Thermal Interface Materials

ISKRATEL **Tech Day**

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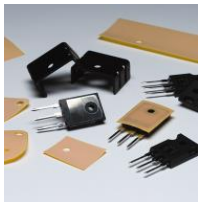
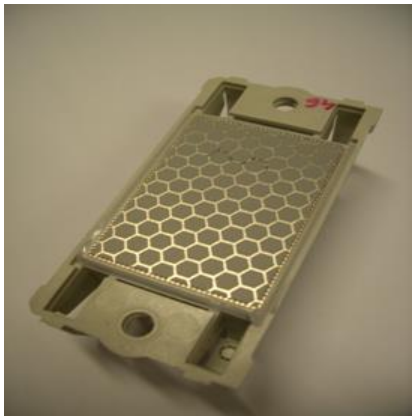
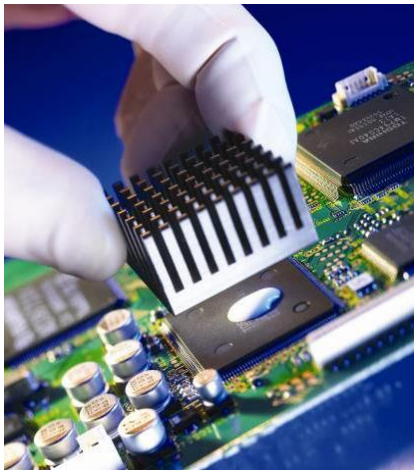
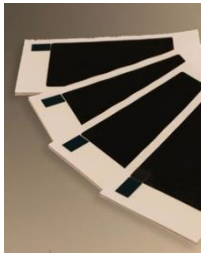
TCS – Europe & IMEA







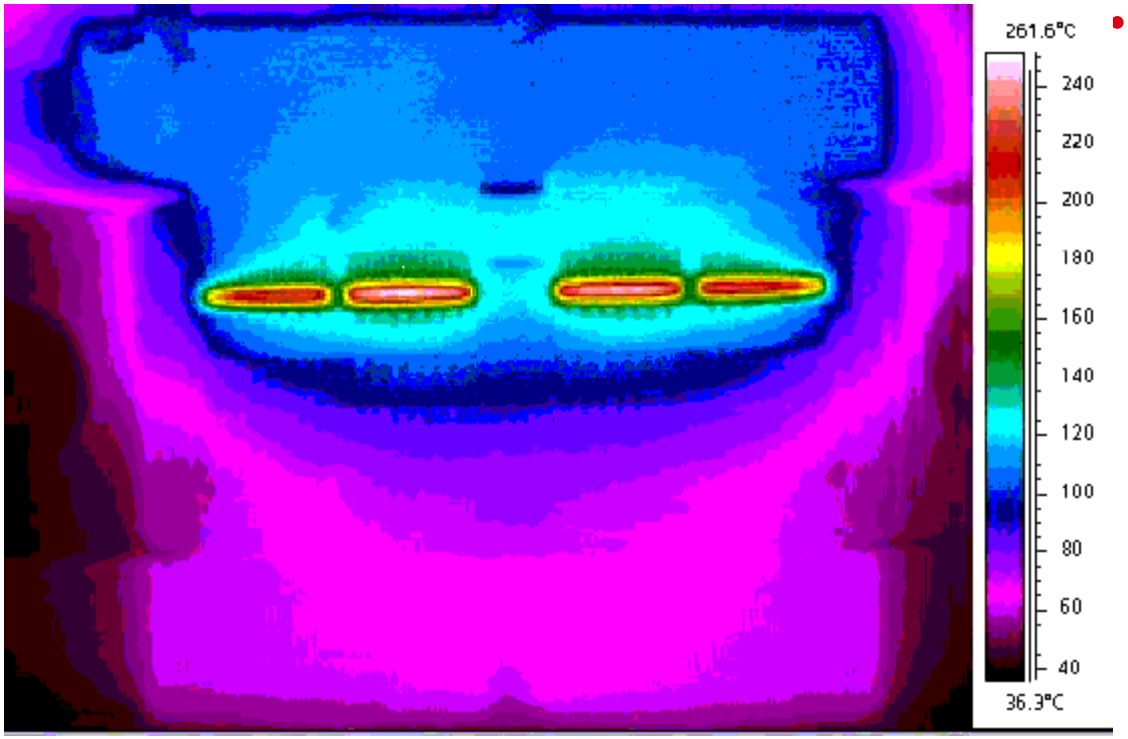


Contents

Thermal Management Overview
Introduction

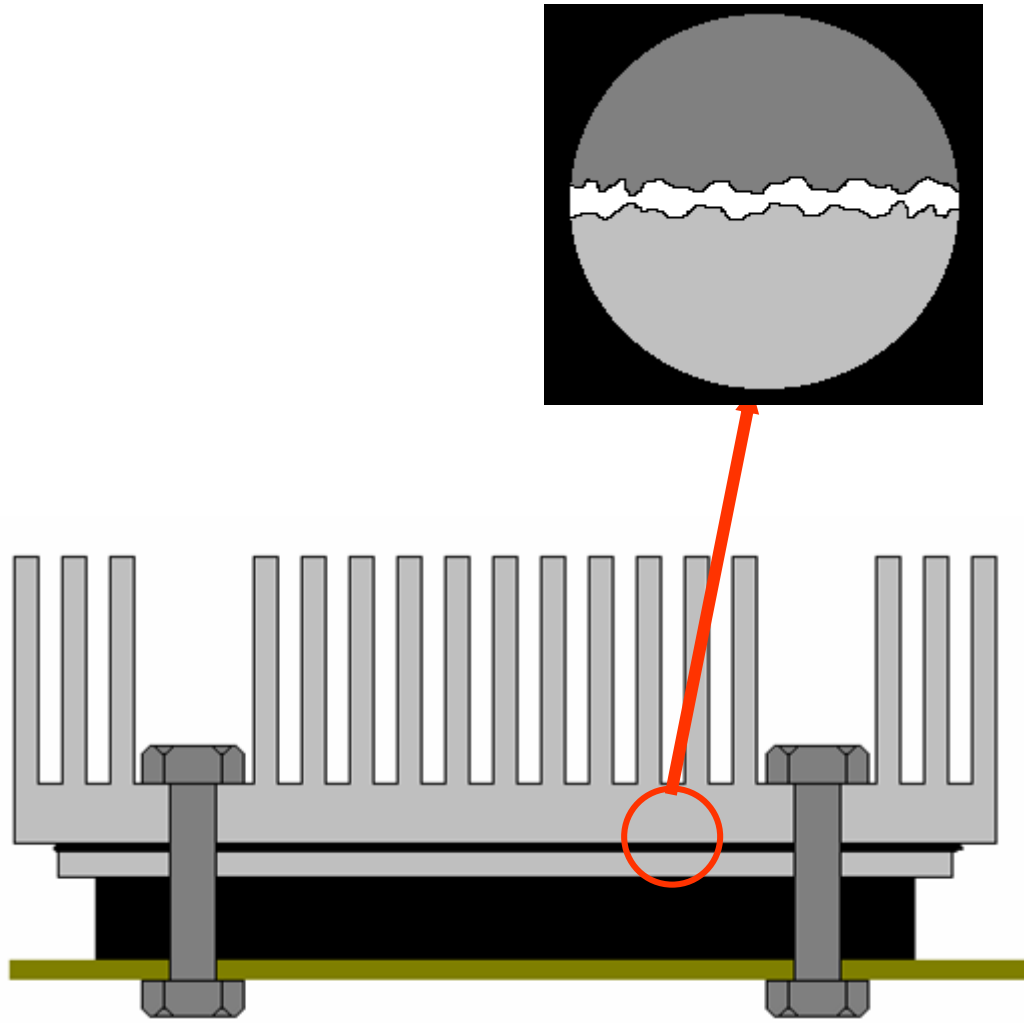
- Semiconductor and Electronic assemblies generate heat as the by-product of normal operation
- Management of heat is essential to optimizing performance and reliability; therefore it is considered during design
- Thermal interface materials optimize heat transfer between components

Thermal Management Overview
Removal of unwanted heat



- Heat generated from an electronic/electrical component affects:
  - System reliability
  - Product performance
  - Thermal Platform Costs
  - Limits design advances
    - size requirements
    - power density

Thermal Management Overview
TIM Functions



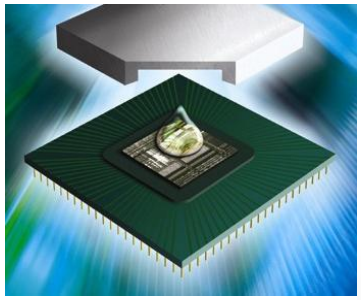
- Inefficient heat transfer
  - Air trapped in the thermal conduction path.
  - Thermal conductivity of air is poor

Replace Air with Thermal Interface Material

Thermal Management Overview

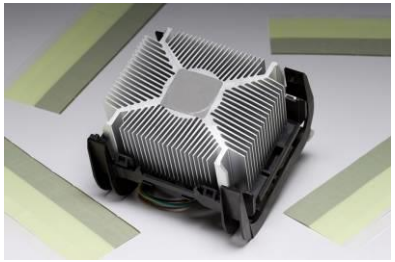
TIM Levels

- **TIM1**



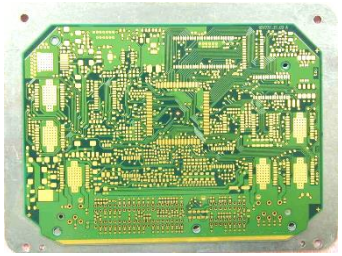
- **Power die-attach – conductive paste, solder**

