

Thermal Interface Material Performance Measurement

Long Win Science & Technology Co., Ltd.

www.longwin.com

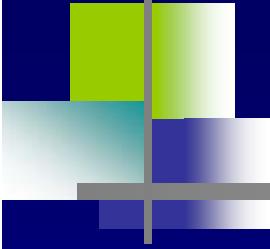
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886-3-4986875

2007/07/16

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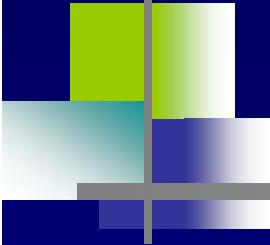
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- 1. Introduction Heat Transfer**

- 2. Thermal Conductivity Measurement**

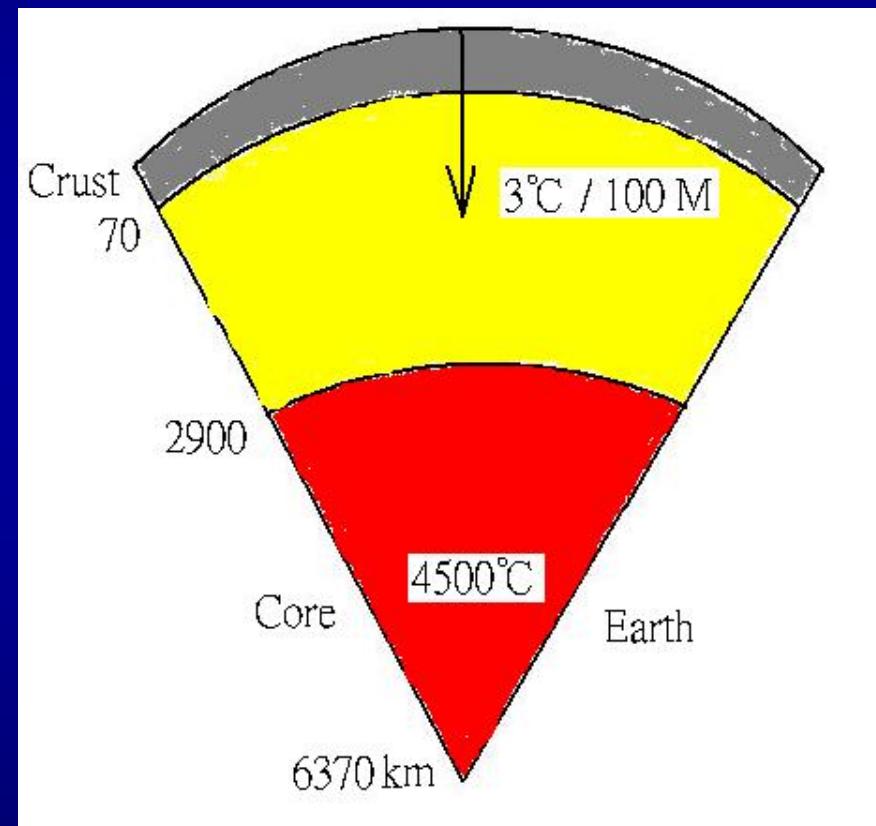
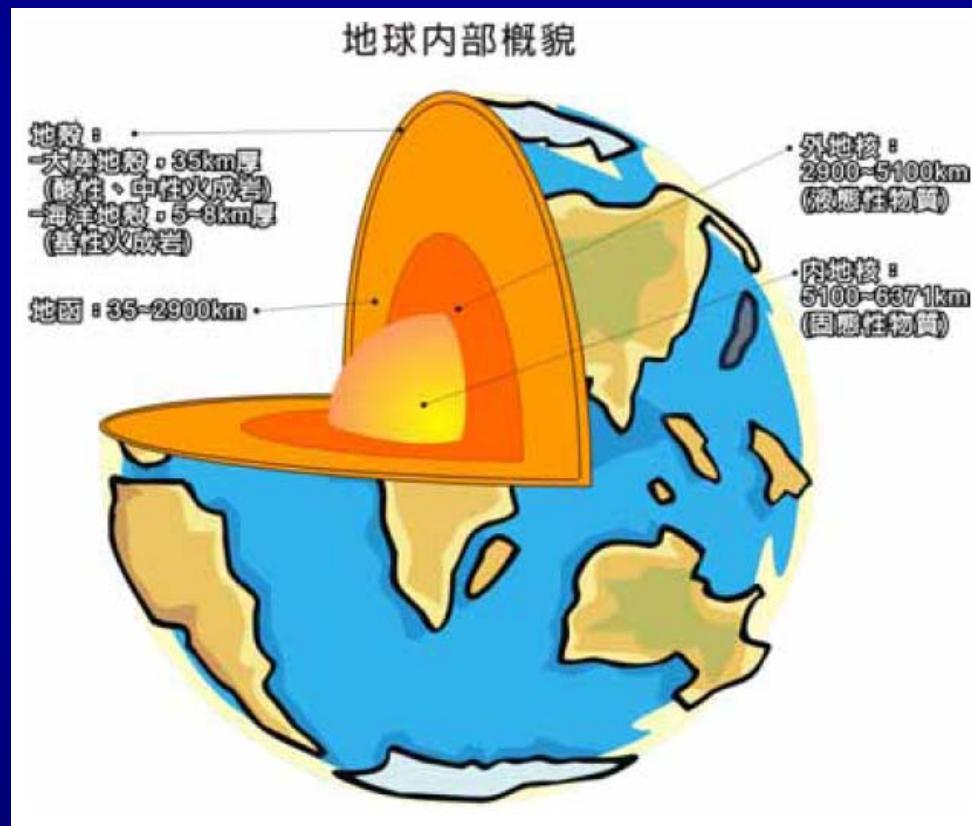
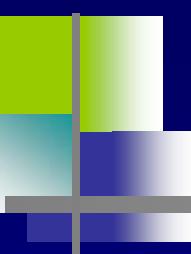
- 3. Contact Resistance**

- 4. Thermal Resistance (Impedance) Measurement**



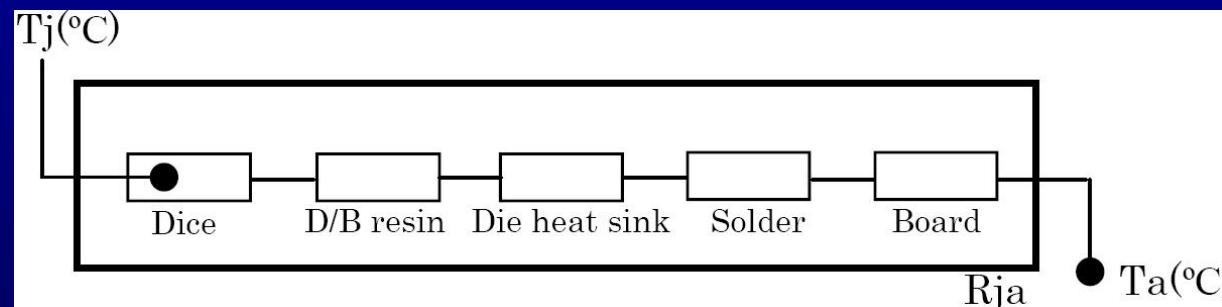
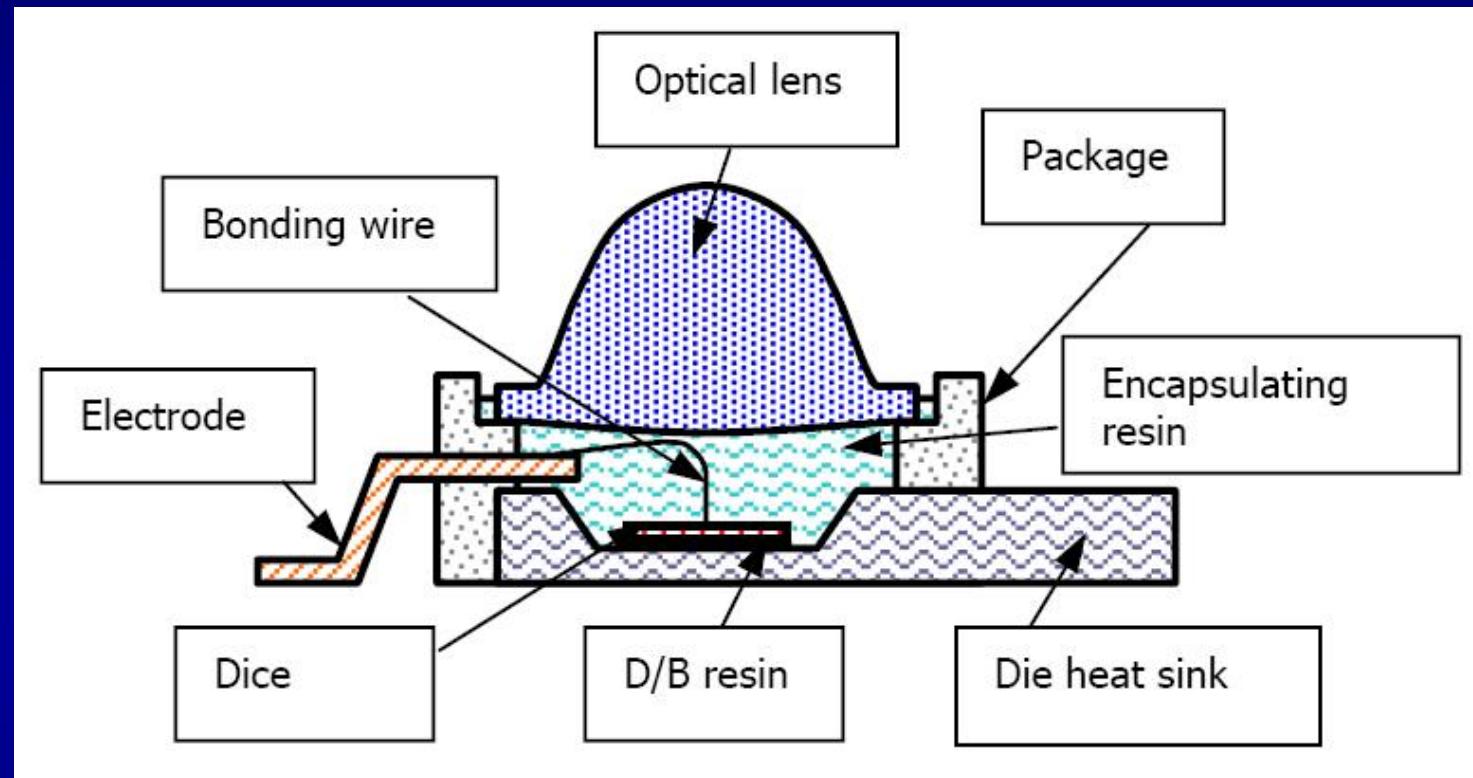
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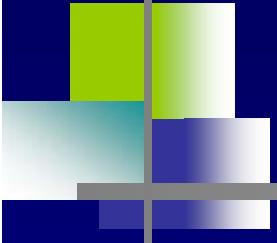
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LED Thermal Flow Path



$$R_{Ja} = \frac{T_j - T_a}{P}$$

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Heat Transfer Mechanism

A. Conduction

$$\dot{Q}_{conduction} = -kA \frac{\partial T}{\partial X}$$

B. Convection

$$\dot{Q}_{convection} = hA(T_s - T_a)$$

C. Radiation

$$\dot{Q}_{radiation} = \varepsilon\sigma A(T_s^4 - T_a^4)$$

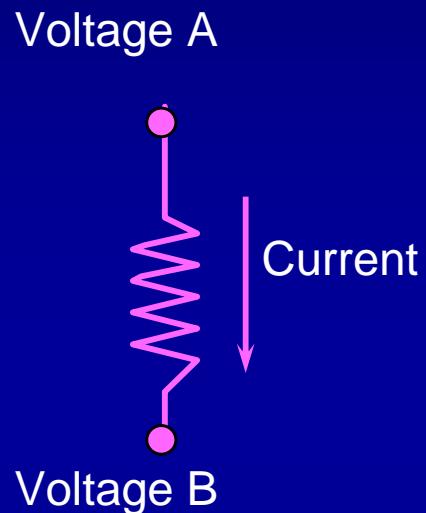
$$= \bar{h}A(T_s - T_a)$$

h (Heat Transfer Coefficient)

Type	h [w/m ² *°C]	Order
Nature convection	2~25	0
Force convection	25~250	1
Liquid force convection	50~20, 000	3
Evaporate and condense	2500~100, 000	4
Radiation		0

