The Ten Myths
Of
Liquid Metal Thermal Interfaces

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Myths

- Bleeding Edge Technology
- Toxic/Hazardous Materials
- Material Won’t Stay Put
- Incompatibility with Other Components
- Unavoidable Degradation from Oxidation
- Messy Handling Characteristics
- Non-standard Manufacturing Needs
- Unexceptional Performance
- Too Expensive to be Practical
- Commercially Unproven

Outline

Why Liquid Metal as an Interface Material?

History of the Approach

Failures and Phobias

Manufacturing, Cost and Commercialization

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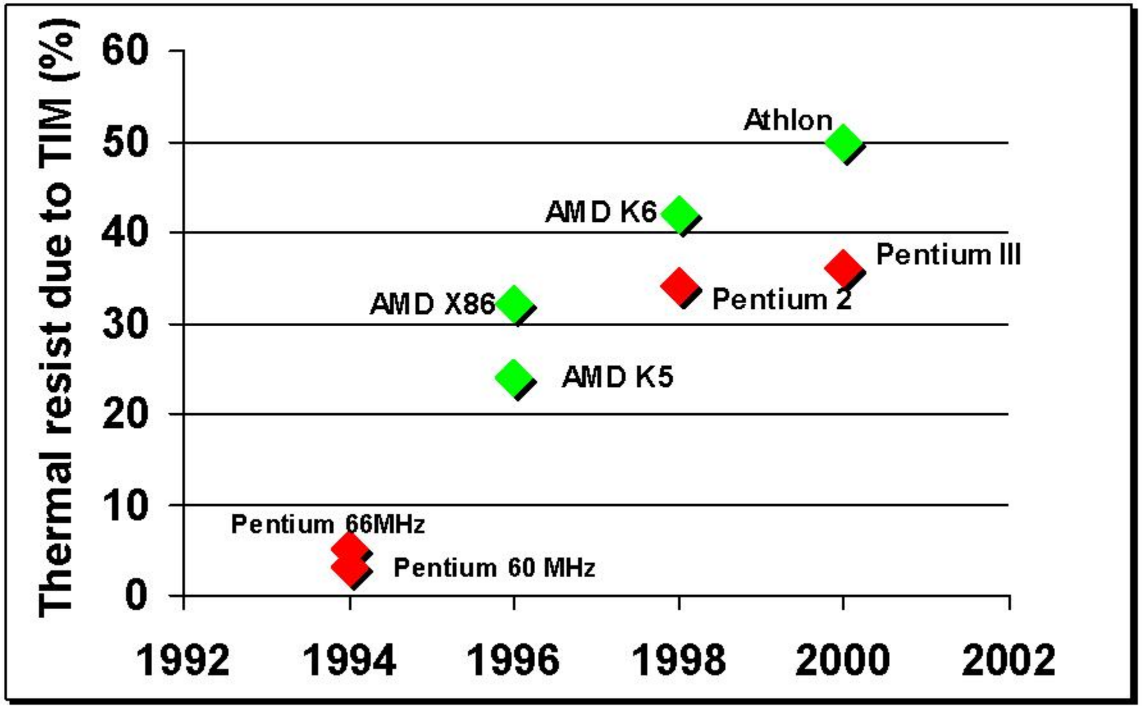
Critical Interface



"Materials for Thermal Management", Dr. Nancy Dean, Advanced Packaging, March 2003, p. 16

- Higher heat flux densities
- More of overall thermal budget consumed by TIM1 interface
- Heat sinks of higher efficiency required to offset TIM1 resistance

Low Melt Alloys (LMAs)

- Typically alloys of Indium, Bismuth, Gallium, Tin
- Phase change typically 60 – 80˚C
- Contains no organics
- No curing required
- Liquid at operating temperature of component
- High bulk conductivity compared to organics
- High degree of wetting to yield low contact resistance