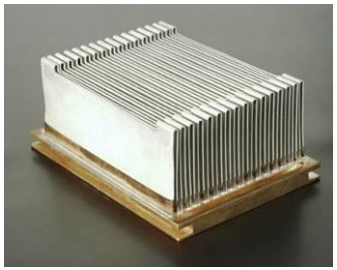
- **TIM2**



- **Package to heat-sink – all TIM's adhesive and non-adhesive**

- **TIM3**



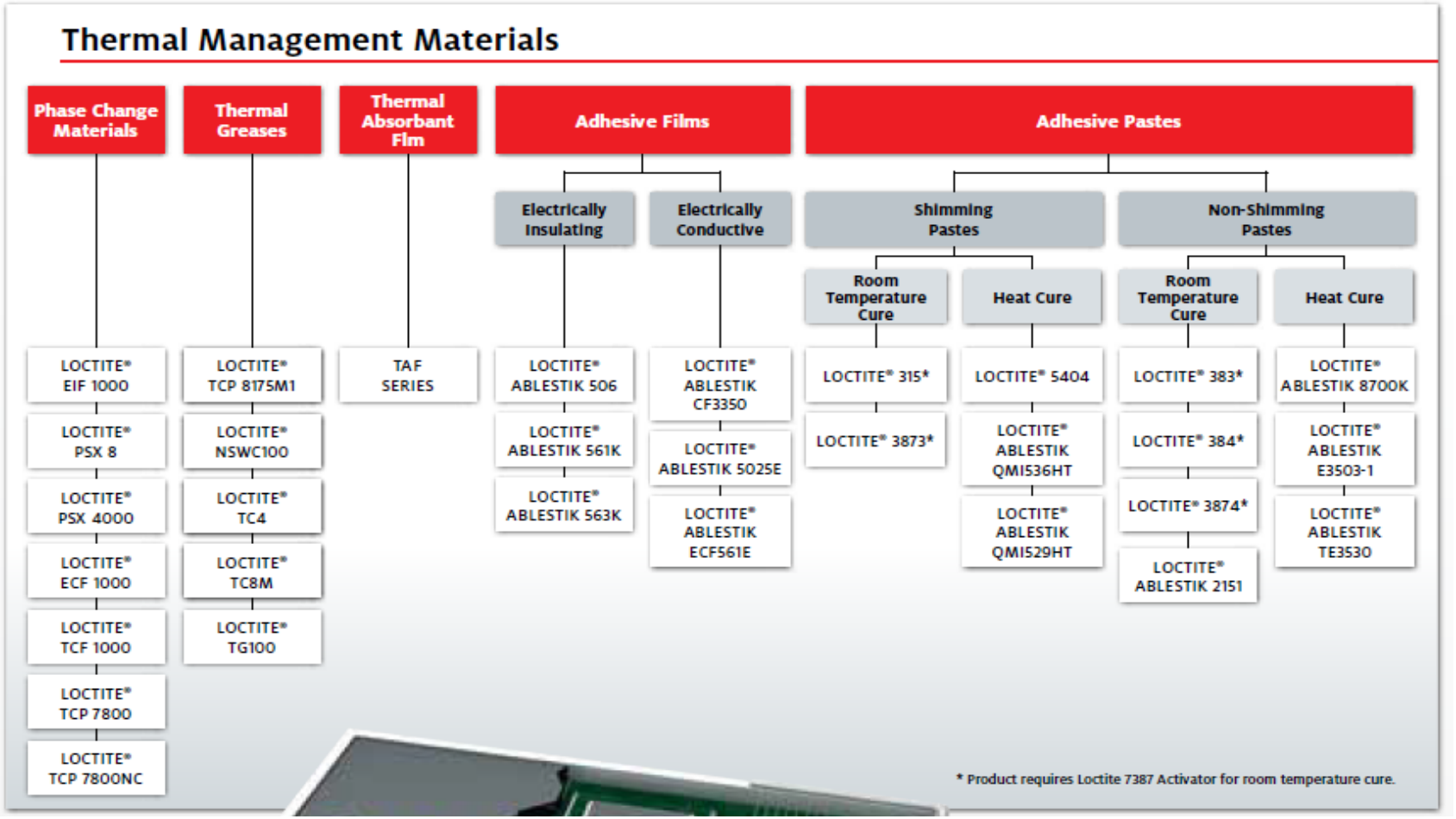


- **Board/module to heat-sink – LMP alloys, grease, adhesive paste and film**

Thermal Management Overview
TIM Selection

- Every application has multiple options
- Best solution driven by many factors
  - Thermal
  - Electrical
  - Mechanical
  - Process
  - Re-work
  - Reliability

Thermal Management Materials
Henkel Product Range



Henkel offers a wide variety of thermal management materials

Thermally Conductive Grease
Product Recommendation

Silicone Free	High Performance	High Temperature
LOCTITE® NSWC100	LOCTITE® TG100	LOCTITE® TC8M

“All Customers Use Thermal Grease”

- The “original” TIM and still widely used
- Requires spring loaded clamp to hold device in place
  - Higher pressure improve performance
- May “pump-out” of the interface in applications that cycle frequently between hot and cold

TIM2 – thermal grease
Standard products

	Description	TC W/mK	Temp. Stability	Volume Resistivity Ω cm	Dielectric Strength V/mil
TG100	Non insulating high thermal conductivity silicone-based	3.4	-40 / +150°C	NA	NA
NWSC100	Silicone-free water cleanable	1.4	-40 / +150°C	$1.9x10^{15}$	250
TC8-M	Electrically insulating silicone-based hi temp stability	2.3	-40 / +200°C	$1x10^{13}$	500
TCP8175-M1	Electrically insulating silicone-based hi temp stability w/175µ spacers	2.3	-40 / +200°C	$1x10^{13}$	500

TIM2 Applications – Henkel Products
Automotive

Thermal Grease | Phase Change | Adhesive Paste | Adhesive Film

Thermally conductive and electrically insulating compound with 175µ spacers beads

Product benefits
- Lower device temperature
- High electrical insulation
- High thermal conductivity, low thermal resistance
- Stable after 2000 TC @-40+125°
- 175µ spacers for uniform bondline thickness

Used in
- Gearbox, Control Units

Product
- **TCP 8175M1**

Phase change materials

- Phase change materials are low temperature thermoplastics that combine the wetting properties of a grease with the convenience of a solid at room temperature
- PCTIM melts to high viscosity liquid at specified temperature
- Requires spring loaded clamp to hold device in place
  - higher pressure improves performance
- Does not “pump-out” of the interface during thermal cycling
- Henkel PCTIMs are available as application specific preforms or standard sheets and as pre-applied systems

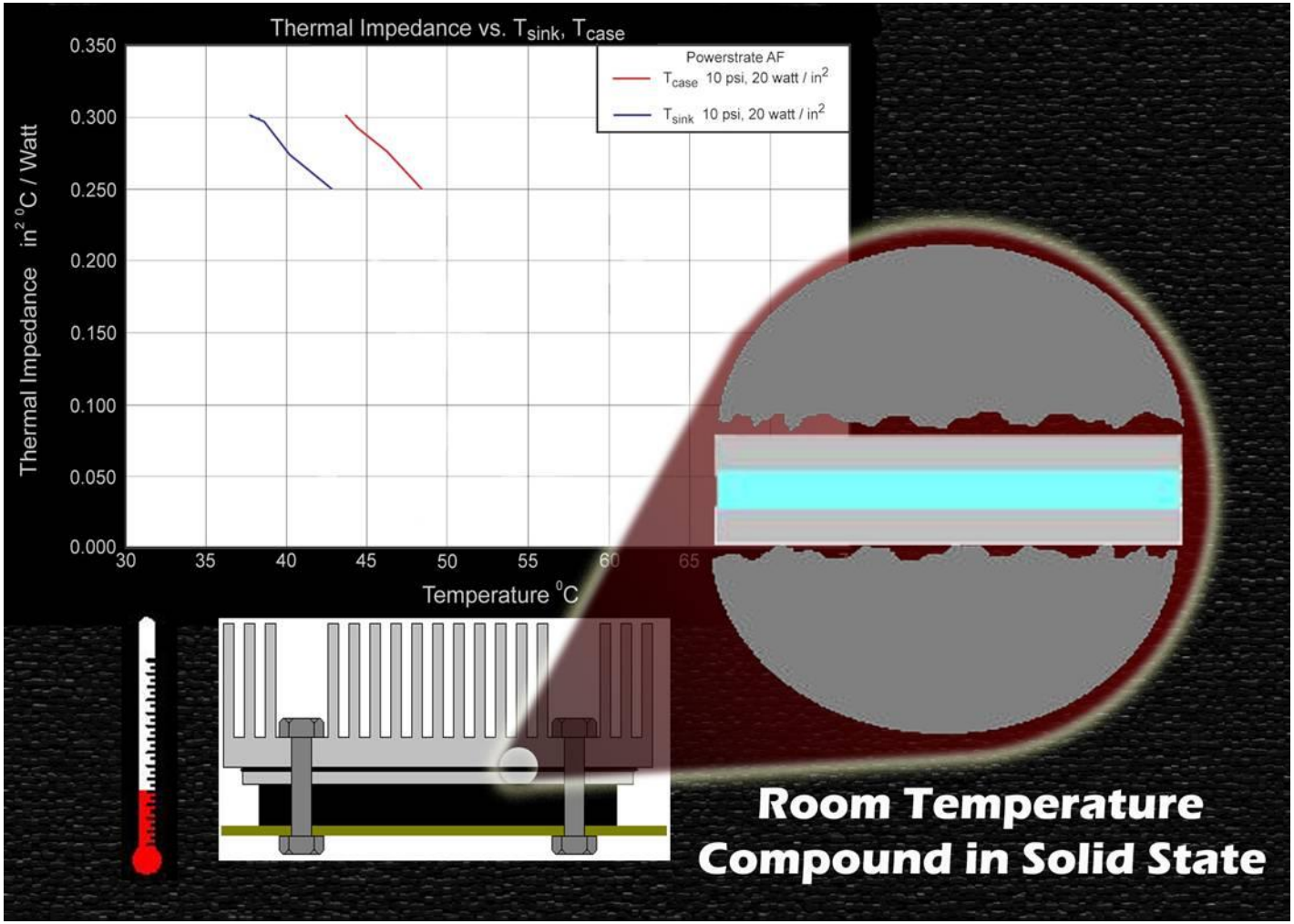
Phase change materials

Properties of Loctite phase-change TIMs:

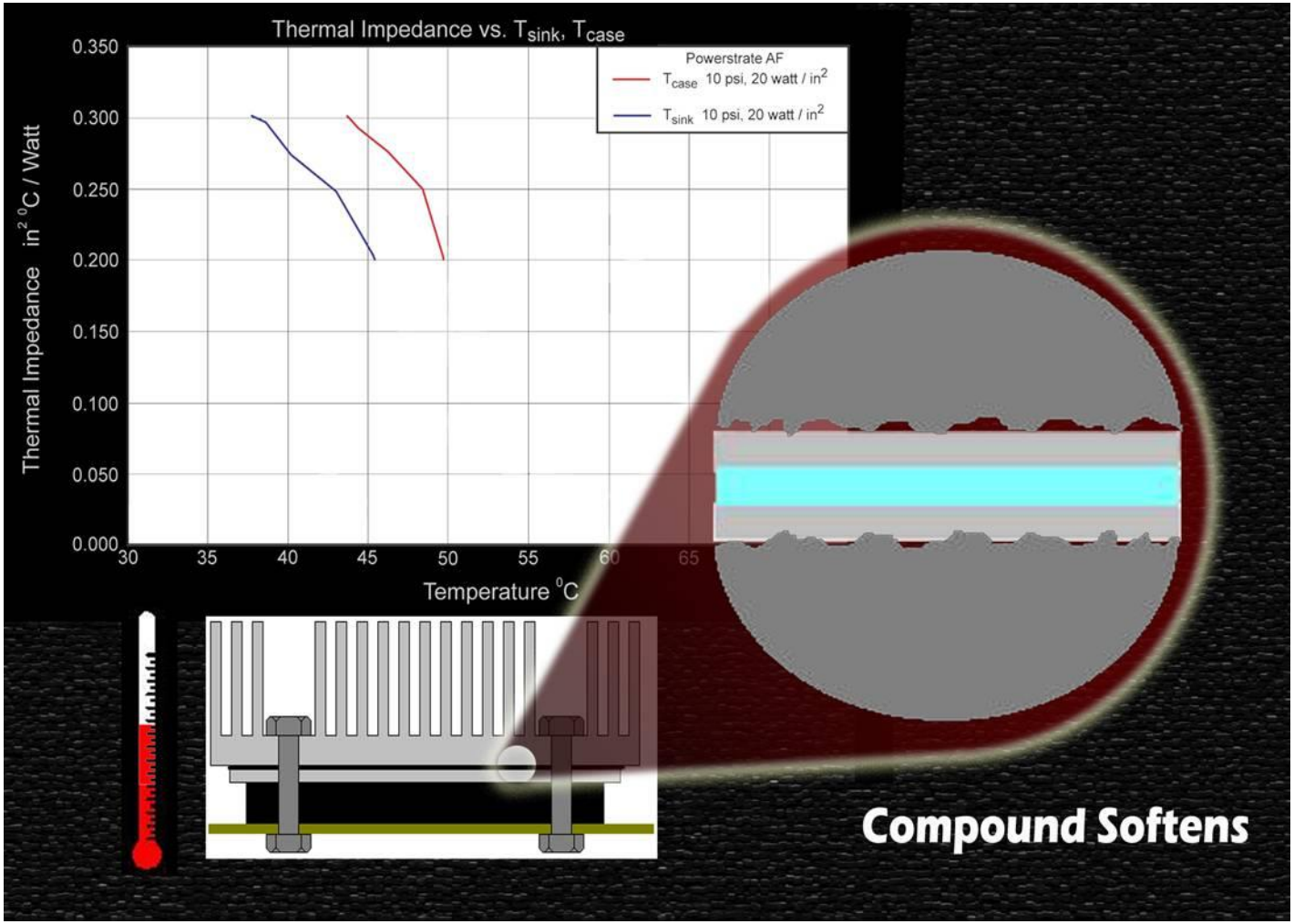
- **100% wetting** at the interface*
- **No interfacial thermal resistance***
  - Phase-change compound to the mating surface
  - Phase-change compound to the aluminum substrate
- Change phase at 45-60°C from solid to liquid
- Compound **expands** in volume*
  - Expansion actively forces out trapped air pockets*
  - Expansion eliminates interstitial voids that penalize performance.