Thermal Resistance and Ohm's Law

Electrical Resistance

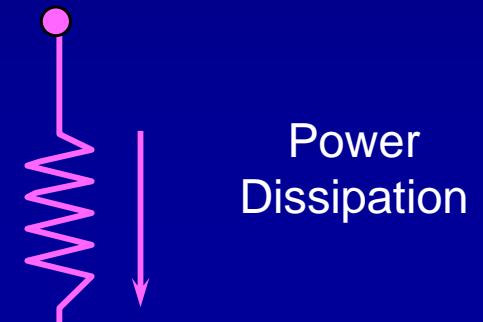


$$R = \frac{\text{Voltage A} - \text{Voltage B}}{\text{Current}}$$

Units: Ohm

Thermal Resistance

Temperature A

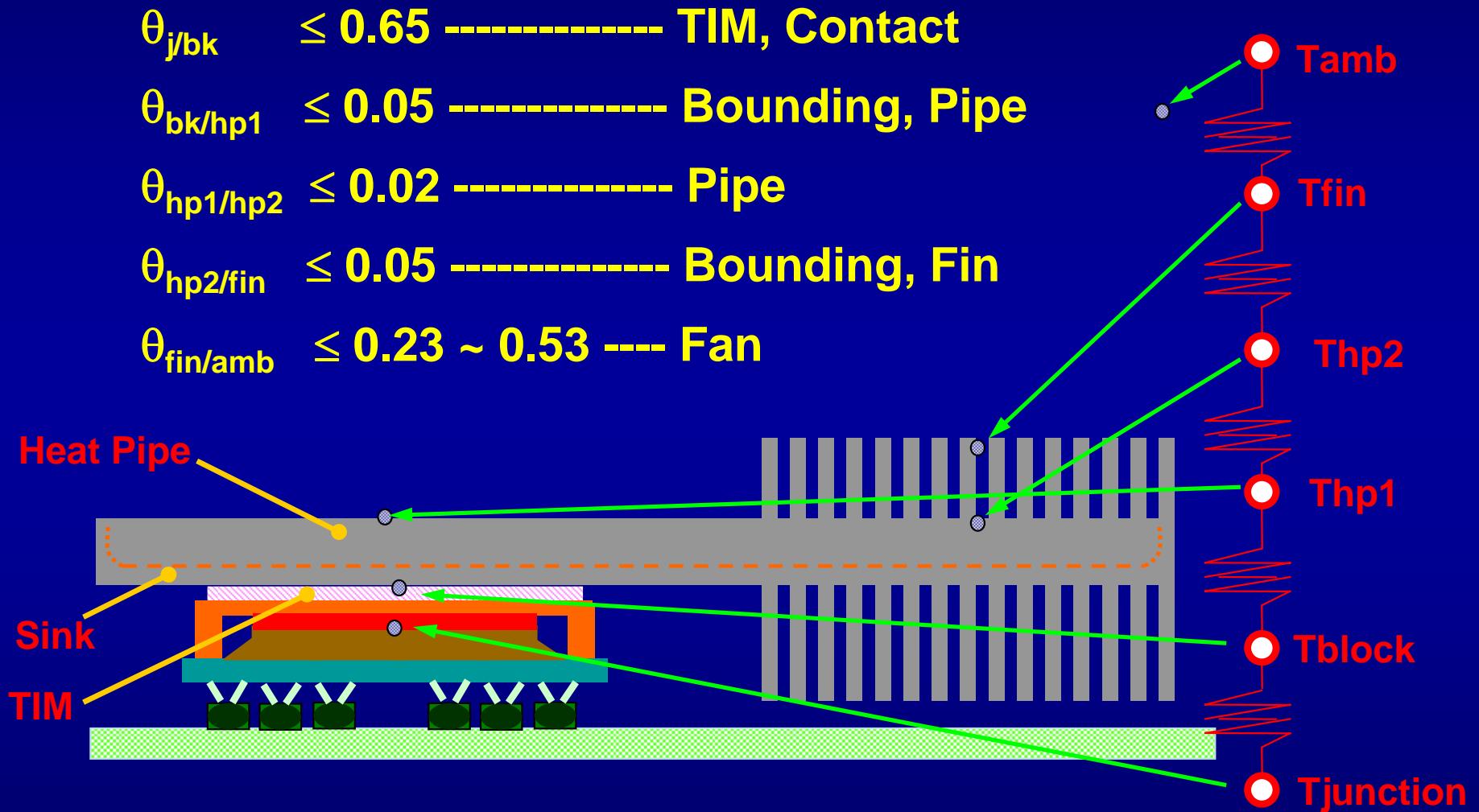


$$\theta_{AB} = \frac{\text{Temp A} - \text{Temp B}}{\text{Power Dissipation}}$$

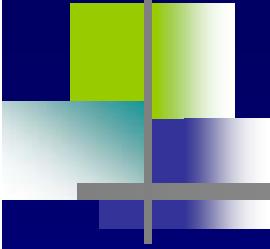
Units: °C/Watt

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Thermal resistance analysis



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Application

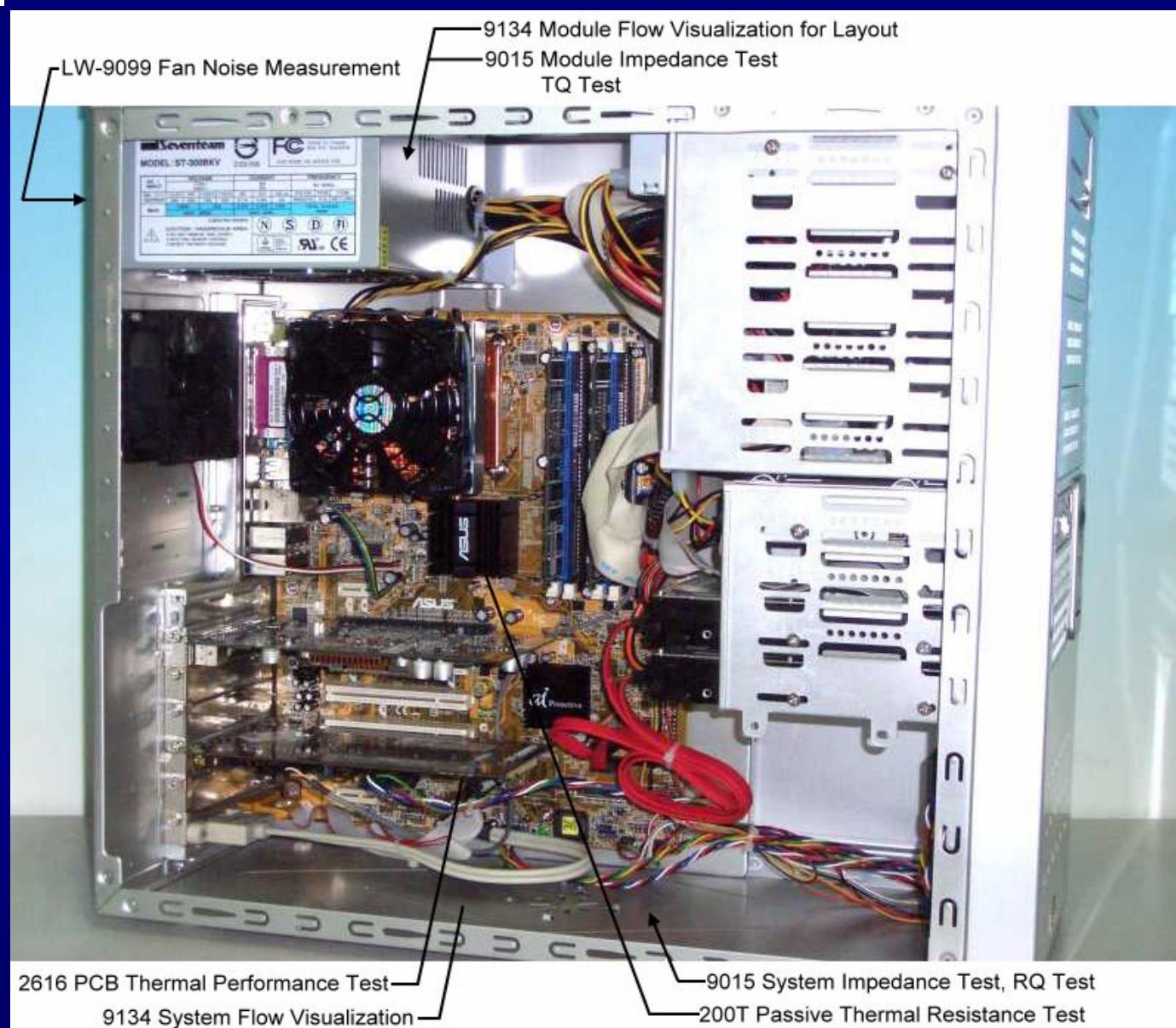
Components:

- A. Cooler
- B. Pad / Grease
- C. Power supply
- D. Interface card
- E. LED thermal module ...

System:

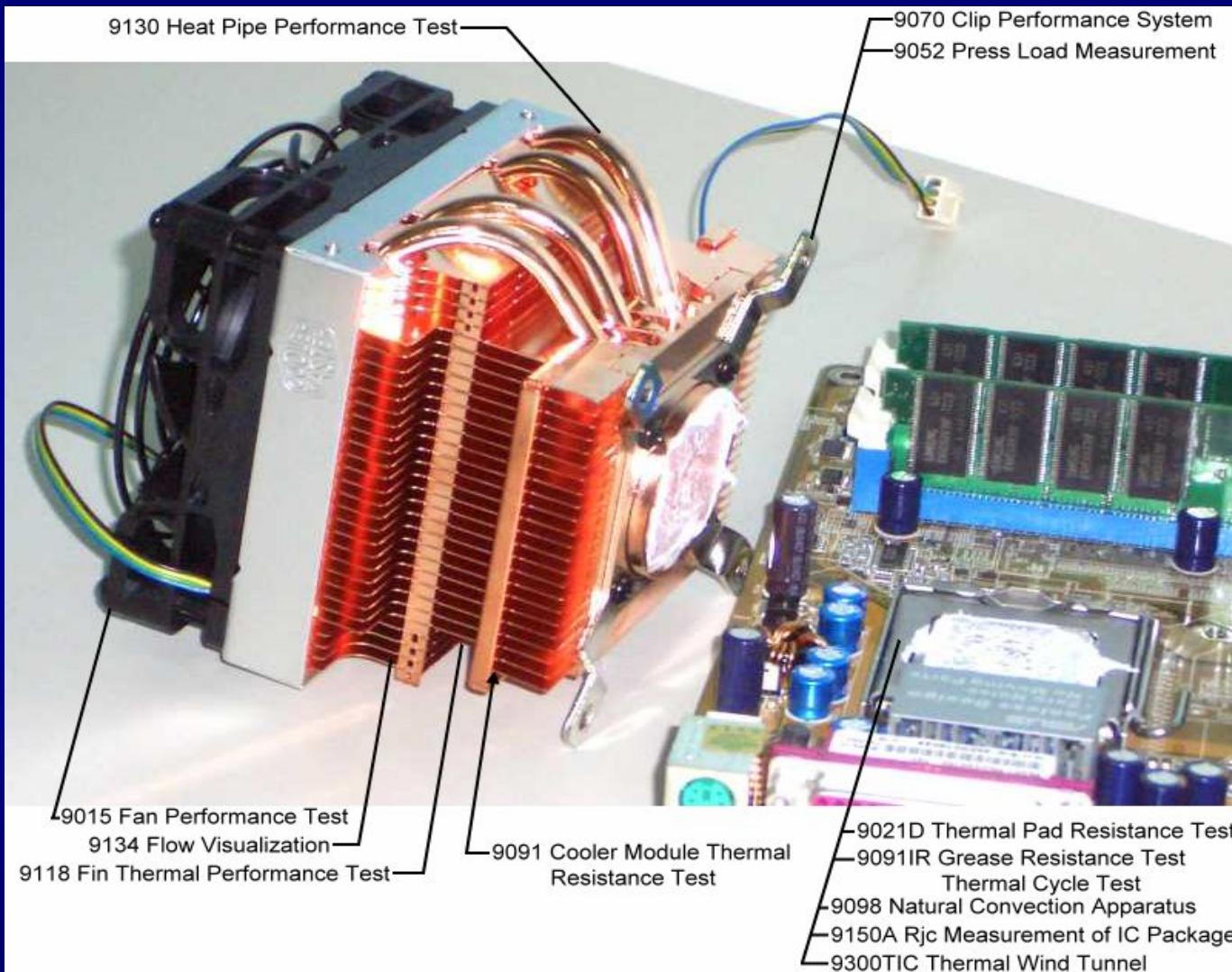
- A. D/T PC
- B. N/B PC
- C. Servo system
- D. Rack system
- E. Projector ...

Application

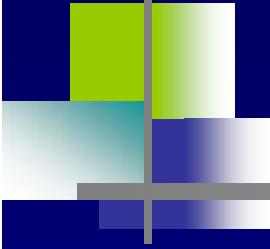


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Application



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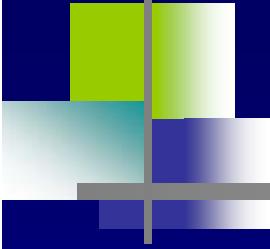


Thermal Conduction

- a. **Solid state structure,**
such as metal heat sink.

- b. **Fluid state structure,**
such as:
 - (a) heat pipe structure
 - (b) compressor coolant structure

- c. **Liquid state structure,**
such as water cooling structure.



Fourier Law

$$Q = K A \frac{T_h - T_c}{L}$$

Not Easy for **DT** & **Thickness**
Measurement

Q : transferred heat

K : thermal conduction coefficient of solid state zone
of substance

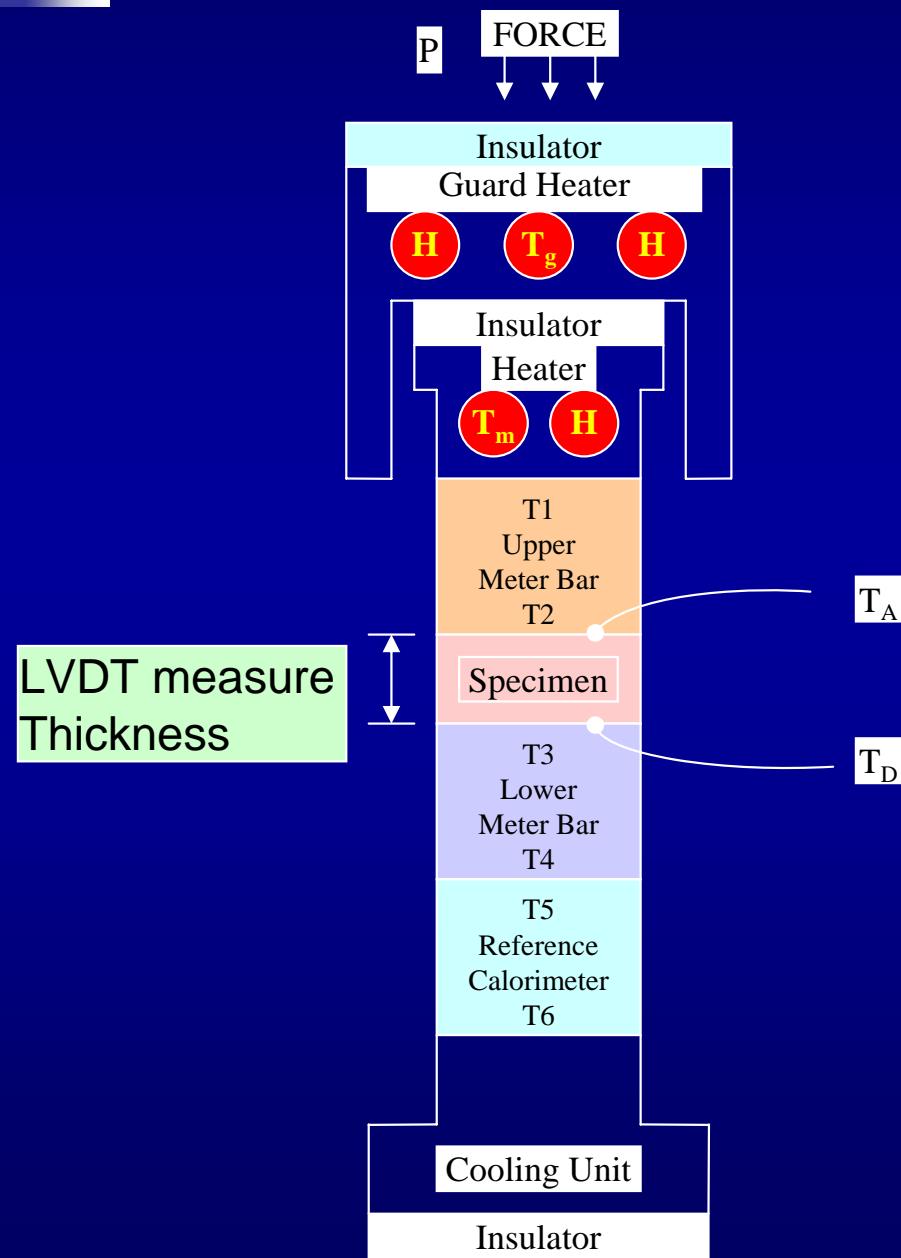
A : effective heat transfer area of solid state zone

