Characterization of PTFE using Advanced Thermal Analysis Techniques

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Overview:

1. Introduction
2. Presentation of the measuring methods used
3. Discussion of the measurement results
4. Summary

Material

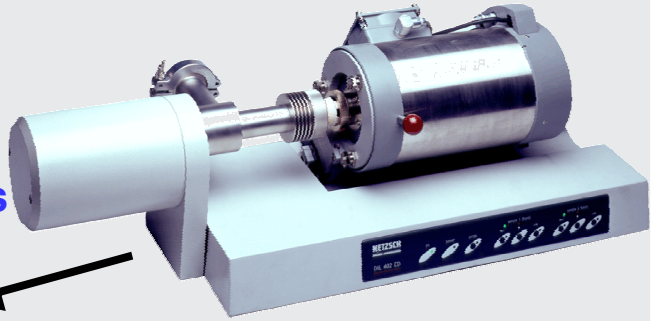
Polytetrafluoroethylene (PTFE) is a synthetic fluoropolymer originally discovered by Roy Plunkett of DuPont in 1938, used in numerous industrial applications. It is often referred to by its trademarked name, Teflon. Compared to other polymers, PTFE generally has a high density (around 2.2 g/cm³) and high melting point (approximately 327°C).

The PTFE analyzed in this work was supplied by ElringKlinger Kunststofftechnik GmbH, Heidenheim.

Methods

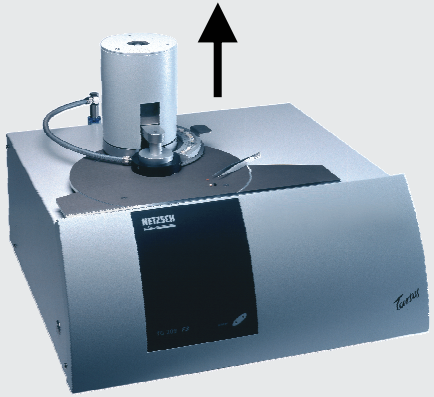
Differential Scanning Calorimetry (DSC 204 F1 *Phoenix*)

Thermal Expansion
Expansion Coefficients
Density Change
Phase Transition Temperatures
Enthalpy Changes
Specific Heat
Thermal Diffusivity
Thermal Conductivity
Storage Modulus
Loss Modulus
Thermal Stability



Dilatometry (DIL 402 C)

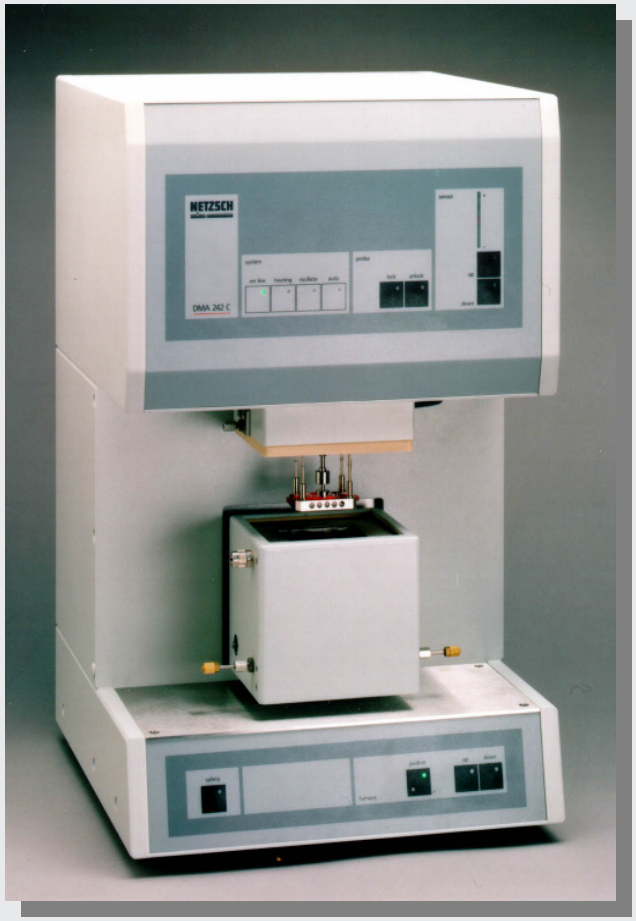
Dynamic Mechanical Analysis (DMA 242 C)



Thermobalance (TG 209 F3 ASC)

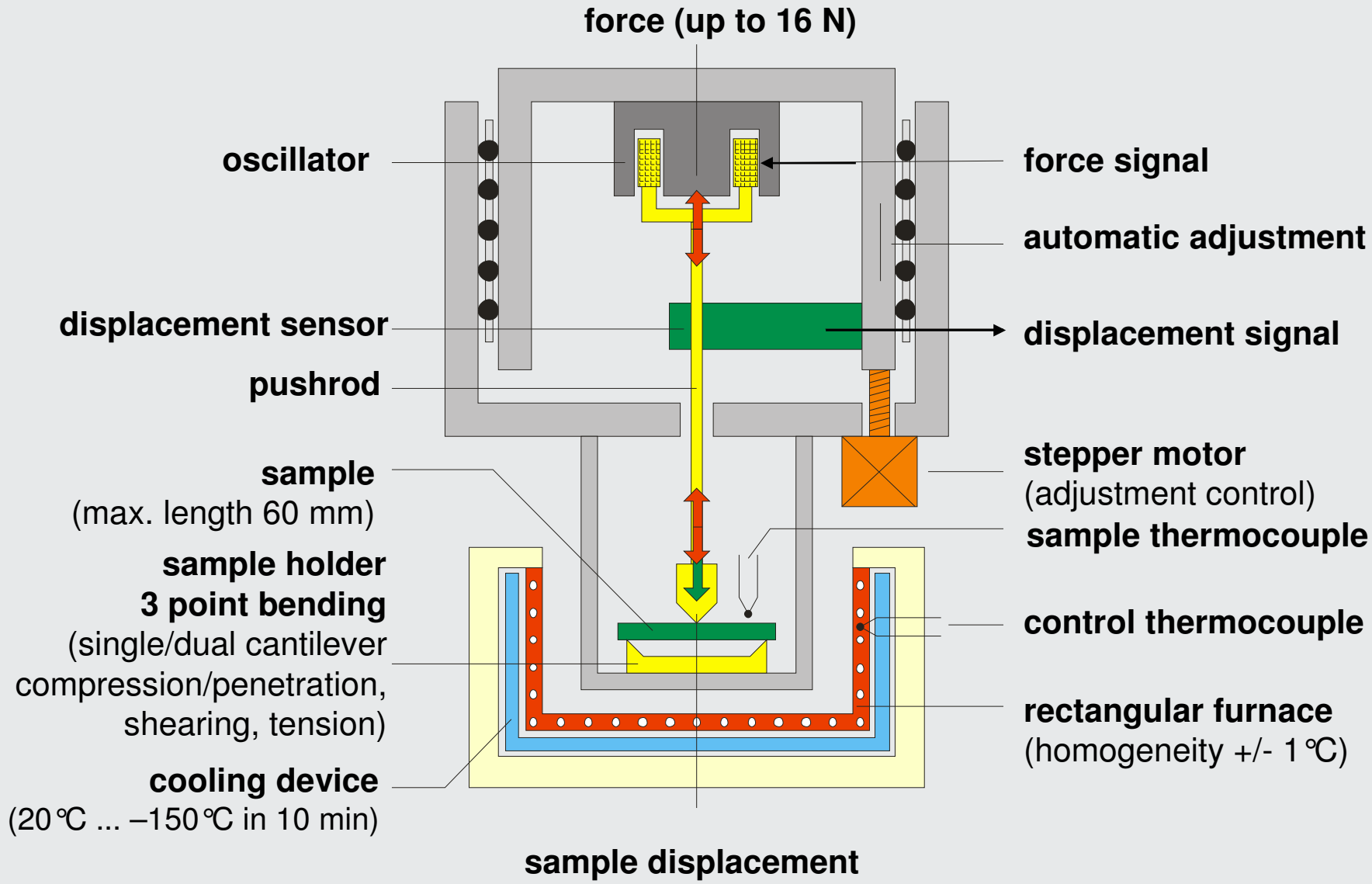
Laser Flash (LFA 457 *MicroFlash*)

