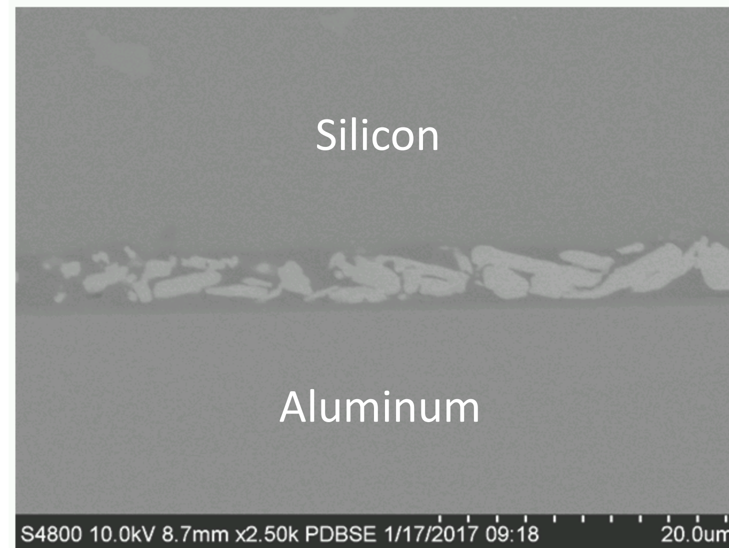
Thermoplastic Polyimide (TPI) Bondlines for RF Packaging



