Analyzing & Testing

NETZSCH

Leading Thermal Analysis

Thermal Resistance and Effective Thermal Conductivity Measurements of Thermal Grease Using the Flash Diffusivity Method

- IMAPS New England Symposium 2018

Introduction

- Reliable performance measurements of thermal grease and other thermal interface materials used in electronics packaging are important for material selection and design validation.
- With thin layers typically 10’s of microns, measurements can be difficult with various steady-state thermal conductivity methods.
- Utilizing multilayer analysis and special sample holders, the flash diffusivity method is well-suited to measurements of interfacial resistance and effective thermal conductivity of thin interfaces.
- Materials including grease, phase-change, filled epoxy, filled elastomeric pads can be tested in a “sandwich” configuration.

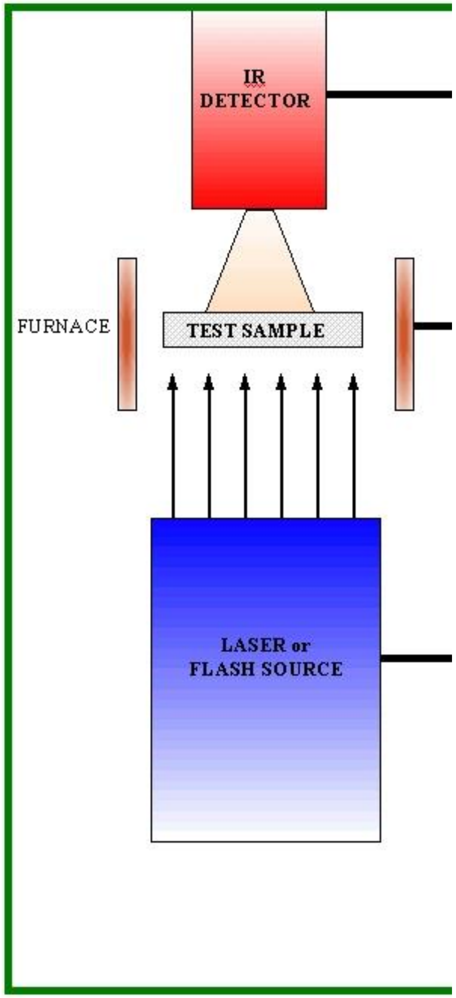
Method - Introduction

Flash Diffusivity Method:
Measurement Principle Introduced by Parker et al. 1961

Thermal diffusivity is a measure of how quickly a material can change its temperature

The front surface of a plane-parallel sample is heated by a single short light or laser pulse.

The temperature rise on the rear surface is measured versus time using an IR detector.