** Properties not found in all thermal greases*

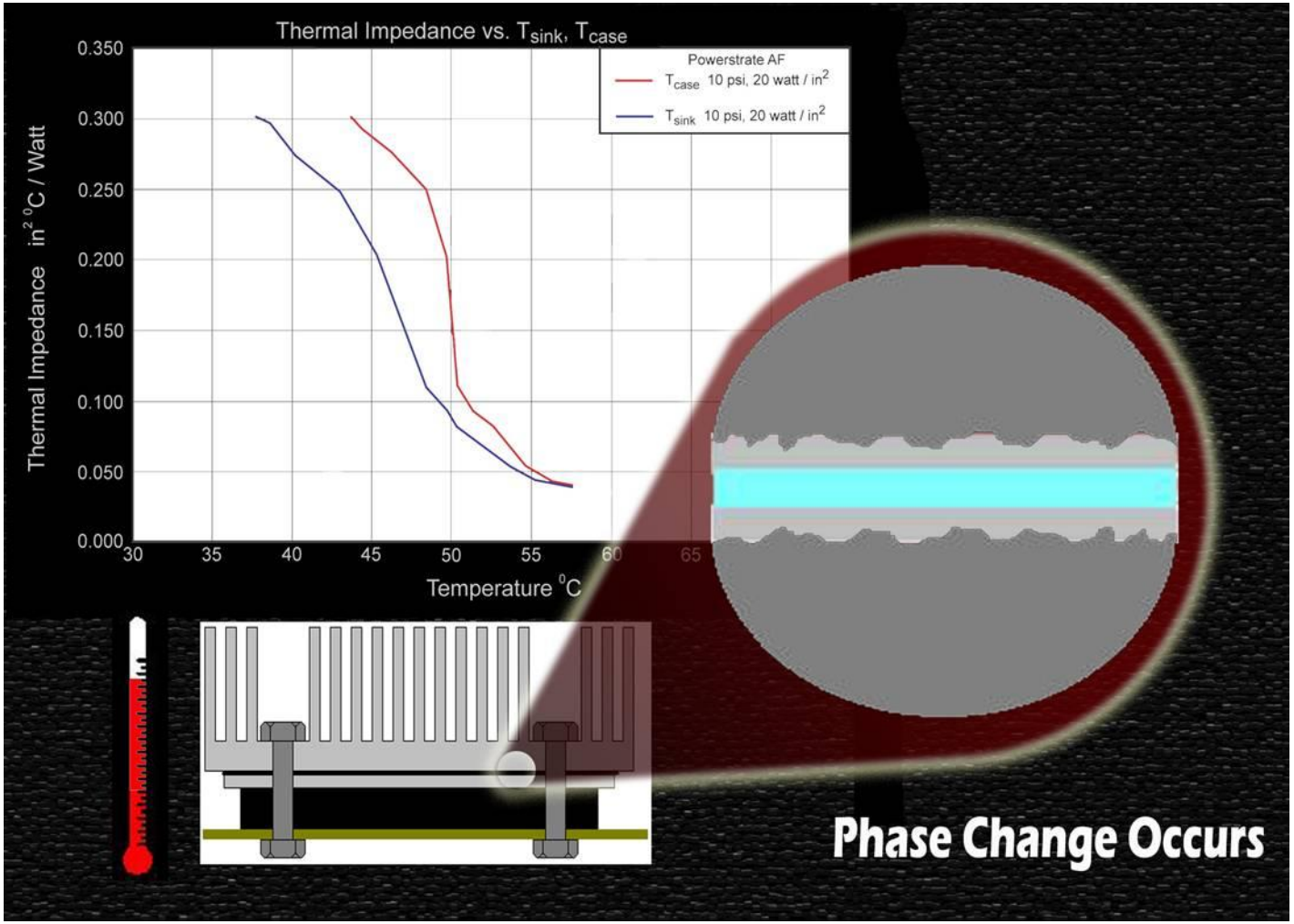
Phase change technology 1



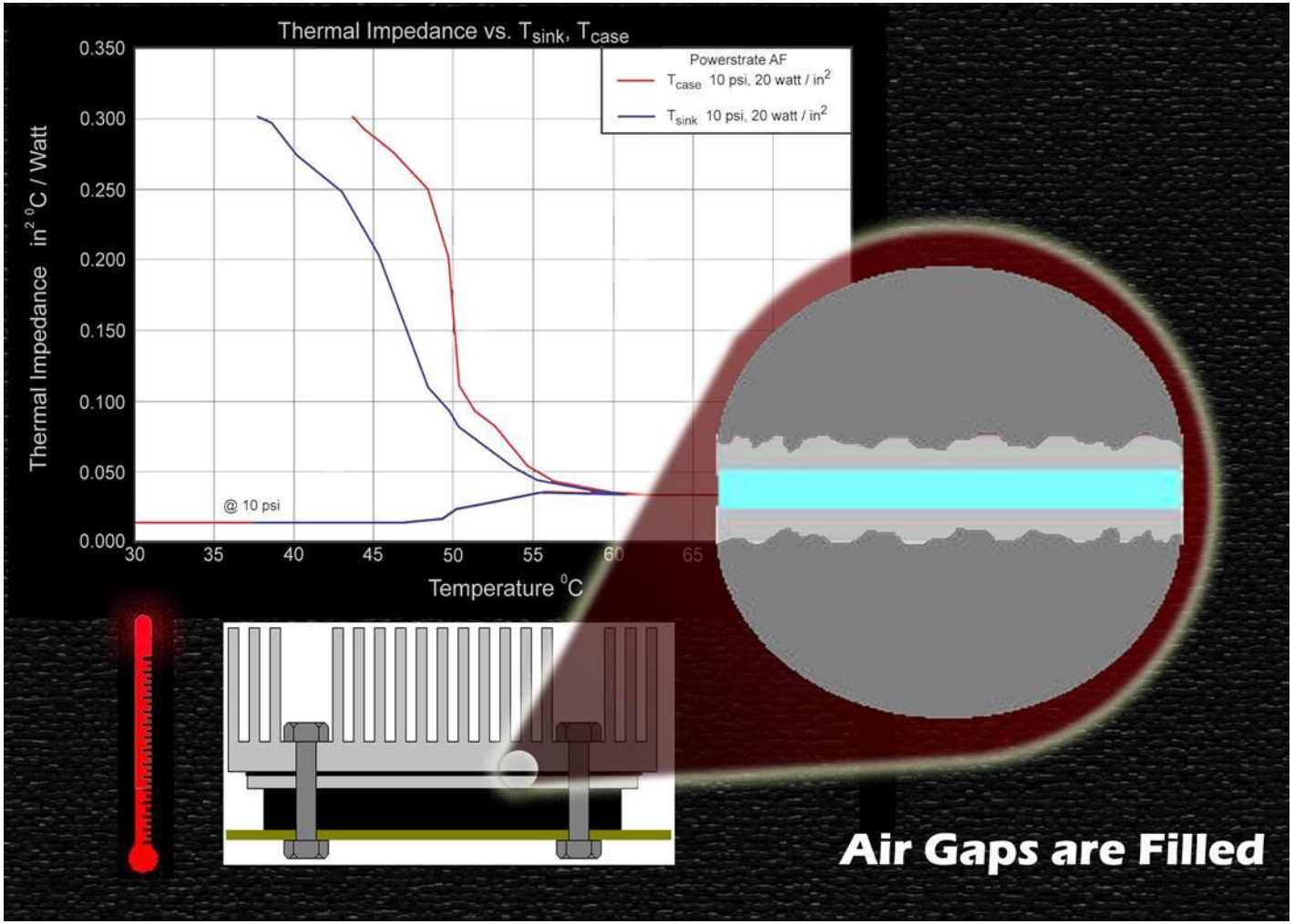
Phase change technology 2



Phase change technology 3

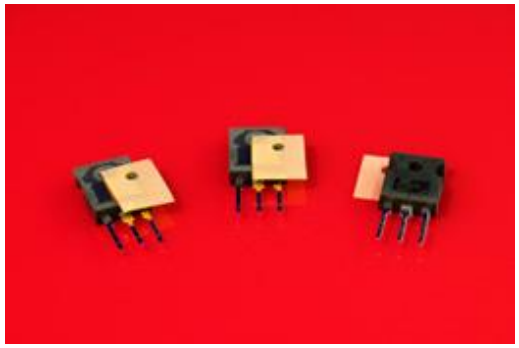


Phase change technology 4



Thermally Conductive Phase Change
Product Recommendation

High Performance & Silicone Free	High Temperature NEW	Electrical insulation	Foil-based Pads
LOCTITE® PSX -D = dispense -P = printable	LOCTITE® 7000 Series	LOCTITE® EIF1000 (Isostrate)	LOCTITE® TCF1000 (Powerstrate)



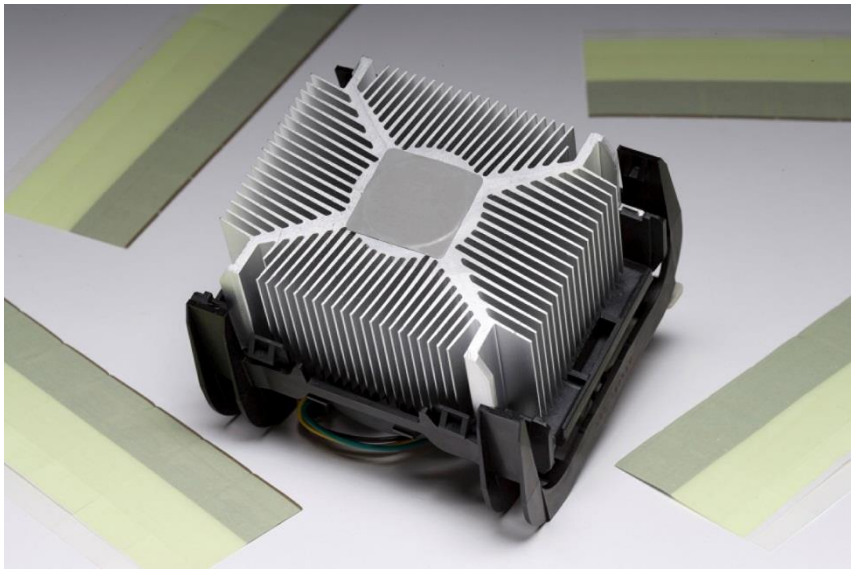
"Henkel is among best products in this segment"

TIM2 – phase change film
Standard products

	Description	TC W/mK	Thickness	Th.imp. °C-cm²/W	Phase Change T
EIF1000 (Isostrate)	Electrically insulating w/kapton MT layer	0.45	50, 63, 75, 100, 150µ	0.78	60
Thermstrate	Non insulating w/aluminium layer	1	75, 100µ	0.143	60
TCF1000 Powerstrate Xtreme	Non insulating unsupported high thermal conductivity	3.4	200, 400µ	0.022	45
ECF1000 Silverstrate	Electrically conductive compound w/al layer	1.5	80, 100µ	0.022	51

