Advances in Thermal Interface Materials (TIM)

H David Rosenfeld, PhD

Technical Laureate, Celanese Micromax® Electronic Inks and Pastes

Micromax® Timeline

Micromax® was advancing circuitry even before the launch of the IBM System/360 computer in 1965. Today, our products are in millions of innovative products used in businesses, homes, and schools around the globe.

1960-1969

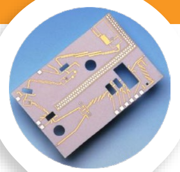
- 1st Commercial resistor paste developed by ceramics division
- Commercialized the first fired-on resistor
- Birox® resistors invented
- The thick film hybrids industry is launched when DuPont thick film Pd/Ag resistors are used in the IBM System/360 computer

1970-1979

- Fodel™ developed
- Copper and gold multi-layer systems developed
- Facilities in Tokyo & Taiwan opened

1980-1989

- Corporation recognizes the significance of electronics; moves R&D from Niagara Falls to the Wilmington, DE, Experimental Station and establishes the Photo & Electronics Products Department
- DEMI Manufacturing plant start-up in Puerto Rico
- GreenTape™ introduced
- Defogger products introduced
- 9535 used for Compaq Luggable with flip PDP screen



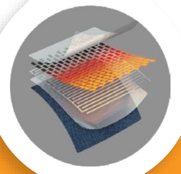
1990-1999

- Fodel™ PDP-TV commercialized
- 00x0 product series introduced

2000-2009

- 1st Generation PV front side paste products used in mass production

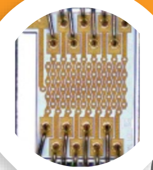
2010-2020



- Solamet PV paste revenue hits $1B
- Launched blockbuster PV17 series for FS Ag
- 1st Generation products for In-Mold Electronics applications introduced
- 1st Generation Intexar™ for wearable applications launched

2020-2022

- Multiple products launched, including AgCl, IME inks, PTC pastes, Sintered AG, and Resistor Renewal
- Product for advanced packaging launched
- Micromax™ brand launched

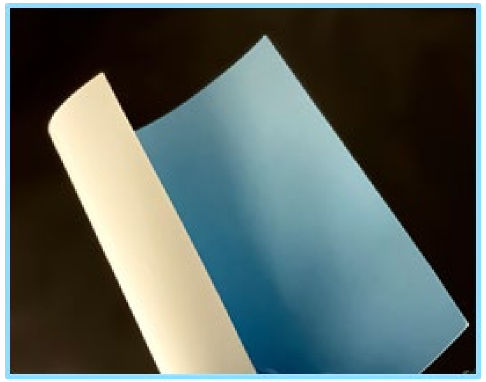


Micromax® Products

Conductive, Resistive, Dielectric inks and paste used in combination to make circuits in a variety of electronic applications.

Sintering silver pastes and TIM materials for advanced semiconductor packaging applications.

Low Temperature Co-fired Ceramics (LTCC) GreenTape™ materials and **Intexar™ TPU Film** that support the sale of our ink products in certain market applications.



Celanese Corporation

MICROMAX™

Micromax’s Global Footprint Accelerates Customer Innovation

Americas

- ★ ● ● Wilmington, DE
- ● Research Triangle Park, NC
- ● Santa Clara, CA
- ● Mexico City, Mexico
- ● Manati, PR

Europe

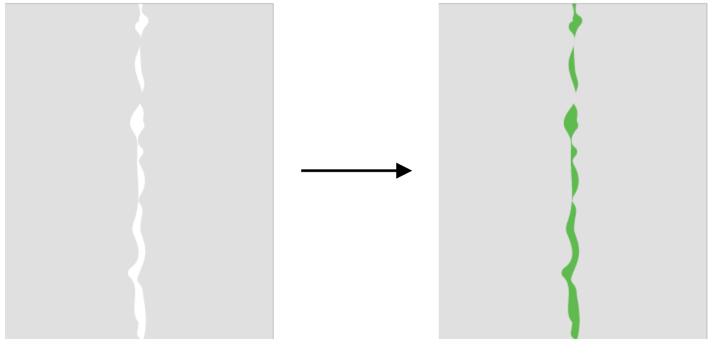
- ● Bristol, UK
- ● Field Sales through Europe