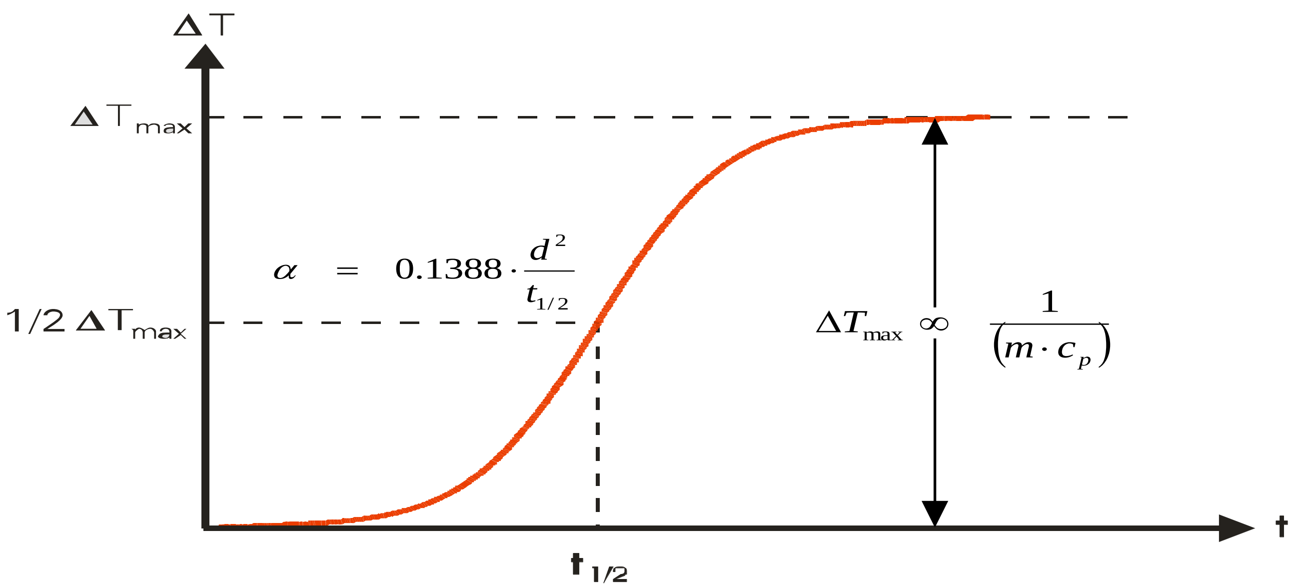


Method - Introduction

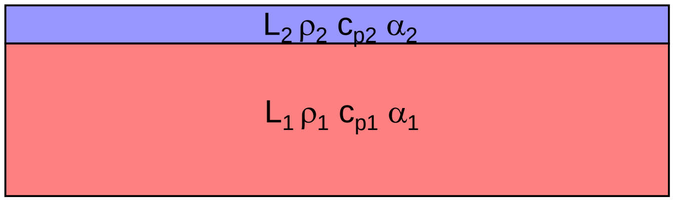
Thermal conductivity can be derived by combining measurements of thermal diffusivity, specific heat and density

$$\lambda(T) = \alpha(T) \cdot c_p(T) \cdot \rho(T)$$

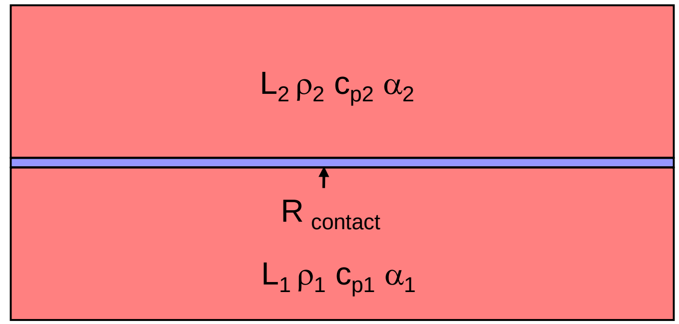
for adiabatic case (Parker formula):



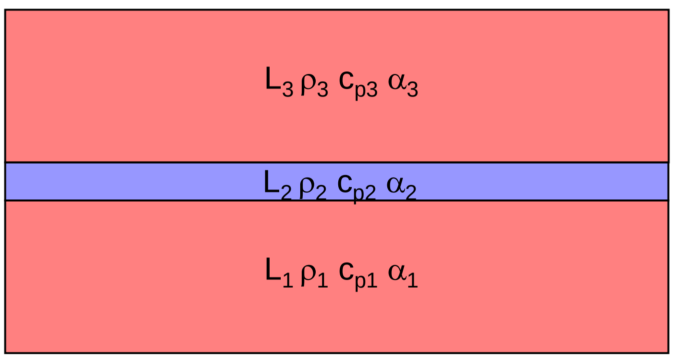
Flash Diffusivity – 2 and 3 Layer Models