Dynamic-Mechanical Analyzer DMA 242 C

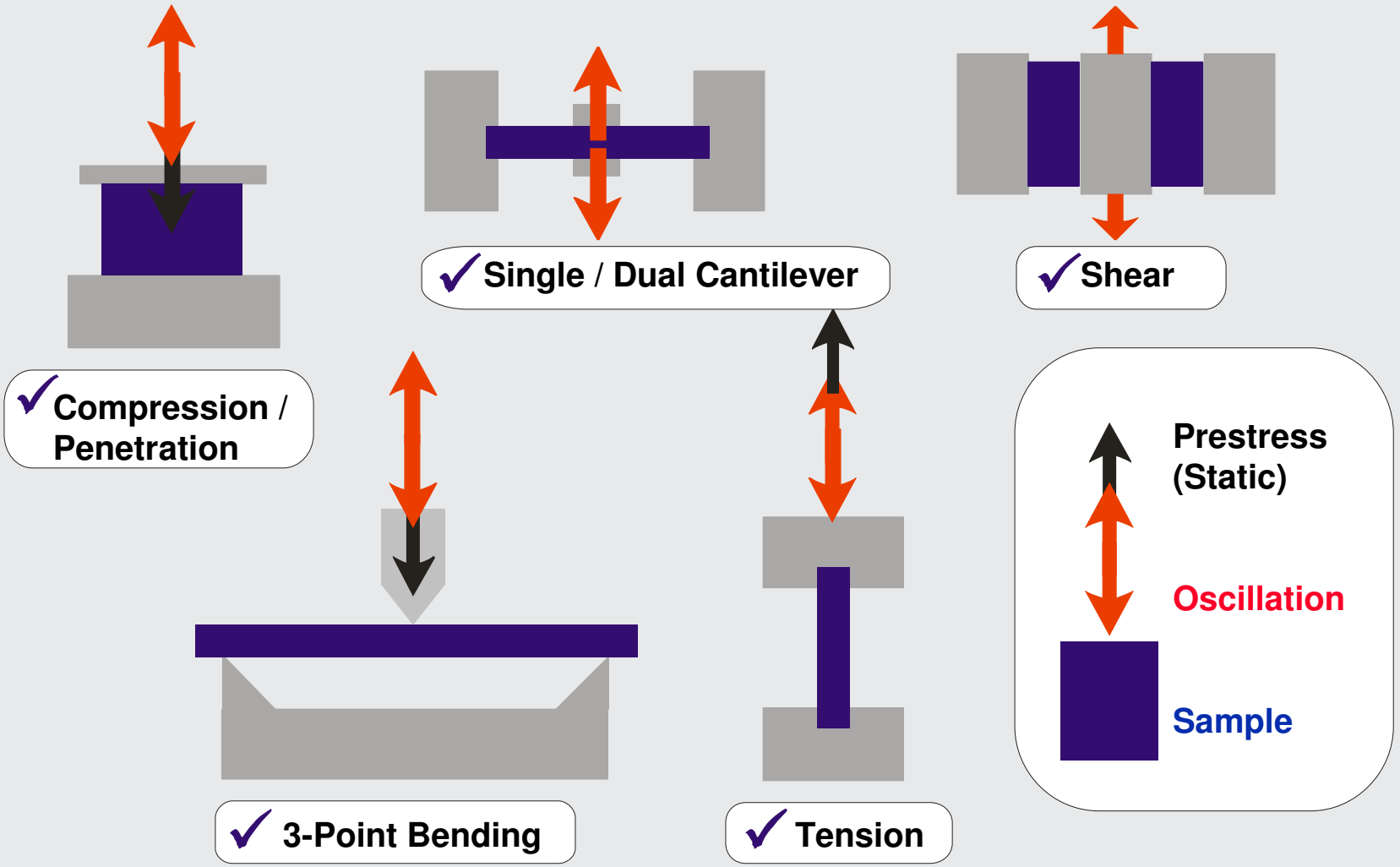


- Wide temperature range (-170 ... 600 °C)
- Robust design
- Rectangular furnace
- Versatile sample holders
- Large sample geometries
- Large dynamic and static forces (up to 16 N)
- High amplitude resolution (up to 0.5 nm)
- Immersion and humid atmosphere tests
- Fourier Analysis
- Comprehensive calibration routines
- User-friendly *Proteus®* software

Schematic Design: DMA 242 C

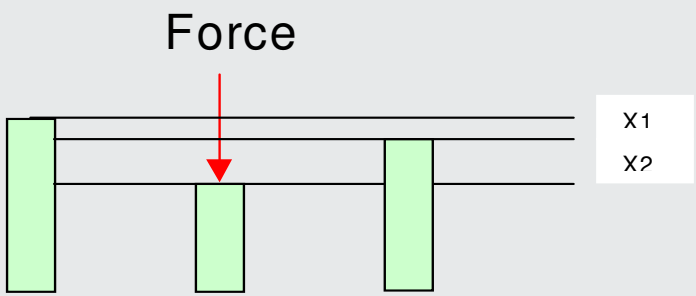


DMA Standard Measuring Modes



Dynamic-mechanical Analysis DMA
Measuring Principle

Viscoelastic sample:



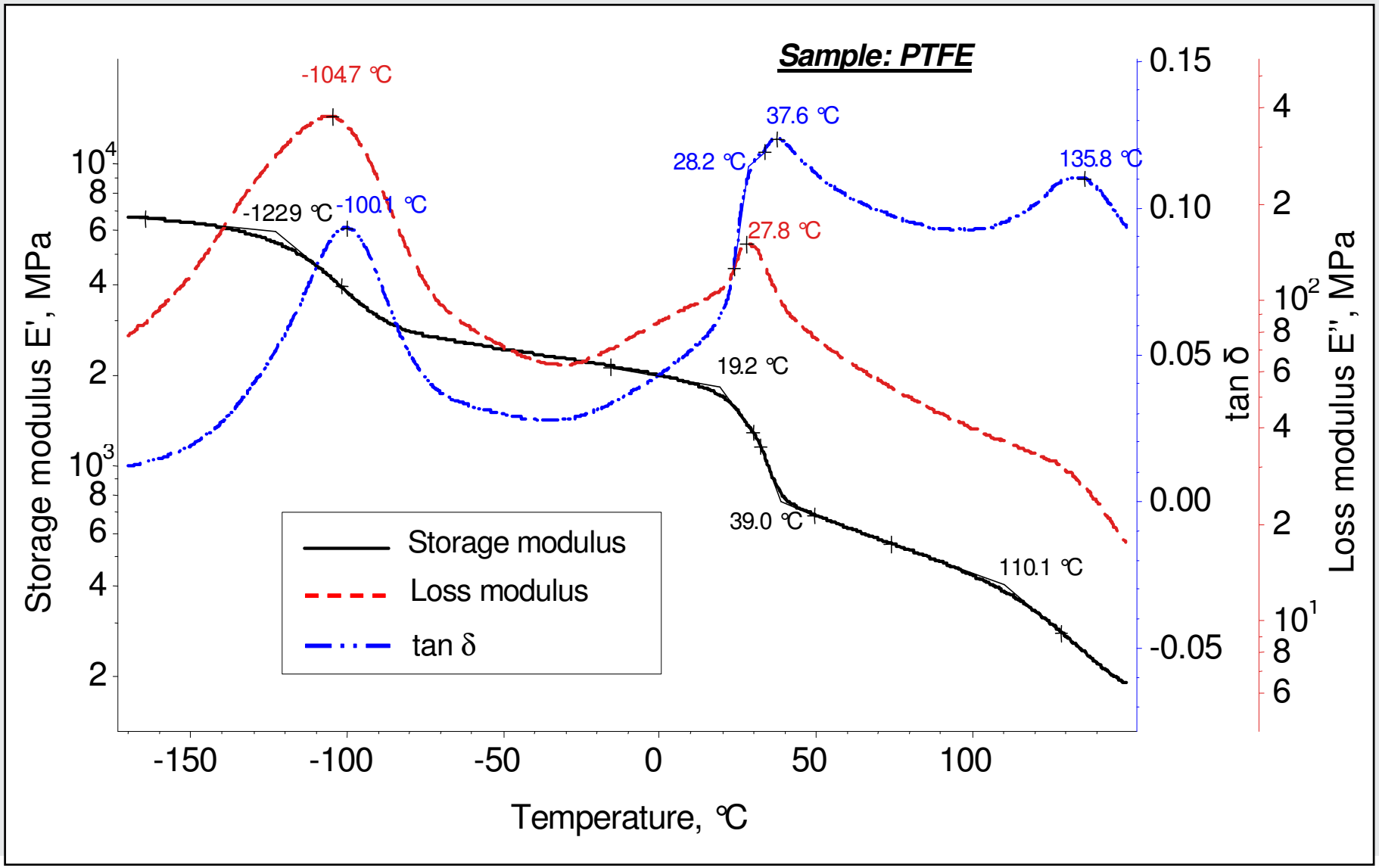
Loss Modulus E´´

Storage Modulus E´

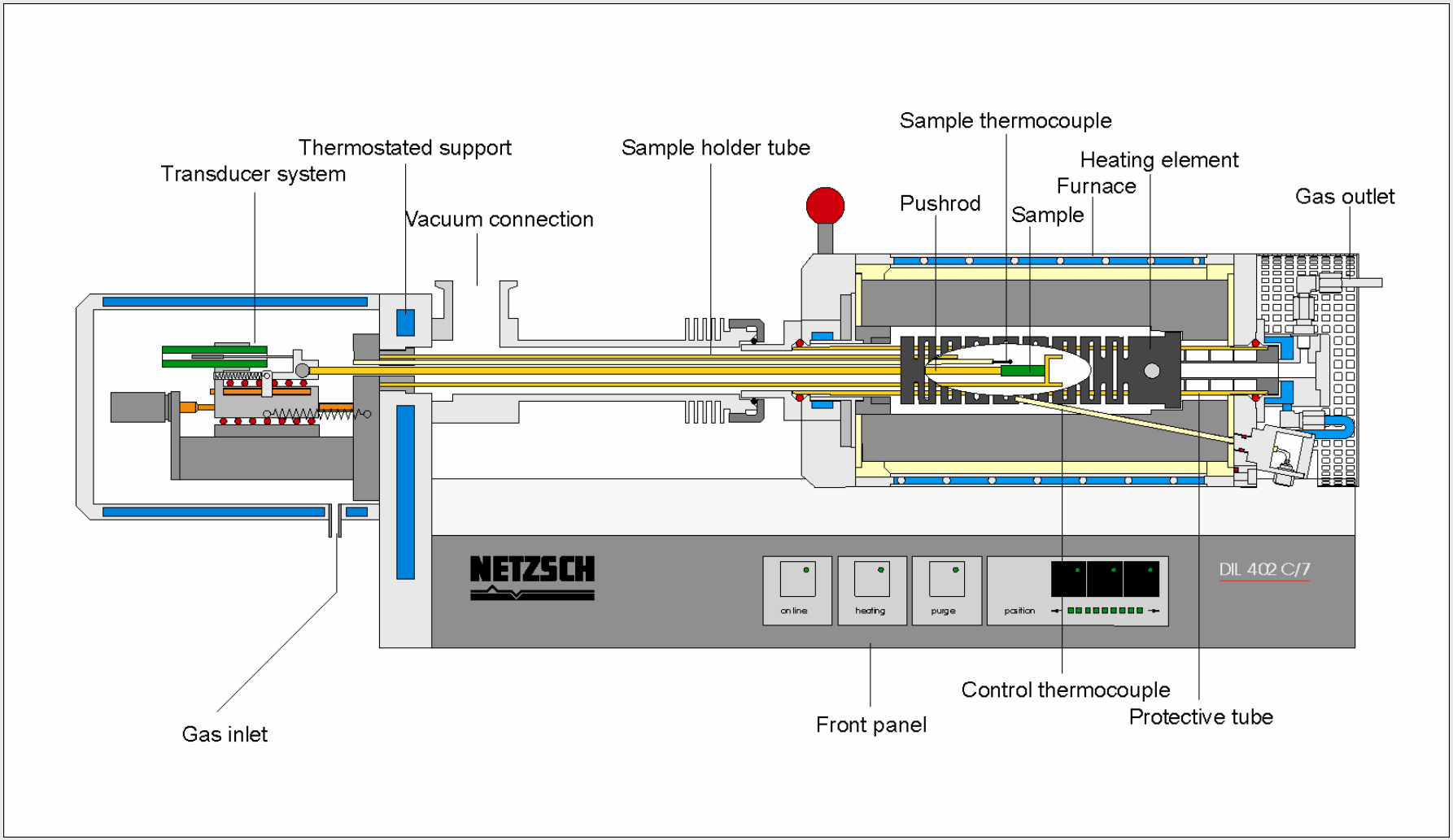
X_1: irreversible part
x_2: reversible part

$$\text{Complex Modulus (E*)} = \frac{\text{Stress amplitude}}{\text{Strain amplitude}}$$