Asia Pacific

- ● ● Shanghai, China
- ● ● ● Kawasaki, Japan
- ● ● ● Taoyuan, Taiwan

★ Headquarters
● Manufacturing
● Office / S&M
● Major R&D Centers
● Technology Sites

Thermal Interface Material



A material placed between two objects to improve the flow of heat between them.

Tapes	Electrically Conductive	Liquid Metal	Dispensed
Films	Electrically Insulating	Solders	Preform
Pastes	Phase Change Materials	Hybrid Sintering	Printed
Putties	Adhesives	Sintering	Jetted
Gels	Non-bonding		
Greases	Anisotropic		
Gap Filling			

Critical to Quality

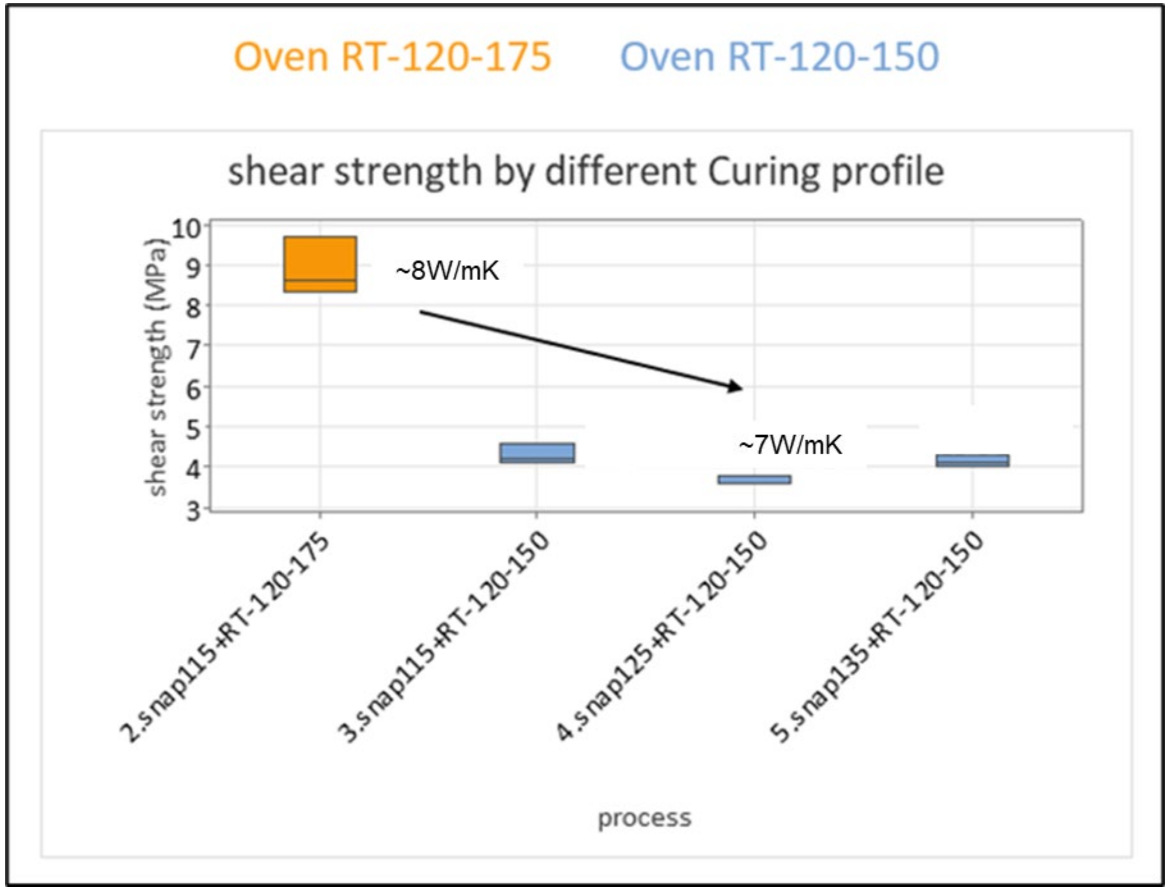
Example – Bonding

- Adhesion