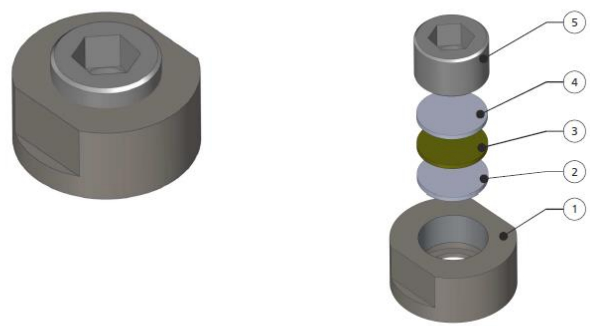
2 layer: film on substrate



2 layer: contact resistance

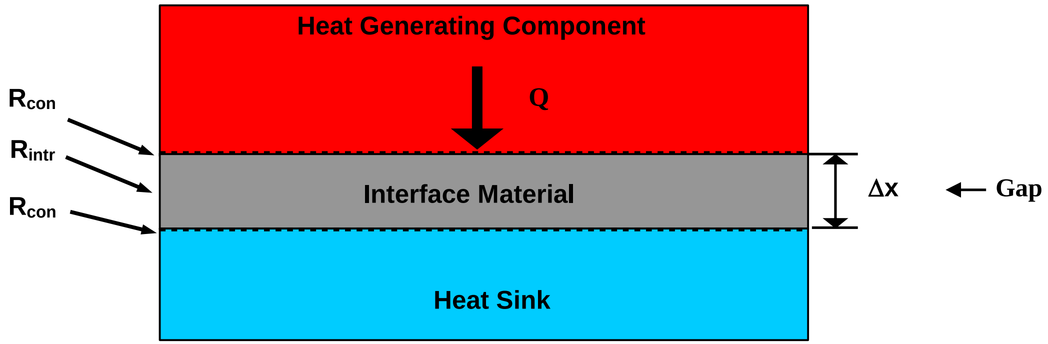


3 layer: film – substrate sandwich



sample holder for application of clamping pressure

Thermal Interface Materials – Sandwich Method



$$R_{th} = \frac{\Delta T \times A}{Q}$$

$$R_{tot} = R_{intr} + 2(R_{con}) = \frac{\Delta x}{\lambda} + 2(R_{con})$$

$$R_{con} = \frac{\Delta T_{int} \times A}{Q}$$

➡ measure and plot R_{tot} vs Δx to determine $2(R_{con})$ and bulk λ

R_{th} thermal resistance (mm^2-K/W)
ΔT temperature difference (K)
Q heat flow (W)
A area (mm^2)
R_{con} contact thermal resistance (mm^2-K/W)
ΔT_{int} interface temperature difference (K)
R_{tot} total gap thermal resistance (mm^2-K/W)
λ_{eff} effective thermal conductivity (W/m-K)

$$\lambda_{eff} = \frac{\Delta x}{R_{tot}} = \frac{\Delta x}{\frac{\Delta x}{\lambda} + 2(R_{con})}$$