Th : temperature in high-temperature solid state zone

Tc : temperature in low-temperature solid state zone

L : sampling distance between high and low temperature
solid state zones

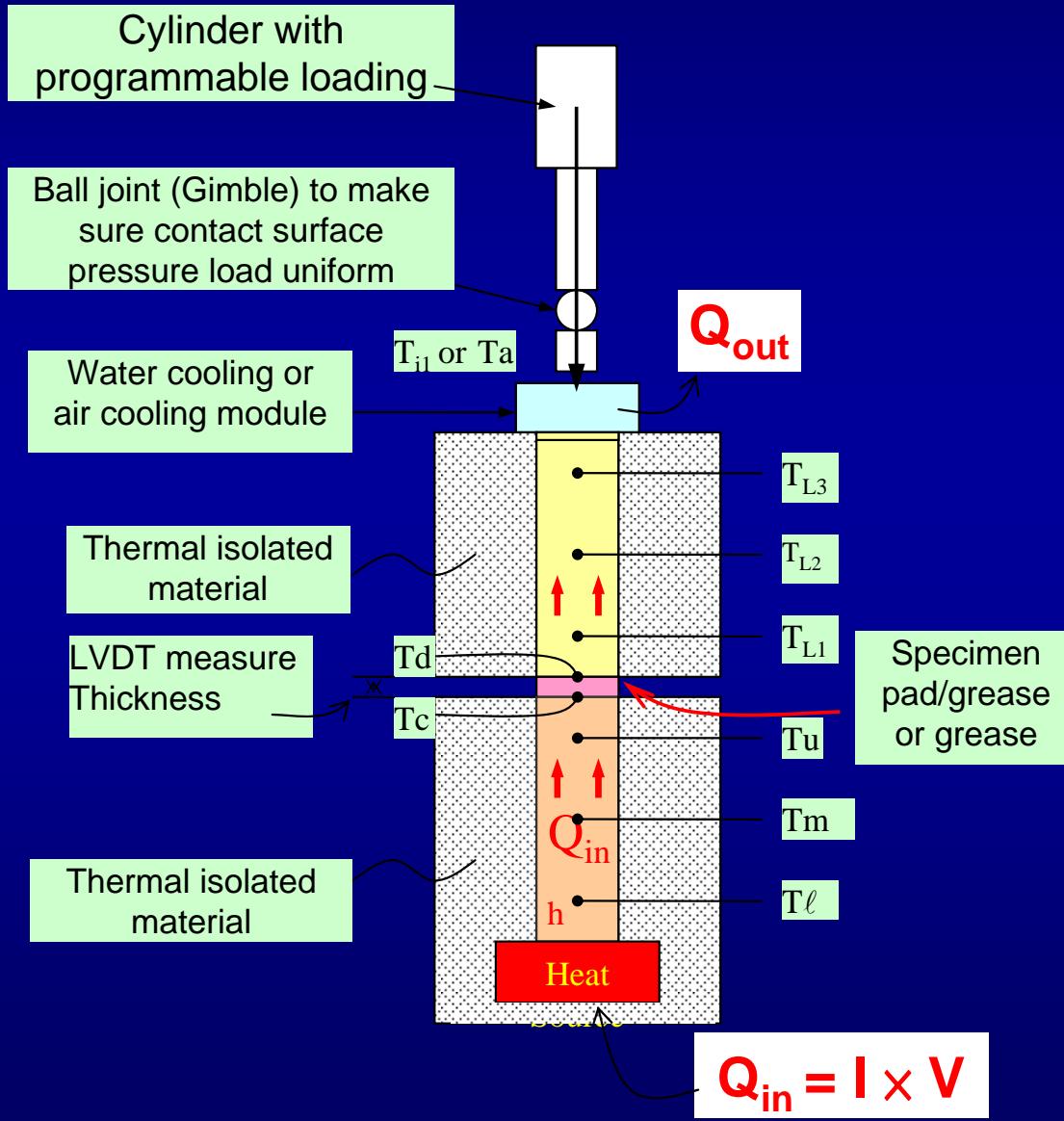
Follow ASTM 5470D Standard



ASTM
(American Society for Testing and Materials)

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Longwin TIM Tester Scheme



@ Upper and lower block with alignment fixture

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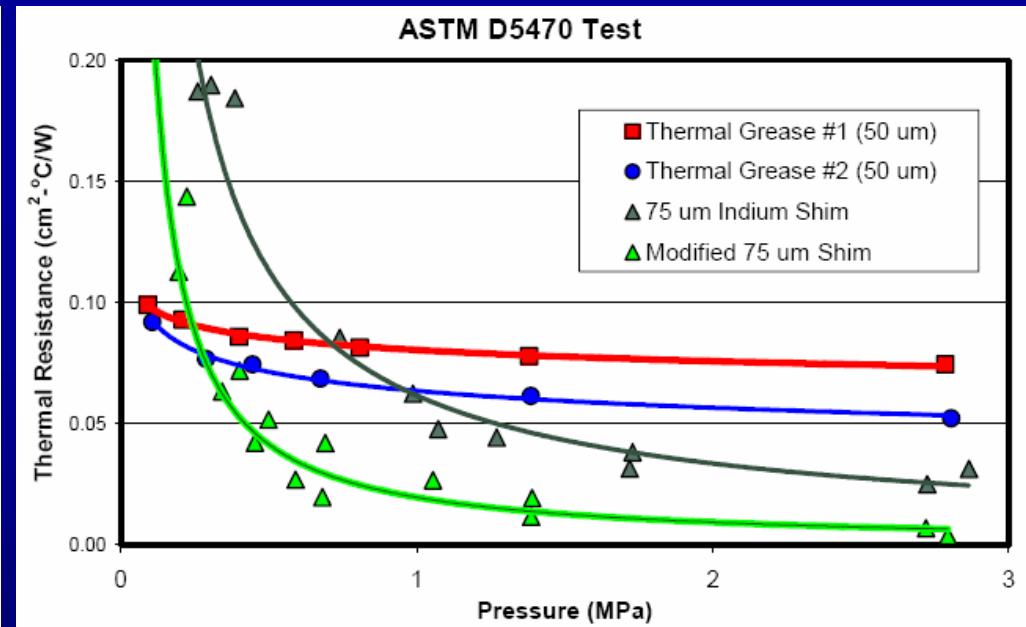
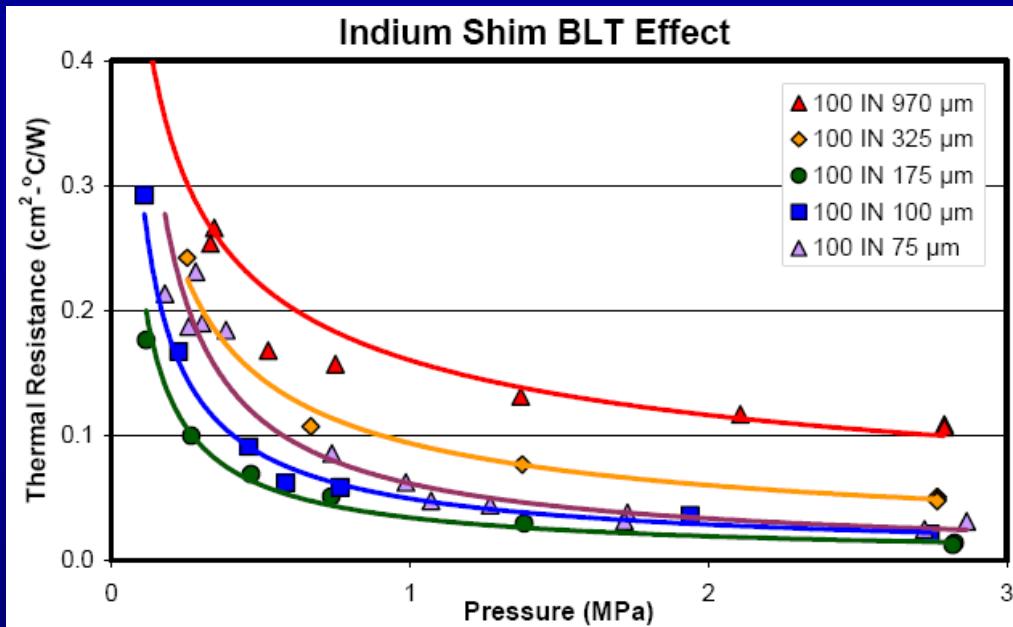
Longwin TIM Tester- 9091IR



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Longwin TIM Tester- 9091IR

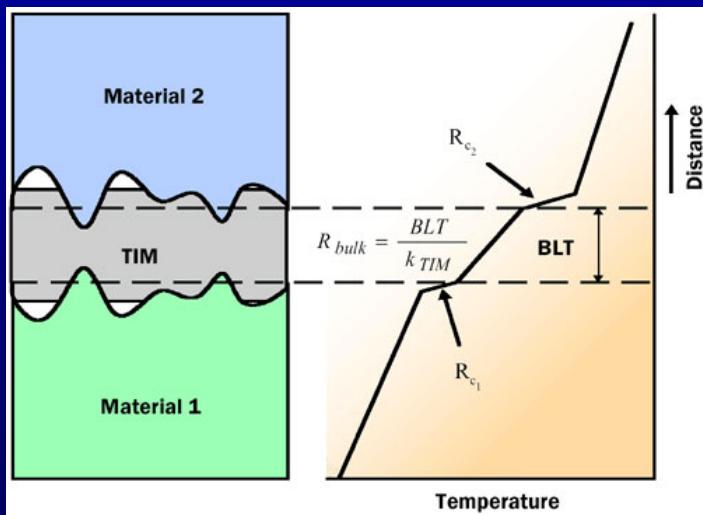
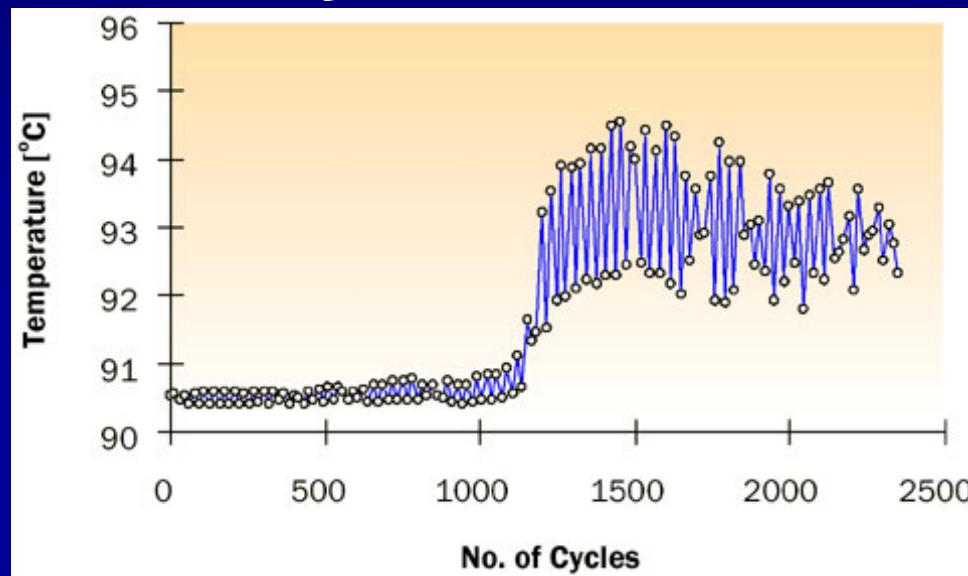
Bond Line Thickness Effect Pressure Effect



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Longwin TIM Tester- 9091IR

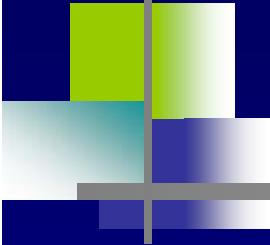
Thermal Cycle Test for Reliability



Die

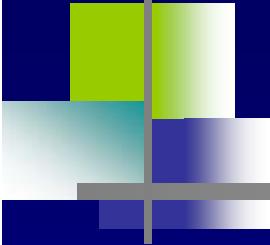
Chuck

Vin



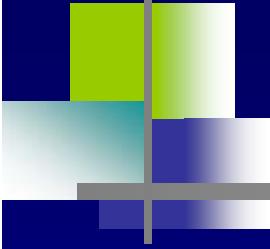
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K (Thermal Conductivity) Measurement

