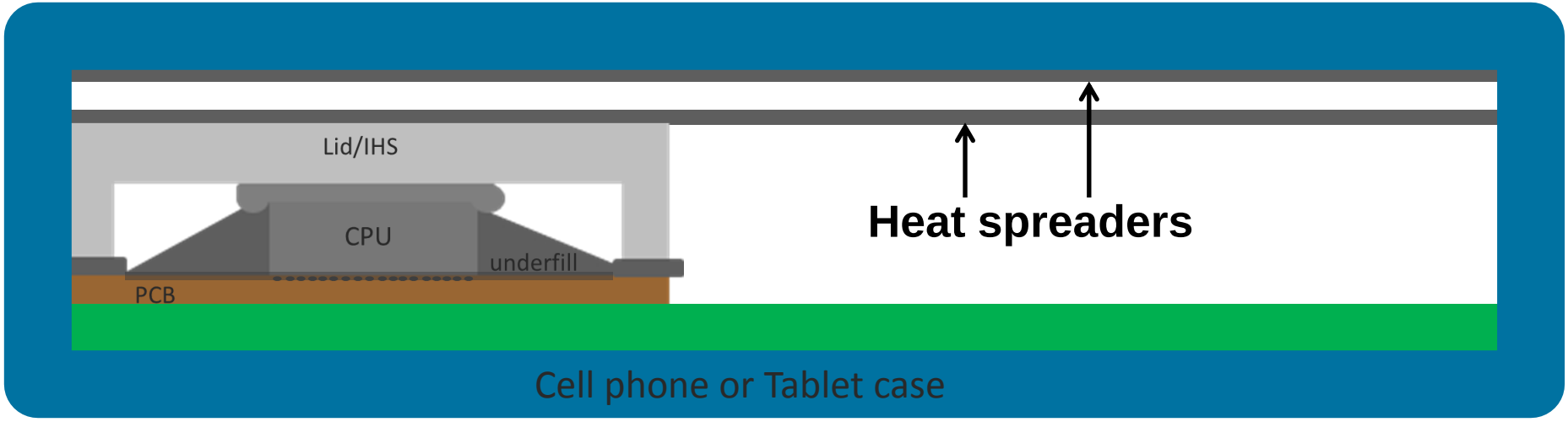
- Applications
  - Mobile computing
    - Cell phones
    - Tablets
    - Laptops/Ultrabooks
  - Displays
- Materials
  - Metal foils
  - Graphite sheets
  - Thermally conductive plastics



Poor heat spreader

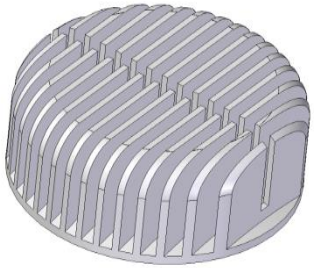


High performance heat spreader



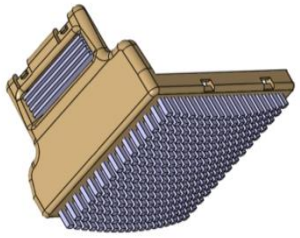
Thermally/Electrically Conductive Plastics

- Thermally Conductive & Electrically Isolating
  - High thermal conductivity (up to 10 W/m-K)
  - Mechanically strong
  - Moldable to small form factor, complex shapes
- Thermally Conductive & Electrically Conductive
  - High thermal conductivity (up to 20 W/m-K)
  - Mechanically strong
  - Moldable to small form factor, complex shapes
- Several Plastics Currently Available
- Applications
  - Mobile device cases
    - Laptop/Ultrabook
    - Cell phone
    - Tablet PC
  - Complex heat sinks
    - LED lighting
  - Light weight heat sinks
    - Automotive applications