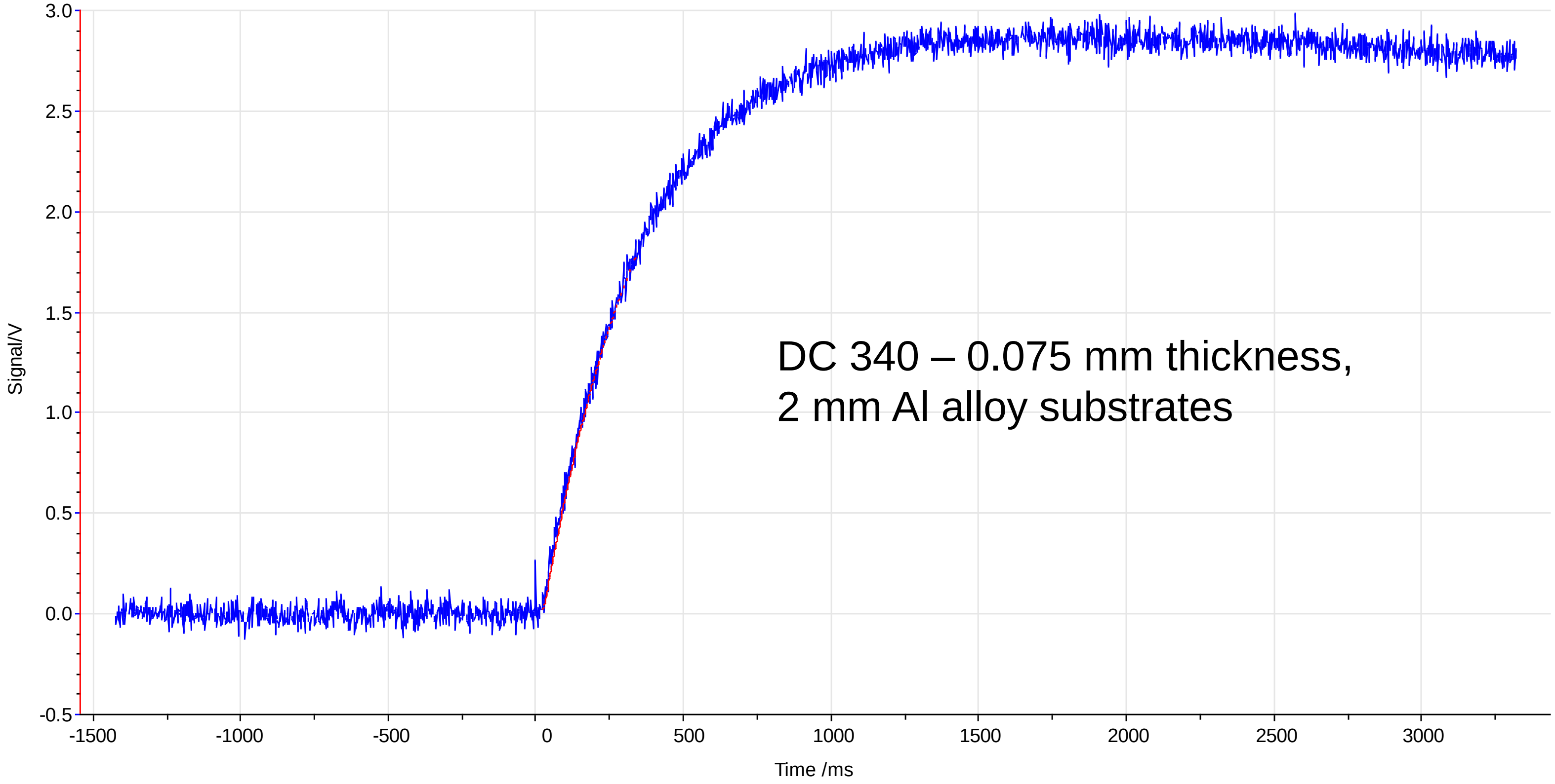
Experimental – 3 layer sandwich thermal diffusivity measurements

Properties at 25°C

		ρ (g/cm^3)	c_p (J/g-K)	λ (W/m-K)
Dow Corning® 340	silicone based, ZnO filler	2.10	0.80	0.67 (datasheet)
Arctic Silver® 5	non-silicone, Ag, Al_2O_3 and BN fillers	4.05	0.60	n.a.
Al alloy substrates	12.7 mm x 2 mm	2.70	0.90	139

Instrument
Netzsch LFA 467 (xenon flash source, InSb IR detector, 400 µs pulse width)

