In-Situ Thickness Method of Measuring Thermo-Physical Properties of Polymer-Like Thermal Interface Materials

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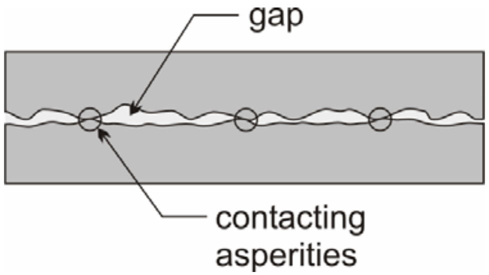
Agenda

- introduction
- thermal interface joint analysis
- motivation
- objectives of the current work
- review of ASTM D 5470 standard
- key features of the experimental system
- experimental results
- conclusions

Introduction

- heat flux density in microelectronic systems
  - Huge increases in past 10 years $0.15 \rightarrow 15 W/cm^2$
  - 2005 projections (NEMI) $> 50 W/cm^2$
- thermal joint resistance becoming critical design area
- typical microelectronics thermal contact
  - low contact pressure, relatively hard materials
  - less than 3% of total joint area is at contacting asperities
  - resistance reduced by filling gaps with thermal interface material (TIM)



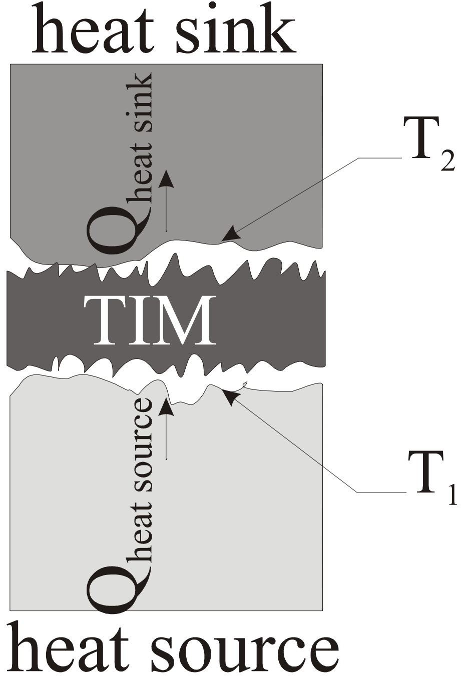
Thermal Interface Joint Analysis

- consider the system as a thermal resistance circuit where

$$R = \frac{(T_1 - T_2)}{Q} \text{ and } r = \frac{(T_1 - T_2)}{Q} A$$

- disregard interface resistance at high load
- determine material thermal conductivity by measuring the TIM thickness and the specific joint resistance as

$$k_{TIM} = \frac{t}{r_{\mathrm{j}}}$$



$$R_{\mathrm{j}} = \left(\frac{1}{R_{contact_1}} + \frac{1}{R_{gap_1}} \right)^{-1} + R_{TIM} + \left(\frac{1}{R_{contact_2}} + \frac{1}{R_{gap_2}} \right)^{-1}$$

$$r_{\mathrm{j}} = r_{\mathrm{int}} + r_{TIM} = r_{\mathrm{int}} + \frac{t}{k_{TIM}}$$

Motivation

- to a thermal designer in the micro-electronics industry, effectively evaluating the thermal conductivity of a particular TIM is critical
- thermal conductivity can be measured in several ways
- one common method is to measure thermal resistance as the thickness of the sample is varied as described in ASTM D 5470
- for thin polymeric TIM materials, thickness during testing can change dramatically and cause the over-estimation of thermal conductivity by as much as 30-40%

Objective

the purpose of this work is to provide experimental evidence of the impact of in-situ thickness changes on the thermal conductivity relative to the ASTM D 5470 method and present a simple and inexpensive method of measuring in-situ thickness for an ASTM D 5470 test method approach.