TCF1000 – “Formerly Powerstrate”

Highest Thermal Performance – non-insulating

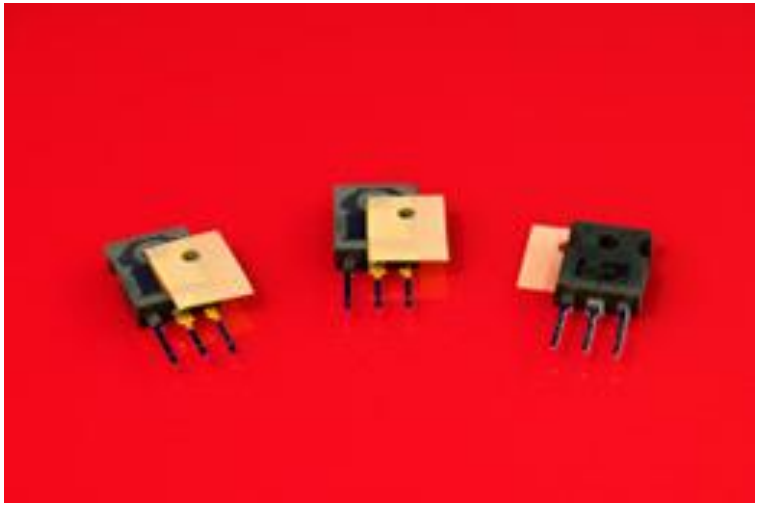


- **Lowest thermal resistance**
- **Thermal conductivity is 3.4 W/mK**
- **No substrate = minimum bondline thickness**
- **45°C phase change temperature**
- **Silicone free**
- **Available in 8 or 16mils thickness**

EIF1000 – “Formerly Isostrate”
Thermal Performance with Electrical Insulation

Product: LOCTITE® EIF
Description: Phase change material on ***Kapton*** MT for electrical insulation.
Phase change temp.: 60°C
Thermal Conductivity: 0.45 W/mK
Typical applications: Heat dissipation and electrical isolation for high voltage devices
Key Benefits:

- High cut-through resistance
- ***High dielectric strength***



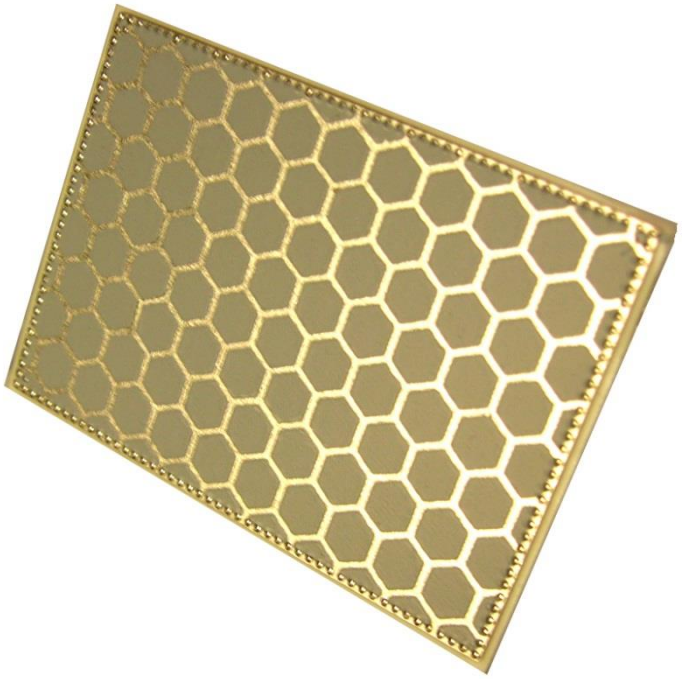
TIM2 – phase change paste
Standard & new products

	Description	TC W/mK	Drying Time 100µ	Th.imp. °C-cm²/W	Phase Change T	Application Method
PSX-D	Non insulating fast dry compound	3.4	5'@60° 3'@125°	0.022	45°C	Dispensing
PSX-Pm	Non insulating medium dry compound	3.4	30'@60° 5'@125°	0.022	45°C	Printing
PSX-Pe	Non insulating extended dry compound	3.4	4h@60° 10'@125°	0.022	45°C	Printing
TCP7000	High temp. stable non insulating medium dry compound	3.0	30'@60° 5'@125°		45°C	Printing
TCP7800-NC	High temp. stable electrically insulating medium dry compound	3.0	30'@60° 5'@125°		45°C	Printing

Non-insulating– PSX-D and P

- Dispensable and printable phase change thermal interface material
- Dries to a solid phase change coating at room temperature and can be accelerated with heat
- Available in fast, medium, extended dry formulation
- Phase change temperature at 45°C
- High Th. Conductivity (3.4W/m°K)
- Low Th. Resistance (small particle size can yield thin bondline)
- Silicone free
- Easy rework
- Excellent long term reliability (no pump-out)

PSX-D and PSX-P



printable phase change in honeycomb pattern

- **Offers flexibility with thickness**
- **Offers flexibility with application**
- **Eliminates part number complexity**
- **Eliminates cost associated with filming, liners, die-cutting, etc.**

Dry Times

Product	Thickness	Dry Time at 22°C	Dry Time at 60°C	Dry Time at 125°C
PSX-D Fast Dry Formulation	2 mil	30 minutes	3½ minutes	3 minutes
	6 mil	2½ hours	8 minutes	3 minutes
	10 mil	5 hours	21 minutes	4 minutes
PSX-Pm Medium Dry Formulation	2 mil	30 hours	22 minutes	3 minutes
	6 mil	50 hours	50 minutes	4½ minutes
	10 mil	65 hours	65 minutes	8 minutes
PSX-Pe Extended Dry Formulation	2 mil	Not Recommended > 500 hours	4 hours	7 minutes
	6 mil		11½ hours	12 minutes
	10 mil		18½ hours	18 minutes

Dispensable/printable phase change

Why a fast, medium and extended dry? Why not just one version?

- Some customers don’t want to dry the material in an oven but want it to dry at room temperature. They should consider the fast or medium dry formulations.
- Other customers don’t want it to dry too fast because that would cause machine downtime (drying on the printer). These customers should consider medium and extended dry formulations.
- So depending on the customers process, application and desired work life, one version may be more suitable than the other.

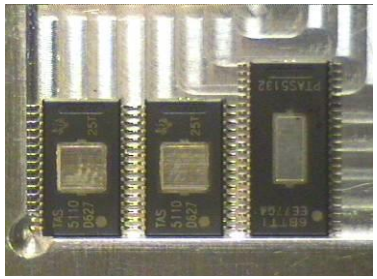
Once dried, all 3 versions are the same formulation

LOCTITE® 7000 Series Phase Change
High Temperature (150C) for power electronics.

- LOCTITE® 7000 and 7800NC (NC = Non-conductive version)

	LOCTITE® 7000	LOCTITE® 7800NC
initial thermal performance	best	better
reliability	better	best
stencil pattern	yes	yes
Phase Change Temp	45C	45C

Application examples



Power IC

(as a pre-applied solution)

Heatsinks

(as a pre-applied solution)

HB LED Applications

TIM2 Applications – Henkel Products
Industrial – Emerging – Automotive

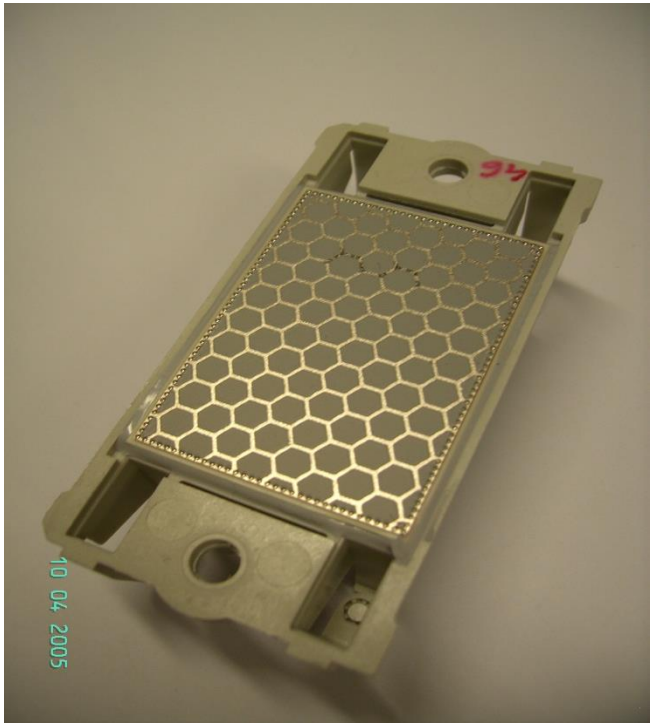
Thermal Grease | **Phase Change** | Adhesive Paste | Adhesive Film

Printable Phase Change thermal interface materials – non insulating

- **Product benefits**
- High TC – very low TR better than grease
- Pre-applied
- Silicone-free
- Thermally stable @ 125°C and 150°C
- 100% surface wetting
- No “pump-out” effect

- **Used in**
- Power modules, IGBT, electric and Hybrid vehicles, wind turbine inverters

- **Product**
- **PSX-Pm, TCP7000 and TCP7800-NC**

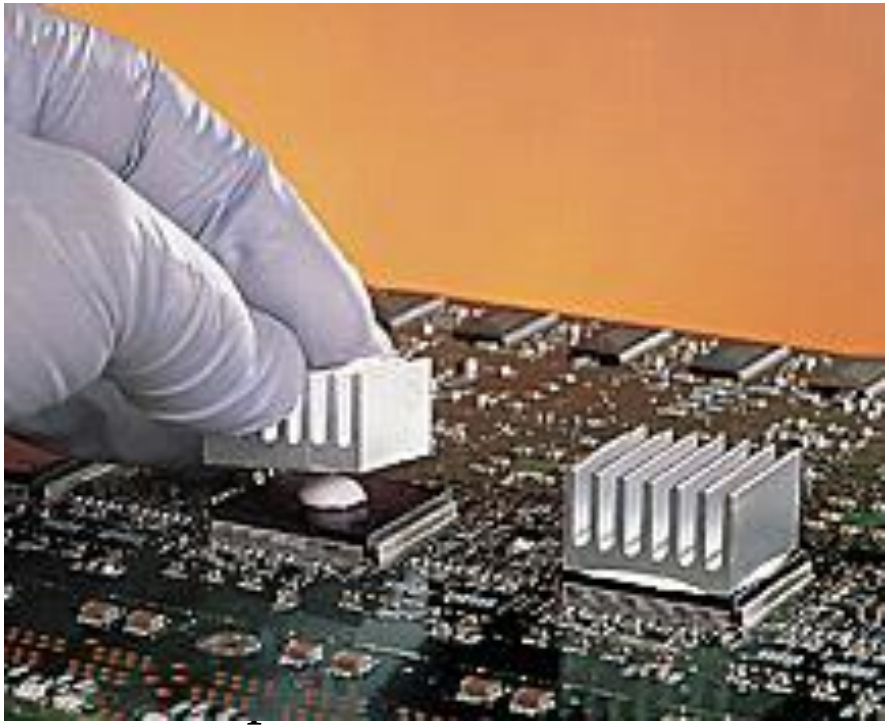


Thermally Conductive Adhesives (TCA)

- Thermally conductive materials that cure from a liquid to a solid when exposed to heat, UV, moisture, activator, etc.