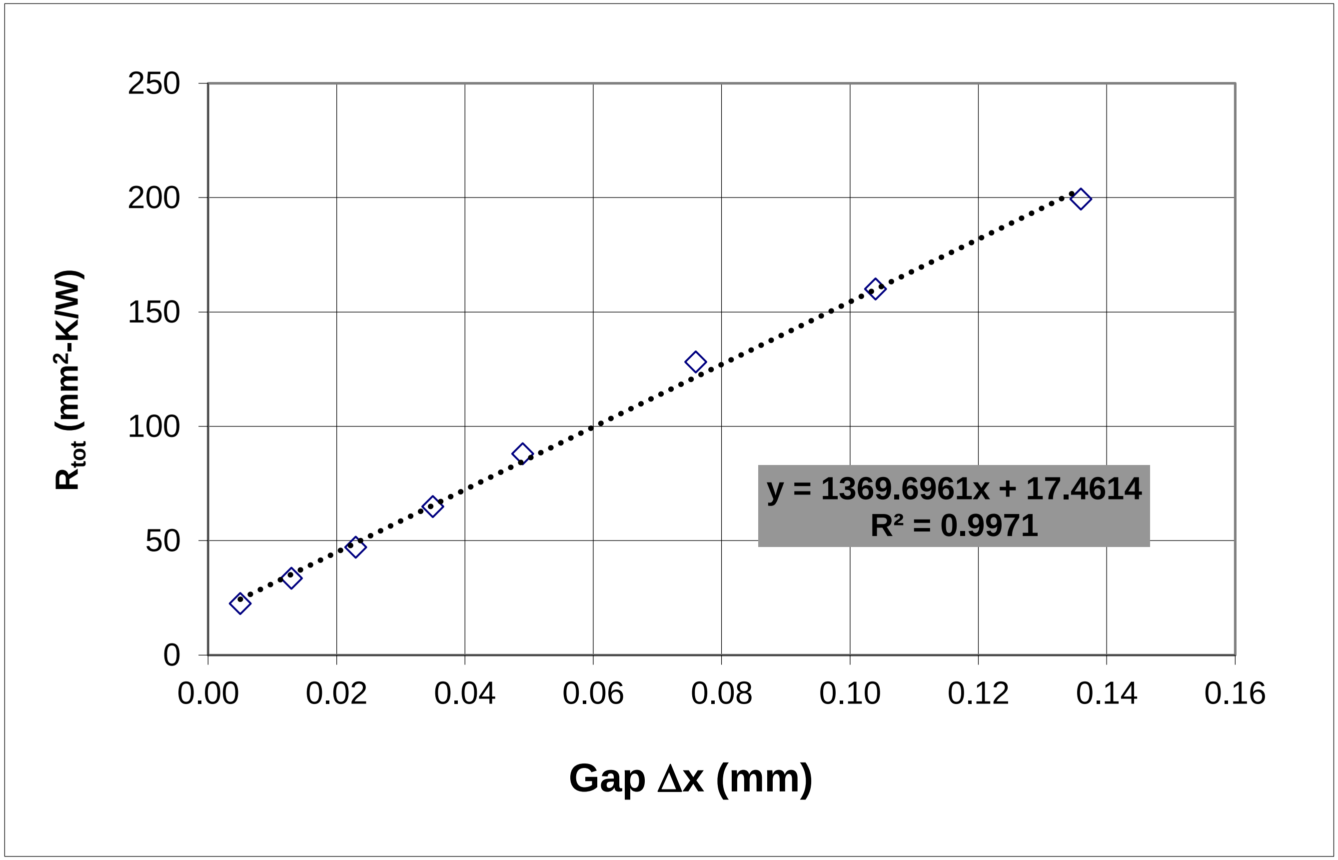
Experimental – 3 layer sandwich diffusivity measurements