IMAPS RF Symposium

May 2019

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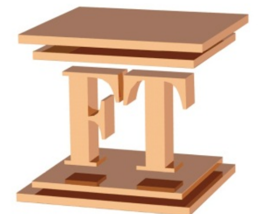
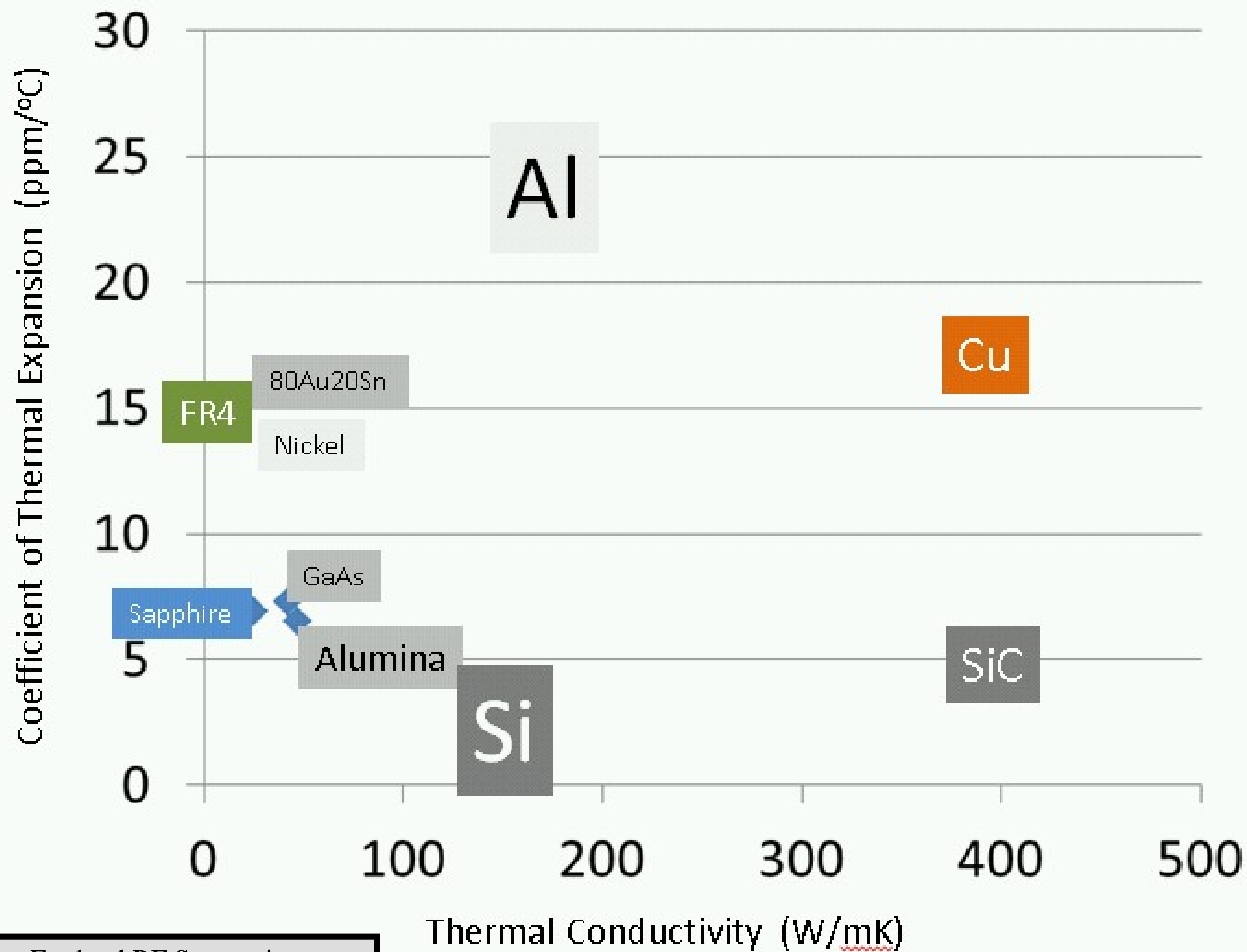
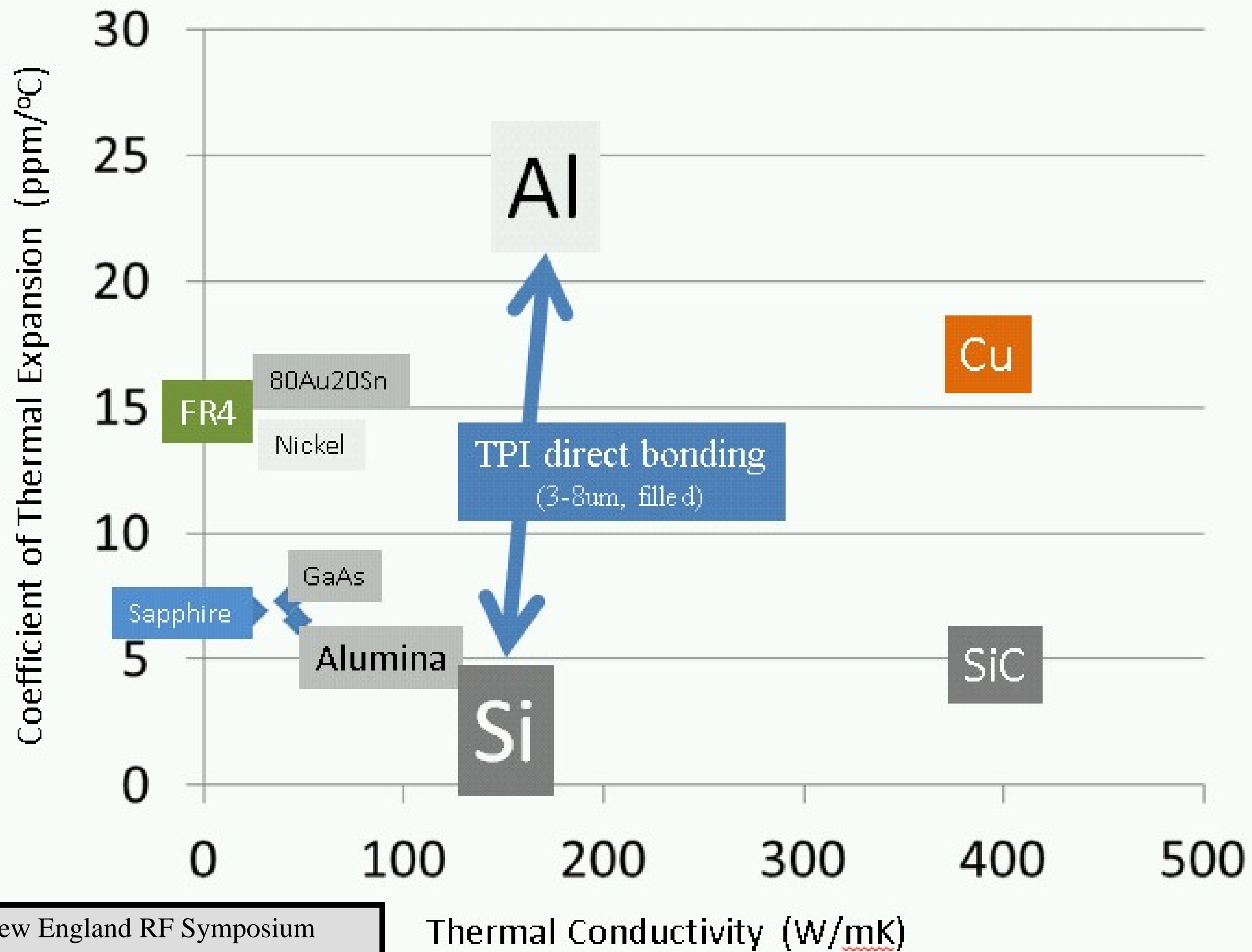
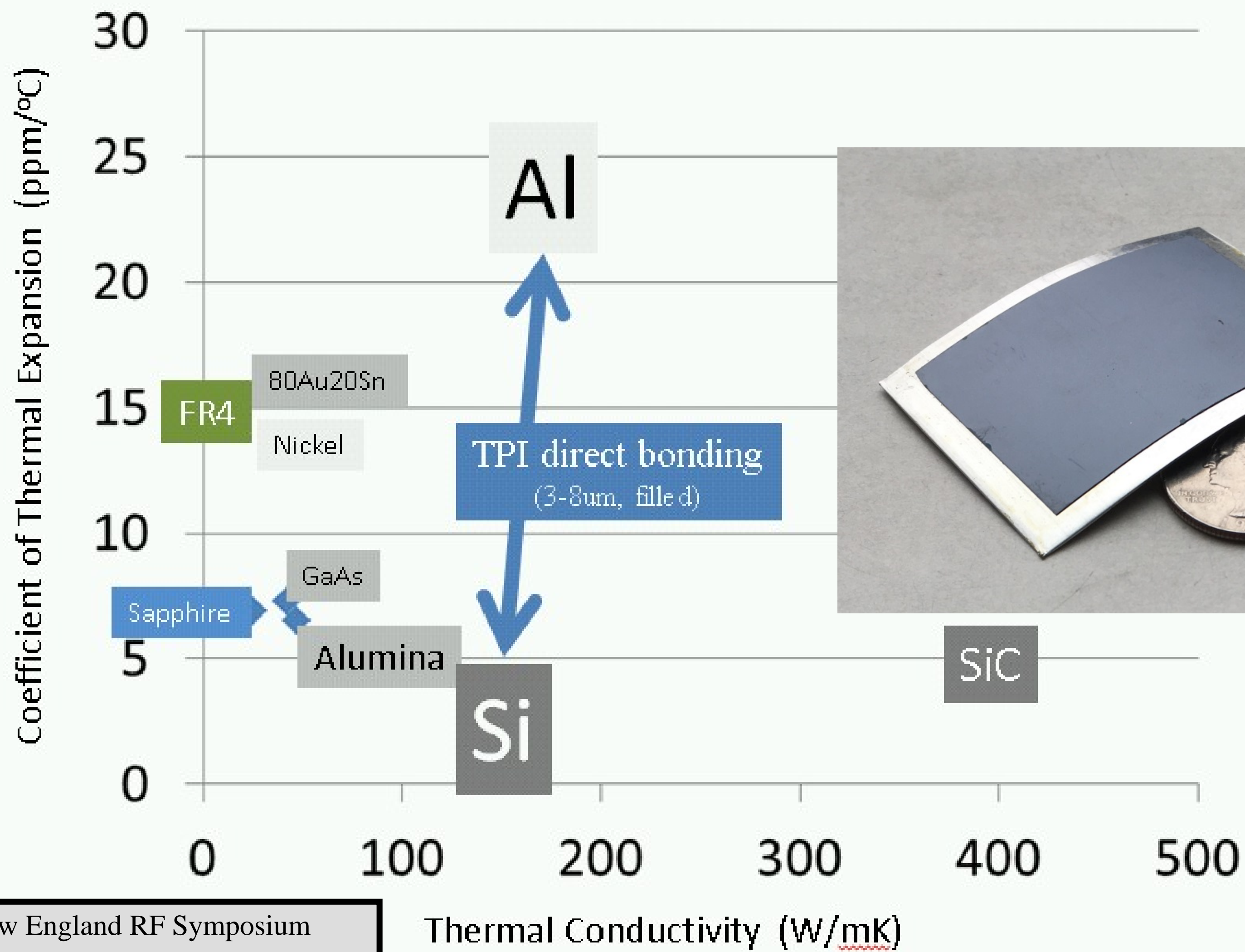