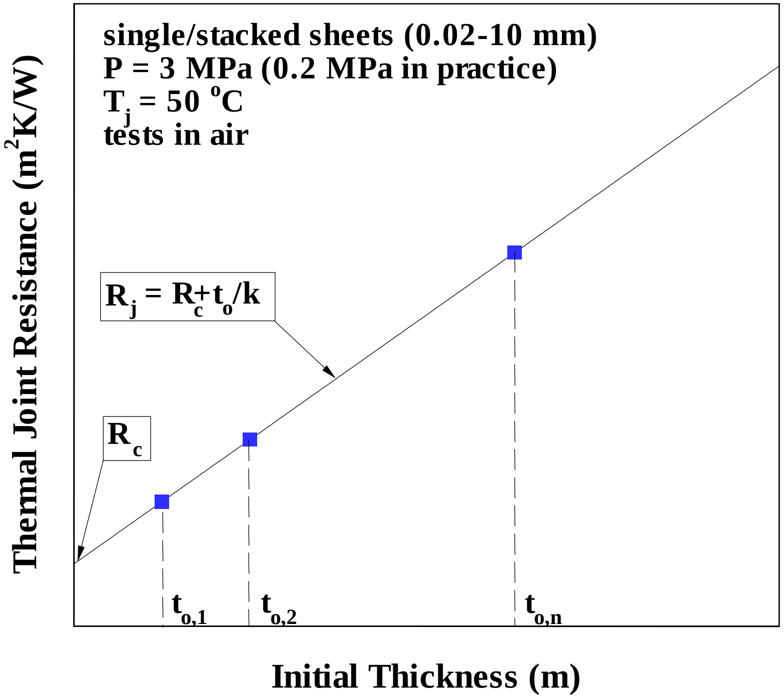
experimental work was performed on three test materials in a vacuum at a temperature of $50^{\circ}C$. Each sample was loaded to a maximum of $6.5MPa$.

Review of ASTM D 5470

- thermal conductivity calculated from measured joint resistance and as-received thickness

$$k_{ASTM} = \frac{1}{R_j\,t}$$

- one, two and multiple layer sample tested at $3\,MPa$
- ignores change of thickness under load
- conductivity overestimated for compressible materials



Test System Key Features

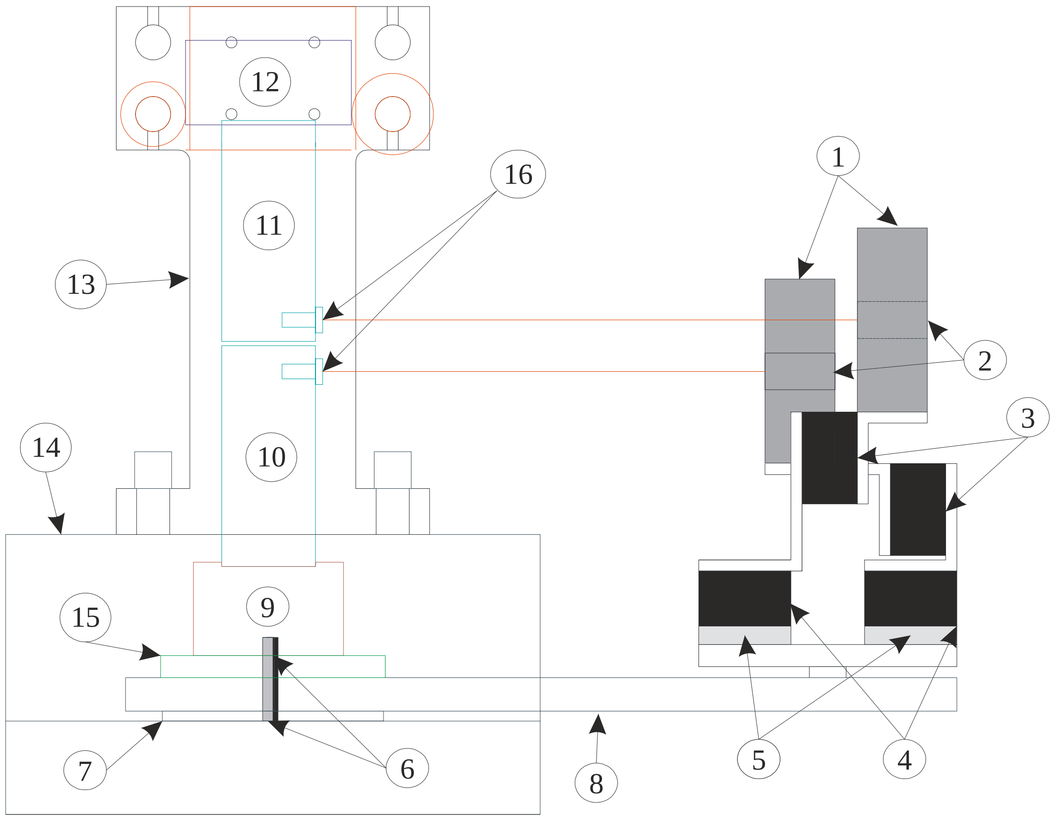
- differential continuous measurement relative to a manually measured initial thickness

$$t_{in-situ} = t_i - \left[\Gamma_u \left(t_{u_i} - t_{u_f}\right) - \Gamma_l \left(t_{l_i} - t_{l_f}\right)\right]$$