  - To what? A single material, mixed materials, metals, ceramics?
  - How much?
    - Is the spec an upper bound or a lower bound?
    - Is rework possible?
    - Preferred failure mode?

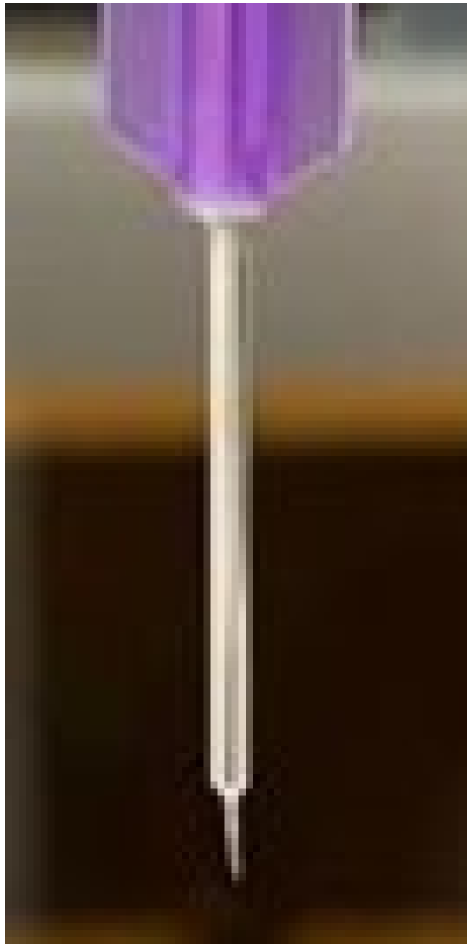
Most TIMs are multi-taskers.

Thermal conductivity is almost always a product of compromise to achieve other important properties.

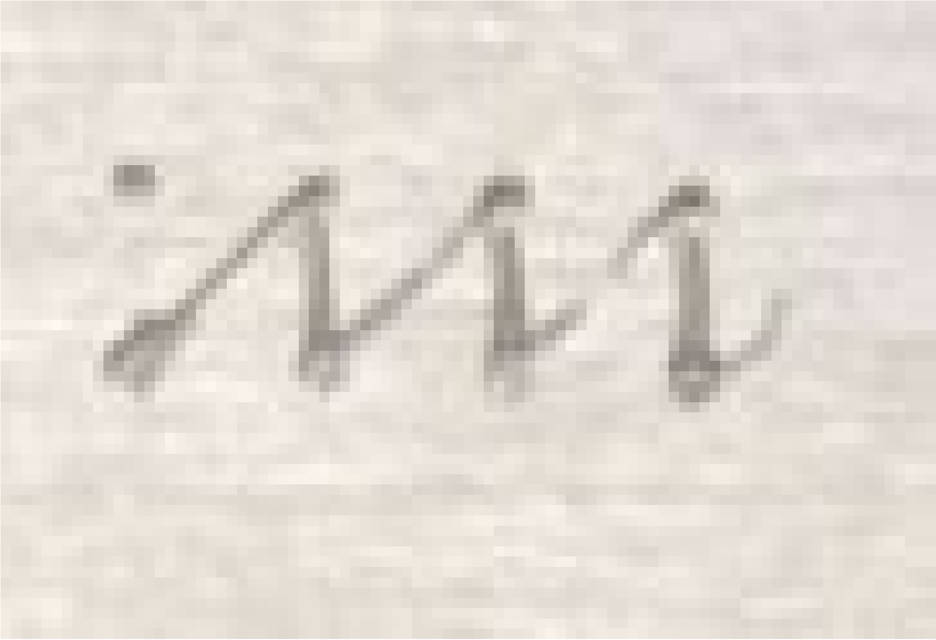
Balancing interactions and process requirements



Rheology - Dispensing



Viscosity and thixotropy are important in determining dispensability. Excessive pressures and tailing issues (left) must be avoided.