TPI Bondline Overview

- Bonds semiconductors, ceramic, metals and plastics
- Bondline thickness: 3-8um+ (depends on surface roughness)
- High loading is possible:
  -- Silver flake (electrically conducting) – up to 85%-by-wt
  -- BN platelets (electrically insulating) – up to 40%-by-wt
- Fast thermoplastic bonding at 250°C
- High shear strength that withstands severe CTE-mismatch and extreme repeated thermal shocks (300°C in seconds)


PACKAGING MATERIAL: CTE vs THERMAL CONDUCTIVITY
Coefficient of Thermal Expansion (ppm/ºC)
Thermal Conductivity (W/mK)
30
25
20
15
10
5
0
0
100
200
300
400
500
Al
Cu
80Au20Sn
FR4
Nickel
GaAs
Sapphire
Alumina
Si
SiC


PACKAGING MATERIAL: CTE vs THERMAL CONDUCTIVITY
Coefficient of Thermal Expansion (ppm/ºC)
30
25
20
15
10
5
0
Al
Cu
80Au20Sn
FR4
Nickel
TPI direct bonding
(3-8um, filled)
GaAs
Sapphire
Alumina
Si
SiC
0
100
200
300
400
500
Thermal Conductivity (W/mK)



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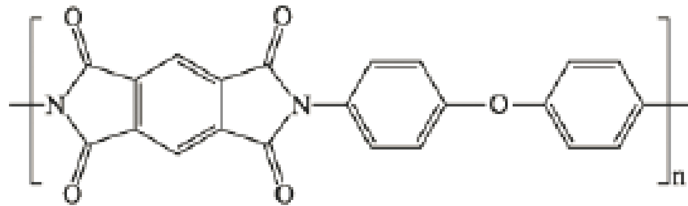
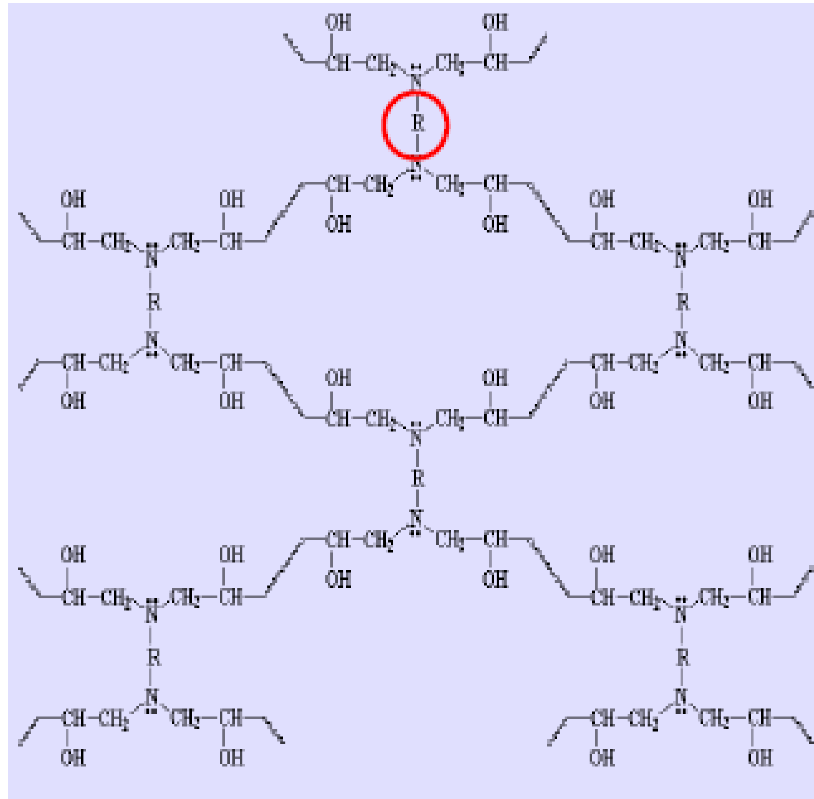
Polyimide –vs– Epoxy