- inexpensive photo-voltaic semi-conductor position sensitive devices to allow for high resolution $(\pm 1.0 \mu m)$
- laser generated light sources allow for precise positioning of incident light
- design excludes any thermal bridging
- allows for accurate calculation of thermal conductivity using in-situ thickness

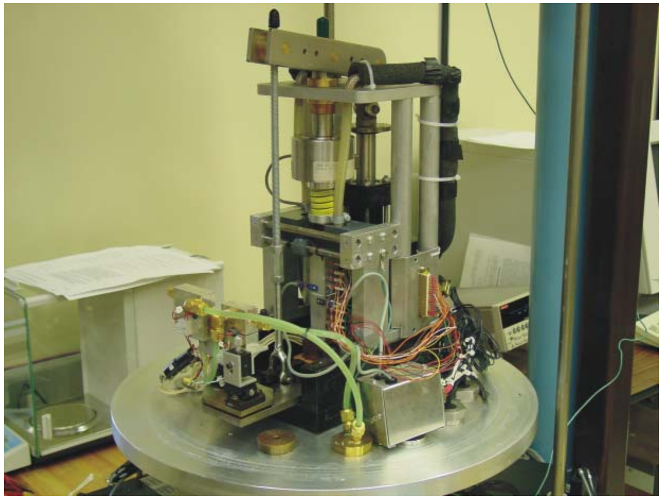
$$k_{TIM} = \frac{1}{R_j \, t_{in-situ}}$$

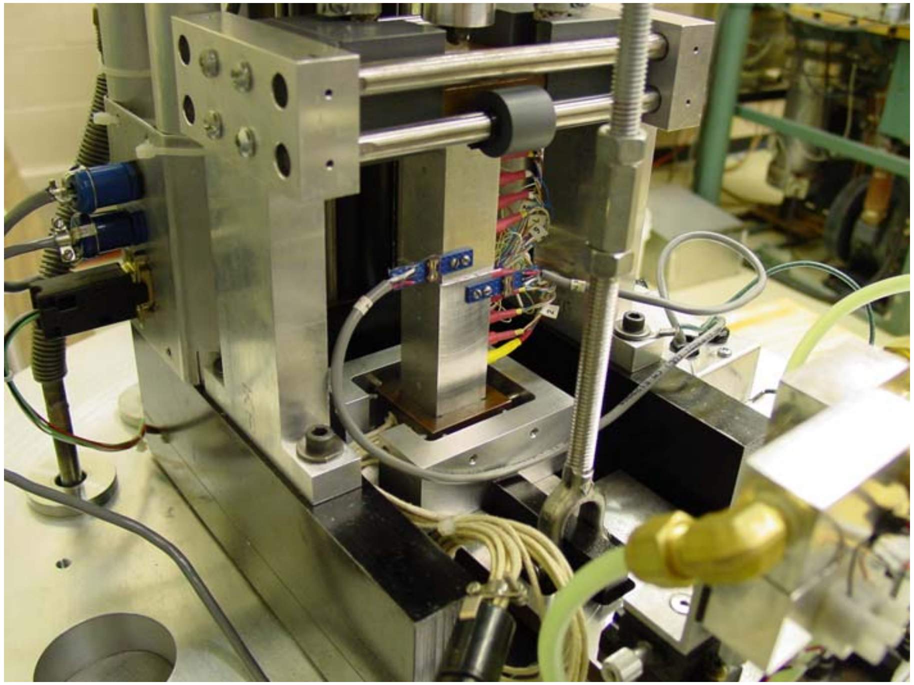
Test System Schematic



1. Cooling blocks.
2. Diode lasers.
3. Vertical stages.
4. Horizontal stages.
5. MT-CL bases.
6. Dowel pins.
7. Isolation pad from main base.
8. Laser cantilever base.
9. Heater block.
10. Lower flux meter.
11. Upper flux meter.
12. Cold plate.
13. Alignment frame.
14. Main reinforced base.
15. Phenolic insulator.
16. Position Sensitive Devices (PSDs).