- Function
  - Provide thermal path
  - Provide mechanical bond

- Features
  - Good thermal cycling resistance
  - Multiple chemistries
  - Multiple cure mechanisms
  - Repairable
  - Different application process
  - Fast fixture/fast cure
  - Bondline control
    - Self-shimming



Paste adhesives

- Thermal Resistance achieved with adhesives as good or better than traditional Thermal Interface Materials
- Smaller, lighter designs achievable through elimination of clamping hardware
- Bonded assemblies are long lived and very reliable
- Electrical properties from highly conductive ground plane quality to highly insulating are available
- Bonding solution for dispense or print applications
- Do not require pressure during cure
- Both electrically insulating and conducting available

TIM2 – adhesive paste
Standard products

	Chemistry	TC W/mK	Viscosity mPa-s	Curing	Spacers	Temp. Stability	Applic. Method	Shelf Life
TE 3530	1K Epoxy Rigid	2.3	60000	10'@150°C 30'@100°C	No	-40/+150°	Dispensing screen printing	6mths @-25°
TCP 3003	1K Epoxy semiflex	1.9	60000	30'@150°C 60'@120°C	No	-40/+150°	Dispensing screen printing	6mths @-25°
3875 A&B **3876 A&B**	Acrylate 2parts	1.75	A: 32000 B: 90000	3-5' @RT	No 175µ	-40/+125°	Dispensing	6mths @+8°
5404	1K Silicone	1	55000	10' @150°C 15' @130°C	130µ	-40/+200°	Dispensing	12mths @+8°
5406M	1K Silicone	1.5	50000	48hrs@ RT	No	-40/+200°	Dispensing	12mths @ RT

TIM2 – adhesive paste
Development products

	Chemistry	TC W/mK	Viscosity mPa-s	Curing	Spacers	Temp. Stability	Applic. Method	Shelf Life
20323-12A	1K Epoxy Semiflex	2.0	70000	30'@150°C	No	-40/+150°	Dispensing screen printing	6mths @-25°
XTY 80288-1	1K Epoxy spot cure	2.2	35000	30"@150° C 1'@120°C 5' @ 70°C	No	-40/+120°	Dispensing	1year @-40

Thermally Conductive Adhesives
Bead-on-Bead

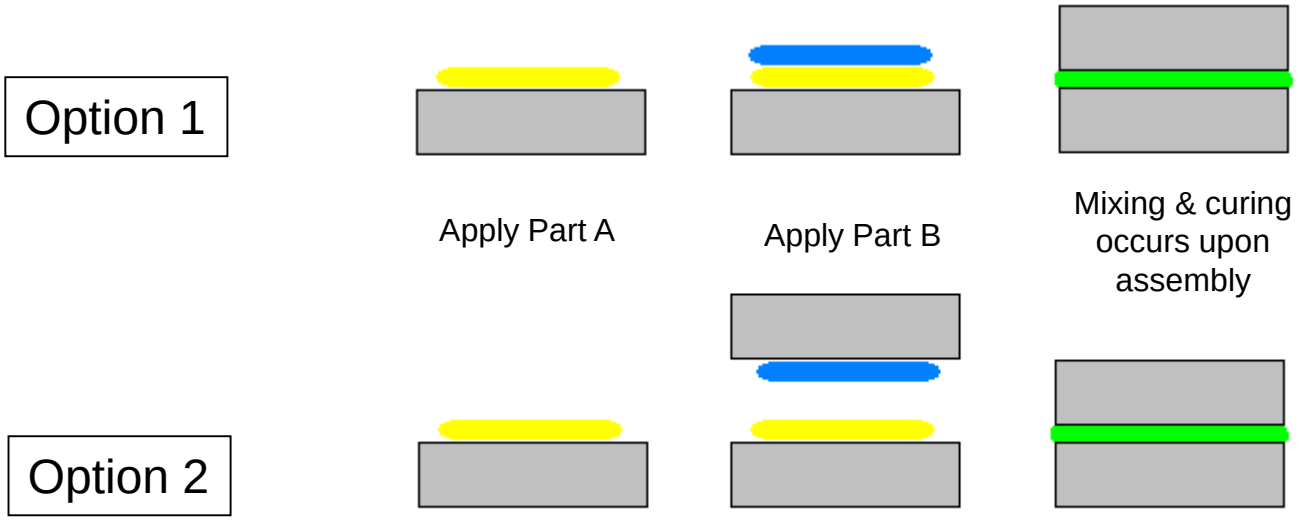
- Bead-on-Bead thermally conductive adhesives are unique products based on proven, proprietary structural adhesive technology
- They represent a new concept in bonding a wide variety of heat dissipating electrical and electronic devices to heat sinks and heat spreaders.

Product	Description
3875	1.75 W/m° K two-part thermally conductive adhesive
3876	1.75 W/m° K two-part thermally conductive adhesive with 7 mil glass spacer beads

Bead-on-Bead

The Process – Basic Concept

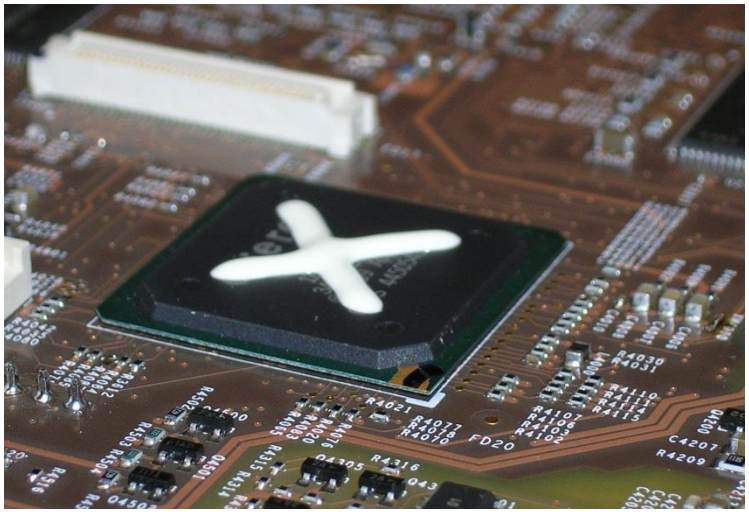
- The term “Bead-on-Bead” describes a unique chemistry for a two-part acrylic adhesive
- Rather than premixing parts A&B, each part is applied to the component and the mixing occurs when the two items to be bonded are joined.
- There are two methods for applying this product type:



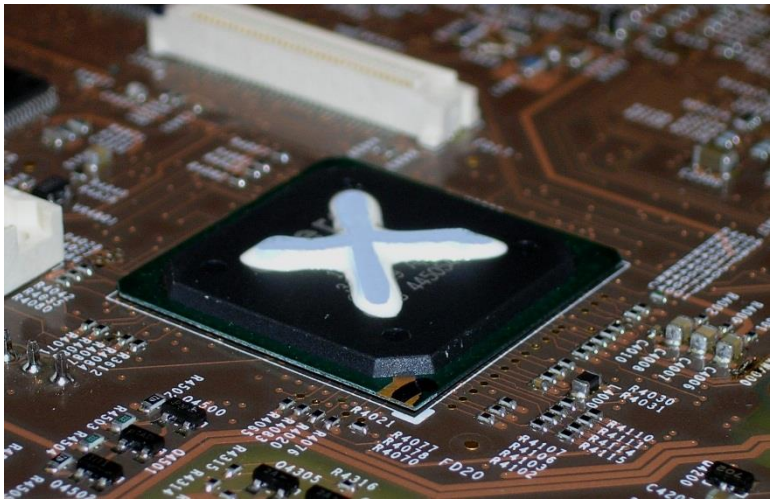
Bead-on-Bead
Features & Benefits

Product attribute	Benefits
High thermal conductivity – 1.75 W/m° K	Improved cooling performance – allows for use of smaller, lighter and more cost effective heat sinks
No mix, no measure, two-part system	Avoids the need for meter-mix dispense systems, solves problems associated with primer-based adhesives, huge process window for assembly
High bond strength	High reliability – no field failures due to heat sinks debonding
Fast fixture	High production throughput
Unique Color Coding	Parts A & B have different colors to avoid confusion and merge into a new color to indicate product has mixed
Lower viscosity	Easy dispensing
Excellent environmental resistance	High reliability in even the most demanding applications
Glass spacer beads	Available 7 mil glass beads provide controlled gap and electrically isolate components from heat-sink

Operating Parameters
Dispensing – Needle Dispense



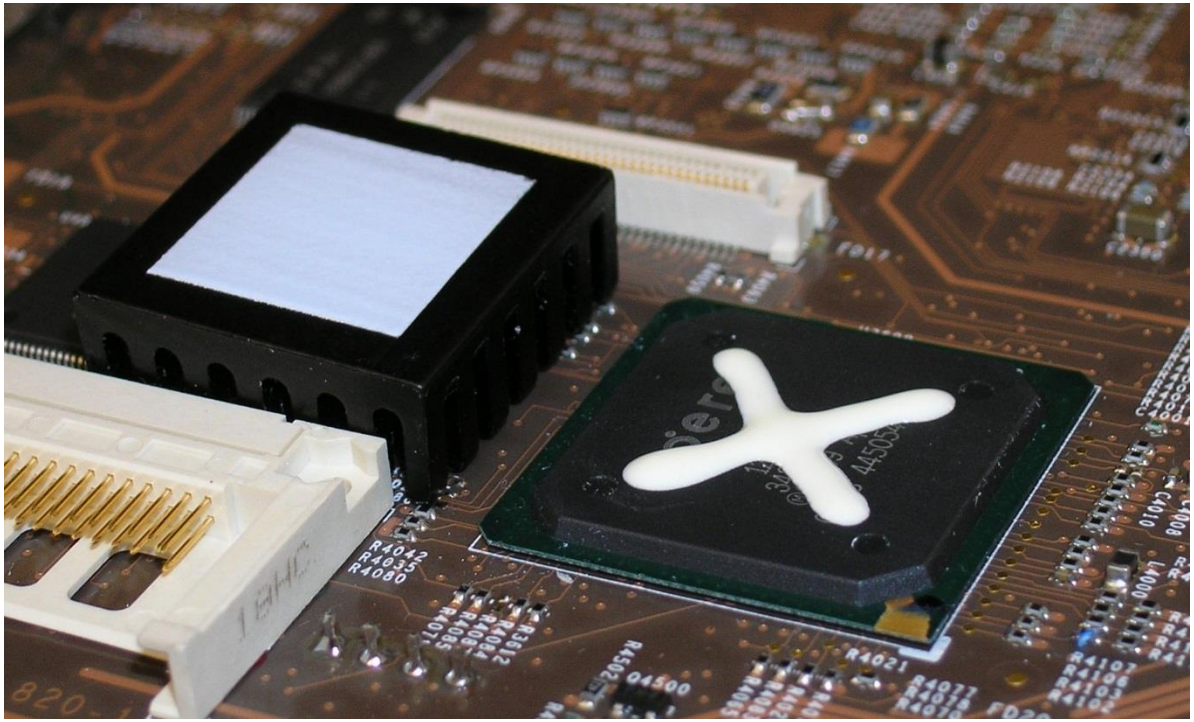
Dispense Part A



Dispense Part B on top

“X” pattern provides most uniform coverage. One large dot in the center is also acceptable.

Operating Parameters
Dispensing – Stencil Printing



Needle dispense Part A onto component, stencil print Part B onto heat sink.

Operating Parameters
Curing – Fixture Time

- Fixture Time 3-5 mins
  - Fixture time is defined as the amount of cure time required for a 320mm^2. Bondline to support a 3kg weight
- Fast fixturing allows parts to quickly gain enough strength to avoid displacement during subsequent processing.
- This product has high tack (or green strength) and average heat sinks will not shift position even before fixture strength is achieved.

