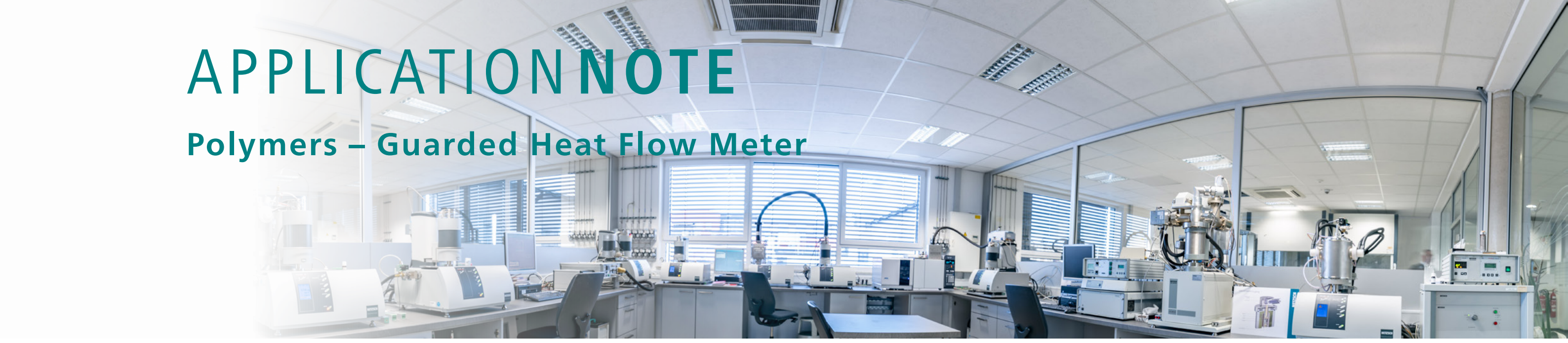

APPLICATION NOTE

Polymers – Guarded Heat Flow Meter

Accurate Thermal Conductivity Determination of PTFE Via the TCT 716 *Lambda*® Guarded Heat-Flow Meter

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Introduction

PTFE (polytetrafluoroethylene), also known as Teflon®, is a thermoplastic polymer known for its excellent resistance to chemicals and heat. It is commonly used in various applications such as cookware, electrical insulation, medical and laboratory equipment, lubricants, seals, and gasket materials. Additionally, fillers can be incorporated into PTFE to modify its properties. For example, glass fillers are often added to enhance its thermal and mechanical characteristics. Therefore, understanding the thermal behavior of both unfilled and filled PTFE throughout its range of operating temperatures is essential.

Experimental

Thermal conductivity was determined using the TCT 716 *Lambda*® Guarded Heat Flow Meter (GHFM). This steady-state technique involves placing a sample of known thickness between two plates maintained at different temperatures, enabling heat to flow through the sample. The heat flow through the sample's thickness is measured, and thermal conductivity is then calculated.

The GHFM method sets itself apart from other methods because it is particularly effective for traditionally challenging specimens, for example non-homogeneous, anisotropic materials, such as multi-layer and composite specimens [1]. In addition to more standard homogeneous materials, the GHFM is also able to accurately determine thermal conductivity of layered or filled materials (e.g., glass-filled polymers).

For this study, PTFE samples (table 1) were obtained from two different manufacturers, including both an unfilled and a glass-fiber filled PTFE sample from one of the manufacturers. Each test specimen had a diameter of approximately 50 mm and a thickness of 3 mm. A summary of the sample information is provided in the table below. Measurements were conducted over a temperature range of approximately -10°C to 200°C, and calibration was carried out using Vespel® SP-1. A thin layer of silicone thermal joint compound was applied between the specimens and instrument plates to minimize interfacial resistance. A pressure of approximately 175 kPa was applied to the specimens during testing.

Table 1 Test Specimens

	Sample 1	Sample 2	Sample 3
Material	Unfilled PTFE	Unfilled PTFE	Glass-fiber filled PTFE
Manufacturer	A	B	B
Sample thickness	2.90 mm	3.20 mm	3.15 mm
Sample density	2.118 g/cm^3	2.166 g/cm^3	2.172 g/cm^3

NGB · Application Note 368 · EN · 0325 · Technical specifications are subject to change.