Straight-chain, 'rigid-rod' polymer

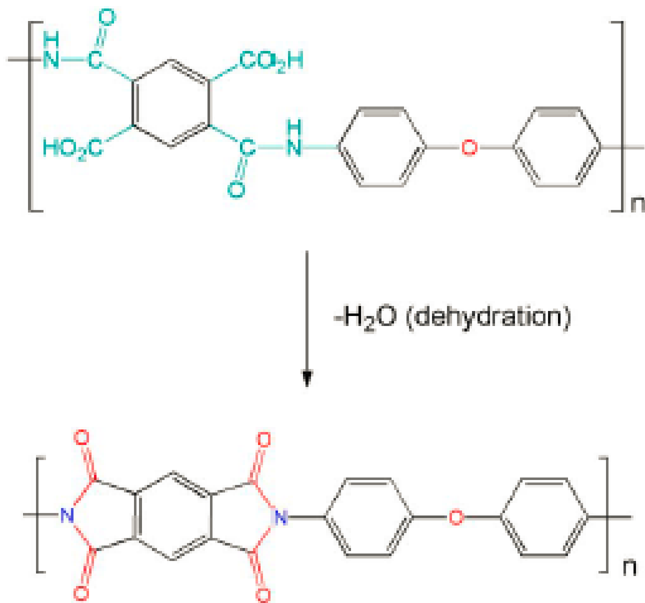


[*Kapton® chemistry*]

