GORE® Thermal Insulation
Technical Note

THERMAL CONDUCTIVITY CHARACTERIZATION

Executive Summary

GORE® Thermal Insulation has unique properties of low thickness (< 300 μm) with conductivity less than air (< 0.02 W/(m•K)) and therefore presents challenges in characterization. A test methodology incorporating a modified heat flow method, ex-situ thickness method, and two thickness conductivity calculation is used to provide reliable and accurate thermal conductivity data. Conductivity results show the distribution of data falls below the conductivity specification of 0.02 W/(m•K).

Introduction

Thin thermal insulation with ultra-low thermal conductivity is a new product for solving complex thermal management challenges in mobile electronic system architecture. Applications include improving heat spreading to maintain safe surface touch temperatures and protecting heat sensitive components from excessive temperatures.

Reliable and accurate thermal conductivity data is essential for modeling early in the design cycle and for maintaining performance through validation and scale up.

An appropriate thermal conductivity test is needed to predict and ensure performance in system. Challenges exist in measuring thin, compressible materials with conductivity lower than air. The primary challenge is making reliable and accurate thickness measurements with enough sensitivity to minimize error in conductivity calculations.

GORE® Thermal Insulation is thin (< 300 μm), compressible, and has conductivity lower than air (< 0.02 W/(m•K)). A test methodology incorporating a combination of a heat flow method, thickness method, and conductivity calculation is used.

The upper specification limit for thermal conductivity is 0.02 W/(m•K). Thermal conductivity is tested on each lot and certified with shipment as part of a standard quality control test plan. Direct verification of each lot is performed to ensure product meets specifications. This characterization is provided to report specific thermal conductivity statistics which may be useful to thermal engineers.

Materials and Method

Thermal Insulation Material

100 μm GORE® Thermal Insulation and 250 μm GORE® Thermal Insulation were sampled from production lots. A lot is defined as a new run of raw material through the entire process. 135 lots of 100 μm material and 28 lots of 250 μm material produced between January 2021 and November 2023 are included in this characterization, which represent the current production capability.

Insulation samples are 2 inch diameter circle cuts taken from beginning and end of rolls produced. Multiple cuts are layered to create thin and thick samples needed for calculating conductivity.

Test Methodology

Two separate tests are used to measure resistance and thickness. Both tests are conducted under 6 psi of pressure on the same sample. The thickness test is performed in a separate, more sensitive, test apparatus immediately after conducting the resistance test. The two-thickness method for calculating conductivity is used to eliminate any effect of contact resistance. It requires a thin and thick sample of the same material be tested for resistance and thickness. This is achieved by layering samples of the same insulation material. Interfacial resistance between layers is assumed to be negligible since the material conductivity is lower than air and the material has good compliance.

Resistance Test Method

The resistance measurement is taken using a steady state thermal transmission method, utilizing a heat flow meter apparatus modified from ASTM C518-17. Resistance on a thin and thick sample, made from layers, is measured for each part number. The two thicknesses are required for calculating conductivity. A heat flow meter (TA Instruments model FOX 50) is used to measure resistance of the sample under 6 psi pressure. Equipment calibration standards are used along with a low conductivity NIST certified standard reference material (NIST 1453 SRM, Expanded Polystyrene) to ensure accuracy in the test range of interest.

Thickness Test Method

Thickness of the same sample used in the resistance method is measured immediately following the resistance test using a modified ASTM F36-15 method. An Instron universal testing system is used in compression mode for precise thickness detection of the sample at 6 psi of pressure. This greatly improves the reliability of the conductivity calculation in the two-thickness method.

Thermal Conductivity Calculation

A two-thickness resistance procedure[1] is used to calculate thermal conductivity (λ). This method is used to eliminate any effects of contact resistance using the heat flow method. The conductivity of the material is equal to the reciprocal of the slope of resistance vs. thickness as shown in equation [A].

[Equation A]

$$\lambda = \frac{t_2 - t_1}{R_2 - R_1}$$

Conductivity calculations are reliable within ± 0.0003 W/(m•K) with 95% confidence.