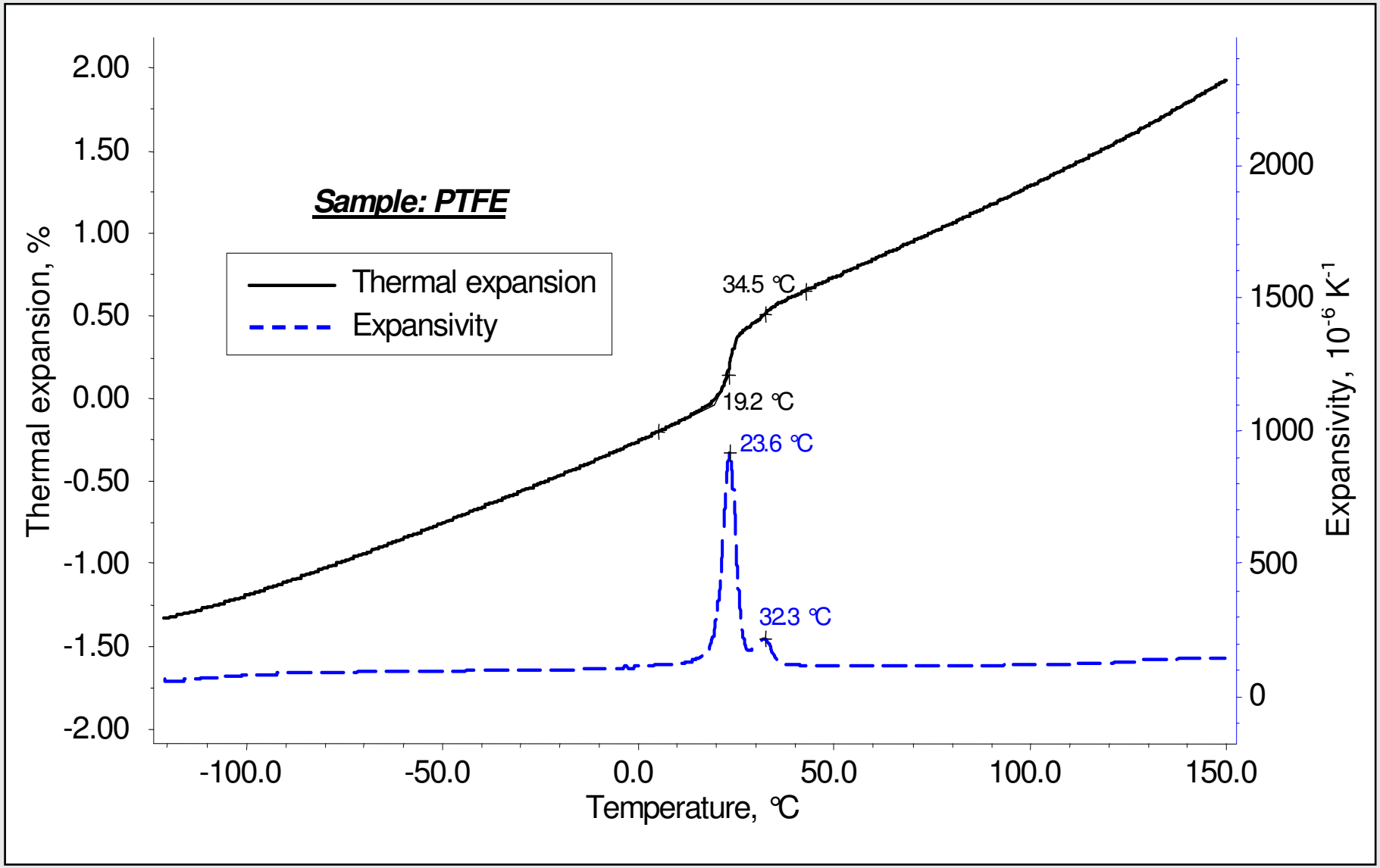
DMA Results


Sample: PTFE
-104.7 °C
37.6 °C
28.2 °C
135.8 °C
-122.9 °C
-100.1 °C
27.8 °C
19.2 °C
39.0 °C
110.1 °C
Storage modulus
Loss modulus
tan δ
Storage modulus E', MPa
Loss modulus E'', MPa
tan δ
Temperature, °C
-150
-100
-50
0
50
100
0.15
0.10
0.05
0.00
-0.05

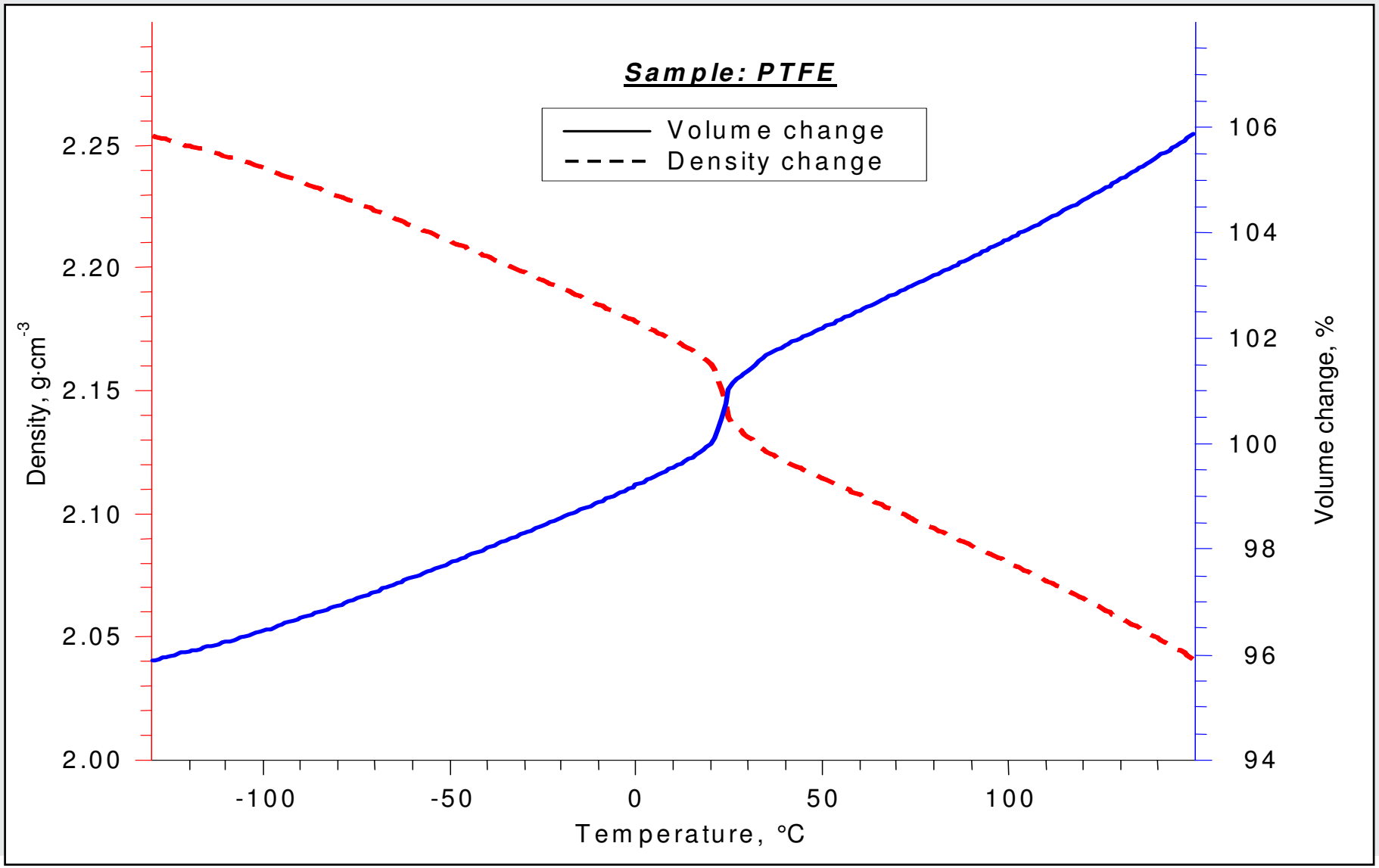
Thermal Expansion Using Pushrod Dilatometry: DIL 402 C