TIM2 Applications – Henkel Products
LED lighting

Thermal Grease | Phase Change | **Adhesive Paste** | Adhesive Film

Thermally conductive silicone flexible adhesive for LED modules onto heat sink attachments

Product benefits
- One component
- Easy and fast dispensing
- Suitable for large bonding areas
- Compensate CTE mismatch
- RTV
- Stable after ThC @-50+200°C
- High TC – low TR

Used in
- Street lights, indoor lights and bulbs

Product
- **5406TA**

TIM2 Applications – Henkel Products
Automotive – LED

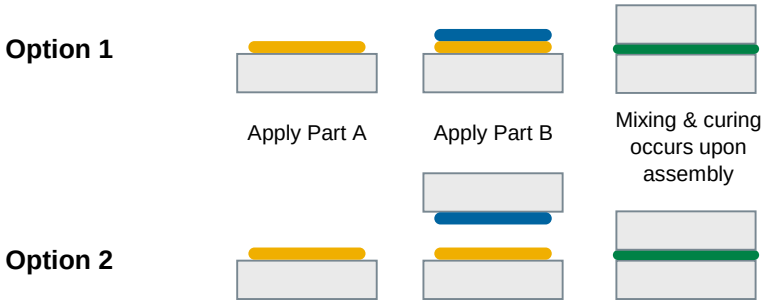
Thermal Grease | Phase Change | **Adhesive Paste** | Adhesive Film

Bead-on-Bead Thermally conductive adhesive

Product benefits
- Very fast fixing time
- Good adhesion
- 2 parts – no need to maintain exact mixing ratio
- Room temperature cure
- Can be either dispensed or screen printed
- High TC – Low TR

Used in
- Automotive LED head lamps

Product
- **3875 A&B**

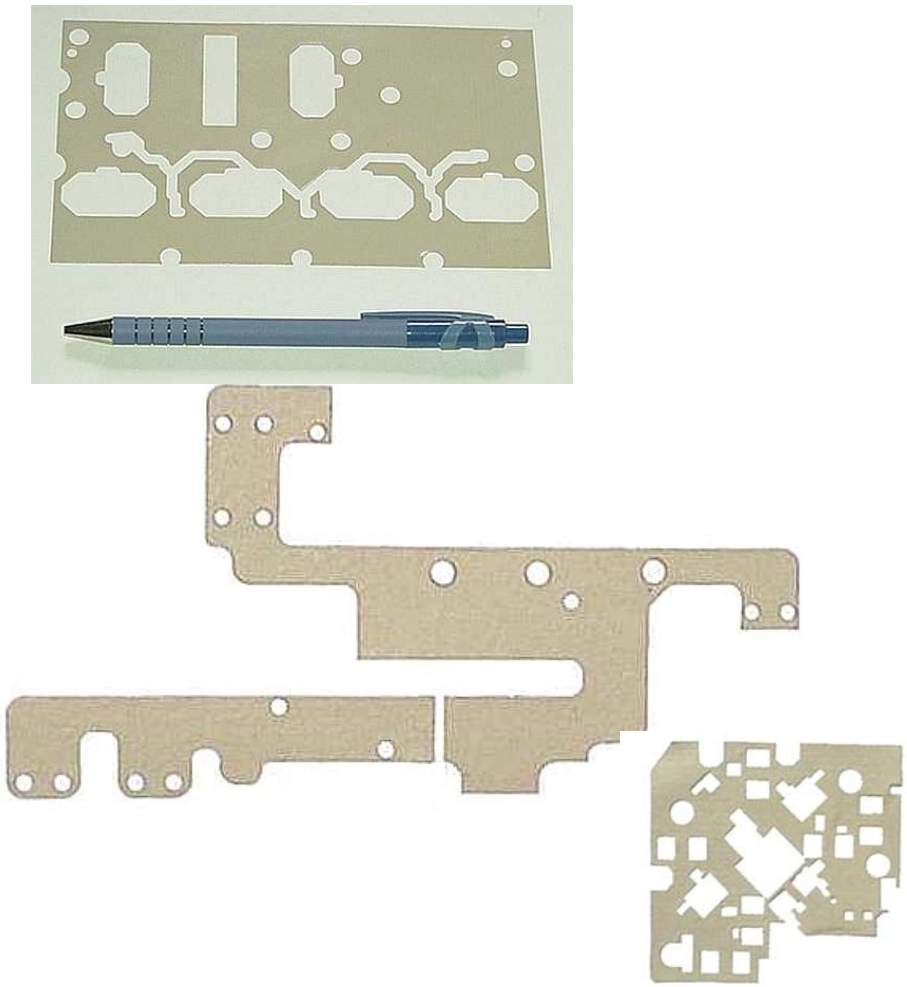


Film adhesives

- Epoxy film adhesives are blends of solid resins, catalysts, fillers in a dry sheet format
- They are made by coating a liquid suspension of the mix onto a support carrier (fiberglass fabric, polyester, polyimide) or a release liner (for making an unsupported film) and then evaporating the solvent
- Film adhesives are typically not b-staged resins because no polymerization has occurred prior to shipment
  - many are quite stable with 3 month work life at room temperature

Film adhesives offer design and manufacturing solutions

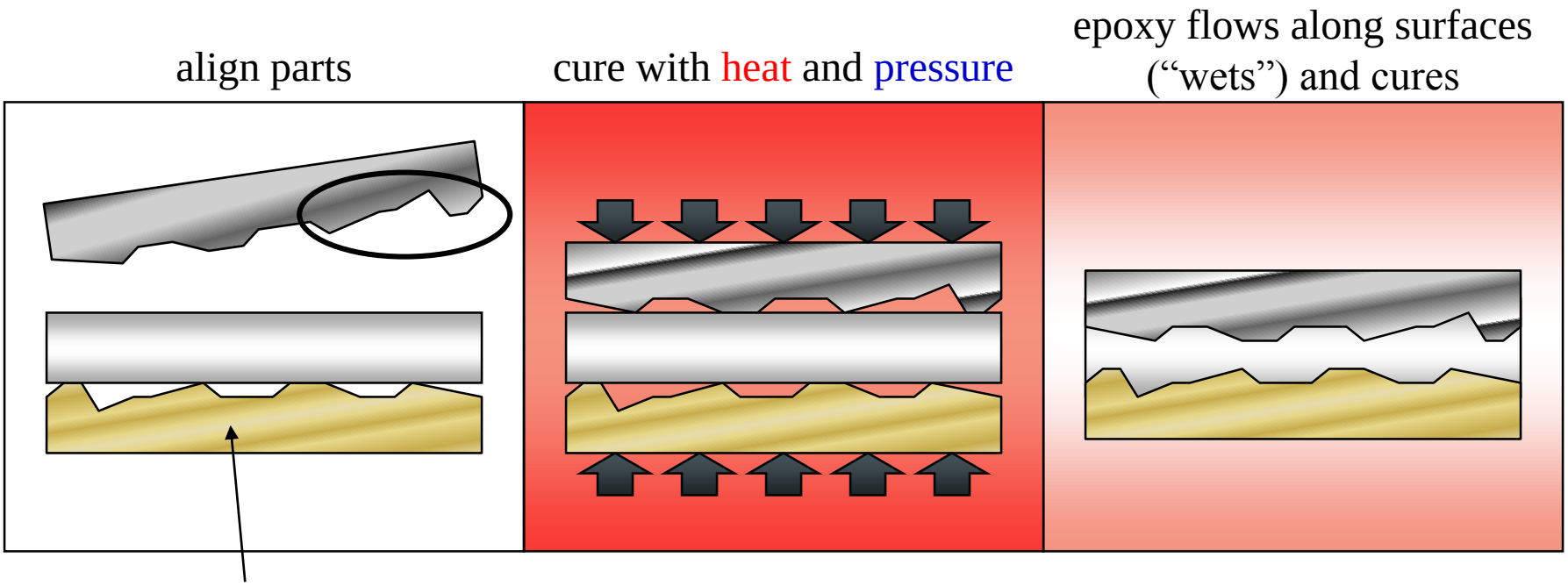
- Customized preforms made of film adhesive enable:
  - precise amount of adhesive exactly where needed
  - void-free bonds
  - controlled bondline thickness
  - pick and place assembly
  - no wasted adhesive
- TIM products have thermal conductivity up to 7 W/mK and thermal resistance down to 0,15 K-cm^2/W



Film types by filler

- Electrically conductive
  - filled with metal powder (silver or gold)
  - allows for electrical and thermal conductivity
- Electrically insulating
  - thermally enhanced - filled with ceramic powder to enhance heat transfer
  - thermally insulating – unfilled. provides electrical isolation, and resists heat transfer, used for simple bonding of parts

Film – the process

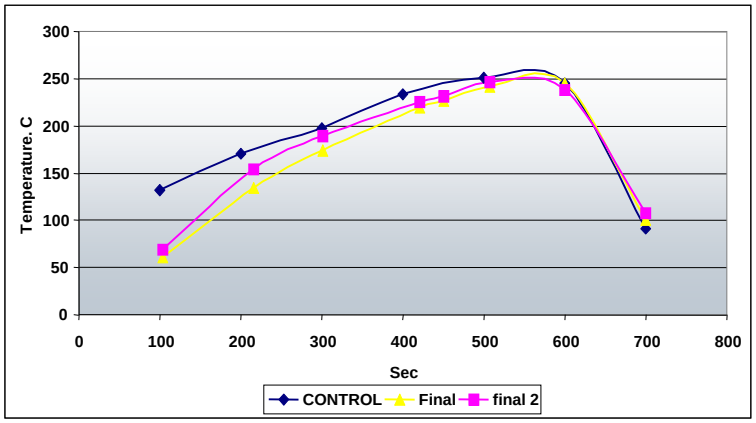


Where are they used?

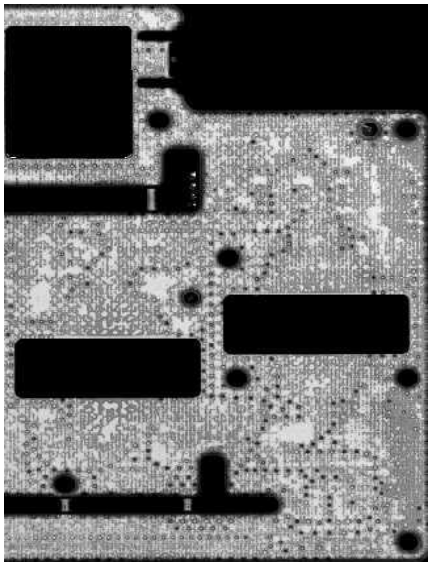
- Bonding large areas
  - best way to put an even distribution of adhesive over a large area
  - desired thickness easier to achieve than with screen printing
  - no solvent and uniform coverage means no voids
- Placing adhesive in complex patterns
  - better edge and flow control than with screen printed adhesives
- When high electrical or thermal conductivity is needed
  - higher fill densities can be achieved with films than pastes
- When “pick and place” is preferred
  - automated or manual assembly lines
  - no wasted adhesive

Void free bond line before and after reflow

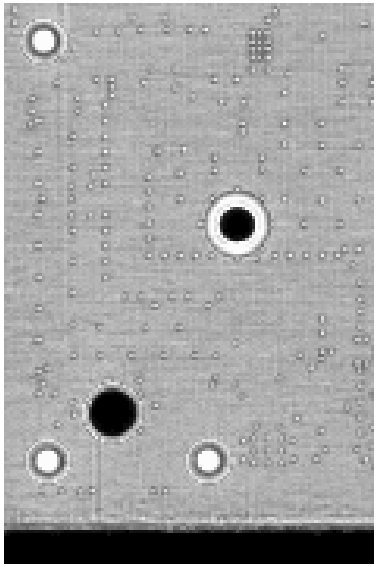
- Scanning Acoustic Microscopy Images indicate that using film adhesives for PCB to heat sink assembly eliminates the risk for air inclusion
- After reflow (260°C peak), the film bondline remains intact, void free