Performance

Myth: Unexceptional performance compared to particle-filled greases

Reality: LMA interface outperforms best organic materials in use today

Performance

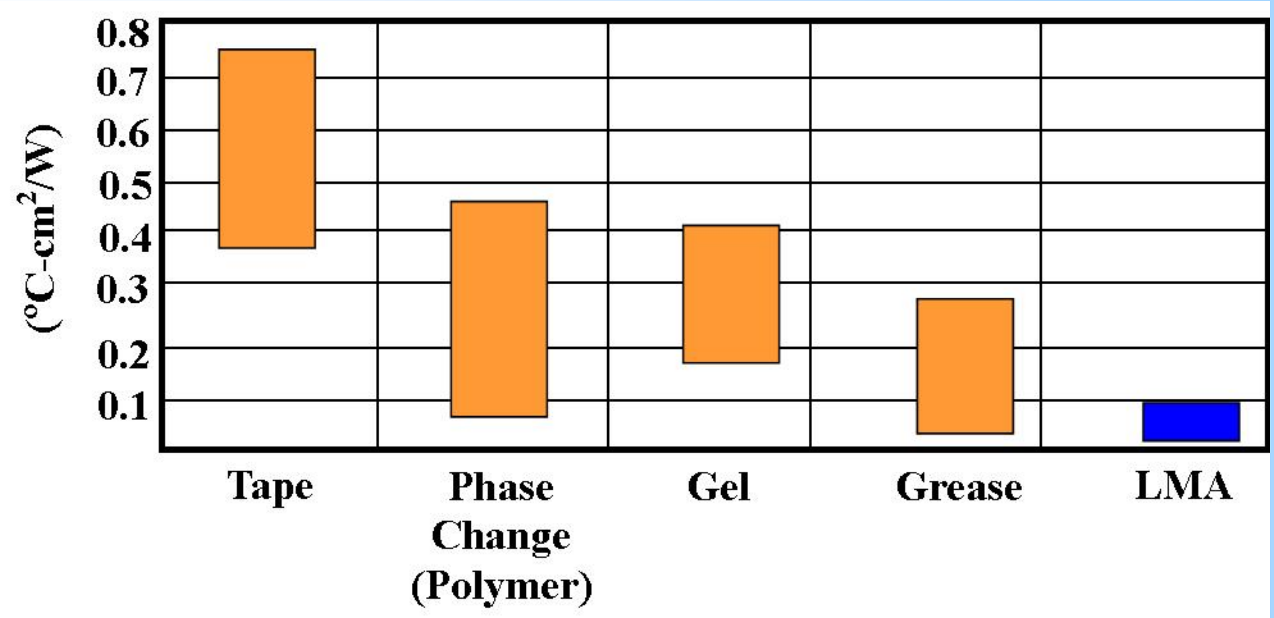
- Conductivity ~25 W/mK
- Impedance < 0.04 °C-cm^2/W

Conductivity measured by Laser Flash method

Impedance measured by ASTM D5470 method (@ 20psi)

Performance

LMA thermal performance exceeds all organic TIM materials



S. Lee, P. Chen, “Development of High Performance Thermal Interface Material”, Intel Technology Symposium, Seattle, Washington, September 27-28, 2001.