1. Laser flash (Transient)
2. Hot disk (Transient)
3. Hot wire (Transient)
4. Heat flux (Steady)



K Measurement

Transient

$$\alpha = \frac{k}{\rho C_p} \quad \left[\frac{m^2}{s} \right]$$

Steady state

$$\dot{Q} = -k A \frac{\partial T}{\partial X}$$

α = Thermal diffusivity

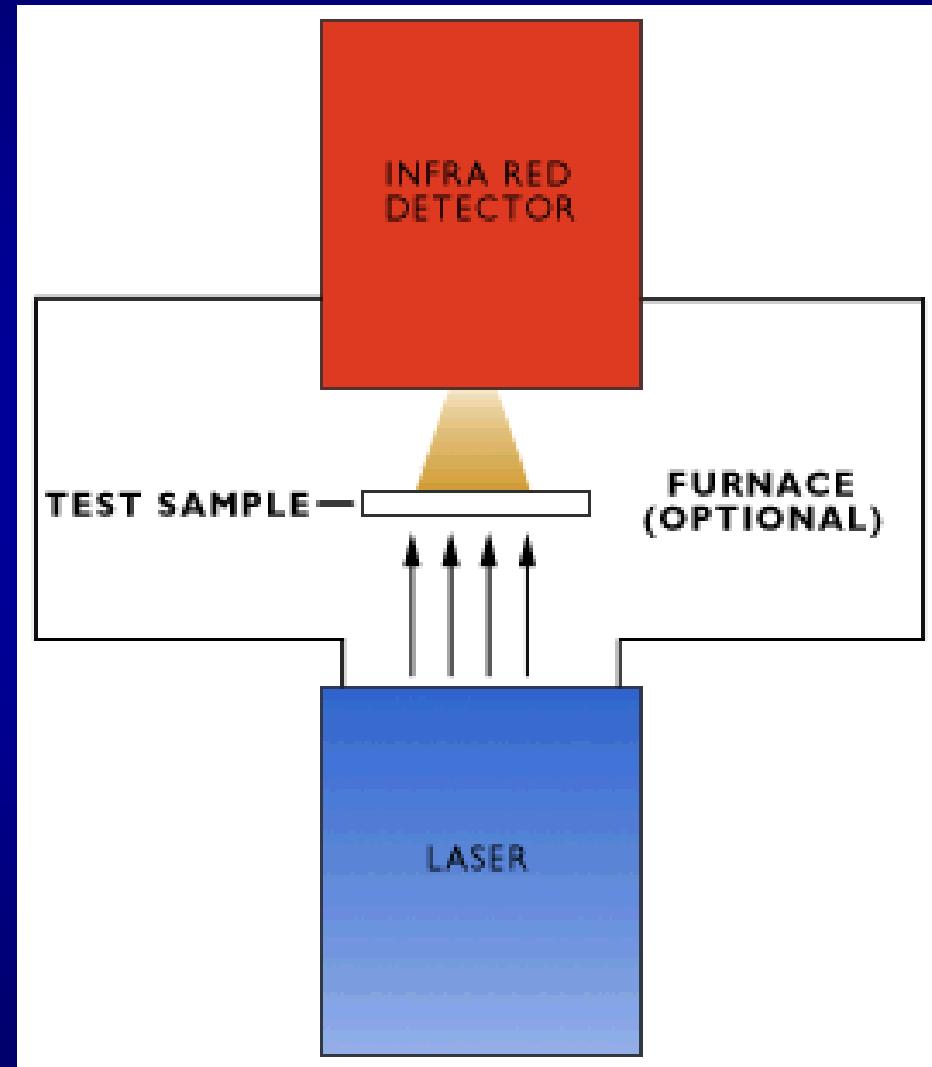
ρ = Density

C_p = Heat capacity

$$\frac{m^2}{s} = \frac{m}{s} \times m = Velocity \times Length$$

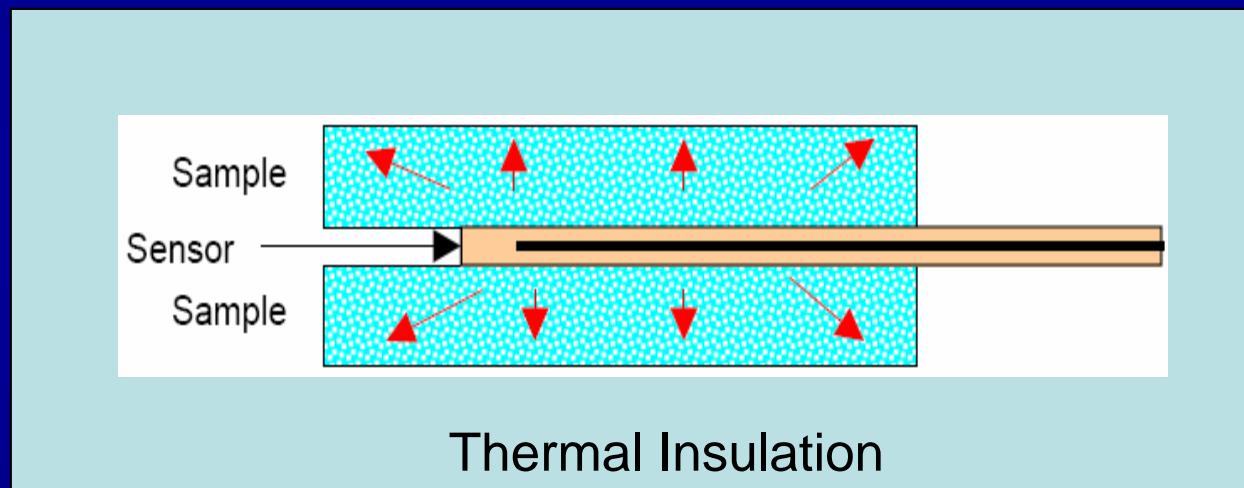
$$\alpha = C_1 \times V \times L$$

Laser Flash



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Hot Disk

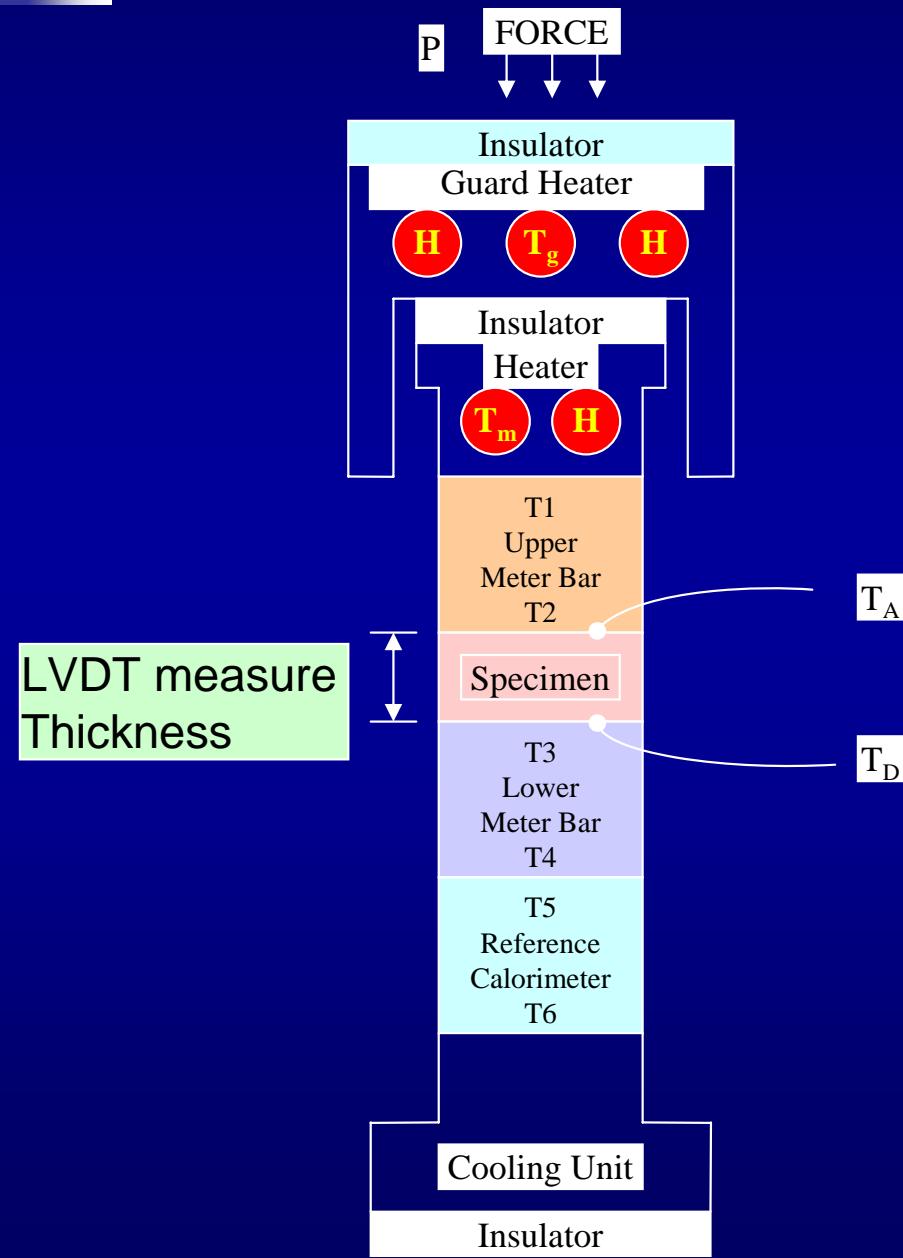


Hot Disk (Transient Plane Source Method, TPS)

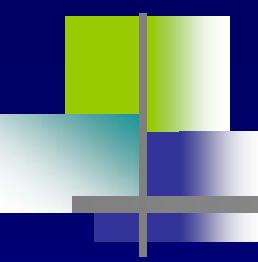
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Heat Flux

ASTM 5470D



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Follow ASTM-5470 D



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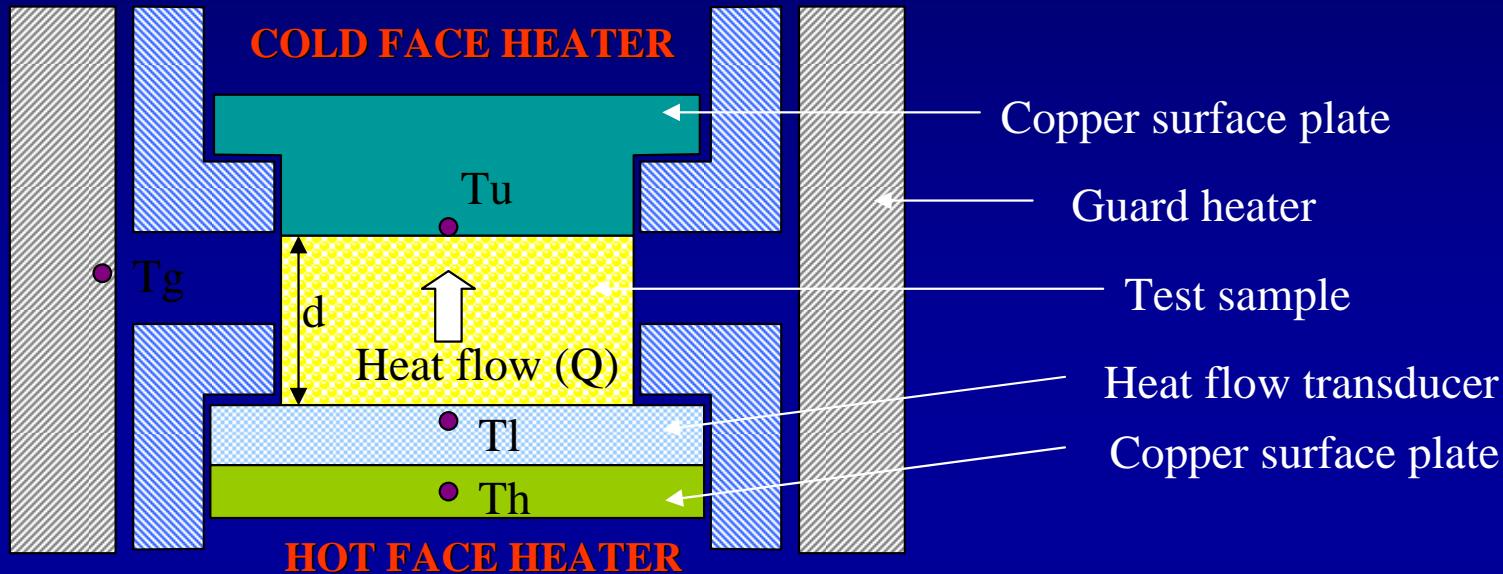
Longwin TIM Tester- 9091IR



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Heat Flux

ASTM E1530



At thermal equilibrium :

$$R_s = N (T_l - T_u) / Q - R_0$$

Where

R_s = sample thermal resistance

N = proportionality constant

T_l = lower surface temperature

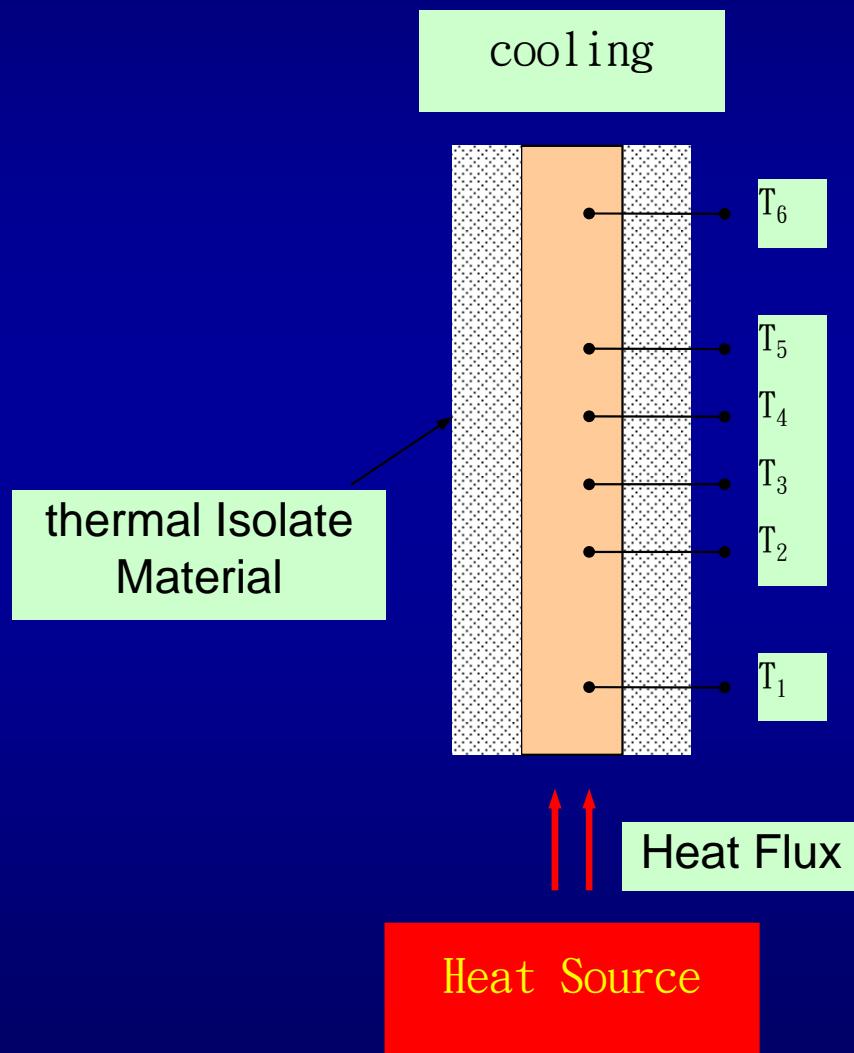
T_u = upper surface temperature

Q = heat flux transducer output

R_0 = constant thermal resistance

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Bar Material K Measurement



$$\frac{\overline{T_1 T_2}}{\overline{T_2 T_3}} = \frac{\overline{T_5 T_6}}{\overline{T_2 T_3}} = 3 \frac{\overline{T_2 T_3}}{\overline{T_3 T_4}} = \frac{\overline{T_4 T_5}}{\overline{T_4 T_5}}$$

Fourier Law

$$q = -KA \frac{\partial T}{\partial X}$$

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Bar Material K Measurement



Fourier Law with ASTM-5470 D Thermal Guard concept,
For steady state can be got k value.