Thermal Expansion Results



Volumetric Expansion and Density Change

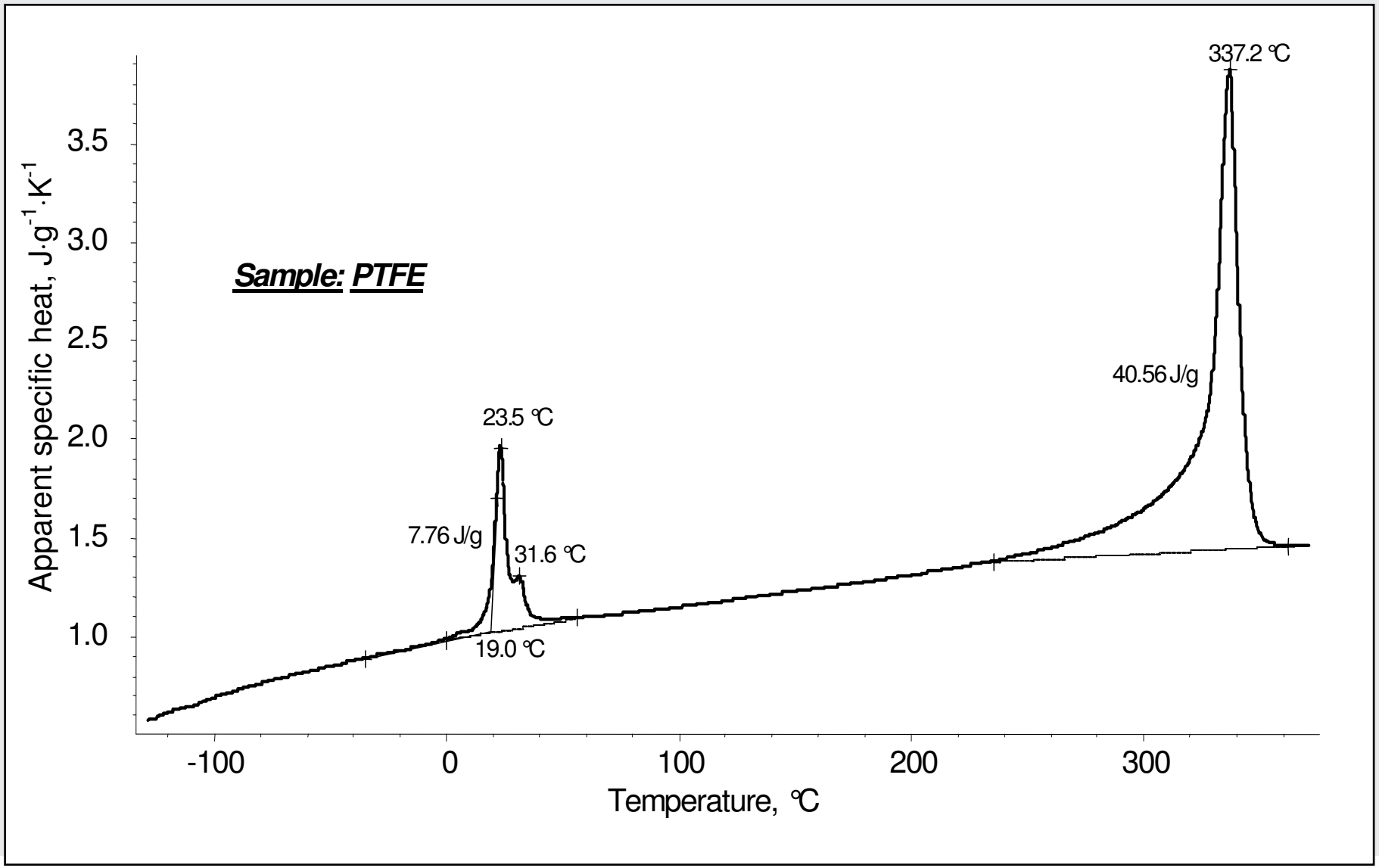


DSC 204 *F1 Phoenix®*, Schematic Design

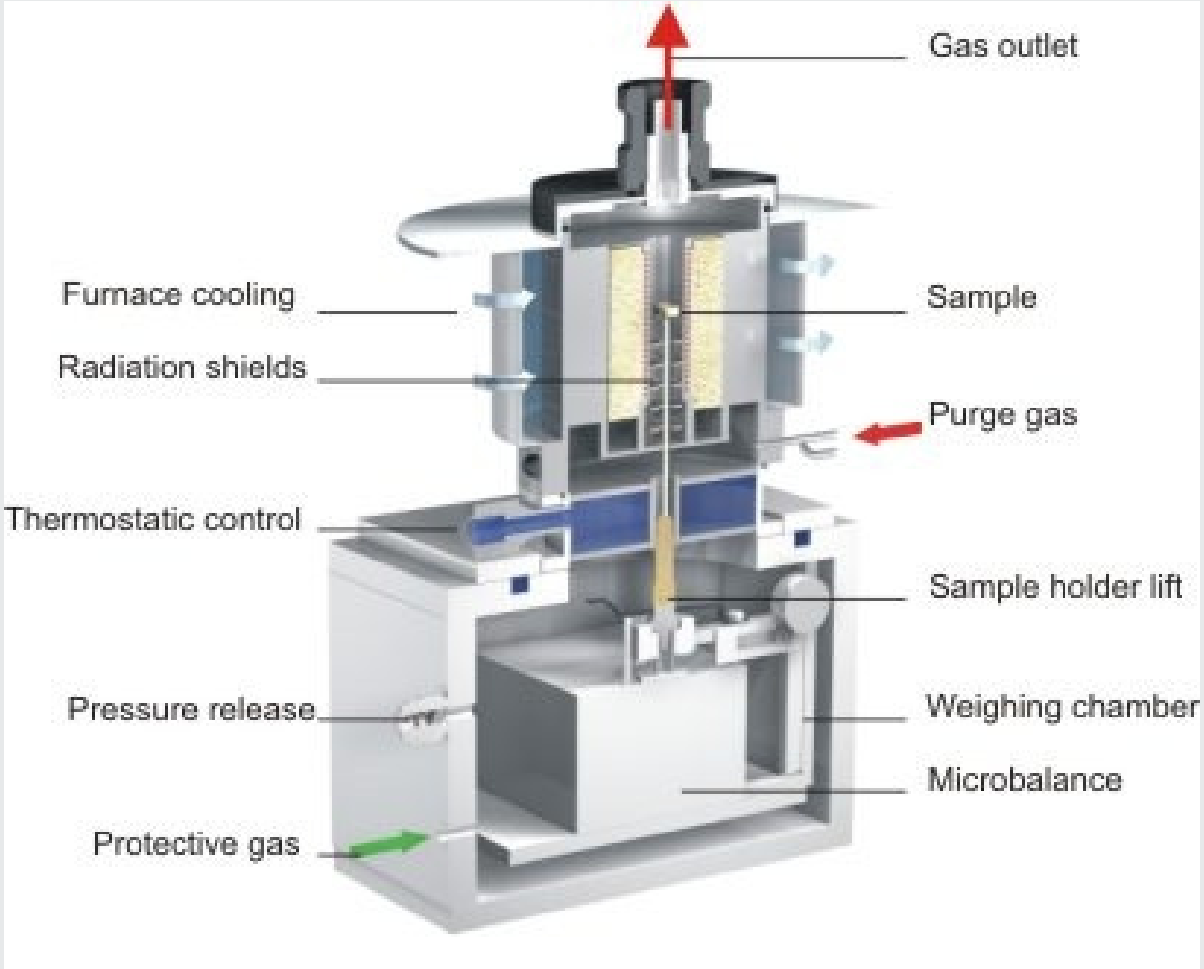
DSC 204 F1 Phoenix®

DSC 204 F1 Phoenix® - ASC

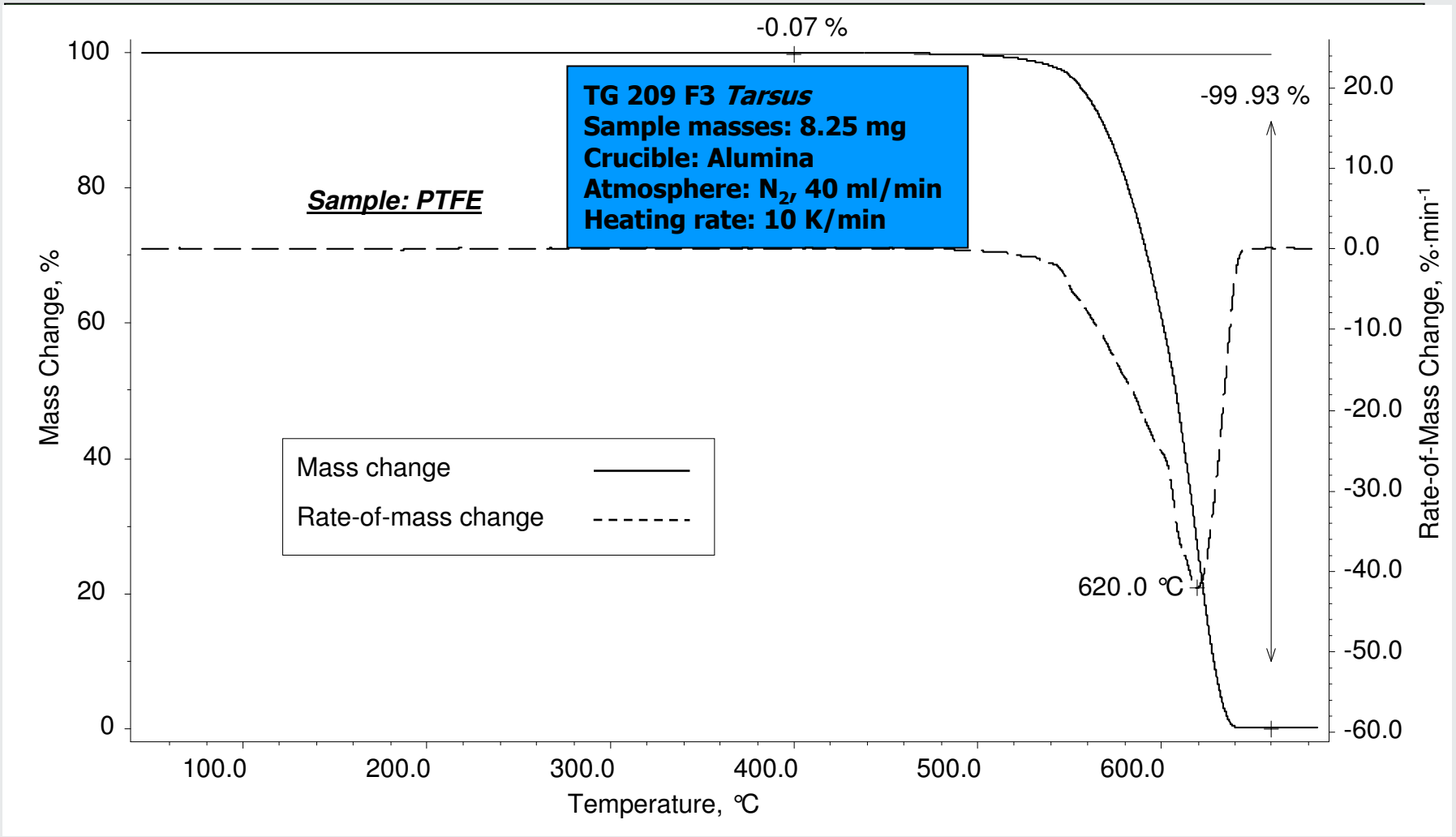