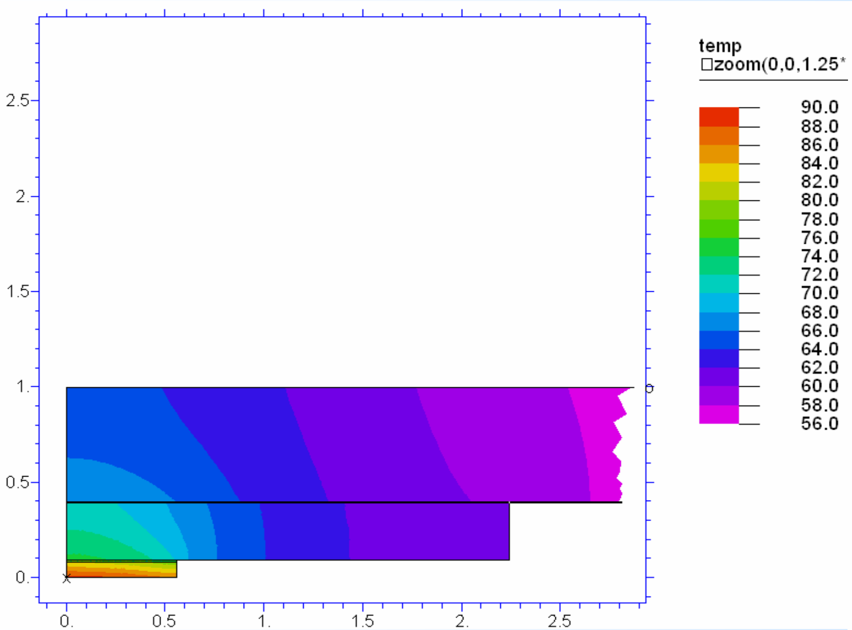
Performance Example

6°C (~11°F) reduction over Cu lid with best silver greases

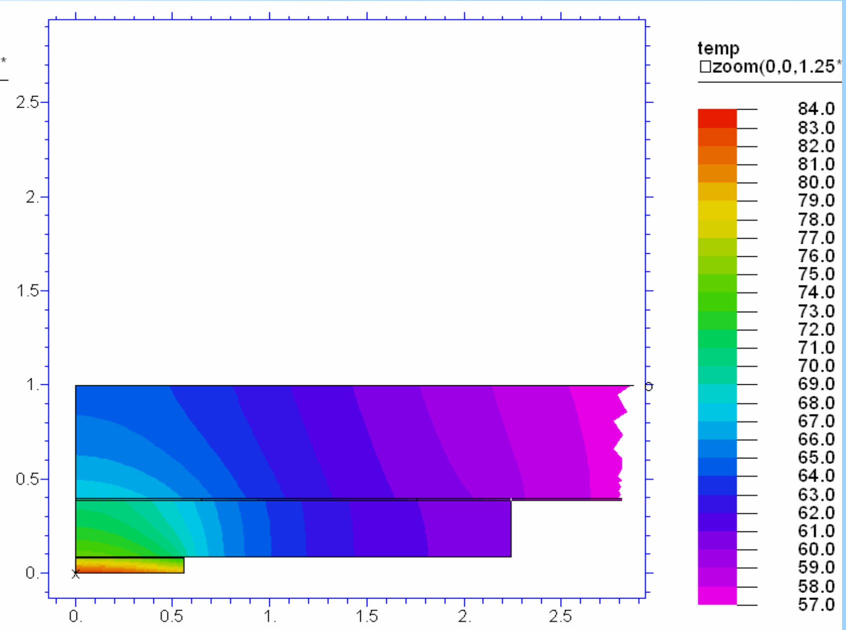
LMA TIM1

1 cm² 80 W die

Ag Grease TIM1



1 mil BLT, 20 W/mK



2.5 mils BLT, 5 W/mK

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Technology Risk

Myth: LMAs are a “Bleeding Edge” uncertain technology

Reality: LMA research and development on-going for more than 30 years

LMA Research

1970's—IBM

1980's—Hitachi, IBM, MMI

1990's—3M, Digital, Fujitsu, IBM, Microelectric Corp., Unisys, Westinghouse

2000's—AMD, Bergquist, Enerdyne Solutions, Hitachi, IBM, Intel, NEC, Nortel, Thermagon, Thermax, Unisys

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Material Safety

Myth: LMAs use toxic and/or hazardous materials/constituents

Reality: LMAs can be made from relatively innocuous materials

Alloy Formulations

- Lead and cadmium alloy candidates may not be viable
- Gallium is a mercury replacement

R. Webb, J. Gwinn, “Low Melting Point Thermal Interface Material”, 2002 Inter Society Conference on Thermal Phenomena, pp. 671-676, 2002.

LMA Alloys with Melting Temperatures Between 10°C and 81°C

Alloy	Liquidus (°C)	Solidus (°C)	Composition (%)
51	10.7E	10.7	62.5 Ga, 21. 5 In, 16 Sn
60	15.7E	15.7	75.5 Ga, 24.5 In
6077	25	15.7	95 Ga, 5 In
85.6	29.8E	29.8	100 Ga
117	47.2E	47.2	44.7 Bi, 19.1 In, 6.3 Sn, 22.6 Pb, 5.3 Cd
136	58E	58	49 Bi, 21 In, 12 Sn, 18Pb
19	60E	60	32.5 Bi, 51 In, 16.5 Sn
21	69	58	49 Bi, 18 In, 5 Sn, 18 Pb
162	72E	72	33.7 Bi, 66.3 In
174	79E	79	57 Bi, 26 In, 17 Sn
27	81E	81	54.02 Bi, 29.68 In, 16.3 Sn

Migration

Myth: LMA material won't stay put

Reality: LMA migration can be prevented

Migration

- Perimeter Barriers
- Surface Finish Optimizations
- Viscosity Modifiers
- Substrates