Indoor Recessed LED Lighting Heat Sinks

Mobile Device Battery Cover



Heat Sink for Automotive Crash Avoidance Camera

Indoor LED Lighting Lamp Bases

Challenges

Courtesy marksanborn.com

Challenge: Performance

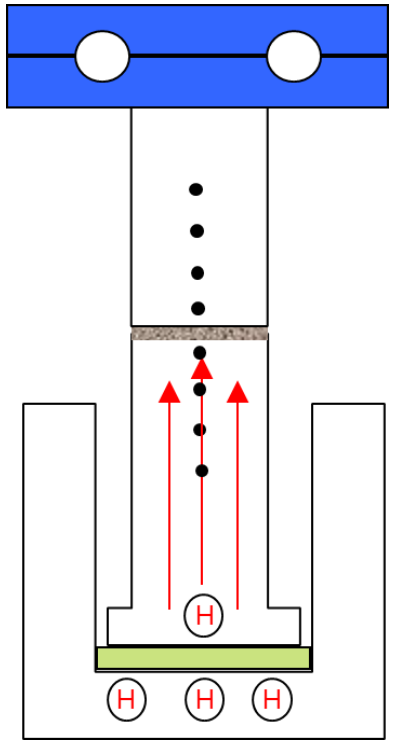
- Reduce total thermal resistance
  - Higher thermal conductivity
  - Low contact resistance (soft easy to flow)
- Non silicones – soft and stable
  - Formulate for reliability
- Higher performance formulations
  - May require process changes
- Easier to use, faster application
  - Easy to peel soft materials without stretching or tearing
  - Low abrasion, no sag, no drip for automated dispensables
- Longer shelf life
- Reduced outgassing
- Shorter design cycles while maintaining reliability and performance

Challenge: Supply Chain

- Raw material volumes are low for many suppliers
  - Limited leverage with large suppliers
  - Problems that do arise
    - Discontinued Products
    - Change of production locations
    - Revision of specifications
- Above 90 weight percent filler is not unusual
  - Requires sophisticated packing
  - Multiple fillers, polymers and additives in a composition
    - Fillers and matrix work together
    - Carefully designed for packing & deflection
    - Dual sourcing is a development challenge
- Suppliers can become competitors
  - Resin suppliers
  - Filler suppliers
- High performance TIM manufacturers must anticipate these issues and design products accordingly
  - Dual sourcing
  - Close contact with suppliers is critical but not easy

Challenge: Thermal Testing

- Thermal conductivity
  - ASTM D5470 for thick materials
    - Build your own tester
    - Time consuming
    - Cannot measure anisotropy
  - ISO Standard 22007-2 - Hot Disk – transient plane
    - Anisotropy requires specific heat
  - Laser flash
    - Expensive equipment
    - Complicated sample prep
- Thermal resistance
  - ASTM D5470
    - Build your own device
    - Difficult for thin high performance materials (grease and pcm)
    - Must combine with thermal test vehicle (TTV), and real application tests for accurate evaluation
- Customer custom testing
  - Build or buy new equipment
  - Develop a new method