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Results and Analysis

The apparent thermal conductivity versus temperature results for the tested samples are presented in figure 1. The unfilled samples from manufacturers A (blue curve) and B (orange curve) align with the expected values from literature, which is approximately 0.27 W/(m·K) at room temperature [2]. Additionally, Sample 2 has a higher density than Sample 1, leading to a corresponding increase in thermal conductivity. As anticipated, the sample with glass fiber filler exhibits a significantly higher thermal conductivity. Furthermore, PTFE is known to undergo a solid-solid phase transition at room temperature [3], which is evident in the noticeable change in apparent thermal conductivity in this temperature region. (It should be noted that during this phase transition region, heat is absorbed by the material, the effects of which are not within the scope of this application note). Above this phase transition region, the effect of temperature increase on thermal conductivity is minimal [4].

Summary

The results showed that the unfilled samples from both manufacturers aligned with the expected thermal conductivity values of unfilled PTFE based on literature sources. The sample with higher density exhibited higher thermal conductivity, and the glass-fiber filled sample demonstrated an increased thermal conductivity. Additionally, PTFE underwent a solid-solid phase transition at room temperature, which was evident in the change in thermal conductivity. Above this phase transition, the effect of temperature on thermal conductivity was minimal. The results of this study demonstrate that the TCT 716 *Lambda*® is highly effective for analyzing the thermal properties of both unfilled and filled PTFE.

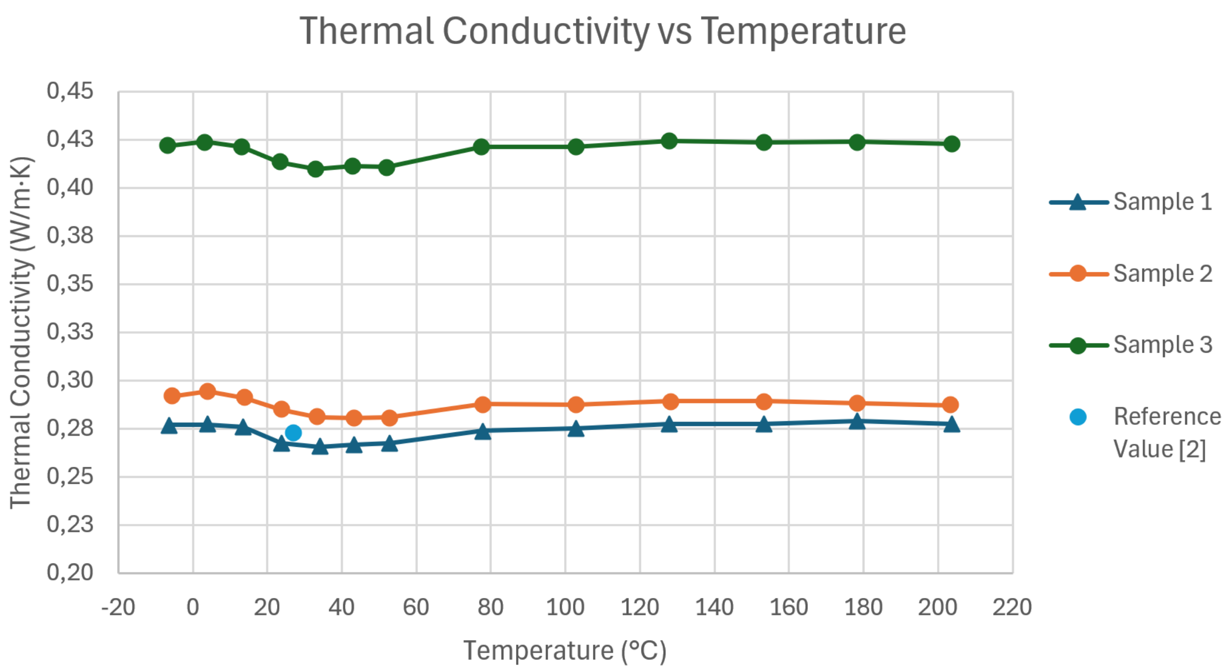
References

[1] ASTM E1530-19, Standard Test Method for Evaluating the Resistance to Thermal Transmission of Materials by Guarded Heat Flow Meter Technique

[2] Marquardt, E.D., Le, J.P. and Radebaugh, R., Cryogenic Material Properties Database, Cryocoolers 11

[3] Plenum Press, New York (2000) 681-687 Villani, Vincenzo (1990) A study on the thermal behaviour and structural characteristics of polytetrafluoroethylene. Thermochimica Acta, 162. 189-193

[4] Blumm, J., Lindemann, A., Meyer, M. et al. Characterization of PTFE Using Advanced Thermal Analysis Techniques. Int J Thermophys 31, 1919–1927 (2010)



1 Thermal conductivity versus temperature

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