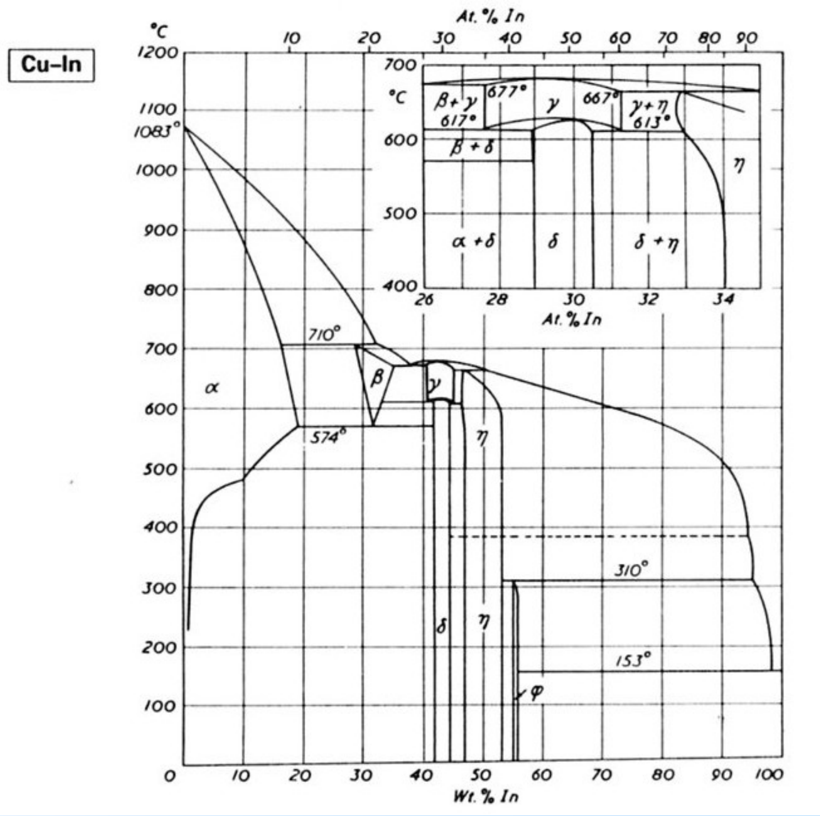
Intermetallics

Myth: LMAs are incompatible with common and critical electronics components

Reality: LMAs are compatible when using appropriate alloy formulation and surface preparation

Intermetallics

- Indium-based LMAs are incompatible with copper surfaces
- LMAs containing gallium are incompatible with aluminum and copper



Intermetallics

Diffusion Barriers

Alloy Modifications

LMA Coated or Used as Particulate

Oxidation

Myth: LMA performance degrades quickly due to alloy oxidation

Reality: Long term performance and reliability achievable today

Oxidation

The Prior Art

Foil-based LMA, 61.1 ^{0}C phase change

STRESS CONDITION	RELIABILITY DATA (R_{jp})
End of Line	0.27 (^{0}C/W) T = 0
T/C (-45 ^{0}C to +125 ^{0}C)	0.82 (^{0}C/W) After 50 cycles
Bake (125 ^{0}C)	0.35 (^{0}C/W) After 144 hours
HAST (130 ^{0}C/ 85% RH)	0.68 (^{0}C/W) After 50 cycles

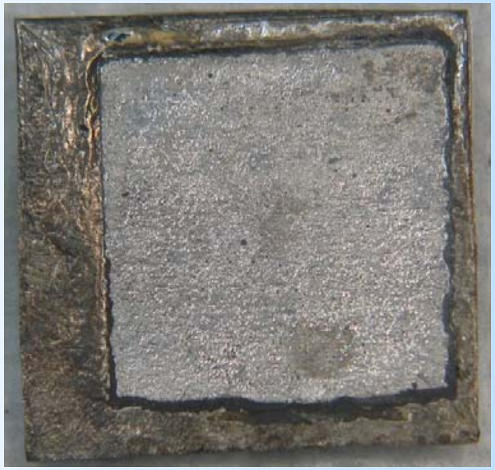
- "Good Initial Performance"
- "Poor reliability due to oxidation"

S. Lee, P. Chen, "Development of High Performance Thermal Interface Material", Intel Technology Symposium, Seattle, Washington, September 27-28, 2001.

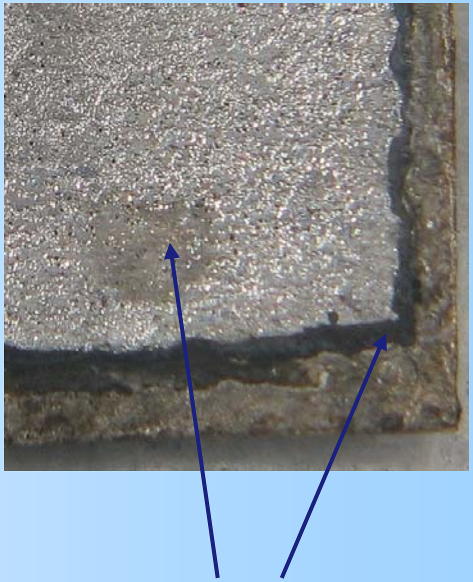
Oxidation

LMA foil

(as supplied)