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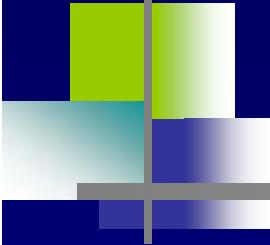


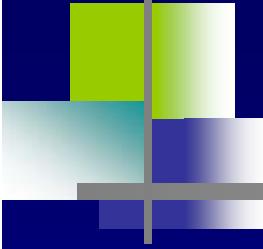
Table of Thermal Conductivity

Diamond	895-2300
Silver	429
Copper	386
Gold	317
Aluminium	237
Brass	120
Platinum	71.6
Iron	80.2
Lead	35.3
Quartz (273K)	6.8-12
Glass	1.35
Wood	0.04
Styrofoam	0.033
Wool	0.04
Silica aerogel	0.017
Air (100 kPa)	0.0262
Water	0.6062
Ice (273K)	2.2
Mercury	8.514

$$\frac{W}{M \text{ } ^0C}$$

(@ 298K)

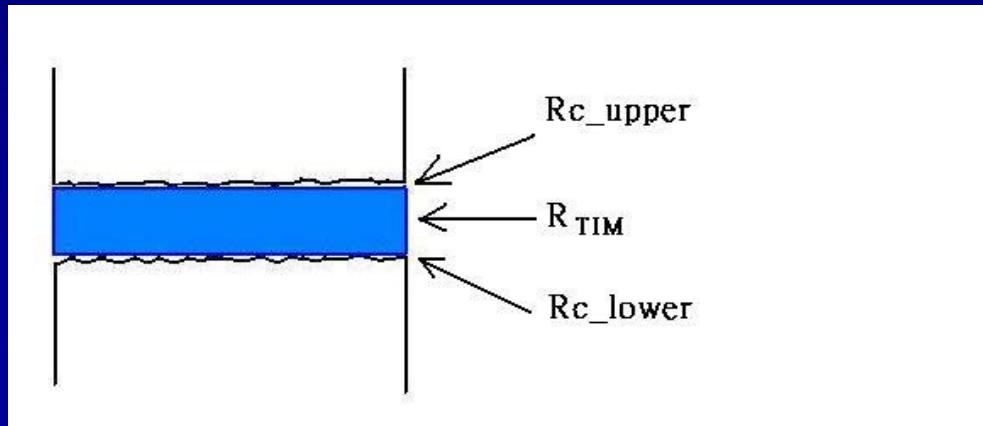
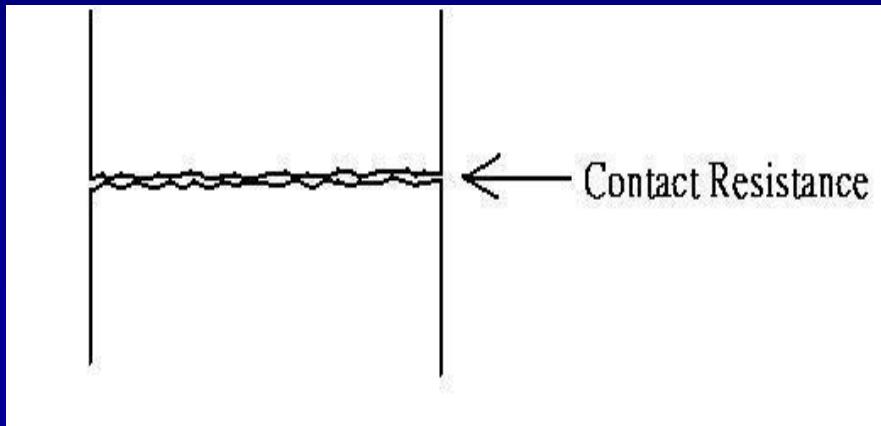
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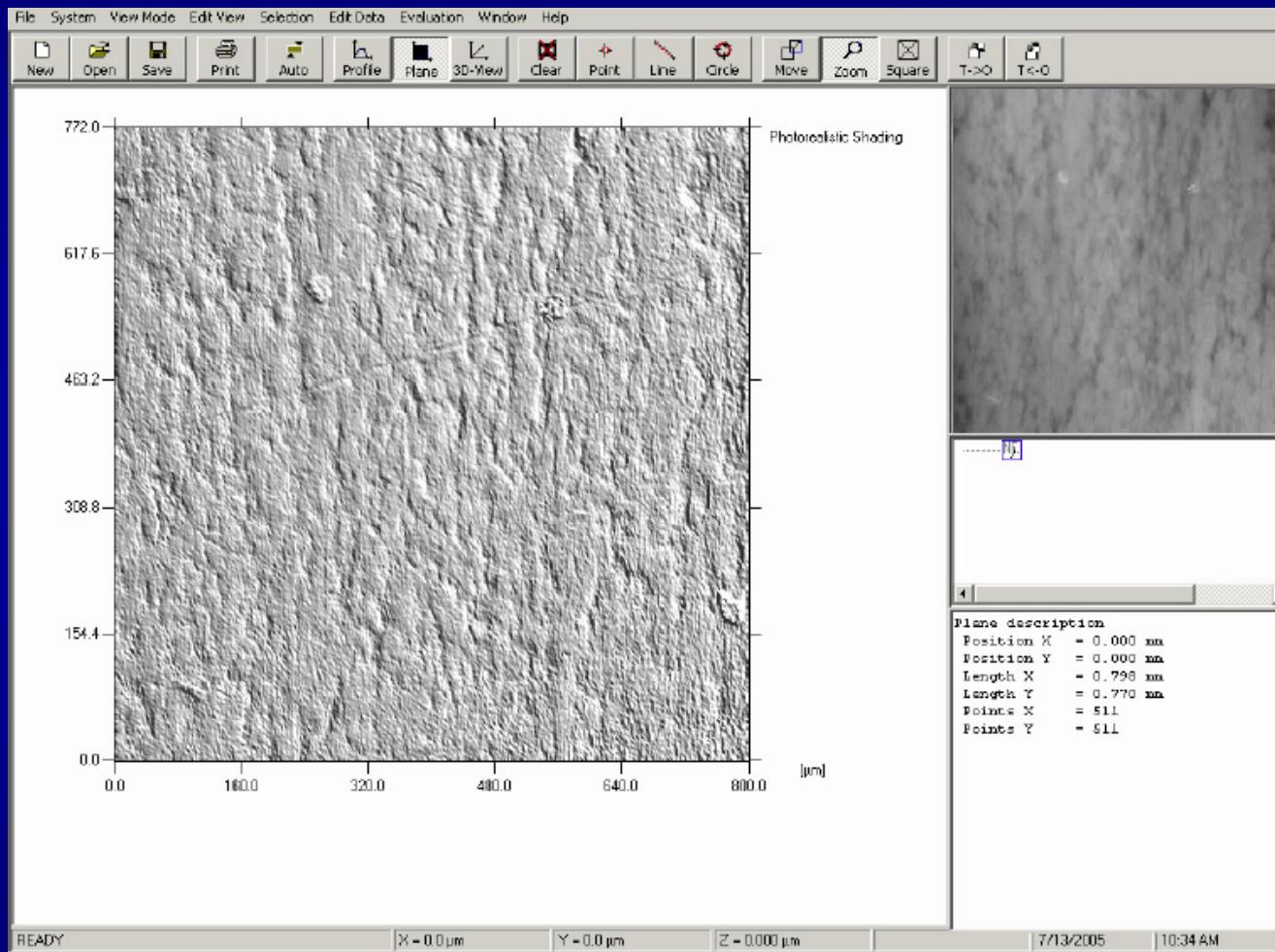
Contact Resistance



Thermal Contact Resistance =
Func.(roughness, pressure, temperature, material, TIM)

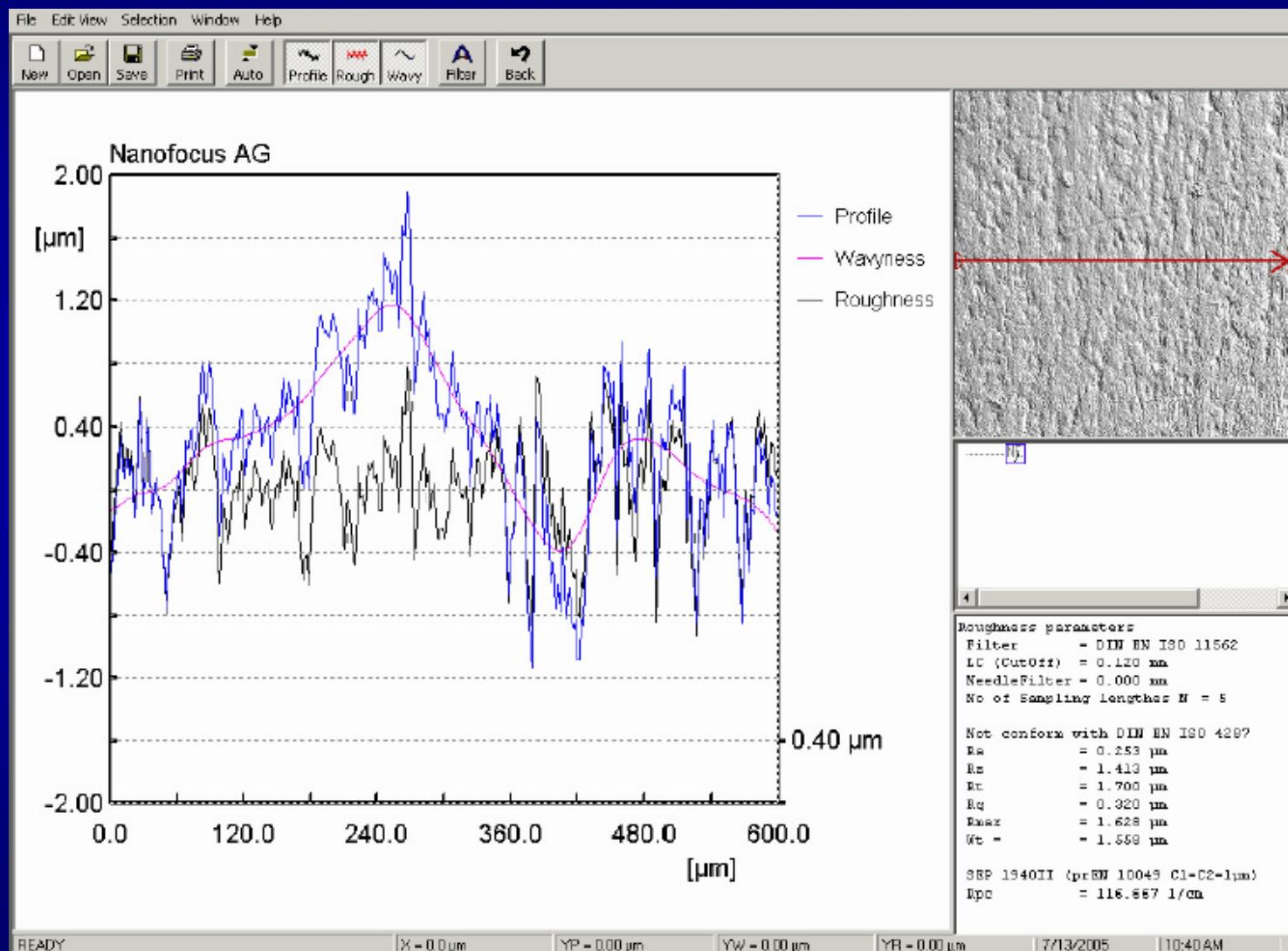
Thermal Contact Resistance = $R_{\text{c_upper}} + R_{\text{c_lower}}$

Surface Roughness Measurement

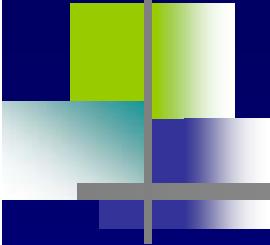


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Surface Roughness Measurement



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Surface Roughness Measurement

Roughness parameters

R_a: 0,17 µm R_{max}: 1,25 µm

R_q: 0,22 µm R_{zISO}: 1,19 µm

R_t: 1,25 µm R_{zDIN}: 0,98 µm

R_p: 0,58 µm

R_v: 0,66 µm

R_{pm}: 0,53 µm

Measurement conditions

Kind of levelling	Polynomial (power3)	Type of filter:	Gaussian filter
Cut-off (high-pass)	0,80 mm	Cut-off (low-pass)	2,50 µm
Length of measurement (total):	4,98 mm	Length of measurement (single):	1,00 mm
No. of meas. points:	498	Measurement length	4,98 mm

Table of Contact Resistance

Different Metal Contact Resistance	Surface	Roughnes s μm	Temperature $^{\circ}\text{C}$	Pressur e MPa	Impedance $^{\circ}\text{C} * \text{cm}^2/\text{W}$
SS-Al	Polish	20-30	20	10	3.45
SS-Al	Polish	20-30	20	20	2.78
SS-Al	Polish	1-2	20	10	0.61
SS-Al	Polish	1-2	20	20	0.48
Al-Cu	Polish	1.3-1.4	20	5	0.24
Al-Cu	Polish	1.3-1.4	20	15	0.18
Al-Cu	Polish	4.4-4.5	20	10	0.83
Al-Cu	Polish	4.4-4.5	20	20~35	0.45

