Testing of Thermal Interface Materials: Preliminary Observations

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Introduction

- Purpose of thermal interface materials:
  - ✓ enhance heat transfer at joint by reducing thermal contact resistance
  - ✓ provide better thermal contact between chip (source) and heat sink / spreader (sink)
- Applications:
  - ✓ heat sink attach
  - ✓ heat spreader attach
- Widely used in industry

Introduction

- Interface materials are divided into four categories:
  - ✓ greases and liquids
  - ✓ compliant materials: deform more than 10% under clamping force
  - ✓ hard rubber materials: deform less than 10% under clamping force
  - ✓ thermally conductive materials: materials such as ceramics and plastics that require high clamping force

Objectives

- Design and construct apparatus for thermal testing of interface materials
- Measure joint resistance and thermal conductivity as function of
  - ✓ temperature
  - ✓ contact pressure
  - ✓ material properties
  - ✓ surface characteristics

Measurement Procedure

- Joint resistance and conductivity calculated based on temperature and thickness measurements
- Thermal joint resistance

$$R_{\text{joint}} = \frac{\Delta T_{\text{joint}}}{Q}$$

ΔT_{joint} = joint temperature drop

Q = total heat flow rate

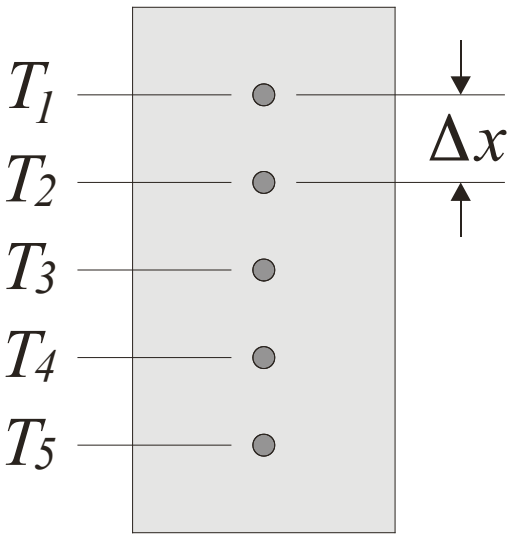
- Thermal conductivity

$$k = \frac{1}{R_{\text{joint}}} \frac{t_{\text{joint}}}{A_{\text{joint}}}$$

t_{joint} = joint thickness

A_{joint} = joint cross-sectional area

Heat Flux Meter



- Isotropic, constant cross section cylinders of known conductivity, $k = f(T)$
- Dual-purpose device
  - ✓ calculate heat flow rate
  - ✓ determine joint temperatures
- Temperature gradient measured by RTDs
  - ✓ accuracy < $0.1\ ^{o}C$
  - ✓ equal spacing – $10\ mm$

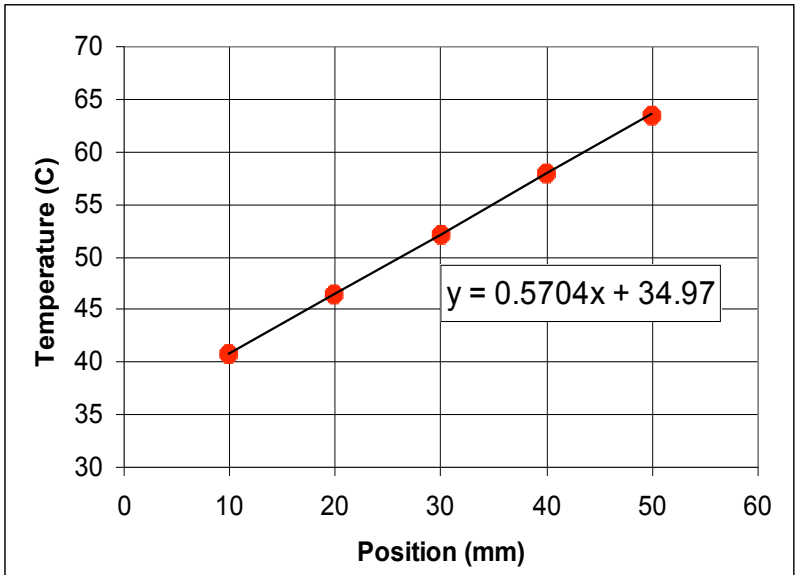
Heat Flux Meter

- Heat flow rate:

$$Q = k\,A\frac{dT}{dx}$$

- Temperature gradient from linear fit of temperature data

$$\frac{dT}{dx} = m$$



- Total heat flow rate = average of upper and lower flux meters

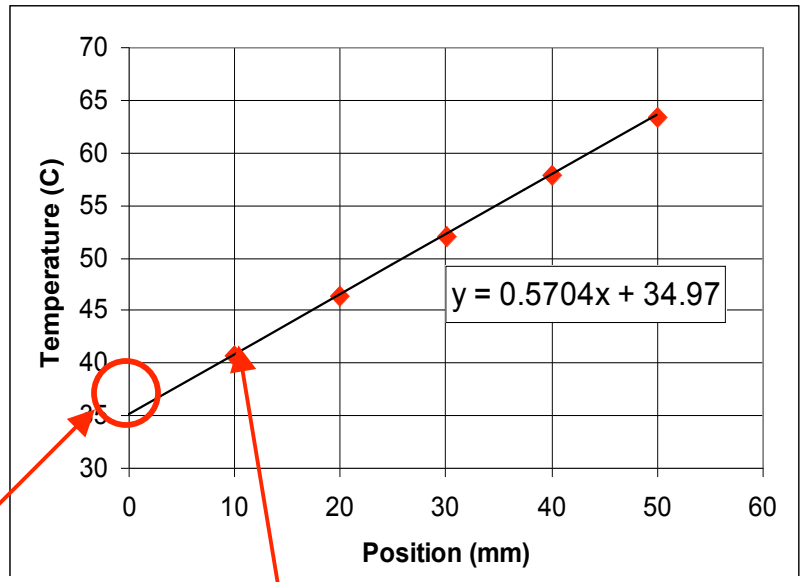
Heat Flux Meter

- Joint temperature determined by extrapolating temperature gradient to the joint surface