24 hrs in 85°C, 85% humidity



Corrosion products

Oxidation

Moisture Barriers

Moisture/Oxygen Neutralization

LMA Surface Modification

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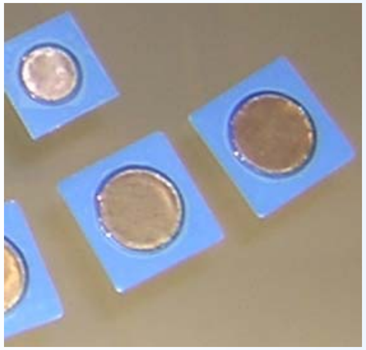
Handling Characteristics

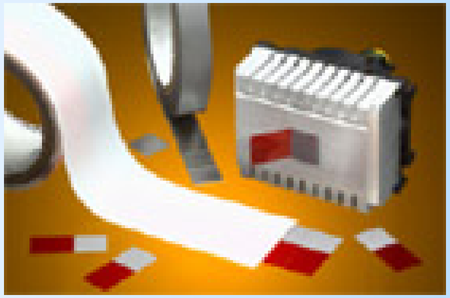
Myth: LMAs are messy and difficult to apply

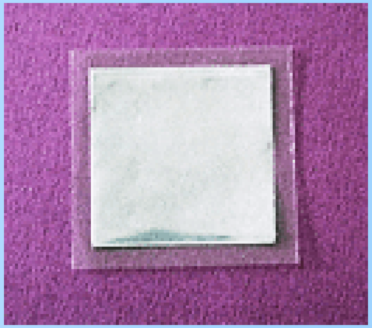
Reality: Preform or foil-based LMAs can be handled just like many other materials

Deployment

Phase change formulations and preform or foil deployments ease handling







Manufacturing

Myth: Use of a LMA interface material requires non-standard manufacturing methods and process steps

Reality: Application of a LMA can be different from a polymeric TIM, but uses proven and widely used techniques and processes

Cost

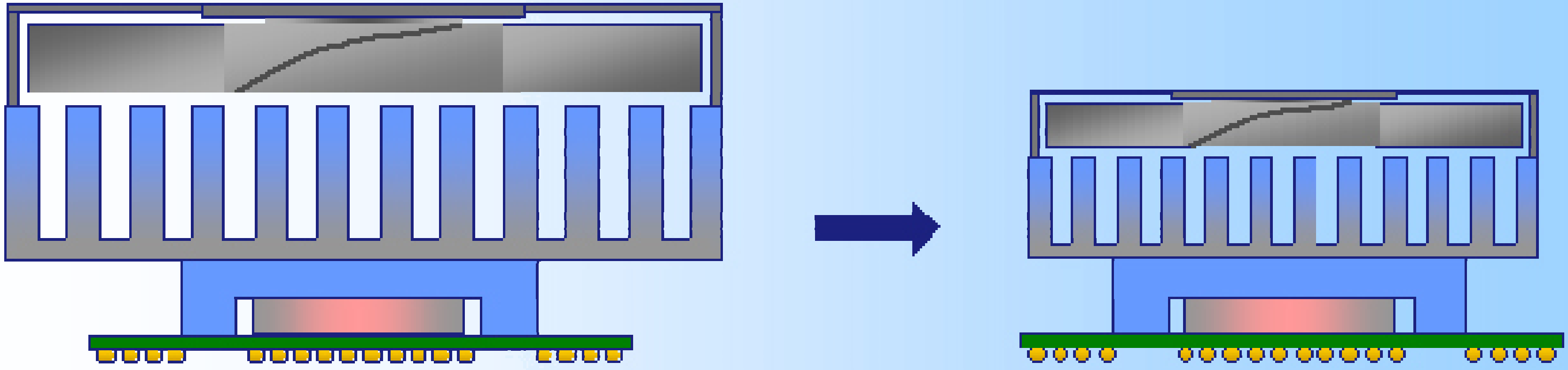
Myth: Typical LMA is impractically costly and is suitable only for niche applications

Reality: LMA allows reduction in overall solution cost—“pays for itself”

Cost

"Conservation of Impedance" —

Better TIM allows reduction of size, cost, and weight of other components



Commercialization

Myth: Use of a LMA TIM is commercially unproven

Reality: LMA TIM products have had production use and are available today

LMA TIM Vendors

Thermagon (T-LMA)
www.thermagon.com

Thermax (HiFlux)
www.thermaxkorea.com

Enerdyne Solutions (Indigo)
www.enerdynesolutions.com

LMA Thermal Interfaces

More Than 30 Years of R&D
Built from Normal Industrial Materials
Stability of Material at Interface
Compatibility with Joined Materials
Long Term Reliability without Oxidation
Simple Handling and Deployment
Standard Manufacturing Techniques
Superior Performance
Modest Cost Providing Overall Savings
Commercially Proven and Available

Thank you.

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