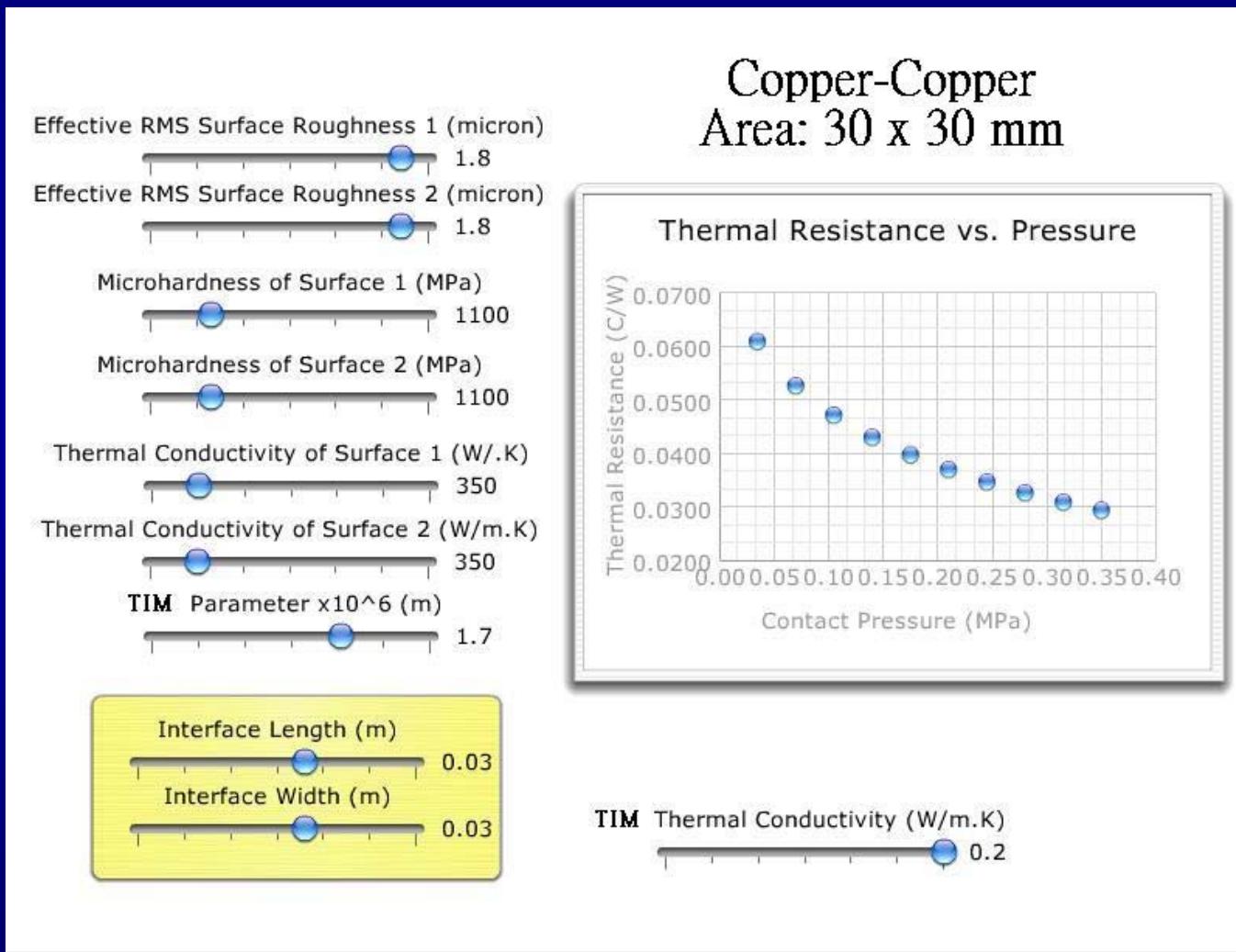
(From Holman, Ref.12, and Kreith and Bohn, Ref.16)

Table of Contact Resistance

Same Metal Contact Resistance	Surface	Roughness μm	Temperature $^{\circ}\text{C}$	Pressure MPa	Impedance $^{\circ}\text{C} * \text{cm}^2/\text{W}$
304 Stainless Steel	Polish	1.14	20	4~7	5.26
416 Stainless Steel	Polish	2.54	90~200	0.3~2.5	2.63
Aluminium	Polish	2.54	150	1.2~2.5	0.88
Copper	Polish	3.81	20	1~5	0.18
Copper	Polish	1.27	20	1.2~20	0.07
Copper (vacuum)	Polish	0.25	30	0.7~7	0.88

(From Holman, Ref.12, and Kreith and Bohn, Ref.16)

Contact Resistance v.s. Pressure



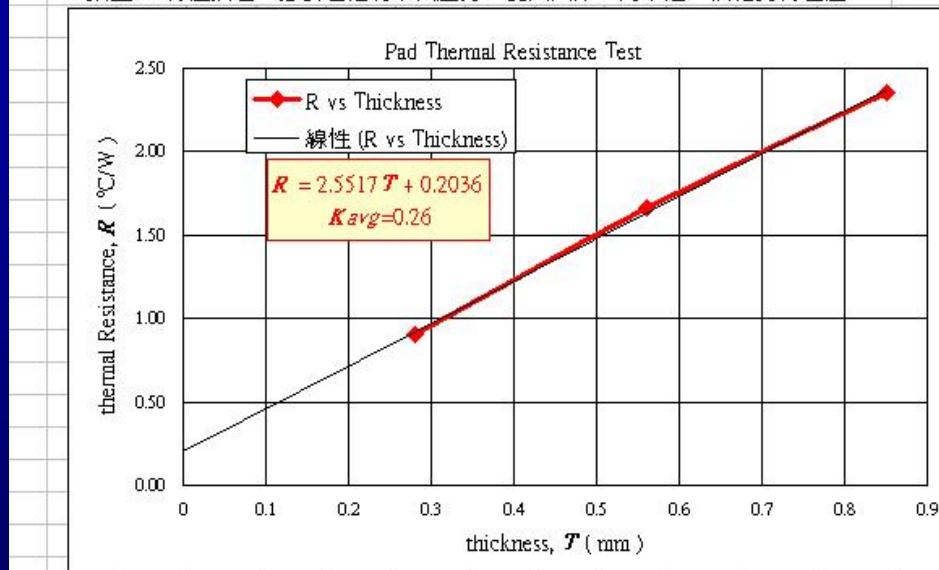
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Contact Resistance Measurement

NO	Pad Thermal Performance Test										20041115			K_real	
	T1 °C	T2 °C	Ta °C	Td °C	T3 °C	T4 °C	T5 °C	T6 °C	Q Watt	Press kgf	Thick- mm	R °C/W	K w/m.°C		
1	55.68	53.12	52.98	46.89	46.75	44.31	43.18	29.34	6.75	43.4	3.5	0.28	0.90	3.2	2.51
2	56.98	55.04	54.93	44.96	44.84	42.66	41.67	29.37	6.00	39.3	3.1	0.56	1.66	3.0	2.61
3	57.38	55.49	55.39	44.05	43.94	41.89	40.96	29.3	5.69	40.5	3.2	0.85	2.36	2.8	2.54
4	57.34	55.19	55.07	44.85	44.73	42.52	41.37	28.78	6.14	90.1	7.2	0.83	2.59	3.1	
5	56.39	54.31	54.19	45.36	45.23	42.97	41.87	28.93	6.31	169.5	13.5	0.82	2.68	3.3	

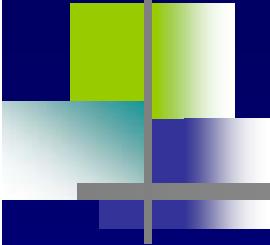
#4、#5 不同壓力負荷時Pad的熱阻跟隨改變。

工業上Pad特性描述，必要包括功率與壓力二變因因素，而不是一個絕對物理值。



測試壓力與接觸熱阻有關，薄的材料，在小壓力狀態下影響測試精度較大。

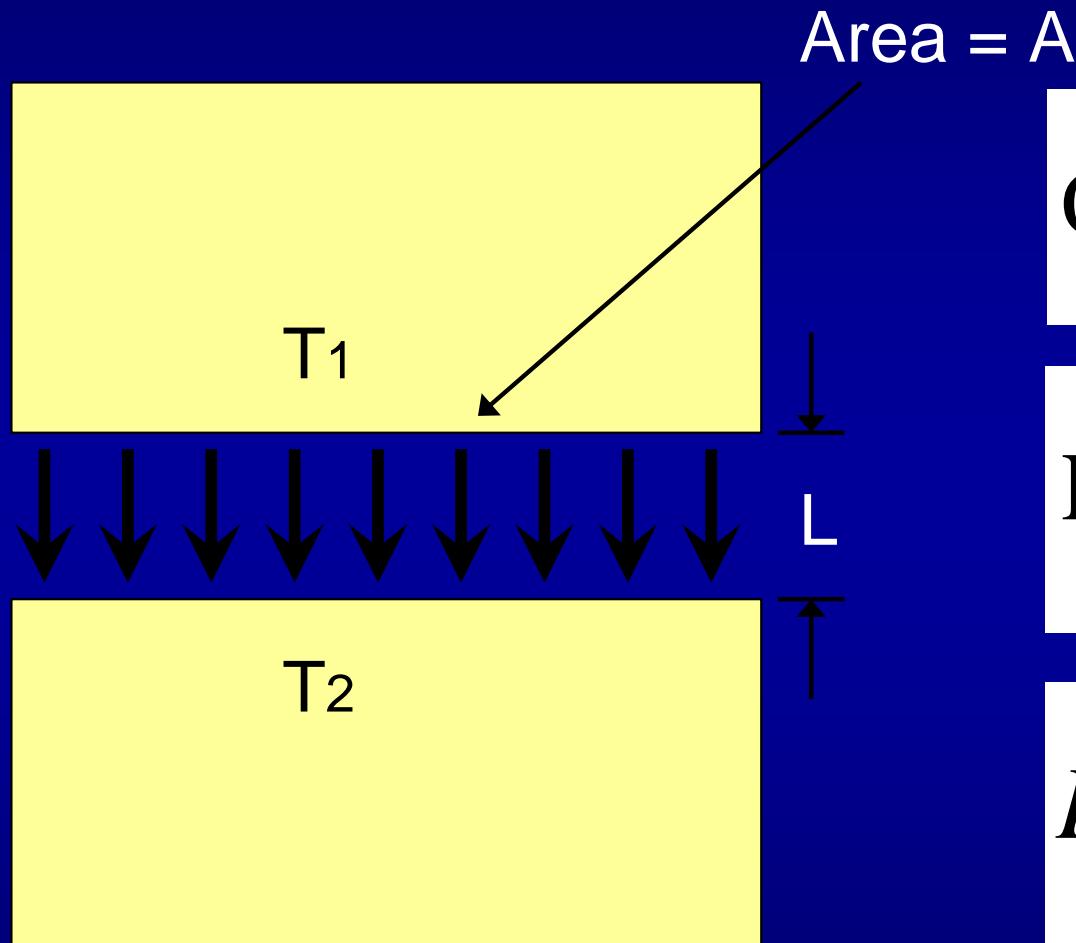
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Definition of Thermal Resistance



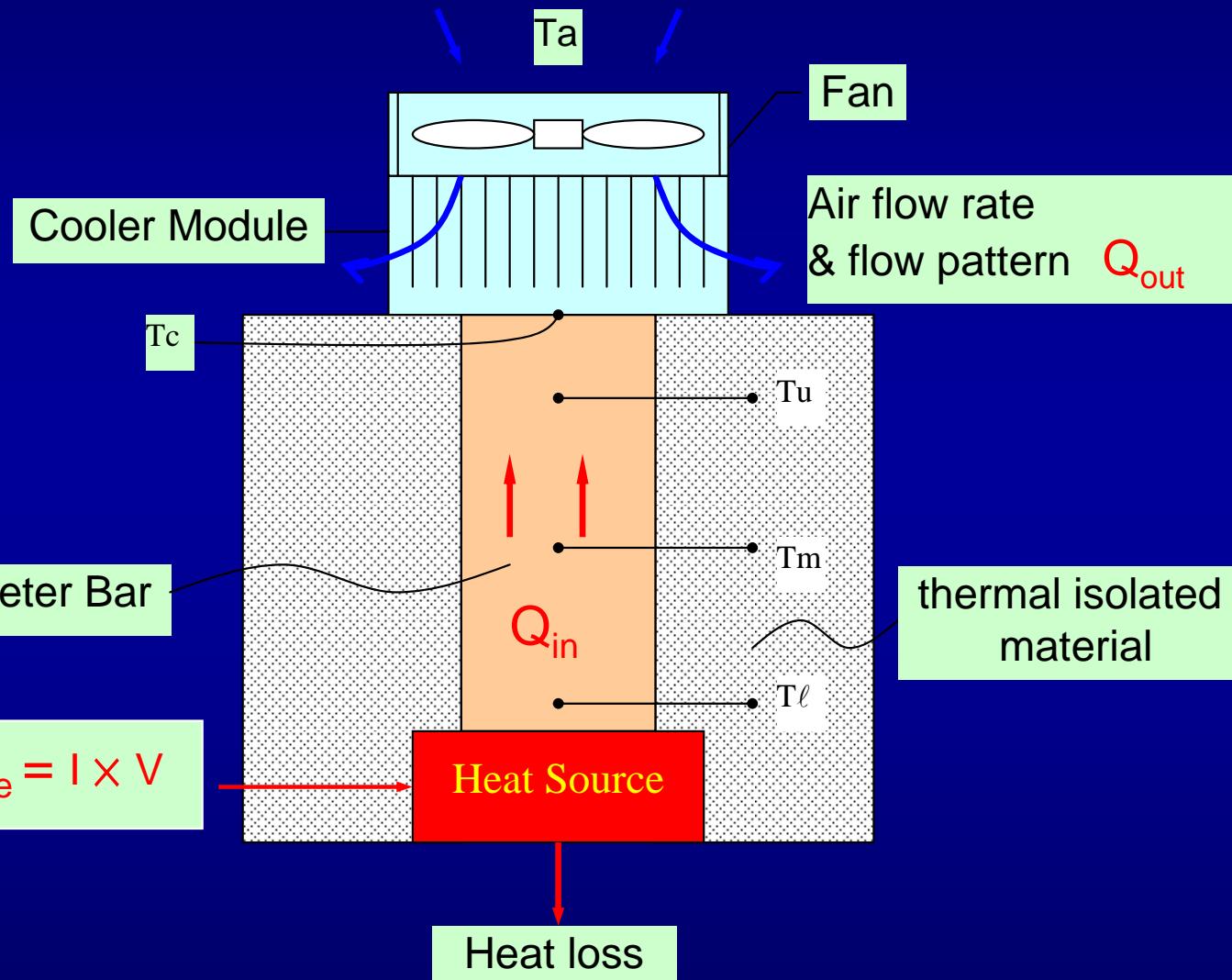
$$Q = K A \frac{T_h - T_c}{L}$$

$$R = \frac{T_1 - T_2}{Q}$$

$$I = \frac{T_1 - T_2}{Q} \times A$$

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CPU Cooler Thermal Resistance



$$Q = K A \frac{T_h - T_c}{L}$$

$$R = \frac{T_c - T_a}{Q_{out}}$$

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Heat Flux Power

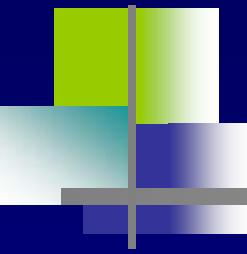
1. Meter Bar Size :