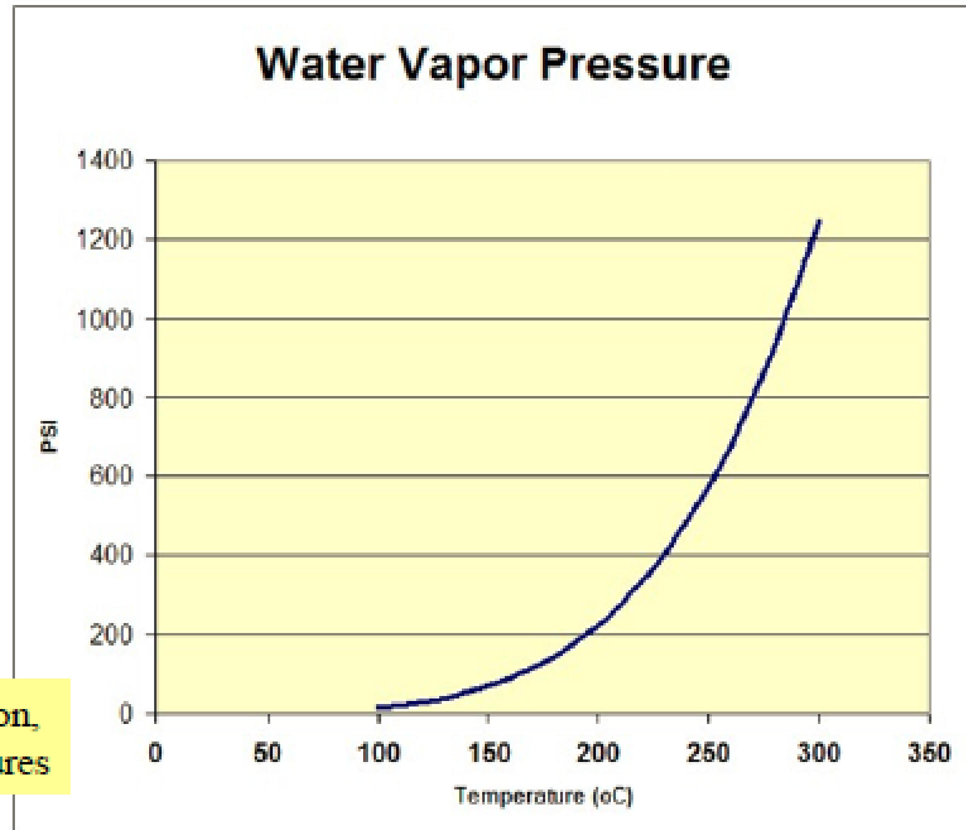
Extensive polymer cross-linking



Key to TPI Lamination:
Management of water-outgassing with polymer-curing



Condensation reaction, at elevated temperatures



TPI Formats

Liquid / A-staged: Polyamic-acid polymer precursor in NMP solvent, with and without inorganic loading.

- Apply with any coating method
- Newtonian in spin-coating semiconductor wafer

Dry coating / B-staged: Stable partially-cured TPI coating on substrate surface, ready for bonding. Laminate with:

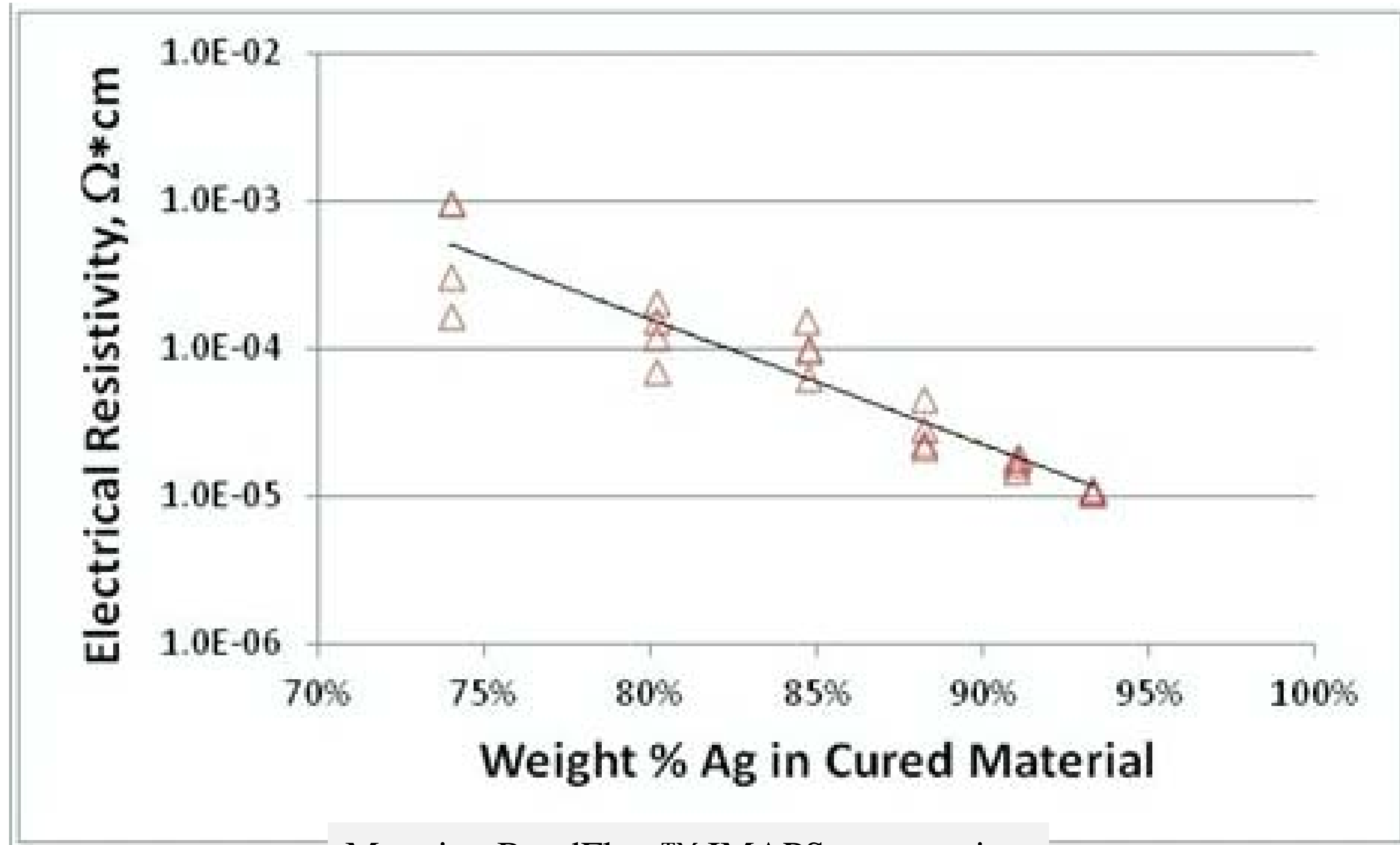
- Thermocompression (automation for die-attach, TIM1)
- Conventional heat+pressure methods -- such as platen press, vacuum-autoclave, or hot plate with dead weight, or oven with binder clips, etc. (TIM2, TIM3)