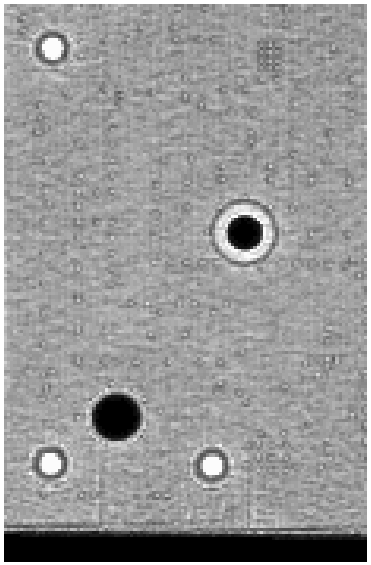
Solder Paste After Reflow



Film Before Reflow



Film After Reflow

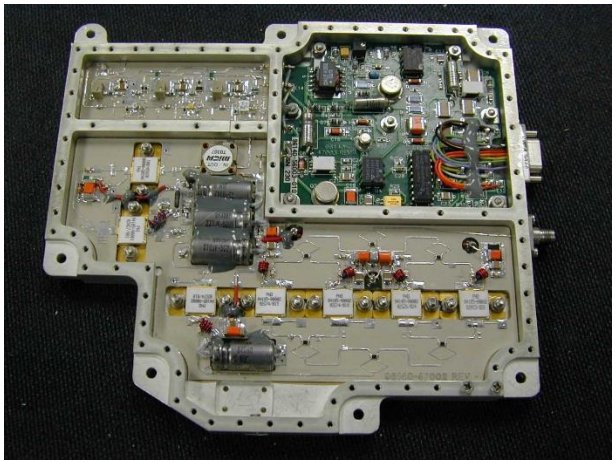


TIM2 – adhesive film
Standard products

	Chemistry	TC W/mK	Thickness	Curing	Carrier	Temp. Stability	Shelf Life
550K – Electrically Insulating	Epoxy	0.8	50-100µ	30'@150°C 2h@125°C	Glass fiber	-40/+150°C	1yr @ -40°C
561K – Electrically Insulating	Epoxy	0.9	100-125-200-250-305µ	30'@150°C 2h@125°C	Glass fiber	-40/+150°C	1yr @ -40°C
563K – Electrically Insulating	Epoxy	1.1	50-75µ	30'@150°C 2h@125°C	None	-40/+150°C	1yr @ -40°C
566K – Electrically Insulating	Epoxy	0.8	100-125-200-250µ	2h @100°C 3h @90°C	Glass fiber	-40/+150°C	1yr @ -40°C
CF3350 – Electrically Conductive	Epoxy	7.0	50-100µ	30'@150°C 1h@125°C	None	-40/+160°C	9mths@ +5°C

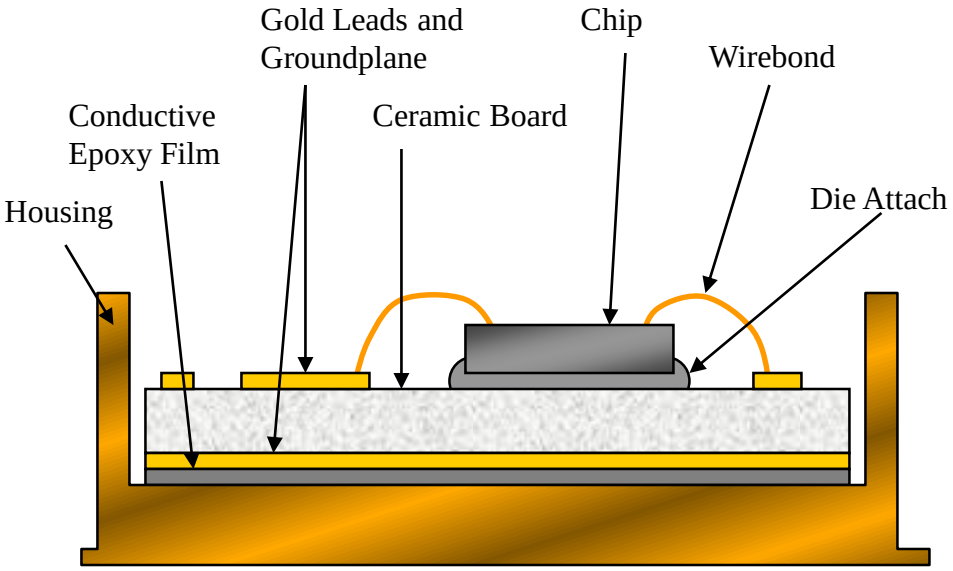
Film adhesive applications

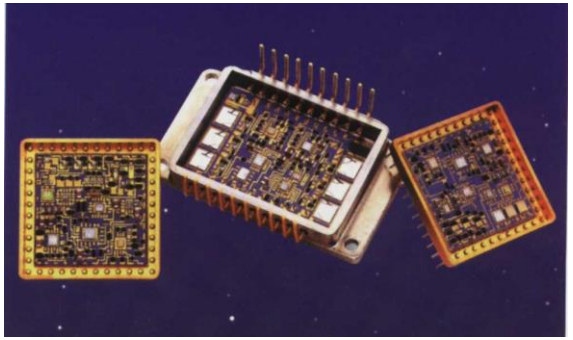
- RF amplifiers and transceivers
  - wireless telecom base stations
    - boards to aluminum backplanes
    - heat sink coins to boards
    - size range from 25mm² to 250mm²
  - automotive radar
    - ceramic circuits to aluminum backplanes
    - typically 25mm² or less
  - military radar (phased array)
    - ceramic and organic circuits to metal backplanes
    - typically 100mm² or less

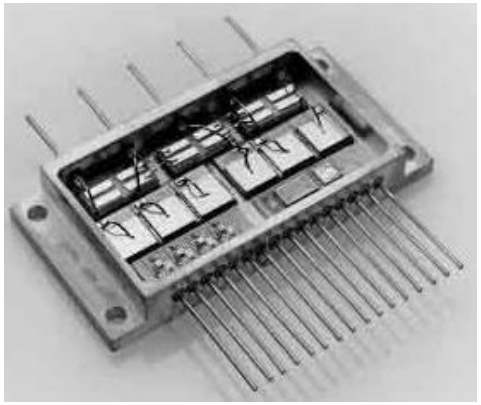


Film Adhesive Applications

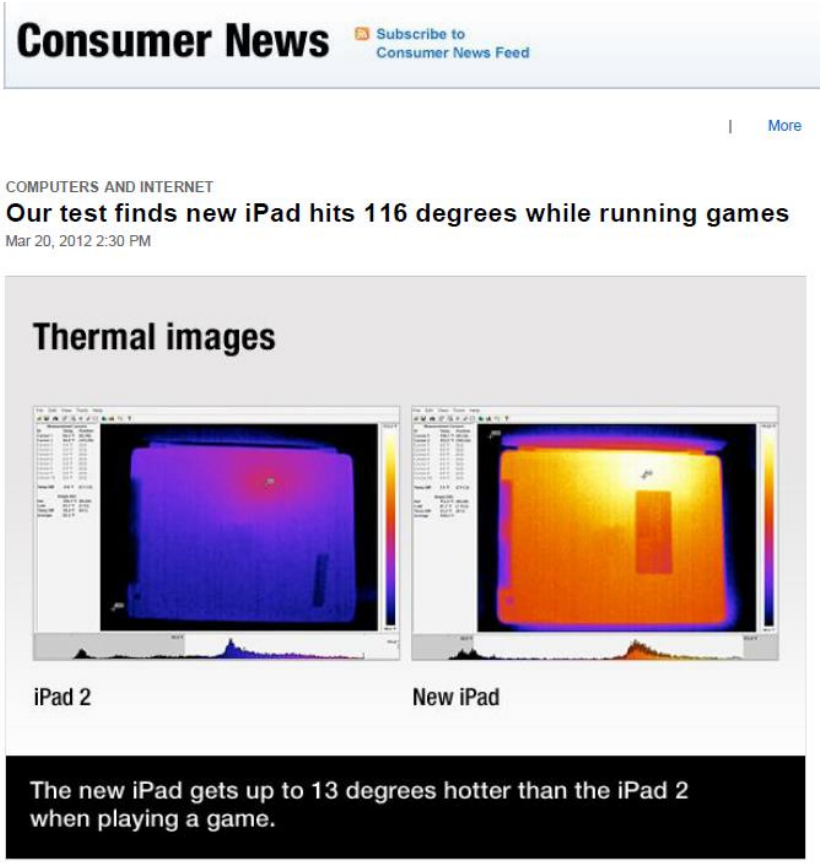
Ceramic Power Module To Metal Package







Thermal Absorber
Project Overview

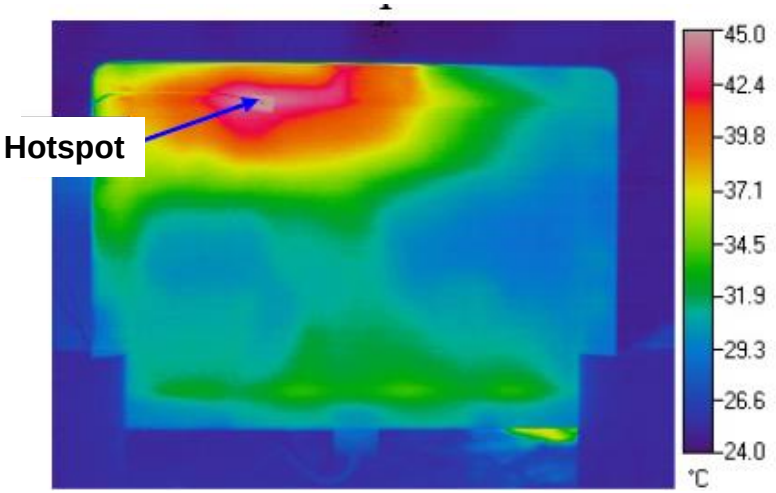


Market Need

- As device functionality increases and designs become more compact, devices become hotter
- Design Engineers aim to keep HH devices under 45C for consumer health and safety
- Excess heat can also shorten component and battery life

Thermal Absorber

Project Overview *cont.*



Thermal Image of outside surface of tablet

Project Objective

- Enable Design Engineers to increase handheld device functionality while controlling skin temperatures with innovative material solutions
- Balanced Junction and Skin temperature

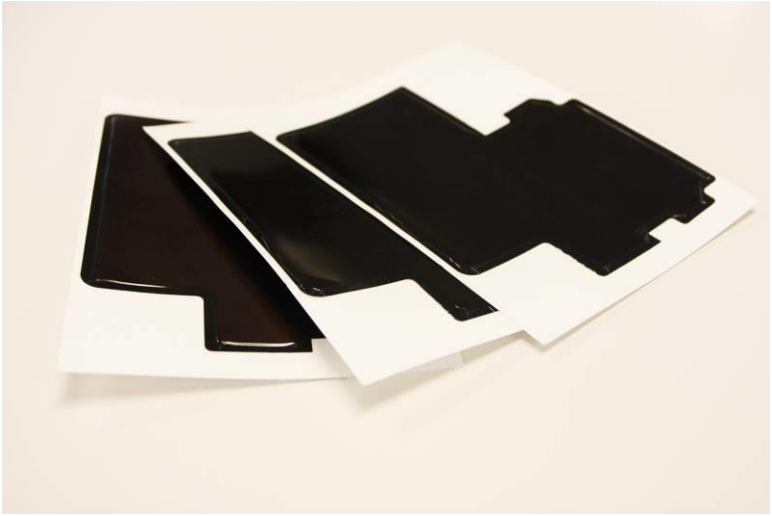
Project Deliverable

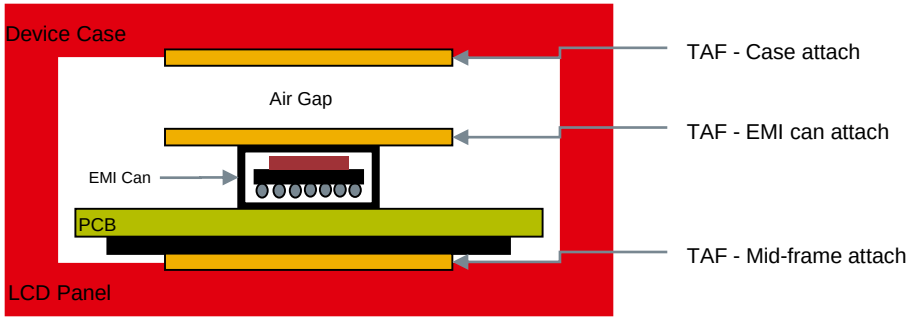
- Develop a material that can be applied in simple or complex pattern and reduce handheld device skin temperatures
  - Drop in skin temperature of >3°C
  - Film manual application
  - Maximum thickness of 0.2mm
  - Halogen free, RoHS compliant