- a. 31×31 mm
- b. 37×37 mm
- c. 25.4×25.4 mm
- d. User define

2. Power Supply :

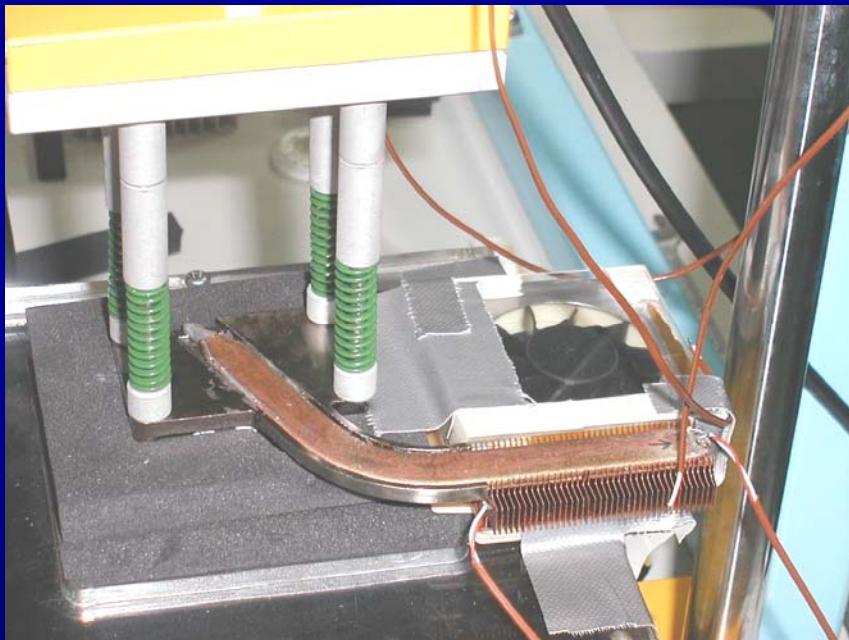
- a. 180W
- b. 300W



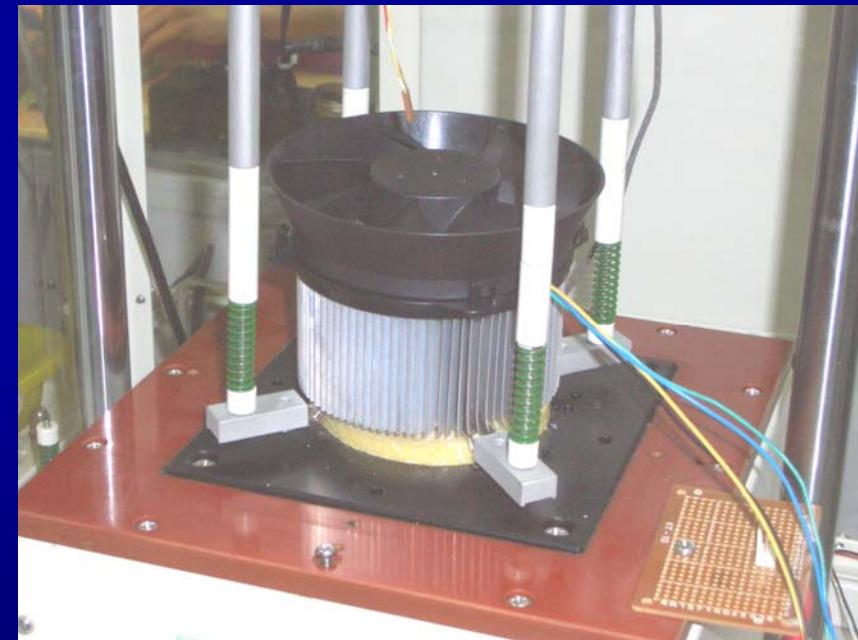


Test Application

NB Cooler Module Test

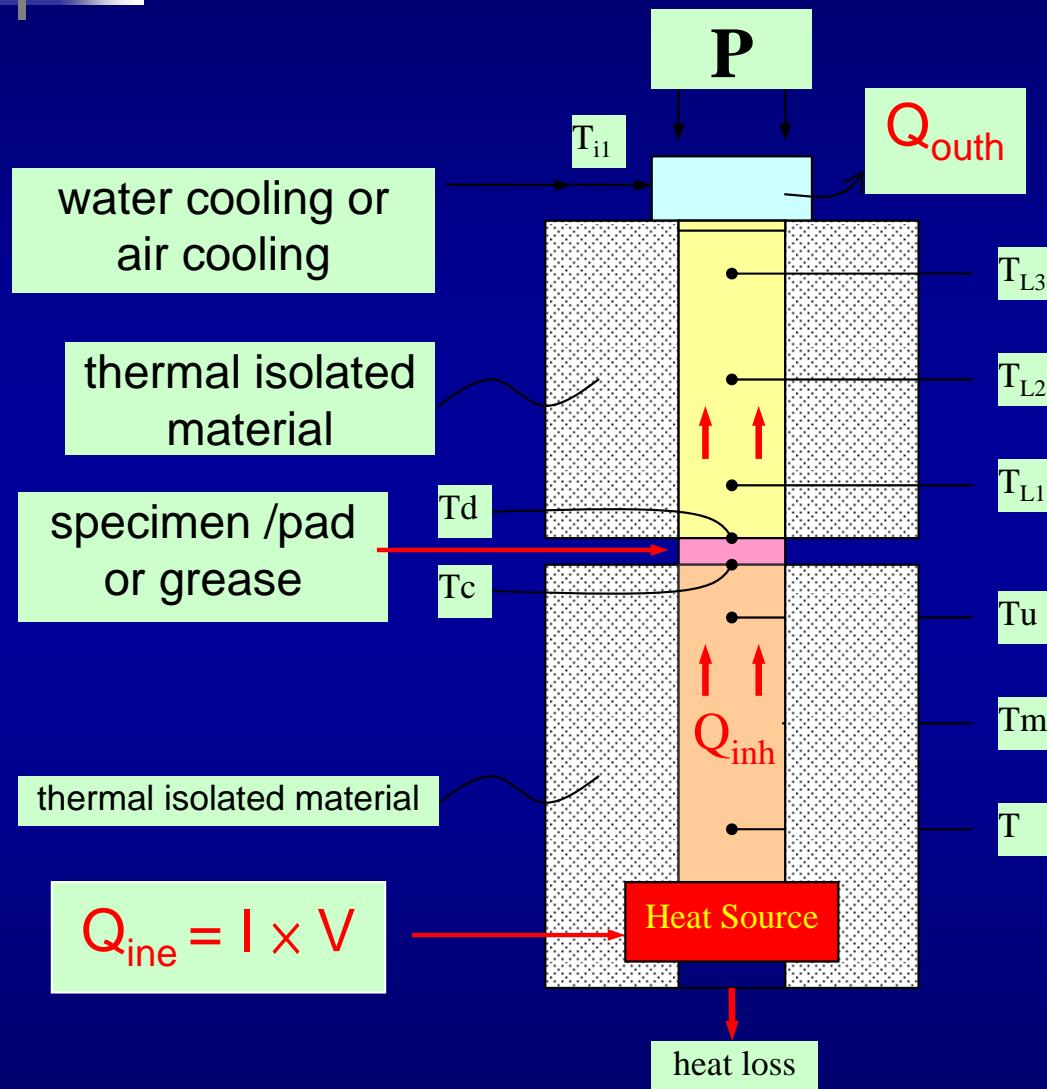


DT Cooler Module Test



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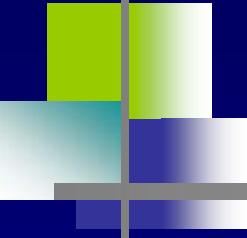
TIM Thermal Resistance



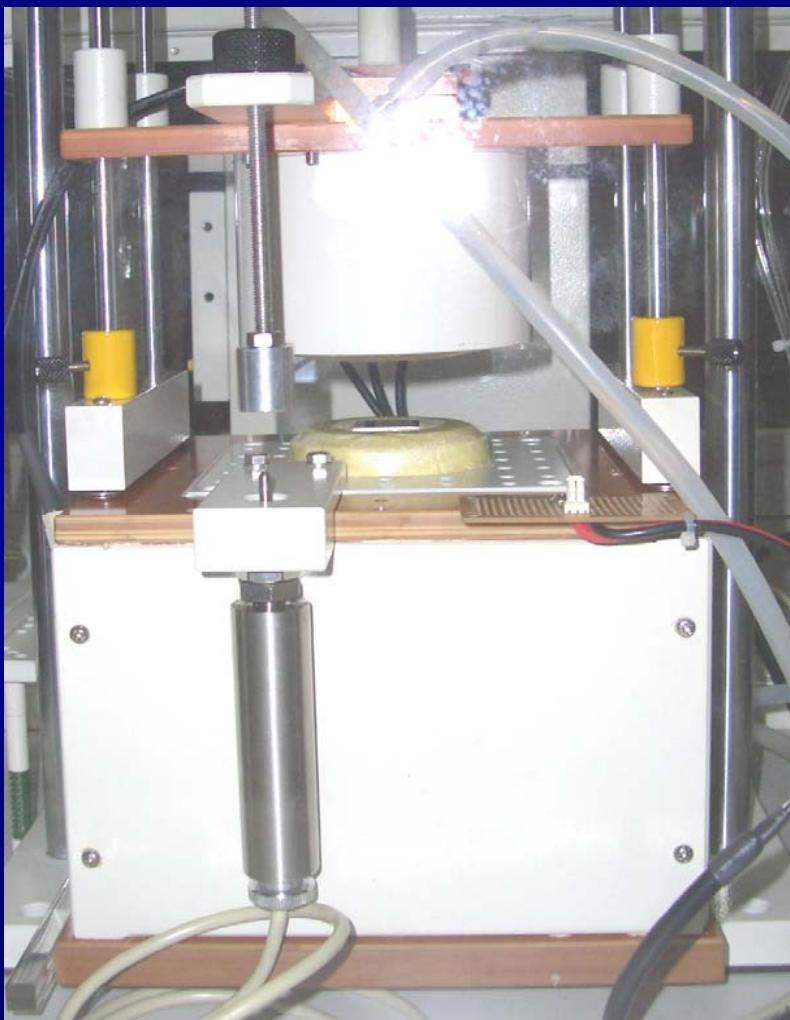
PAD / Grease

$$\begin{aligned}
 T_c &= T_u - \frac{T_\ell - T_u}{X_1} \\
 T_d &= T_{L1} + \frac{T_{L1} - T_{L2}}{X_2} \\
 Q &= KA \cdot \frac{T_\ell - T_u}{X_3} \\
 R &= \frac{T_c - T_d}{Q}
 \end{aligned}$$

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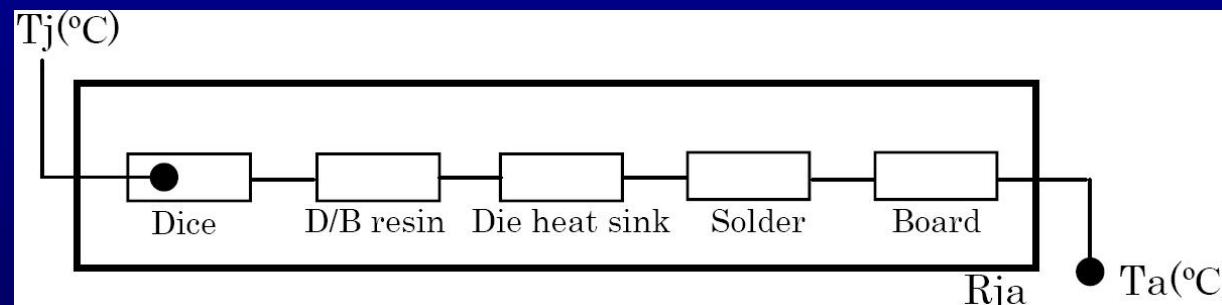
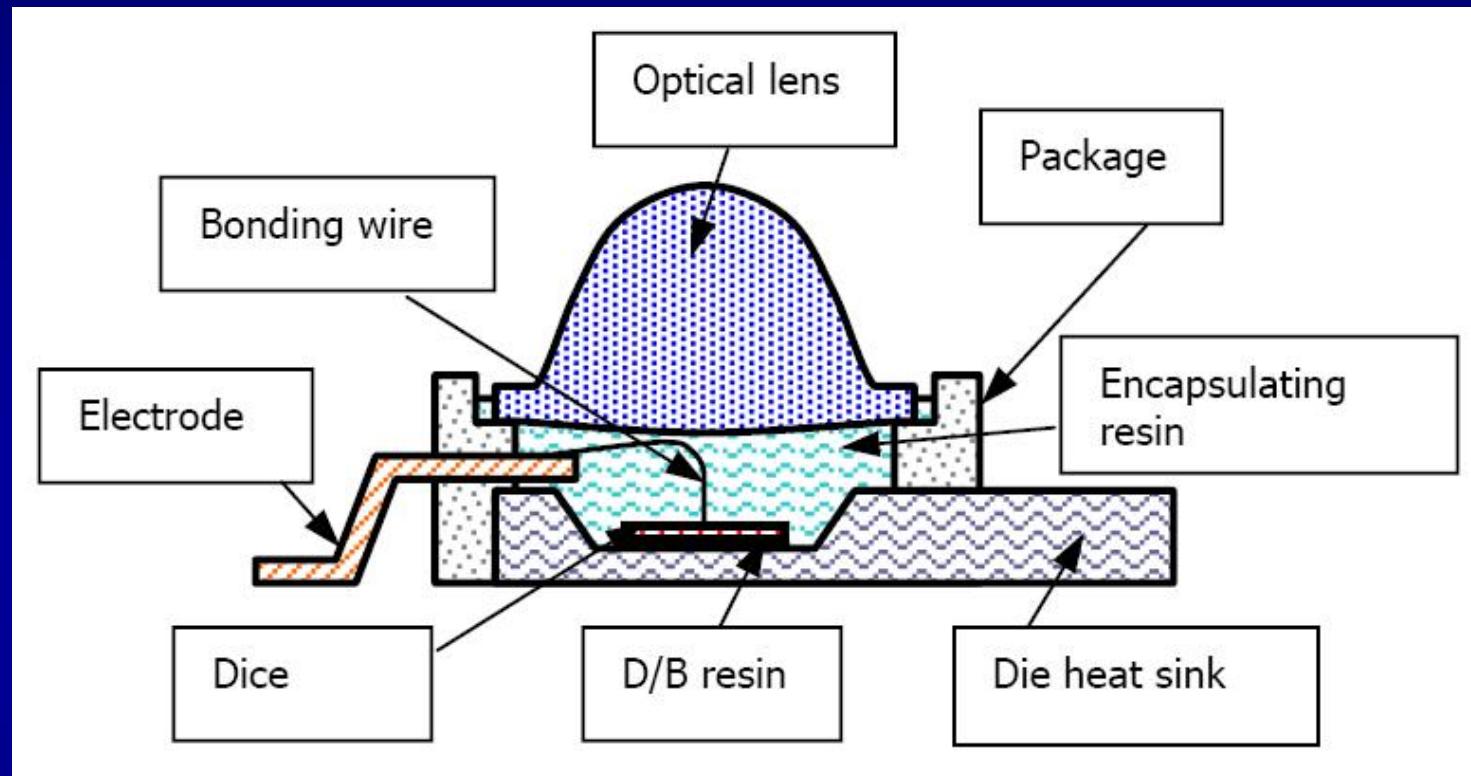