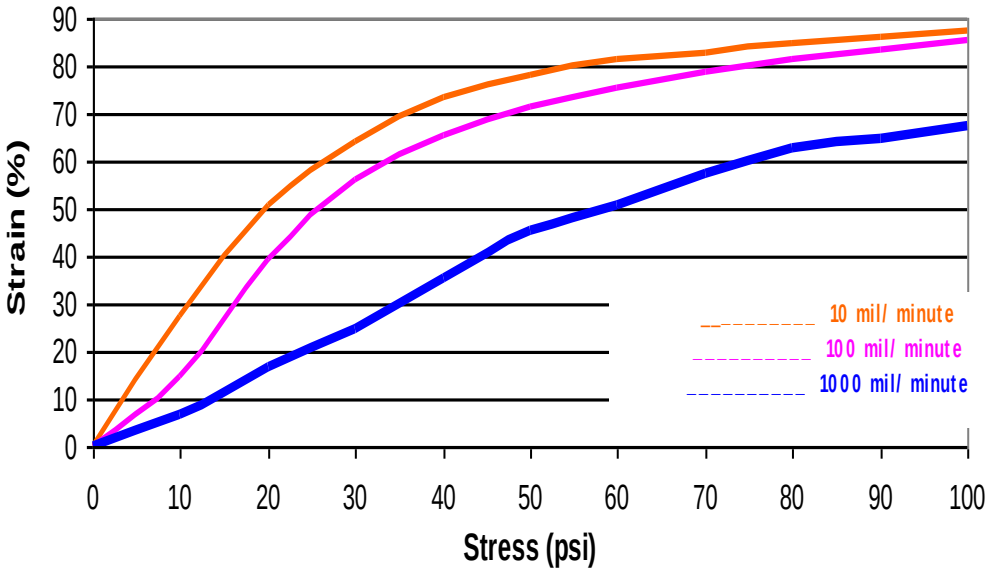


Courtesy of thermtest.com

ASTM D5470

Challenge: Mechanical Testing

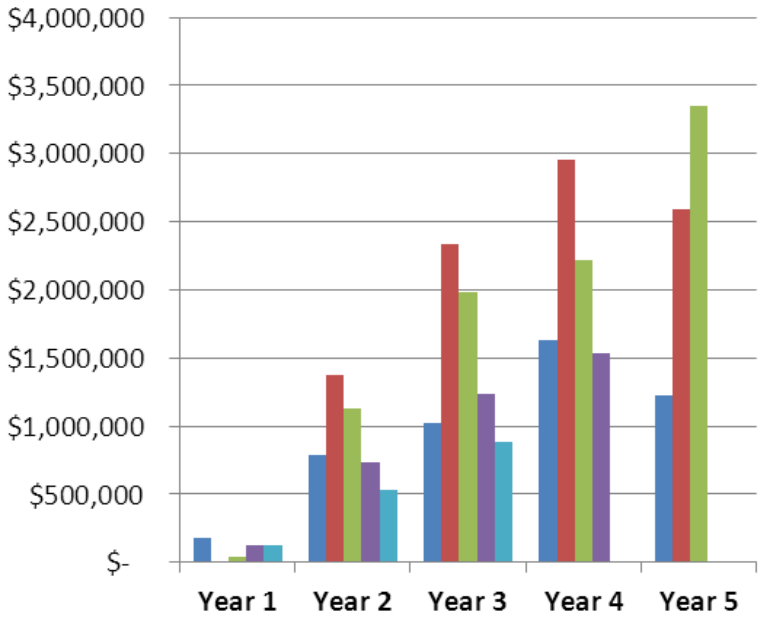
- Deflection (not compression)
  - Educate the customer
  - Material comparison only
  - Deflection rate – users do not assemble components in mm per minute but mm per second
  - Specimen size
  - Fixture size
  - Test surface properties
- Hardness (Durometer)
  - Hardness is not deflection
  - Over-simplification used by industry
  - Indentation test



Popular Gap Filler Strain vs Stress at three Different Strain Rates

Challenge: Capturing Value

- Time to acceptance
  - Development costs
  - Equipment cost
- Recognize the value that your products bring to the customer is more than thermal performance!
  - Reliability over many years
  - Consistency
  - Reliable supply chain
  - Products meet promised performance values
  - Speed of new development and order delivery
  - Pay pennies more for a good TIM to reduce dollars on other component



Challenge: Capturing Value

- Counterfeiters
  - Your company name and logo is on the package
    - The products look and feel like yours
    - You are getting performance complaints by customers
    - It may not be something you made!
  - Serious consequences for the “manufacturer of record”
    - Product recalls
    - Fails agency recognized test
      - Not flame retardant – Injuries!
    - Performance can be inferior
    - Environmental regulations violated
    - You can get sued!

- Suppliers must have protection systems
  - Intellectual Property (IP)
    - Develop an IP strategy
    - Patents vs. trade secrets
    - Enforce the IP your technologists develop
    - Affords protection in the market place
  - Good customer relationships
  - Unique Identifiers

Challenge: Growth

- Mature markets
  - Market research firms show growth at ~3-6%
  - How to grow faster?
    - Avoid price war
      - Develop and use IP for protection from race to the bottom
    - Adjacent markets
    - Transformational Products
- Adjacent Markets
  - Filled thermoplastics for new applications
    - Thermally conductivity
    - Electrical conductivity
  - Heat Spreading
  - Electromagnetic interference (EMI) materials
  - Multi-functional materials
    - EMI & Thermal
    - Absorbing & Thermal
  - Microelectronic packaging materials