Results

Table 1 shows the average and standard deviation of 250 μm and 100 μm. Multiple beginning and end samples are taken to characterize each lot.

Thermal Conductivity W/(mK)

Product	Average	Standard Deviation
100 μm	0.0173	0.0005
250 μm	0.0162	0.0003

Table 1: Conductivity results for 100 μm and 250 μm GORE® Thermal Insulation

Figure 1a and 1b show distributions of both 100 μm and 250 μm GORE® Thermal Insulation fall below the upper specification limit (USL) of 0.02 W/(m•K).

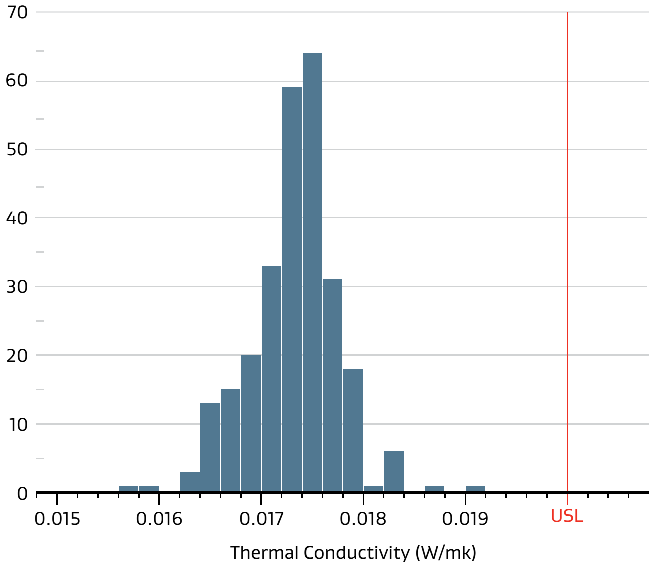

Figure 1a: Conductivity distributions relative to USL for 100 μm GORE® Thermal Insulation

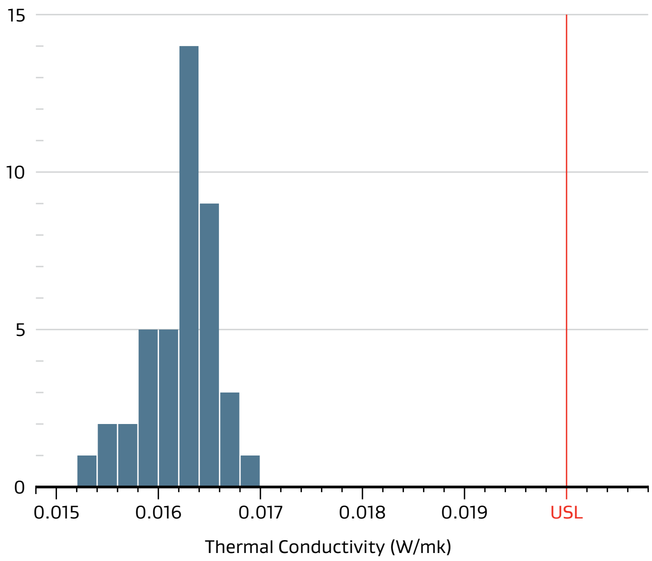

Figure 1b: Conductivity distributions relative to USL for 250 μm GORE® Thermal Insulation

1. LaserComp, Inc. "Tests of thin samples stacked (using FOX50 instrument)" Application Note AN-TSS © 2008 (October 23)

Discussion

Gore's production is capable of making product that falls below the upper specification limit of 0.02 W/(m•K). Each lot is verified to meet conductivity specification as part of Gore's quality control release criteria.

For thermal modeling, a suggested approach is to use a range spanning from our upper specification limit of 0.02 W/(m•K) down to 0.017 W/(m•K).

Gore also conducted the testing at the Ajou University, Korea, with identical results.

Future improvements to test methodology and/or methods may be incorporated to improve test reliability and accuracy. This will be especially important as Gore aims to further decrease both thermal conductivity and thickness in future product offerings.

Contact Us — For additional assistance, please contact a Gore representative.

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PEV-212-TEC-EN-NOV23