TIM Test Section-9091IR



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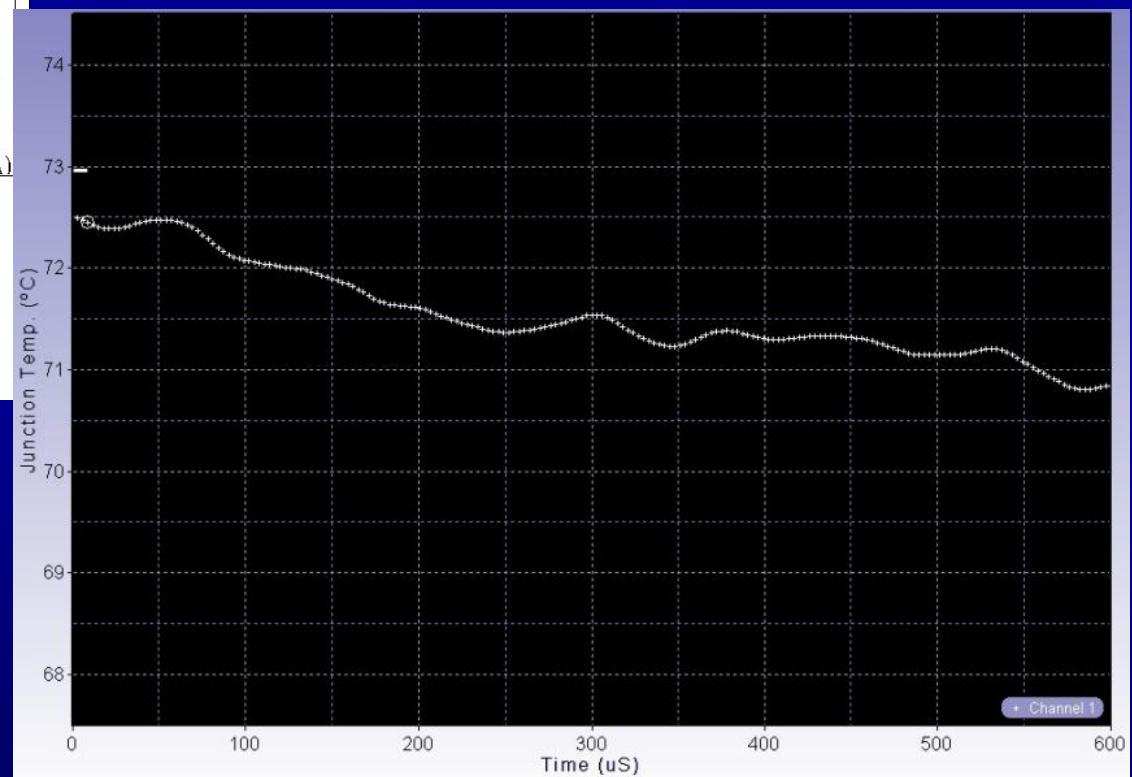
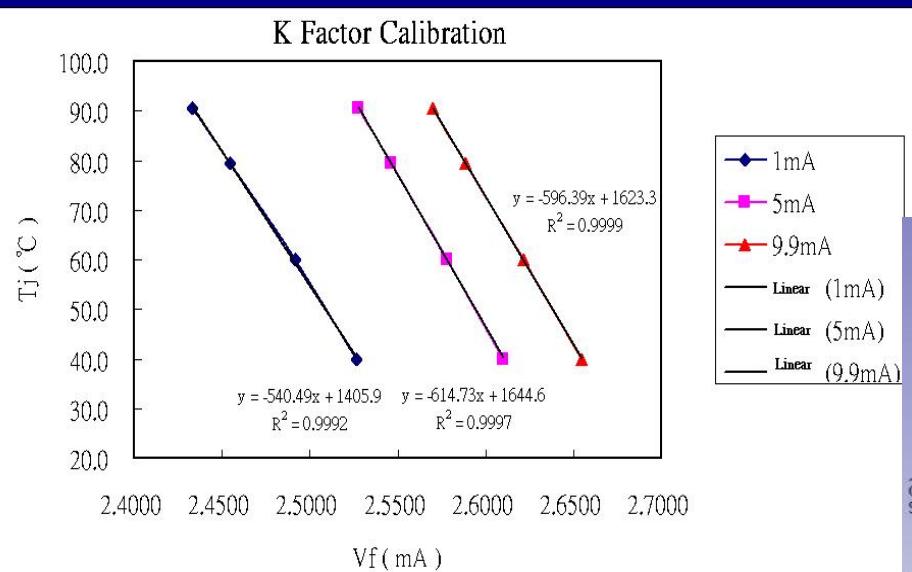
LED Thermal Resistance



$$R_{ja} = \frac{T_j - T_a}{P}$$

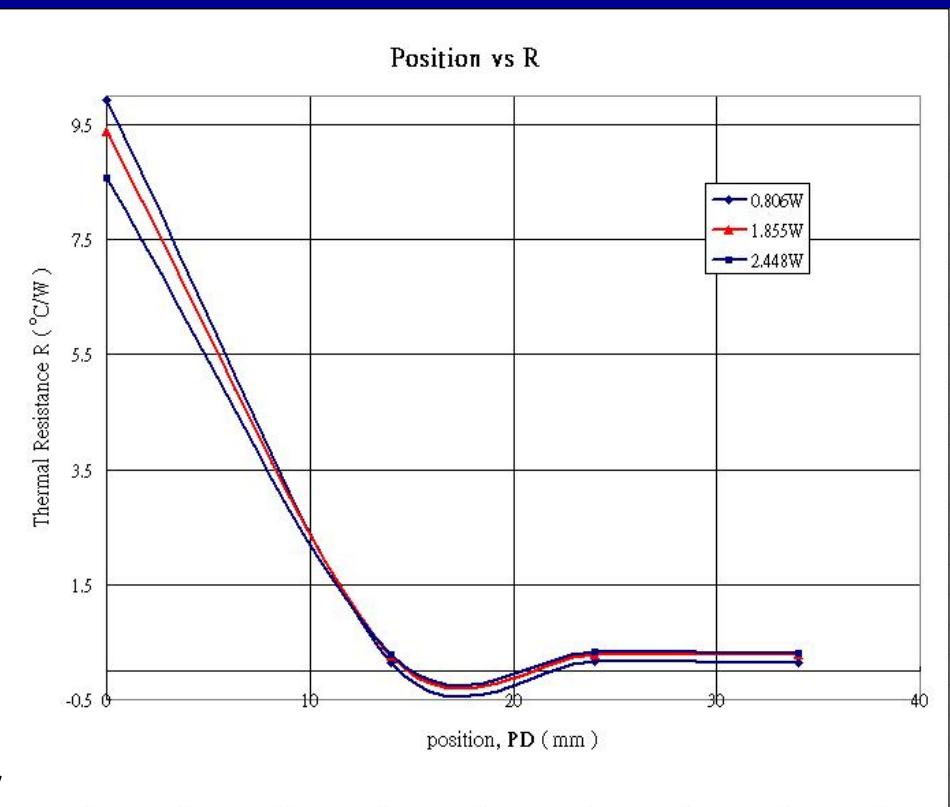
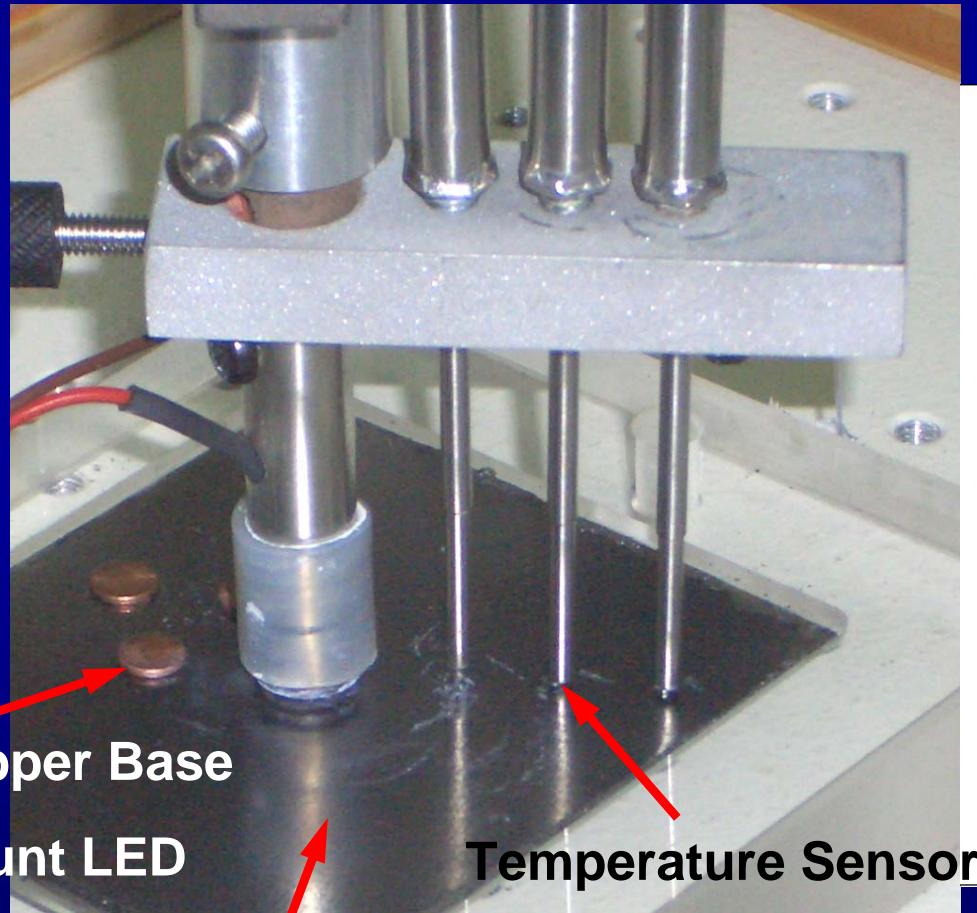
LongWin

LED Junction Temperature Measurement

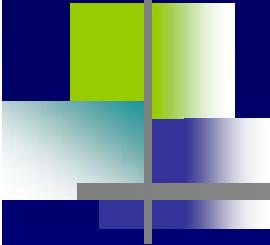


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LED Graphite Heat Spreader

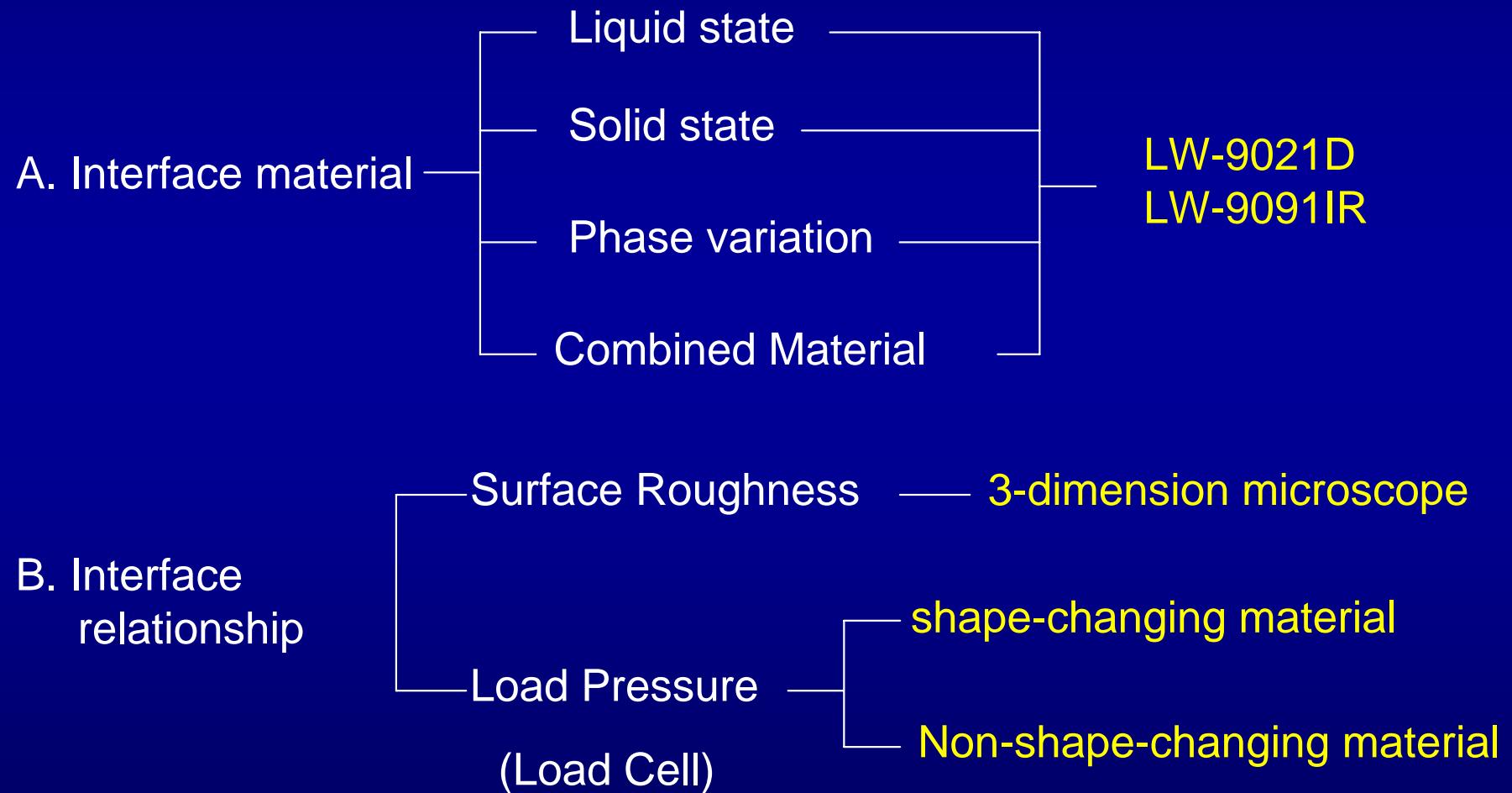


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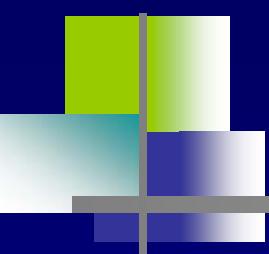


Thermal Lab Apparatus

TIM Research Equipments



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Thank You

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