Specific Heat Results



TG 209 *F3 Tarsus®* - Technical Design



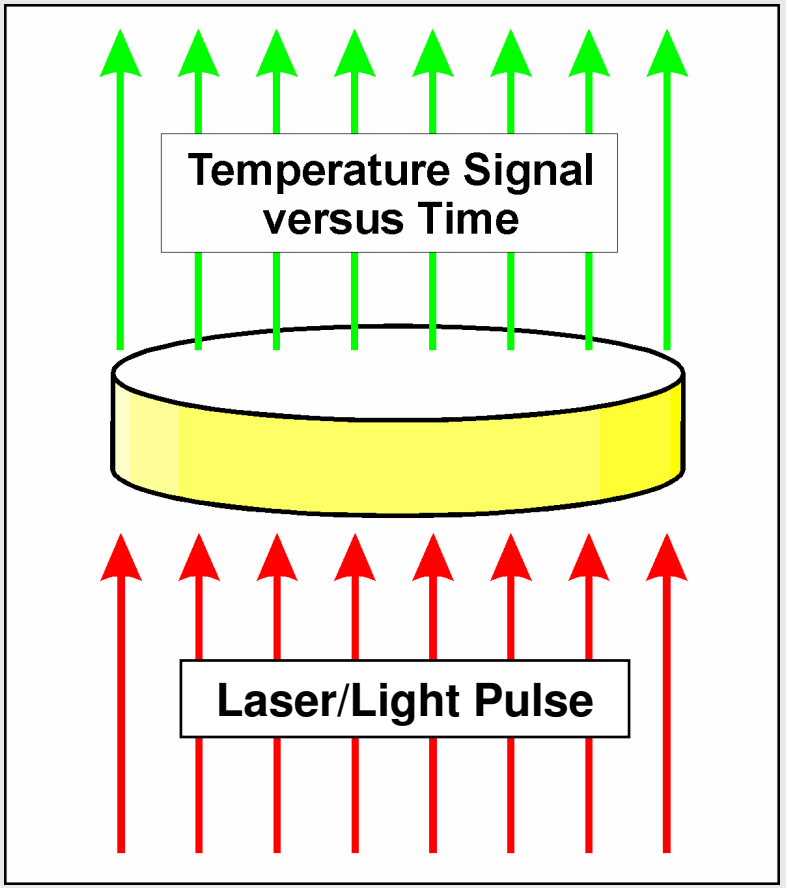
Thermal Stability Results



Measurement of the Thermal Diffusivity Using the Laser Flash Method:

The front surface of a plan-parallel sample is heated by a short light / laser pulse.