$$T_{\text{joint}} = T_{\text{last}} + \frac{dT}{dx} \cdot \Delta x$$

- Joint temperature drop

$$\Delta T_{\text{joint}} = T_{\text{joint,lower}} - T_{\text{joint,upper}}$$



Extrapoloted Joint Temperature

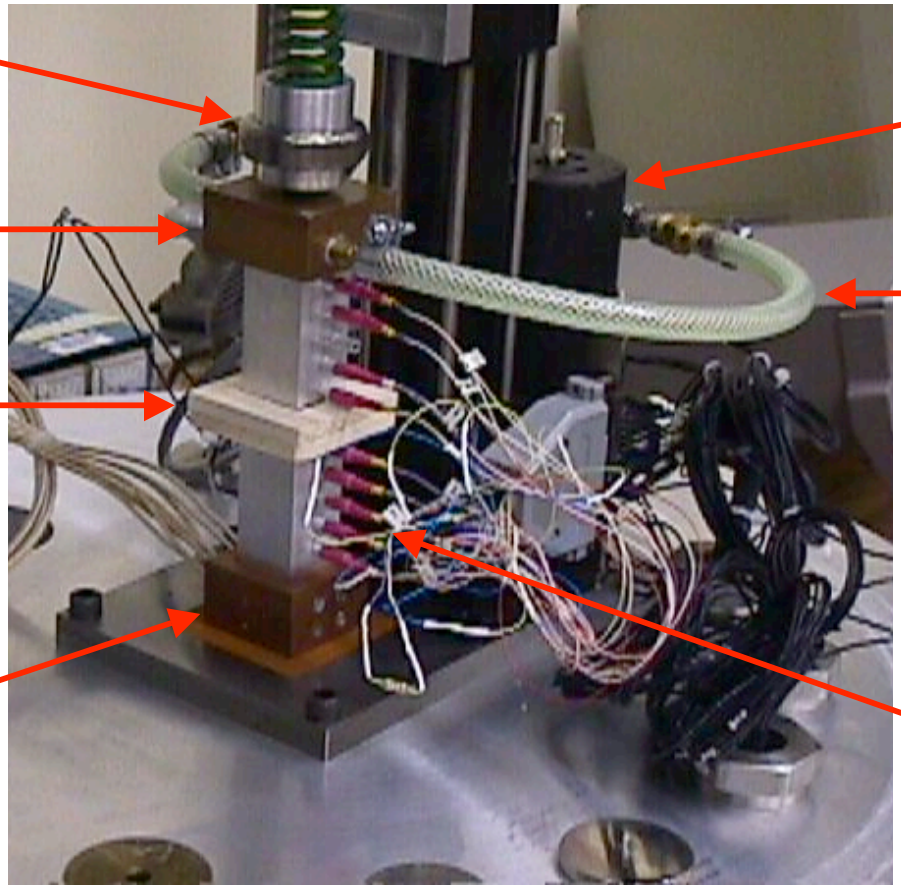
T_{last}

Apparatus

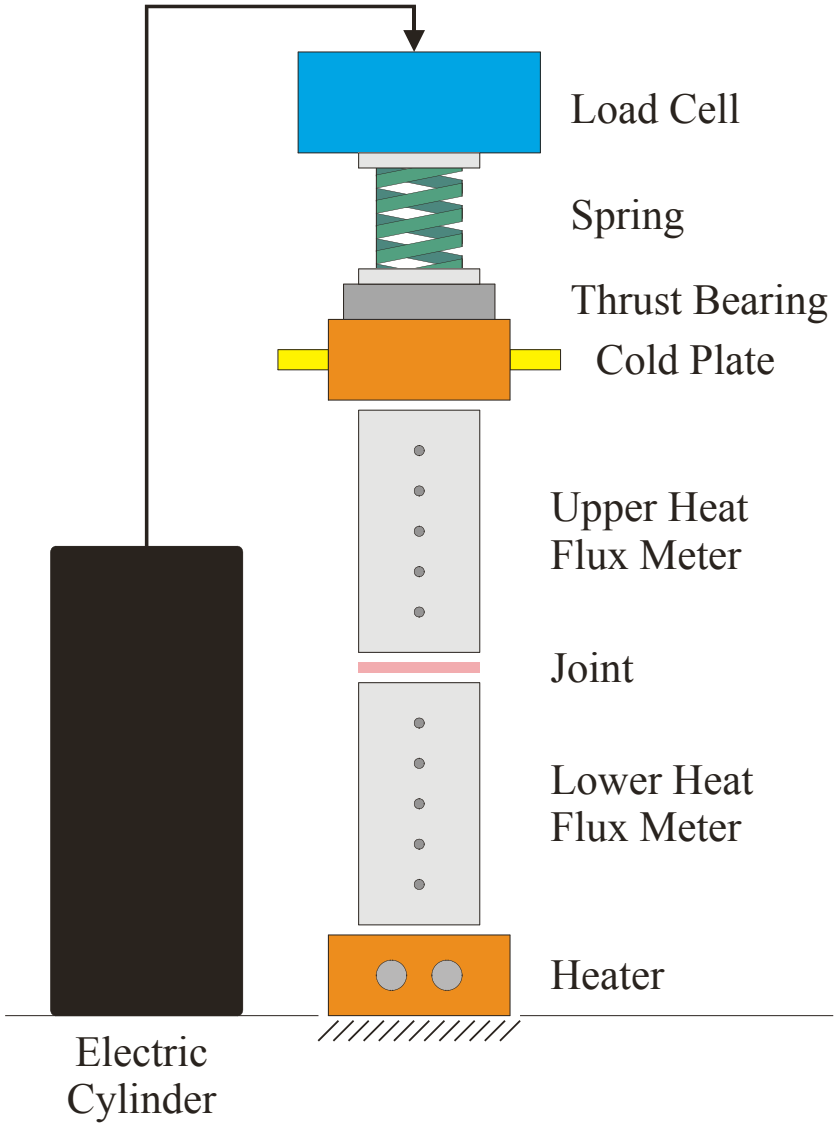
- All testing performed in vacuum chamber
  - ✓ $P \approx 10\,Pa\ \left(1 \times 10^{-4}\,atm\right)$
  - ✓ remove heat losses due to convection
  - ✓ maintain close balance between flux meters