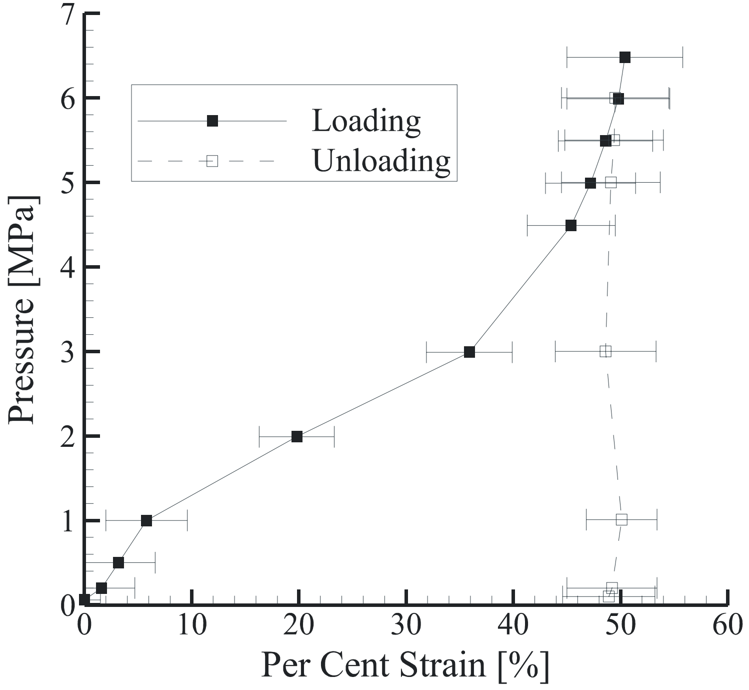
Test System Photographs



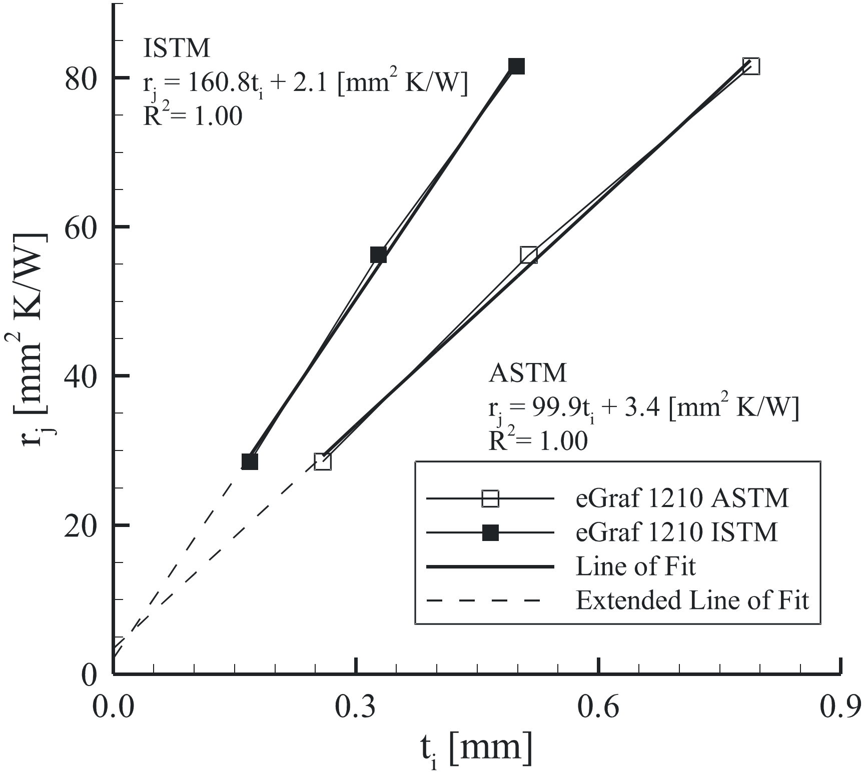


Experimental Results

Averaged Stress vs Strain eGraf 1210



In-Situ Thickness Method vs ASTM method



Summary of Results

	eGraf 1210	CHO-THERM 1671	CHO-THERM 1674
$k_{ISTM}[W/mK]$	6.2	2.9	1.3
$k_{ASTM}[W/mK]$	10.0	3.0	1.3
$k_{mfg}[W/mK]$	10.0	2.6	1.0
$\varepsilon_{BRM}\ @3MPa\ [\%]$	35.9	7.0	-0.9

Conclusions

- a successful effort was undertaken to develop a system capable of measuring in-situ strain with repeatability and reproducibility of approximately ±3% of the initial thickness of the material
- comparisons between the final manually measured thickness and the final measured in-situ thickness agreed well.
- not accounting for in-situ compression of samples in ASTM D 5470 can cause over-estimation of the TIM thermal conductivity by over 30%