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Thermal Interface (Joint) Conductance and Resistance

Definitions

Thermal interface resistance occurs whenever two solids of different materials are brought together to form an *interface*. When there is steady heat transfer from one solid to the second solid through the interface, there is a temperature drop which is related to the interface (joint) heat transfer rate $\dot{Q}_j$ and the interface (joint) resistance R_j and the interface (joint) conductance h_j. The relationships are

$$T_{\rm s1} - T_{\rm s2} = \dot{Q} R_j = \frac{\dot{Q}}{h_j A_{\rm a}}$$

where $A_{\rm a}$ is the apparent or nominal contact area. The temperatures $T_{\rm s1}$ and $T_{\rm s2}$ represent solid temperatures on either side of the interface. The units of thermal contact conductance and thermal contact resistance are $W/m^2 \cdot K$ and K/W respectively.

The relation between the interface resistance and the interface conductance is:

$$R_j = \frac{1}{h_j A_{\rm a}}$$

Resistances

In general the interface resistance consists of three resistances in parallel:

$$\frac{1}{R_j} = \frac{1}{R_s} + \frac{1}{R_g} + \frac{1}{R_r}$$

where R_s, R_g, and R_r are (i) the resistance due to the contacting surface asperities, (ii) the resistance of the material in the interstitial gaps, and (iii) the resistance due to radiative heat transfer across the gaps when the gap substance is transparent to radiation (eg dry air). For most micoelectronic applications, radiative heat transfer is negligible because the interface temperature level is *low*, ie in the range: $300\,K < T_i < 450\,K$. In this case the interface resistance consists of two components:

$$\frac{1}{R_j} = \frac{1}{R_s} + \frac{1}{R_g}$$

Conductances

In general the interface conductance consists of three conductances in parallel:

$$h_j = h_s + h_g + h_r$$

where h_s, h_g and h_r are (i) the conductance associated with the heat transfer rate through the contacting surface asperities, (ii) the conductance associated with the heat transfer rate through the interstitial gap substance by conduction, and (iii) the conductance associated with the heat transfer rate by radiation across the gap when the gap substance is transparent to radiation. For most mico-electronic applications, radiative heat transfer is negligible because the interface temperature level is *low*, ie in the range: $300\,K < T_i < 450\,K$. In this case the interface conductance consists of two components:

$$h_j = h_s + h_g$$

Typical Interface Formed by Two Conforming Rough Surfaces

Factors Influencing Thermal Contact Conductance

The thermal contact conductance is a complex geometric and thermophysical parameter which depends on many factors. Some important factors which influence thermal contact conductance are given below:

- Surface microtopography such as the surface asperity roughness, mean asperity slope, etc.
- Surface macrotopogragraphy such as surface waviness and anisotropy
- Surface microhardness
- Solid thermal conductivities
- Surface cleanliness, oxides, coatings
- Type of substance in the interstitial gaps (gas, liquid, grease, solid)
- Contact pressure and mechanical load cycle (e.g. first load cycle)
- Gas pressure if the interstitial fluid is a gas
- Temperature level of the interface

Typical Ranges of Interface Conductances

Interface	$h_j,\ W/m^2 \cdot K$
Ceramic – ceramic	$500 - 3000$
Ceramic – metals	$1500 - 8500$
Graphite – metals	$3000 - 6000$
Stainless steel – stainless steel	$1500 - 4000$
Aluminum – aluminum	$2000 - 12,000$
Stainless steel – aluminum	$3000 - 4500$
Copper – copper	$10,000 - 25,000$
Iron – aluminum	$4000 - 40,000$
Rough aluminum – aluminum (vacuum conditions)	$150 - 500$

The lowest values of interface conductance correspond to any combination of: low contact pressure, rough, non-flat surfaces, hard contacting solids, low conductivity contacting solids and low conductivity gap substance.

The highest values of interface conductance correspond to any combination of: high contact pressure, smooth, flat surfaces, soft contacting solids, high conductivity contacting solids and high conductivity gap substance.