Apparatus

Testing of thermal grease with 0.003” shim

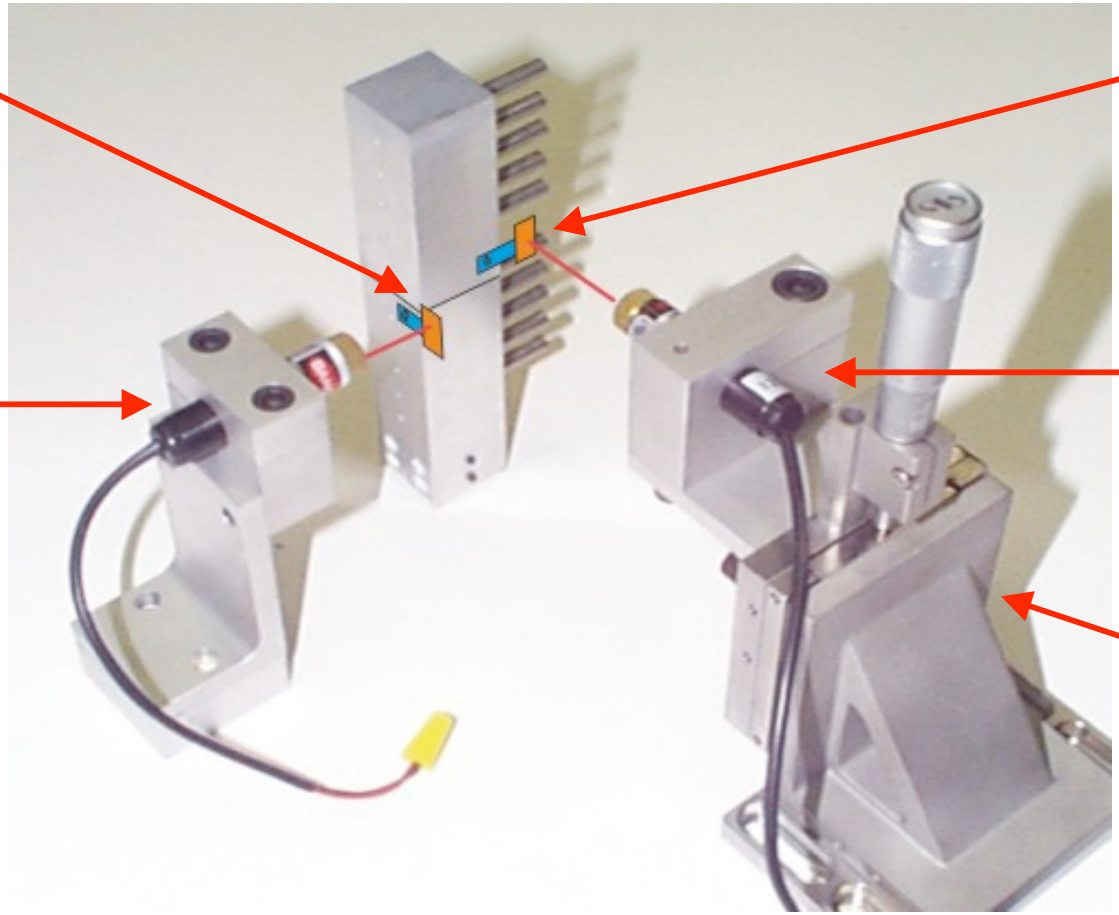


Apparatus

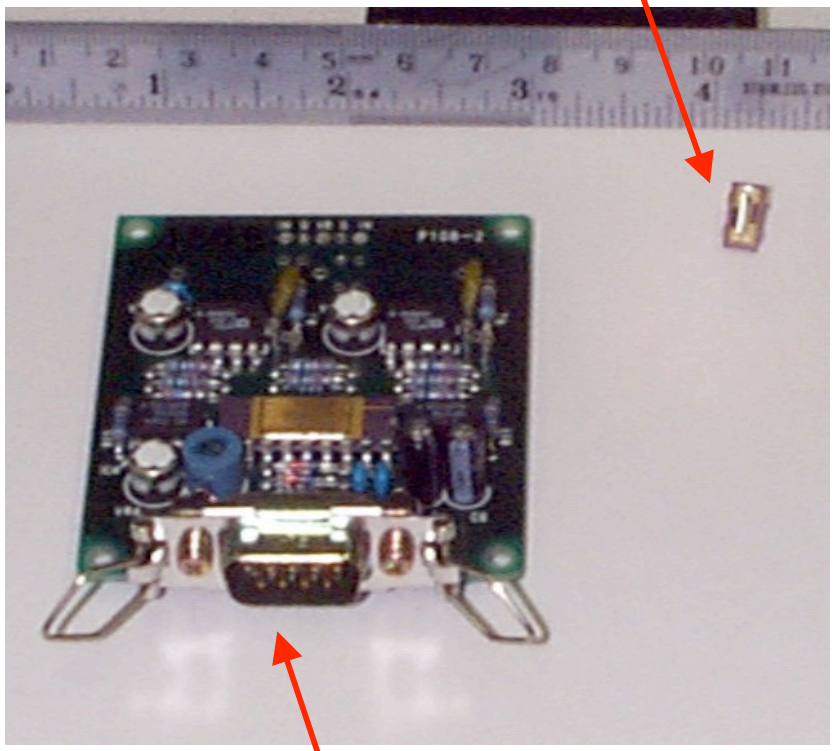


- Load cell
  - ✓ 100 or 1000 lbs
- Spring to compensate for thermal expansion
- Thrust bearing to remove torque loads
- Electric cylinder
  - ✓ digitally controlled stepper motor
  - ✓ 400 steps / rev 0.1” per revolution

Thickness and Deflection



Thickness and Deflection



- Lasers
  - $5\ mW$
  - $670\ nm$ wavelength
  - $100\ \mu m$ at 4” columation
- Detectors