Manipulating rheology

Formulation ID	100	101	102
Metal Flake	91.81	91.93	89.91
Epoxy Resin	5.24	5.25	6.56
Additives	2.75	2.75	3.41
Catayst A	0.21		
Catalyst B		0.08	0.10
Resisitivity (mΩ-cm)	238	54	87
Viscosity 5rpm (Pa*s)	138	194	91
Viscosity 50rpm (Pa*s)	80	115	48
Thixotropic Index	1.73	1.69	1.90

Sometimes, a change of one raw material in a formulation can open new opportunities to solve multiple issues.

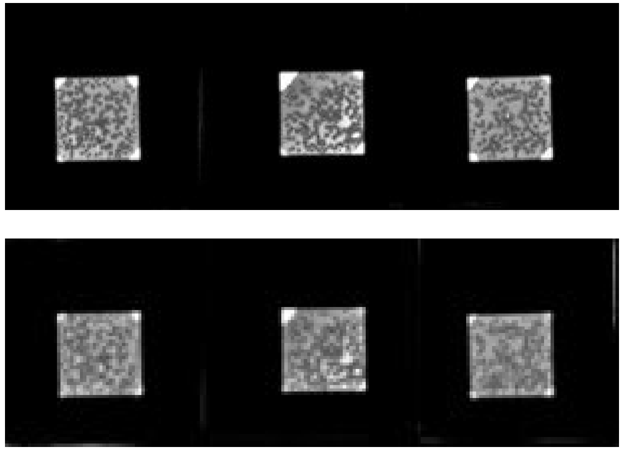
Here, a change in catalyst lowered resistivity, but increased viscosity.

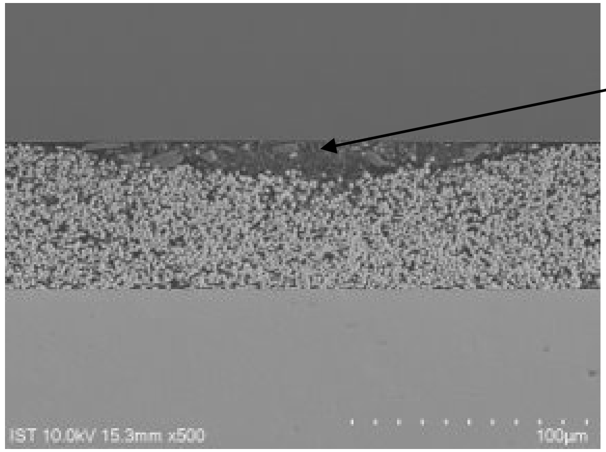
Fortunately, the improved resistivity allowed a reduction in metal loading which improved both viscosity and thixotropy.