Experimental – 3 layer sandwich diffusivity measurements

Dow Corning® 340

Properties at 25°C



Experimental – 3 layer sandwich diffusivity measurements

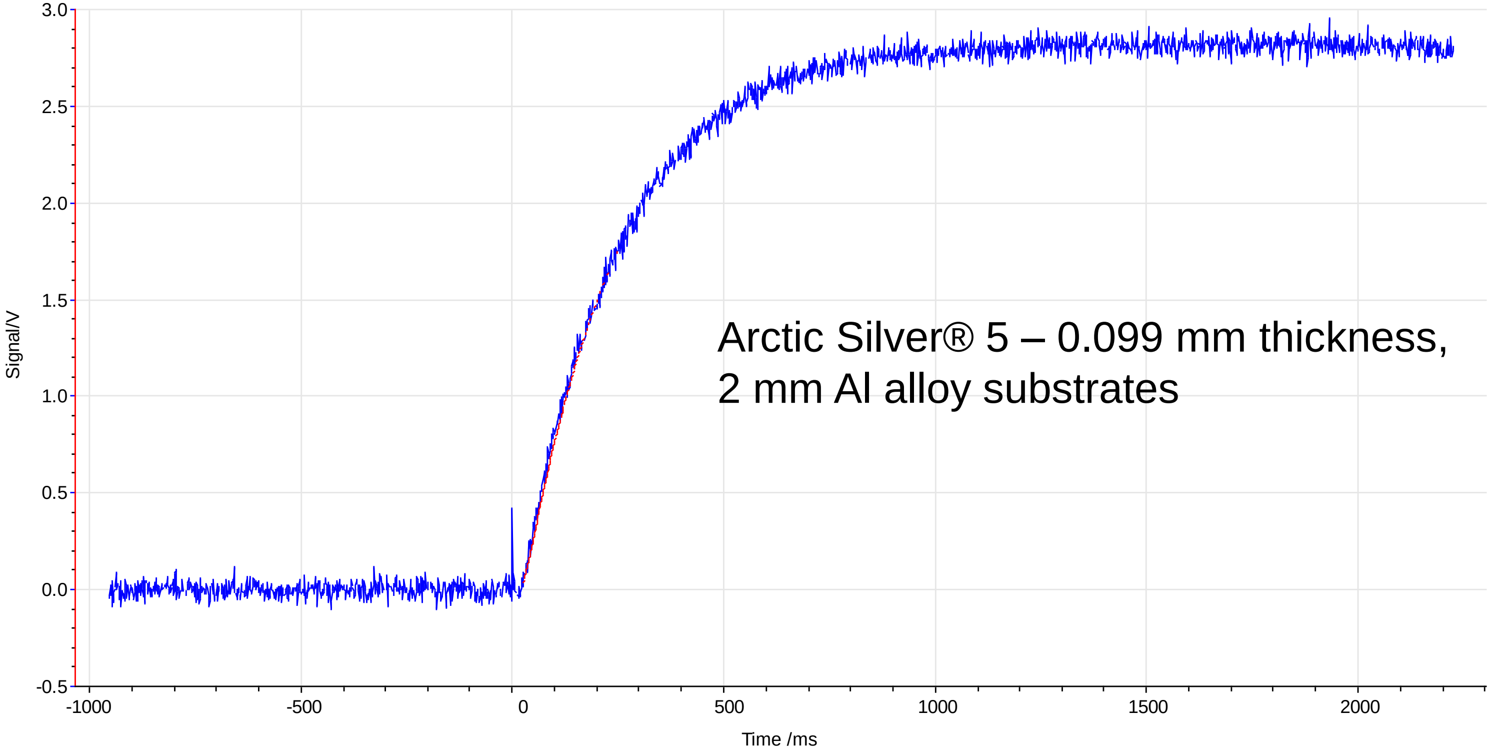
Dow Corning® 340

Properties at 25°C

Gap Δx (mm)	λ_{eff} (W/m-K)	R_{tot} (mm^2-K/W)
0.136	0.682	199
0.104	0.650	160
0.076	0.59	128
0.049	0.56	88
0.035	0.54	65
0.023	0.49	47
0.013	0.39	34
0.005	0.22	23

