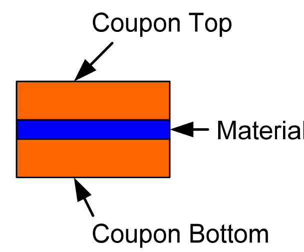
TEA

TECH BRIEF
(TB-19)

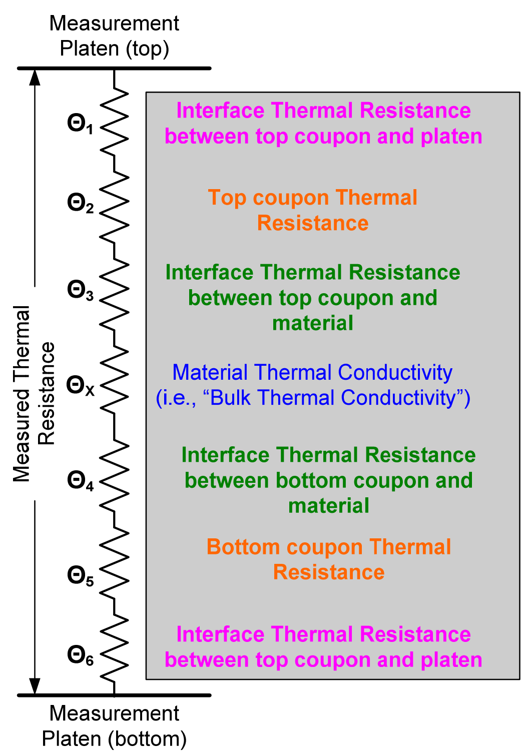
Technique for determining Bulk Thermal Conductivity (BTC) of material in a multi-element Measurement Coupon

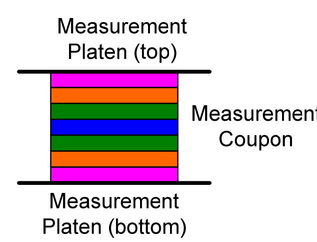
The measurement of BTC of very thin and/or non-solid material requires construction of a Measurement Coupon (MC) that protects the material and allows for getting the desired measurement data.



The MC, pictured at right, adds a solid, high thermal conductivity material on both sides of the material being measured. The top and bottom coupon pieces do not have to be the same material but should have thermal conductivities much larger (typically >10X) than the material to be measured if possible.

When the MC is inserted into the measurement system, the individual thermal resistances of the entire setup has to be considered. The figure at the right shows each of the resistance involved, including all the contact resistances. Given the seven different thermal resistances in the circuit, the main issue is how to determine the thermal resistance (Θ_X) of the subject material.





The total measureable thermal resistance equation is

$$\Theta_M = \Theta_X+\Theta_1+\Theta_2+\Theta_3+\Theta_4+\Theta_5+\Theta_5+\Theta_6 = \Theta_X+(\Theta_1+\Theta_2+\Theta_3+\Theta_4+\Theta_5+\Theta_5+\Theta_6) = \Theta_X+(\Theta_F)$$

The equation for each thermal resistance is $\Theta = L/(K_\theta \times A)$. If the area (A), BTC ($K_\theta$), and thickness (or length L) for Θ_1 through Θ_6, then repeated measurements of these components should remain constant – except for the variability induced by insertion and removal of the MC in the measurement system and the system variability. The same applies to the material under measurement. However, if the material thickness varies, then the coupon's measured

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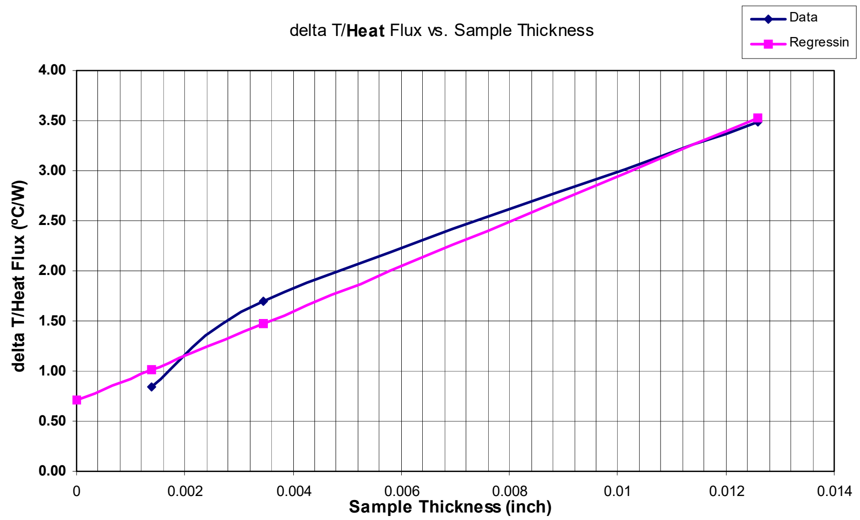
thermal resistance will vary as well. When the measured thermal resistance is plotted against the material thickness, as shown below, the line will reveal the Y-axis intercept (Y_O), the value of which will be the sum of all the other resistances. With the Y_O value known, the equation below can be used to calculate the BTC of the subject material.

$$K_\theta = \left[\frac{1}{\frac{\Delta T}{Q} - Y_0} \right] x \frac{L}{A}$$



Determination of the various contact resistances is the next step. If the MC is symmetrical with the same top and bottom material, then determining the contact resistance between the these pieces and the measurement platen can be accomplished by making thermal resistance measurement on a sample of the same material that has the same area and a thickness equal to the sum of the two individual pieces. The contact resistance will be half of the measured thermal resistance minus the calculated thermal resistance of the material. Care must be taken to use the same interface material between the material and the measurement platens, and to use the same force on the measurement sample. The resultant measurement data and calculations will yield values for Θ_1, Θ_2, Θ_5, and Θ_6.

The contact resistance between the subject material and the top and bottom coupon material is $\Theta_3 + \Theta_4 = \Theta_M - \Theta_X + \Theta_1 + \Theta_2 + \Theta_5 + \Theta_6$. If the top and bottom coupon material is the same, then the contact resistance values should be the same and the value for either Θ_3 or Θ_4 is half the above calculated value.

Additional information on making thermal conductivity measurements can be found in Tech Brief TB-10.