KEY PROPERTIES OF THERMAL INTERFACE MATERIALS

LEADER TECH a HEICO company
The Leading Edge In EMI/RFI Shielding Technology

Introduction

In this day and age most, if not all, the electronic devices we use generate heat. This heat must be removed in order to maintain a safe operating temperature of the device. The process to remove this heat often involves the conduction of two mating surfaces, a package surface to a heat sink that allows the heat to be transferred efficiently into the environment. However, these surfaces usually have a roughness that is not visible to the naked eye, microscopic concave, convex or twisted shapes characterized these surfaces. When two such surfaces join, the contact will only occur at the high points, the low points are just voids filled with air. These air voids represent a notable resistance to heat flow, essentially acting as a barrier to the heat dissipation path and forcing the heat to flow through the contact points (see figure #1). This constriction resistance is known as surface contact resistance (Rcontact) in section ii.

Enter thermal interface materials (TIMs). Thermally conductive materials used to eliminate air gaps and transfer the heat between two mating surfaces. They conform to uneven microscopic mating surfaces, allowing heat to flow from one surface to the other in order to reduce the overall device temperature.

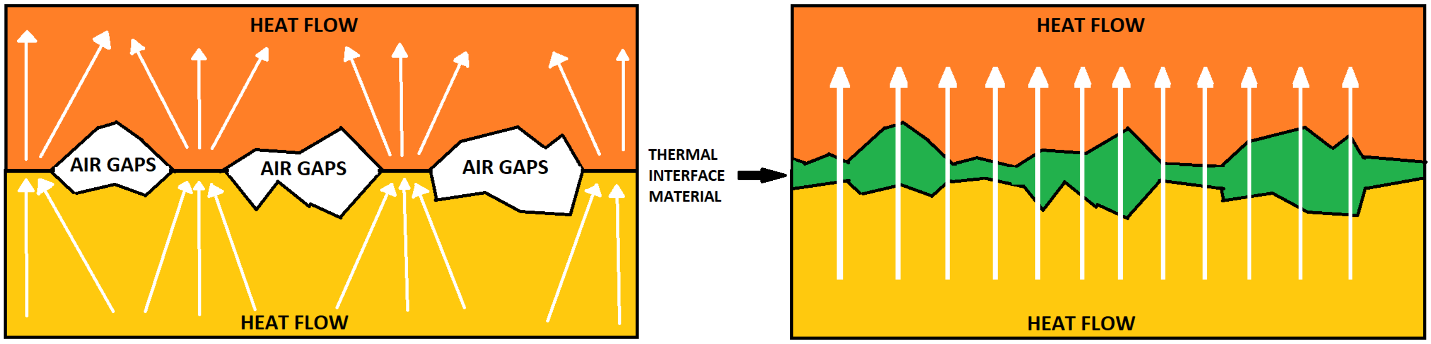


Figure #1. Two surfaces in contact and heat flowing across the surfaces without (left) and with thermal interface material (right).

General Theory

For a one dimensional steady state heat conduction, we use Fourier's Law of heat conduction for a material [i]:

Equation #1: $Q=kA\,(\Delta T/L)$

Where
Q = the heat flux through a plane [W]
k = the material's conductivity [W/m-K]
A = contact area [m2]
L = thickness of the material [m]
T = Temperature difference, [K]

From equation #1, we can determine the material's thermal resistance:

Equation #2: $R=A\,(\Delta T/Q)$

Where the relationship between R and k can be demonstrated by solving for Q in Equation 2 and substituting it into 1:

Equation #3: $R_{material}=L/k$

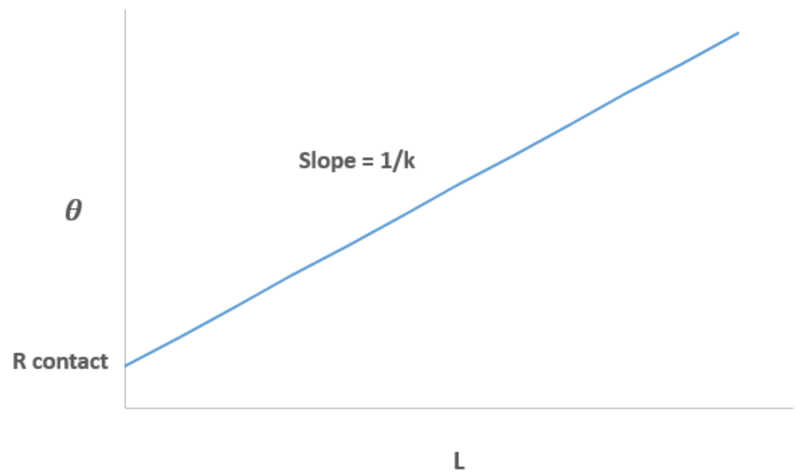
The material's impedance is calculated by the sum of its material's inherit thermal resistance ($R_{material}$) and the constriction resistance, also known as the surface contact resistance ($R_{contact}$)

Equation #4: $\varnothing = R_{material} + R_{contact}$

Finally, we can substitute Equation #3 into #4 which we can then plot to properly observe its linear correlation.

Equation #5: $\varnothing = L/k + R_{contact}$

Figure #2. Thermal Impedance vs Thickness



Thermal Properties

a. Thermal Impedance

Also known as thermal resistance, is a material property of the total resistance of heat that flows from a high temperature environment to a low temperature environment. This shows how a specific thickness of a material can resist the flow of heat through it. The relation between thermal resistance and conductivity is reciprocal, as demonstrated in Equation #3. However, based on ASTM D5470-60 standard, the correlation is linear between impedance and material thickness as shown in Figure #2.

b. Thermal Conductivity

Fourier's Law of Thermal conduction is defined as: a value that accounts for any property of the material that could change the way it conducts heat. In other words, materials with a higher thermal conductivity are good conductors of thermal energy. Since heat transfer by conduction involves transferring energy without motion of the material, it is logical that the rate of the transfer of heat would depend only on the temperature difference between two locations and the thermal conductivity of the material.[ii] However, based on Equation #5 and its plot (Figure #2), the thermal conductivity is just a reciprocal slope that won't be a contributing factor as opposed to the material thickness.

References:

[i] https://www.thermal-engineering.org/what-is-fouriers-law-of-thermal-conduction-definition/
[ii] https://energyeducation.ca/encyclopedia/Thermal_conductivity