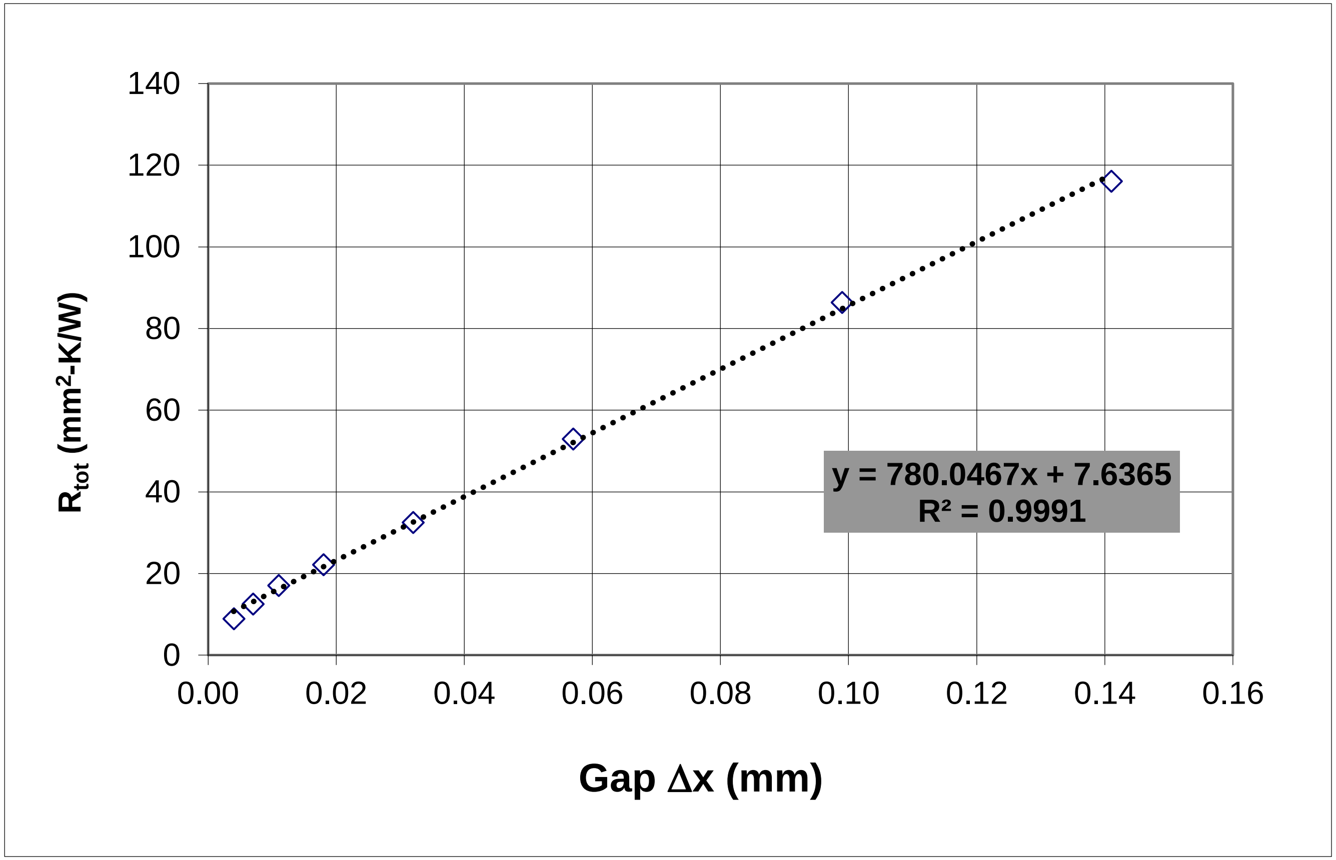
bulk λ (1/slope):	0.73	W/m-K
2(R_{con}) (y-intercept):	17.5	mm^2-K/W

Experimental – 3 layer sandwich diffusivity measurements



Experimental – 3 layer sandwich diffusivity measurements

Arctic Silver® 5
Properties at 25°C



Experimental – 3 layer sandwich diffusivity measurements

Arctic Silver® 5
Properties at 25°C

Gap Δx (mm)	λ_{eff} (W/m-K)	R_{tot} (mm^2-K/W)
0.141	1.21	116
0.099	1.15	86
0.057	1.08	53
0.032	0.98	33
0.018	0.81	22
0.011	0.64	17
0.007	0.56	13
0.004	0.45	9.0

bulk λ (1/slope):	1.28	W/m-K
2(R_{con}) (y-intercept):	7.6	mm^2-K/W

Conclusions

- The flash diffusivity method is well-suited to measurements of thermal resistance and effective thermal conductivity for thin interfacial layers.
- With three-layer “sandwich” measurements over a range of gap thickness, contact thermal resistance and bulk thermal conductivity can be estimated.
- Measurements of two commercially available thermal greases showed significant differences in bulk thermal conductivity and contact resistance.

Thank you for your attention!

NETZSCH

Robert Campbell

Applications Laboratory Manager

NETZSCH Instruments North America, LLC
129 Middlesex Turnpike
Burlington, MA 01803

Phone: +1 781 418 1803

e-mail: Robert.campbell@netzsch.com
www.netzsch-thermal-analysis.com