TPI Bondline Properties

- Shear strength: 4000 psi, with optimal bonding
- Bondline thickness: 3-8um+ (depends on surface roughness)
- Thermal conductivity:*
  Silver flake (80%-by-wt) – 3 W/mK
  BN platelets (40%-by-wt) – 1 W/mK
- Thermal impedance (D5470; 80% Ag/3um): **0.002 $^oC\text{-}in^2/W$**
  $<$ 0.04 $^oC\text{-}in^2/W$ is considered 'Good' (*20X!*)
- Dielectric strength (BN-filled): 140 Vdc/um (*theoretical limit: 300 Vdc/um*)
- Electrical conductivity (Ag-filled) – consistent with other polymers (see following chart)

** Laser-flash tests run on artificially-thick, multiple-coating TPI bondlines.*

TPI Electrical Conductivity vs. Silver Loading



Materion BondFlow™ IMAPS presentation

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In addition, TPI bondlines are ultra-thin.

TPI Processing

- Small footprints (die) – automated thermocompression needs higher pressure for ultra-thin coatings (3-4um) with high loadings (Ag80%) … no outgassing issues with small rigid surfaces, bonds in second(s).

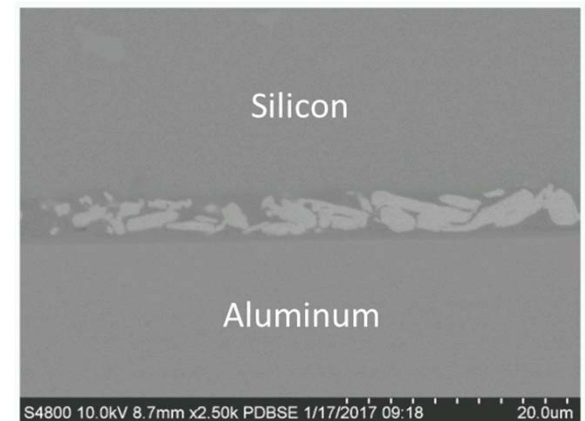
- Larger footprints (submounts, baseplates)
  -- Gradual heat-up to assist outgassing
  -- If low-pressure bonding (< 50 psi), bondline 6-8um+

TPI CONSTANT: Enable inevitable outgassing!
PAA => PI + **H_2O at 250°C**

Conclusions

- TPI adhesive bonds a wide range of electronic materials, even severely CTE-mismatched substrates.
- Bondline can withstand extreme conditions, including thermal shocks.
- TPI allows a high loading of flat inorganic particles (Ag or BN).
- Ultra-thin bondline enables very low thermal impedance, down to **0.002 ^{o}C-in^{2}/W** (80% Ag, 3um), as well as high electrical conductivity.
- Simple fast thermoplastic bonding, in seconds for B-staged die-attachment.

Bondline 'bottom line'…



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