Investigating defects

Initial

Post Reliabilty Testing

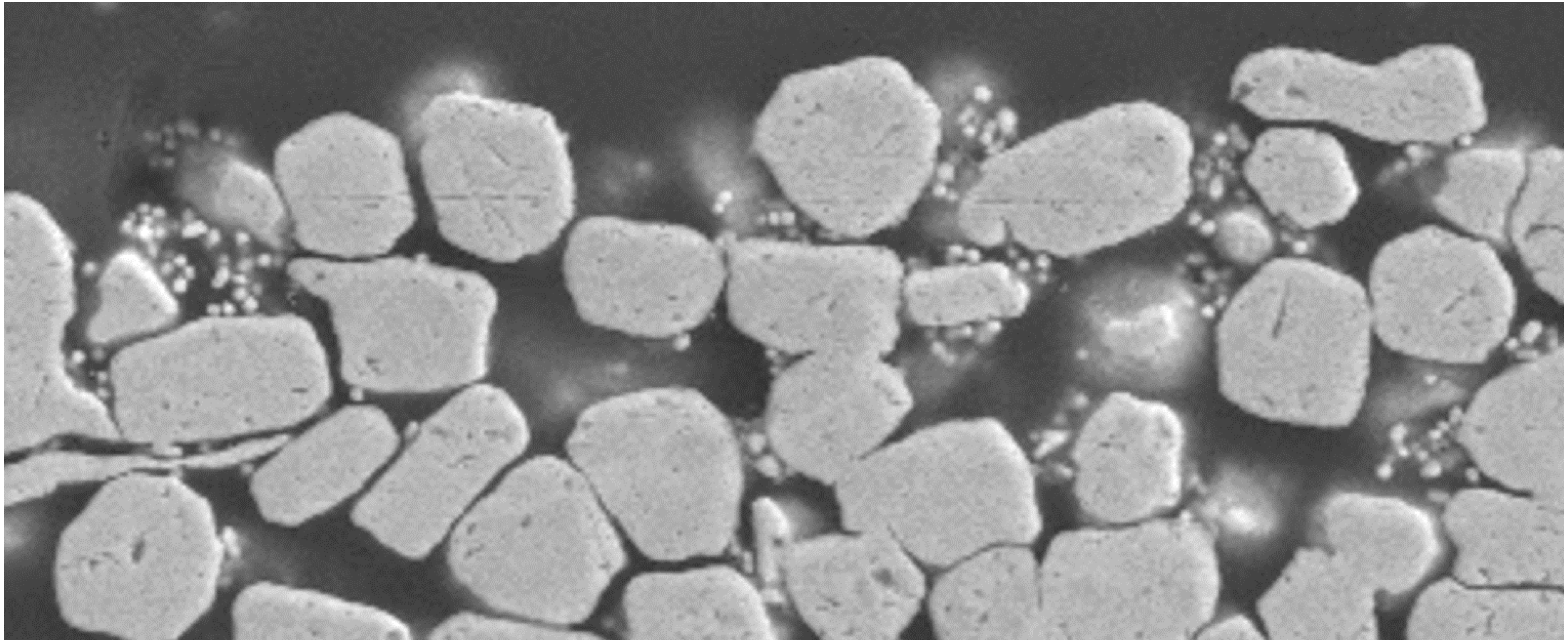




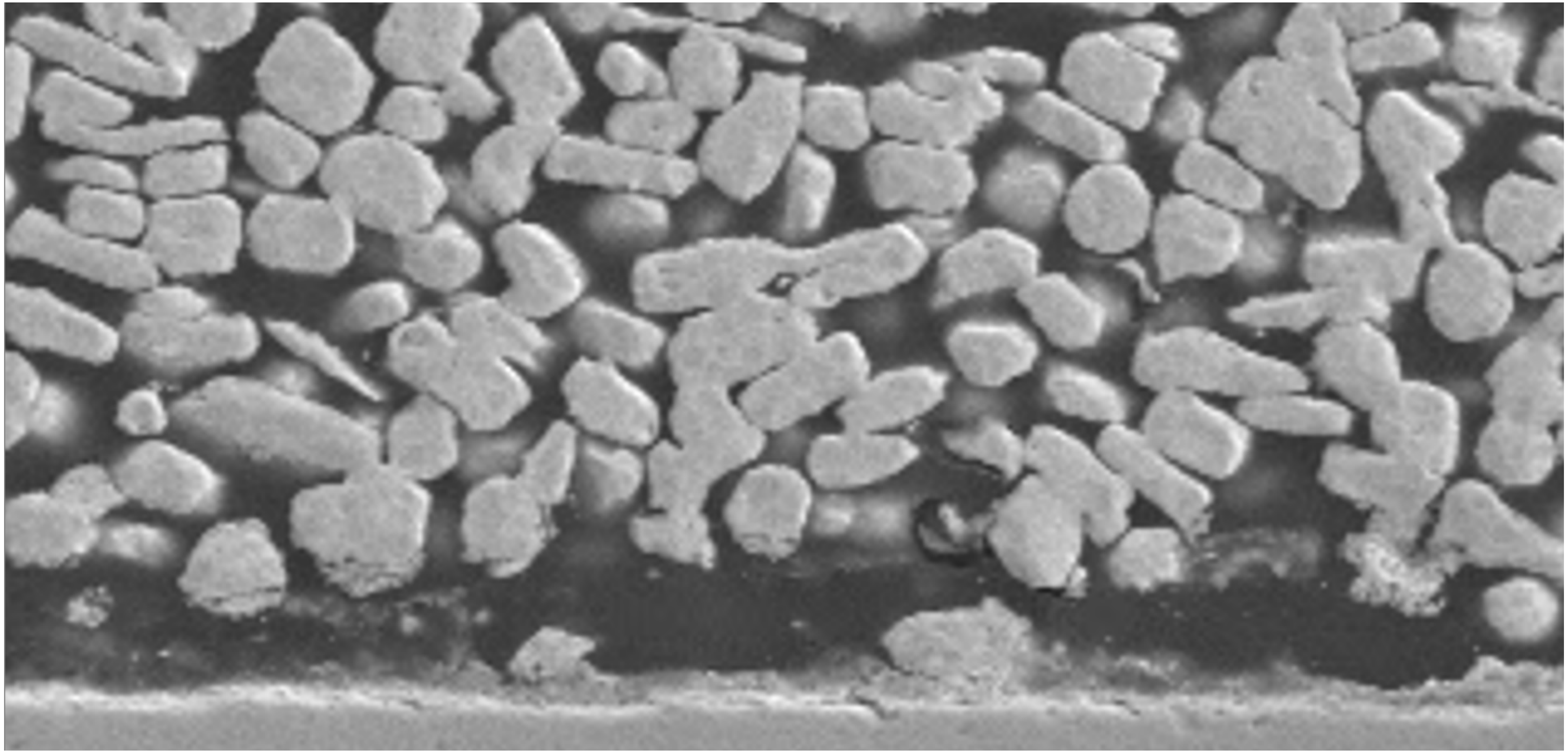
Resin rich areas reflect similar to voids, but maintain adhesion

Testing hypotheses

Example
Hypothesis - Addition of small metal particles will fill interstices and improve conductivity.
Finding – No improvement. Why not?



It’s about the interfaces



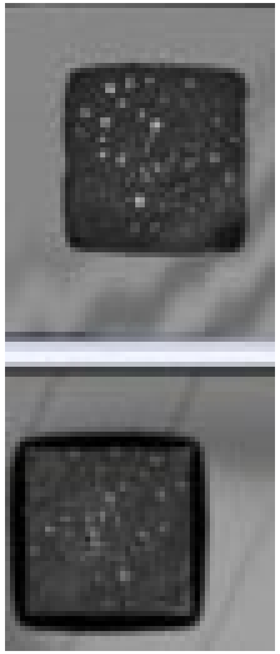
Transient thermal analysis with structure functions