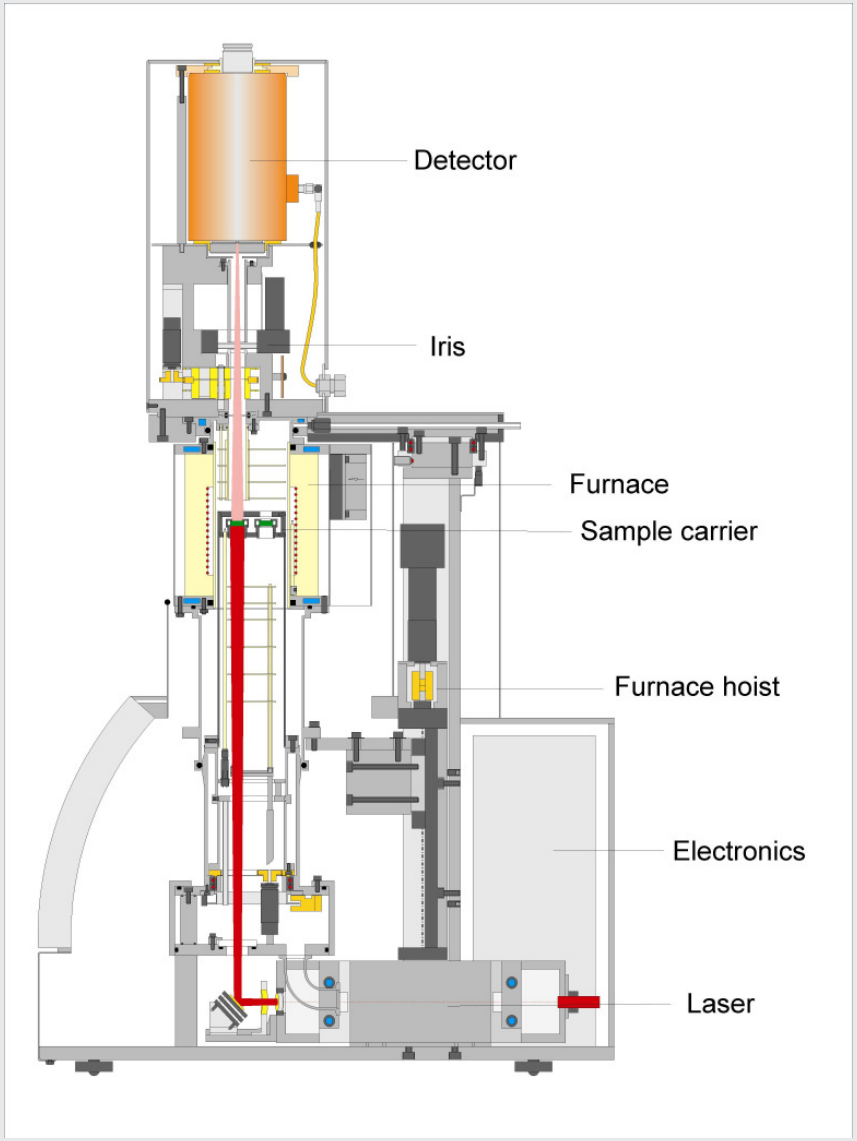
The temperature rise on the rear surface is measured versus time using an IR-detector.



Laser Flash System
NETZSCH LFA 457 MicroFlash

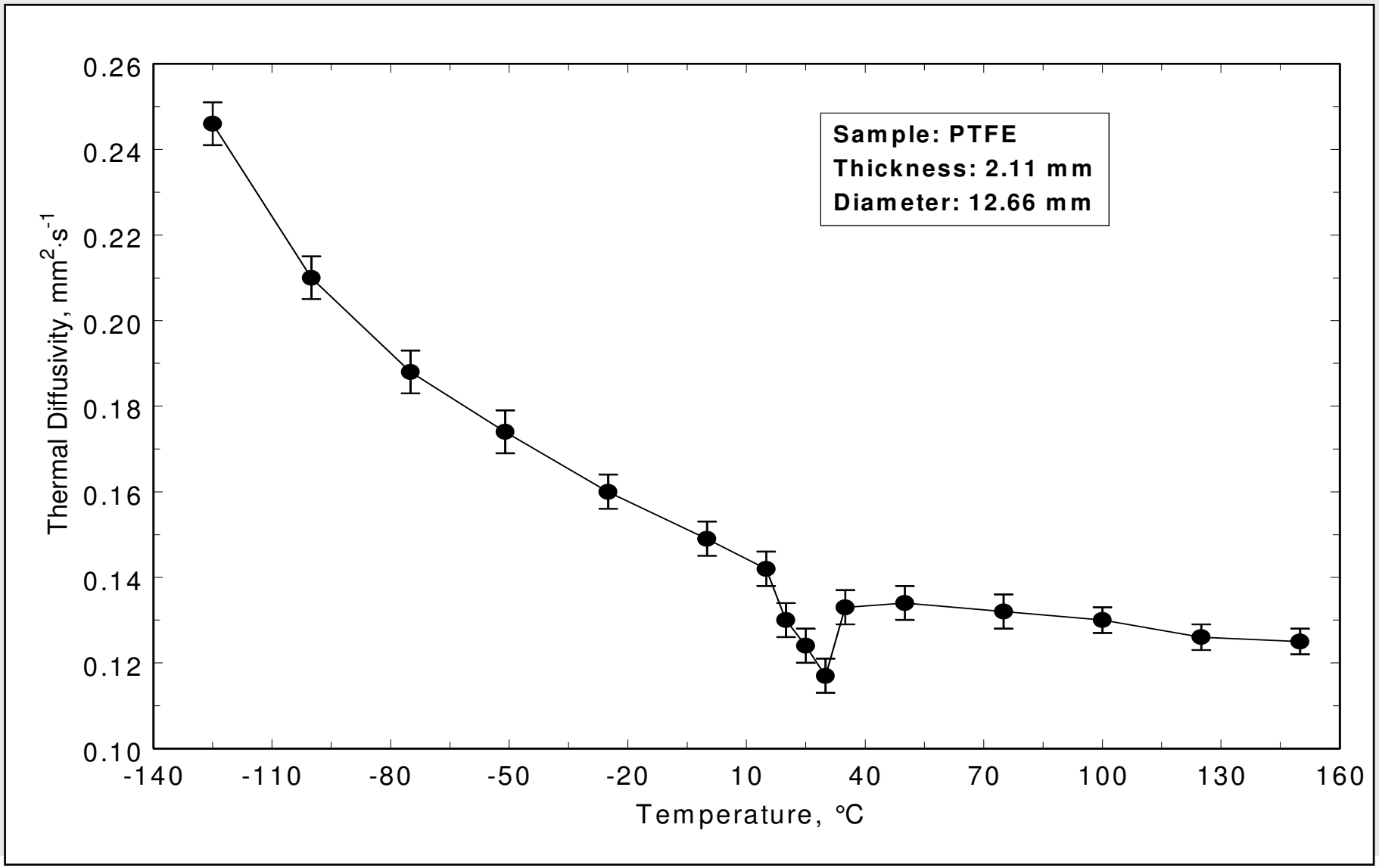
- **Table-top unit**
- **Temperature range:**
  -125 to 1100 °C
  (with two furnaces)
- **Integrated sample changer**
- **Vacuum-tight**