Thermal Absorber
Product Developed

LOCTITE TAF series - Thermal Absorber

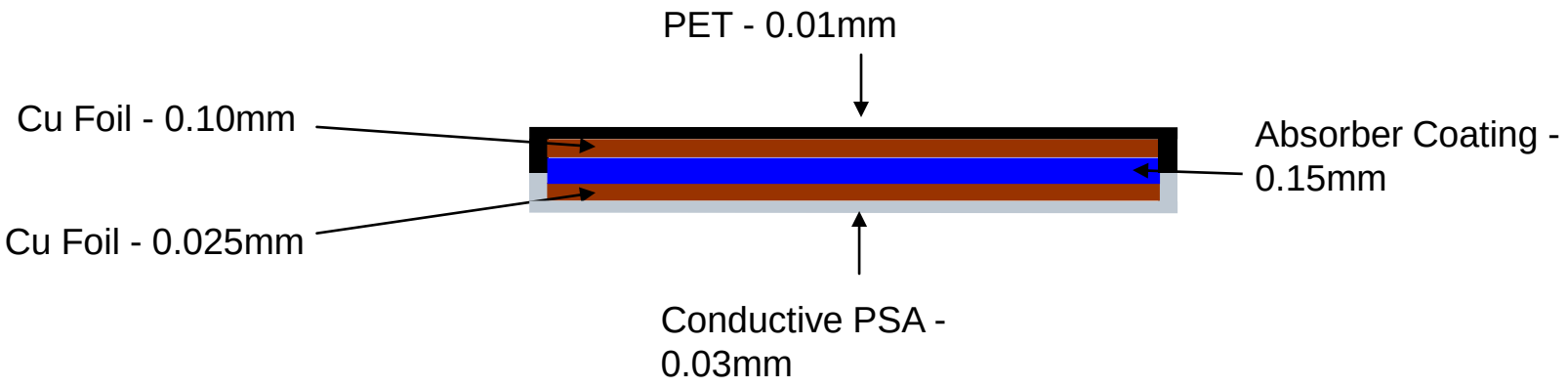
- Advanced phase change composition coated between foil substrates
- First thermal absorbing & spreading hybrid material introduced to the market
- Combination of energy storage, heat spreading, thermal insulation, thermal conductivity
- Patent Pending





Thermal Absorber

LOCTITE TAF Construction example

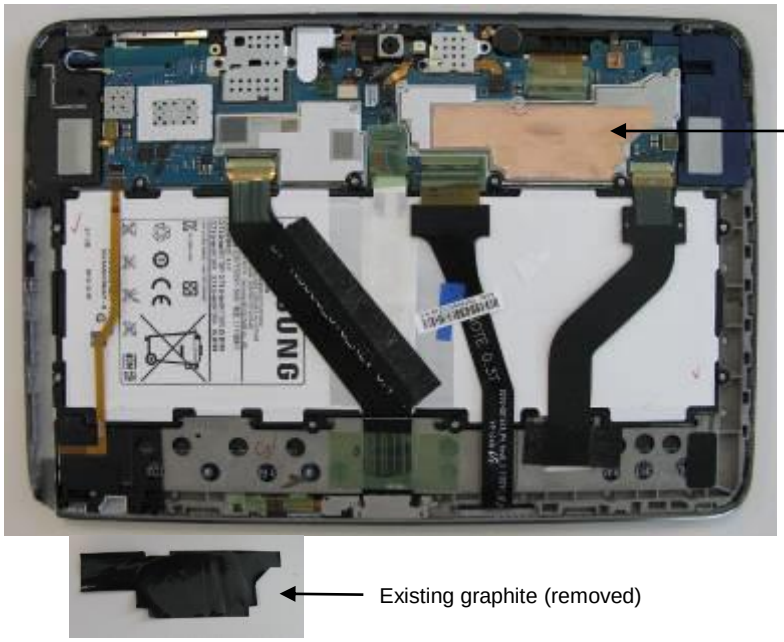


- PET layer - Offers electrical isolation from Cu
- Cu layers - Offers heat spreading & EMI Shielding
- Absorber Coating - Offers thermal absorbing and insulation
- Conductive PSA - Fixed attachment and EMI shielding

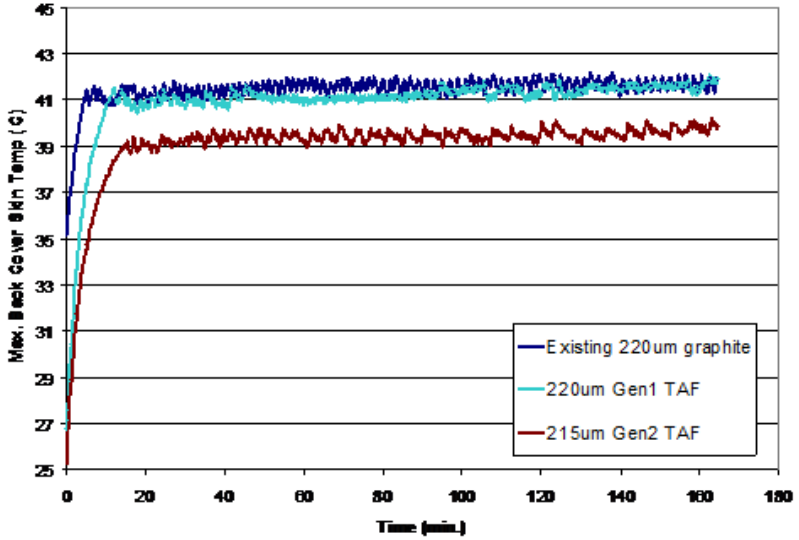
Fully customizable X, Y & Z dimensions ≥80µm Solutions

LOCTITE TAF
Performance on Galaxy Note 10.1

Reducing Handheld Device Temperatures



Existing graphite (removed)



- Fast transient temperature rise for all materials
- 215 um TAF exhibits improved transient and steady state temperatures
- Older Gen1 TAF performs more like existing thermal solution

1. Run “Benchmark Stability Test” to generate heat
2. Measure skin temperature with FLIR SC655 Infrared Camera
3. Continuous recording for >2hrs to reach equilibrium

LOCTITE TAF
Current Technology Status

Benefits Over Competition

- **Equivalent to higher performance** over competitive materials by 1-3C on skin and junction when ≥80µm
- **Customizable dimensions & flexible absorption and insulation** solution that can be oriented over/under components
- **Lower price** than graphite & composite alternatives
- **Global Reach** with world class supply chain and Technical Support capabilities

Industry Proven Technology

Google Nexus 7

Barnes & Noble Nook HD

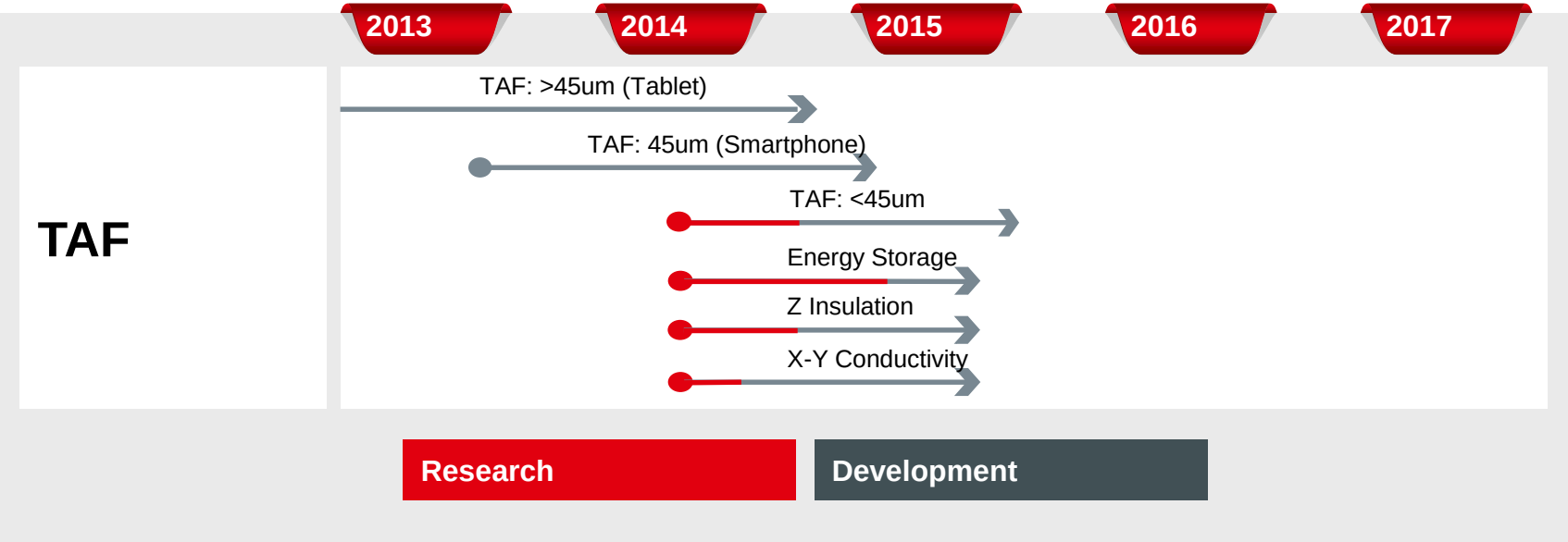
HP Pavilion X2

ASUS MeMO Pad 8

Others: Dell Venue 11, Obelix Wacom

LOCTITE TAF
Roadmap

Developing Innovative Thermal Solutions

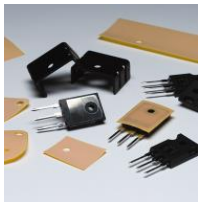


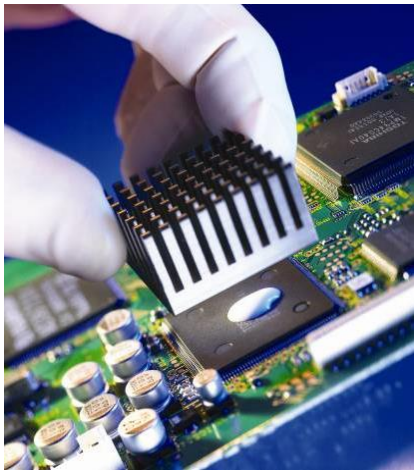
To enable Design Engineers to increase handheld device functionality by controlling skin and component temperatures with innovative material solutions

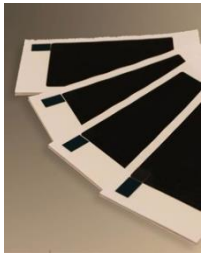
Conclusion

- Henkel offers a full range of thermal interface materials
- Solutions for both non-bonding and bonding applications
- We can help you get the heat out

Thank you!







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