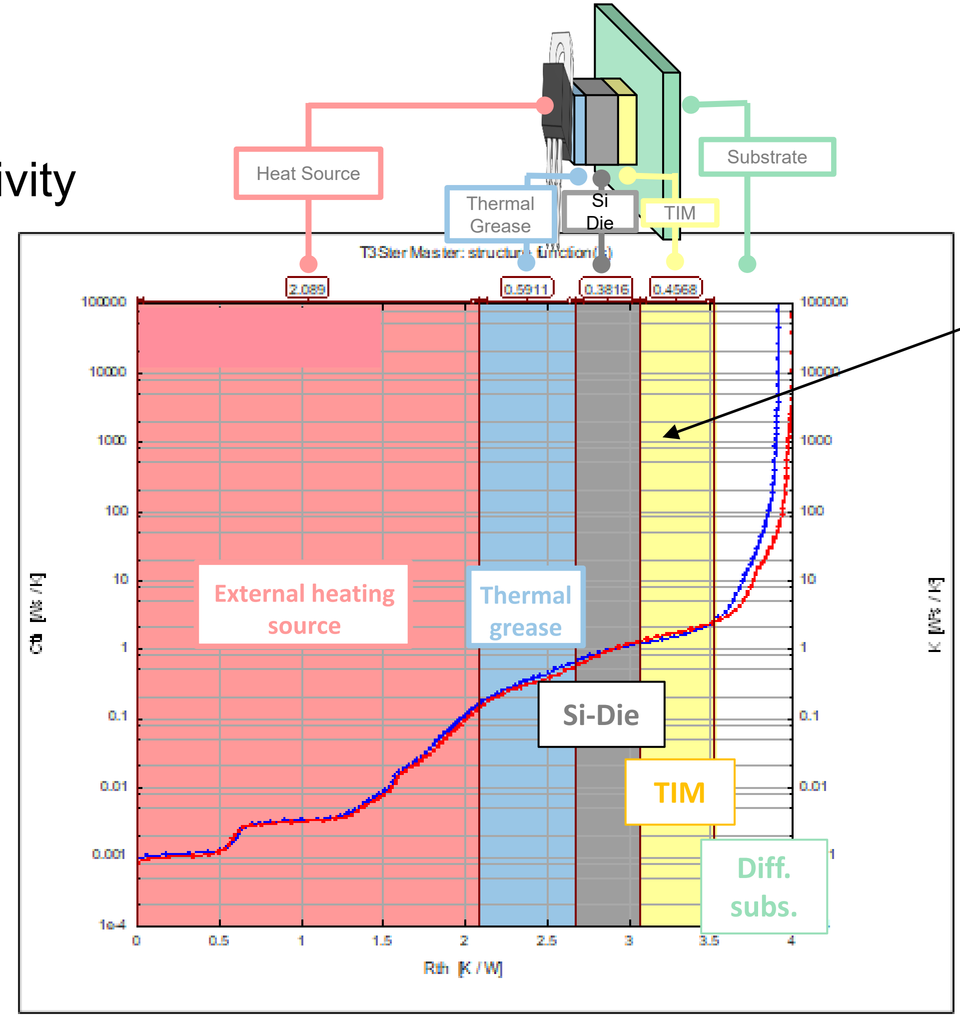
TC by hot disk = 8-9W/mK
150-250μm thickness
Agrees with estimate based on electrical conductivity

SAT

TIM/Substrate

Si-die/TIM





TIM Thickness = 80μm
TC = 1.75W/mK

Conclusions and acknowledgements

Thermal Interface Materials are multi-taskers.

It is almost always impossible to adjust a formulation to improve one property without impacting several others.

Test hypotheses. Maximize learning.

Have the right tools. Know what will happen to your material in the hands of your customer.

Our Team – Angel Lee, Ivan Chen, Dean Yang, Vincent Yeh, Bruce Carter, Shufang Yu, Yuji Saga

Celanese

MICROMAX™

Micromax™ is a leading brand of printable, stretchable, and moldable functional thick film inks, pastes and ceramic tapes. Micromax™ brand products are utilized for circuitry, interconnection and packaging of electronic devices in automotive, passive components, telecom, consumer electronics, healthcare and military applications featuring properties such as enhanced circuit density, improved thermal management, higher reliability and other critical functionality. Micromax™ represents over 60 years of experience in the development, manufacture and sale of specialized electronic materials, and offers leading global customer support and product quality and consistency.