Laser Flash System
NETZSCH LFA 457 MicroFlash

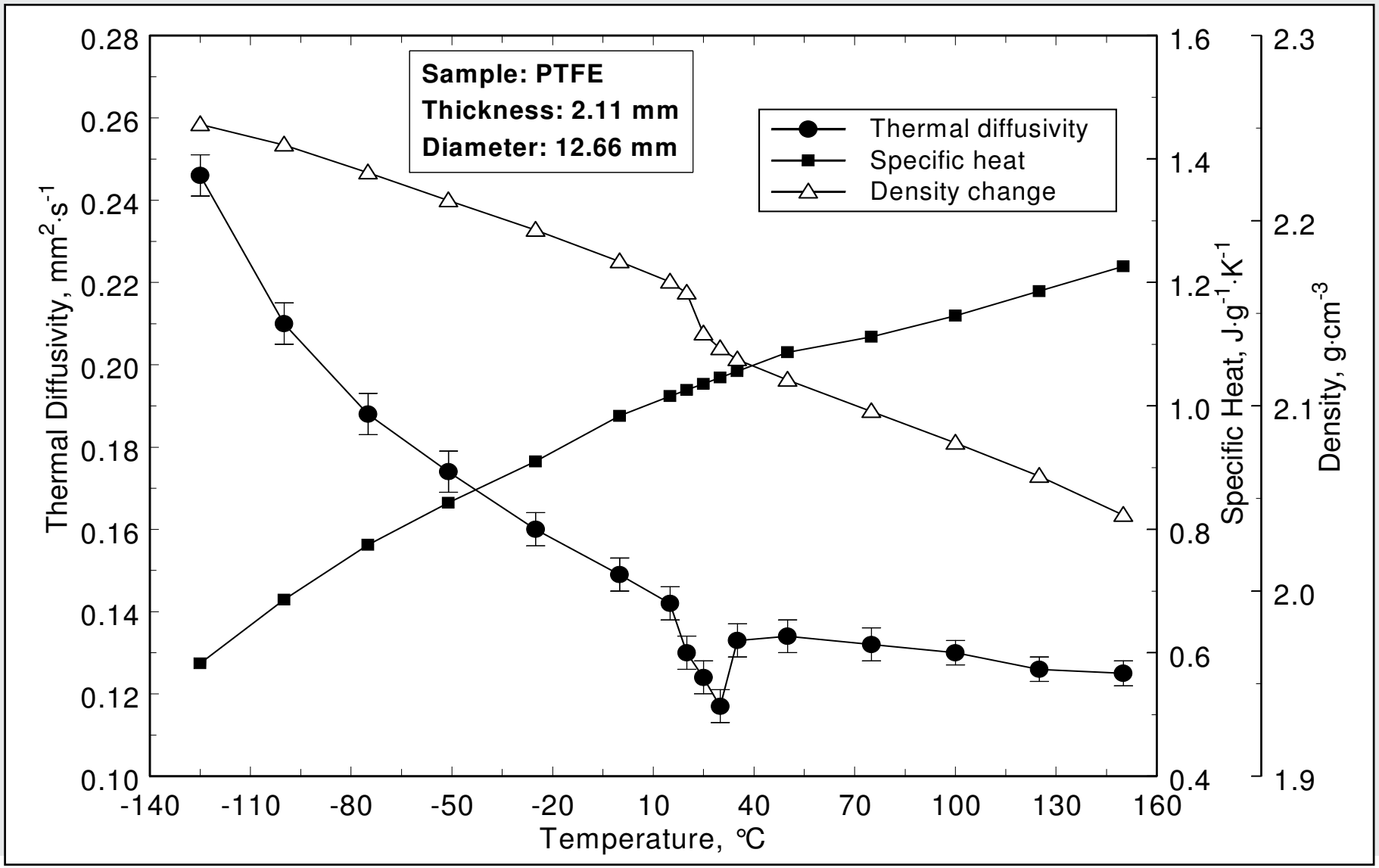


- **Vertical system**
- **ASC for up to three samples (up to 12.7 mm in diameter)**
- **Special sample carrier for large samples (up to 25.4 mm in diameter)**

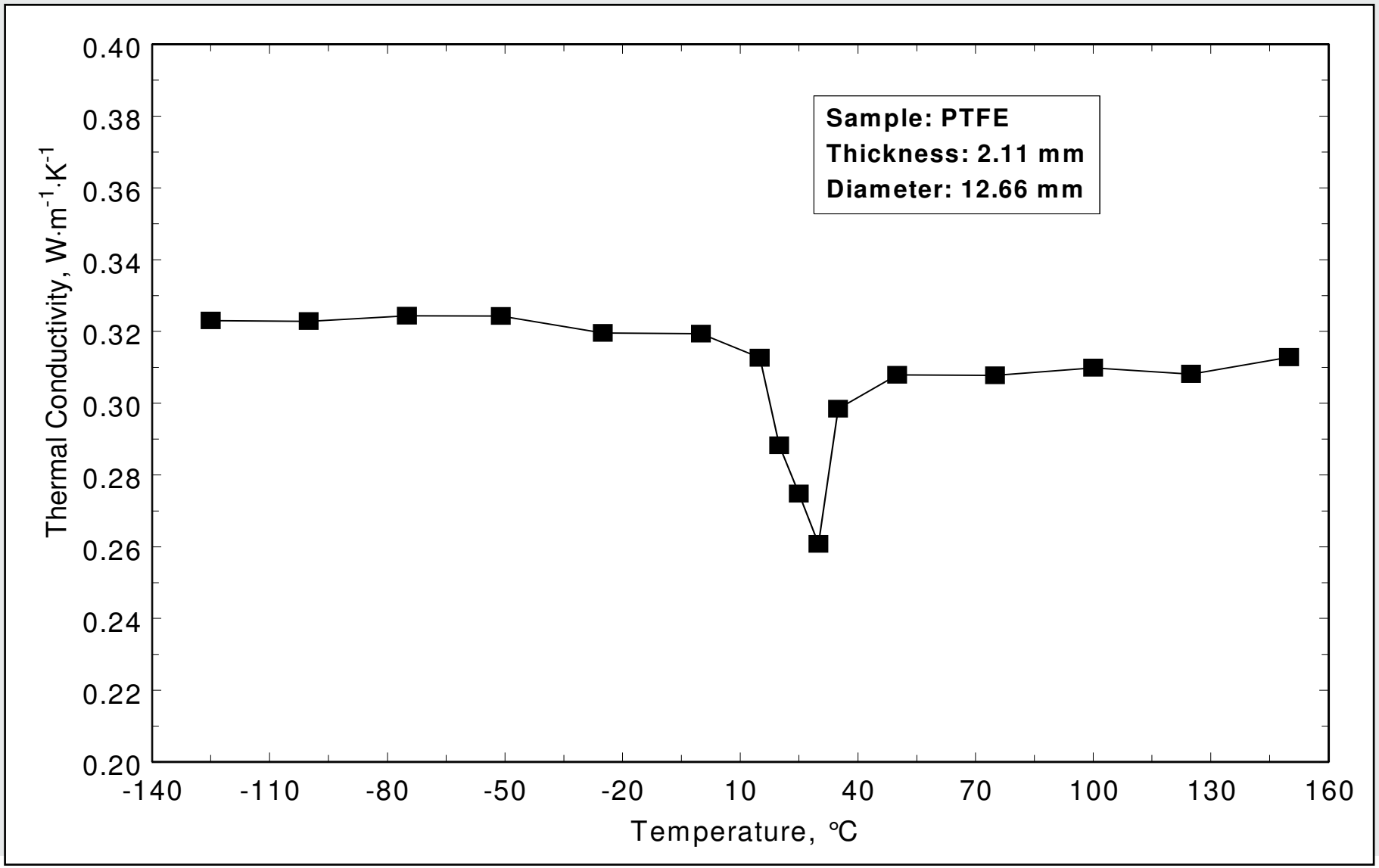
Thermal Diffusivity Results



Thermal Diffusivity, Specific Heat and Density



Thermal Conductivity – Measurement Results



Summary

Various thermophysical and thermomechanical properties were measured on Polytetrafluoroethylene (PTFE) from -170°C to 370°C.

Comparison of the different physical properties allows more detailed insight into the phase transitions during during thermal treatement.

From the test results, it can be gathered that the phase changes from the ordered to the disordered structures has significant impact on the material's mechanical strength.

The influences on the thermal expansion and the thermal transport properties are less strong but can be clearly seen as well.