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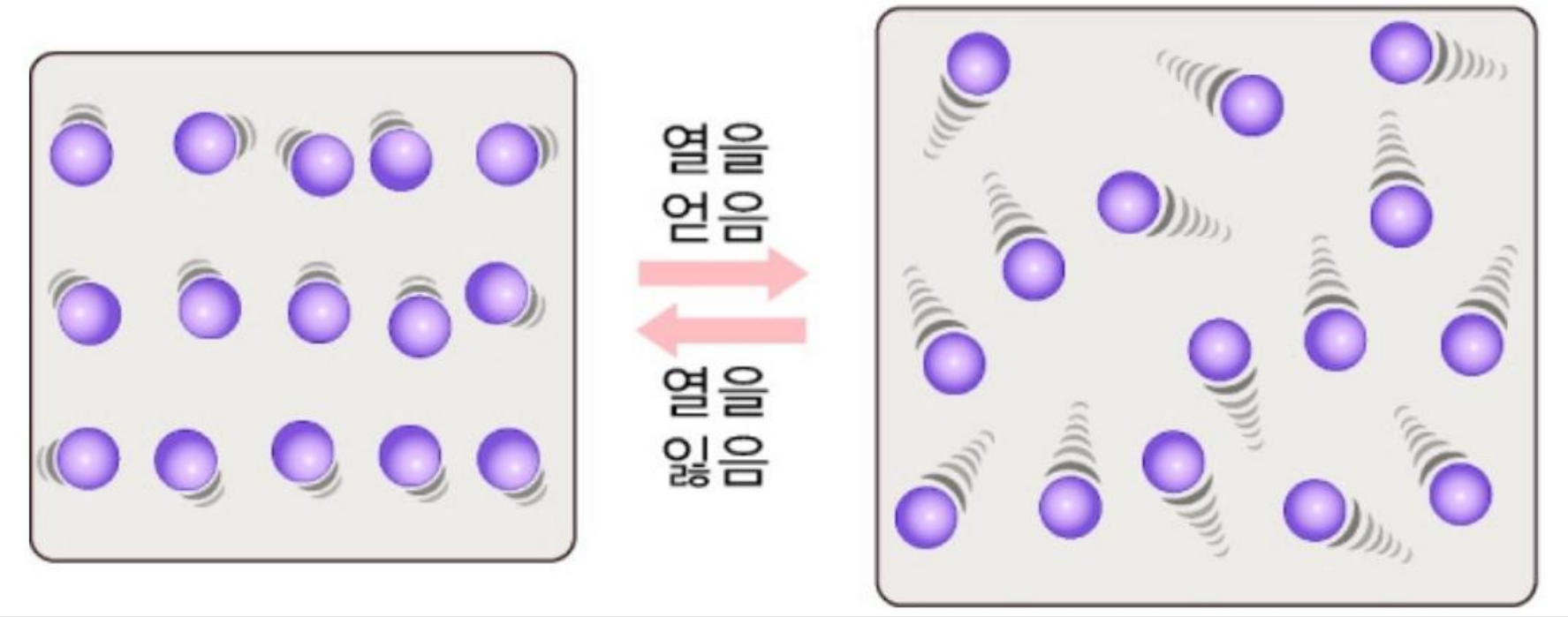
Comprehensive Thermomechanical Analysis by DIL and TMA

Thermal Shrinkage/Expansion Behavior

Inkoo Kim
Assistant Manager

Research Center, A&T Laboratory
NETZSCH KOREA Co., LTD.

Expansion/Shrinkage behavior



Expansion/Shrinkage behavior

Expansion/Shrinkage behavior

The **(relative) linear length change $\Delta L/L_0$** is the dimensional change of a material in one direction:

$$\frac{\Delta L}{L_0}(T) = \frac{L(T) - L_0}{L_0} \quad .$$

Besides the linear length change, there is also the **volumetric expansion or relative volume change $\Delta V/V_0$:**

$$\frac{\Delta V}{V_0}(T) = \frac{V(T) - V_0}{V_0} \quad .$$

$$1 + \frac{\Delta V}{V_0}(T) = \left(1 + \frac{\Delta L}{L_0}(T)\right)^3 \Rightarrow$$

$$\frac{\Delta V}{V_0}(T) = 3 \cdot \left(\frac{\Delta L}{L_0}(T)\right) + 3 \cdot \left(\frac{\Delta L}{L_0}(T)\right)^2 + \left(\frac{\Delta L}{L_0}(T)\right)^3 .$$

From the volumetric expansion, the **density change $\rho(T)$** can be calculated by means of the following equation, where ρ_0 is the room-temperature bulk density.

$$\rho(T) = \frac{\rho_0}{1 + \frac{\Delta V}{V_0}(T)} \quad .$$

Expansion/Shrinkage behavior

The **rate-of-length-change** derived from the length change according to time *t*:

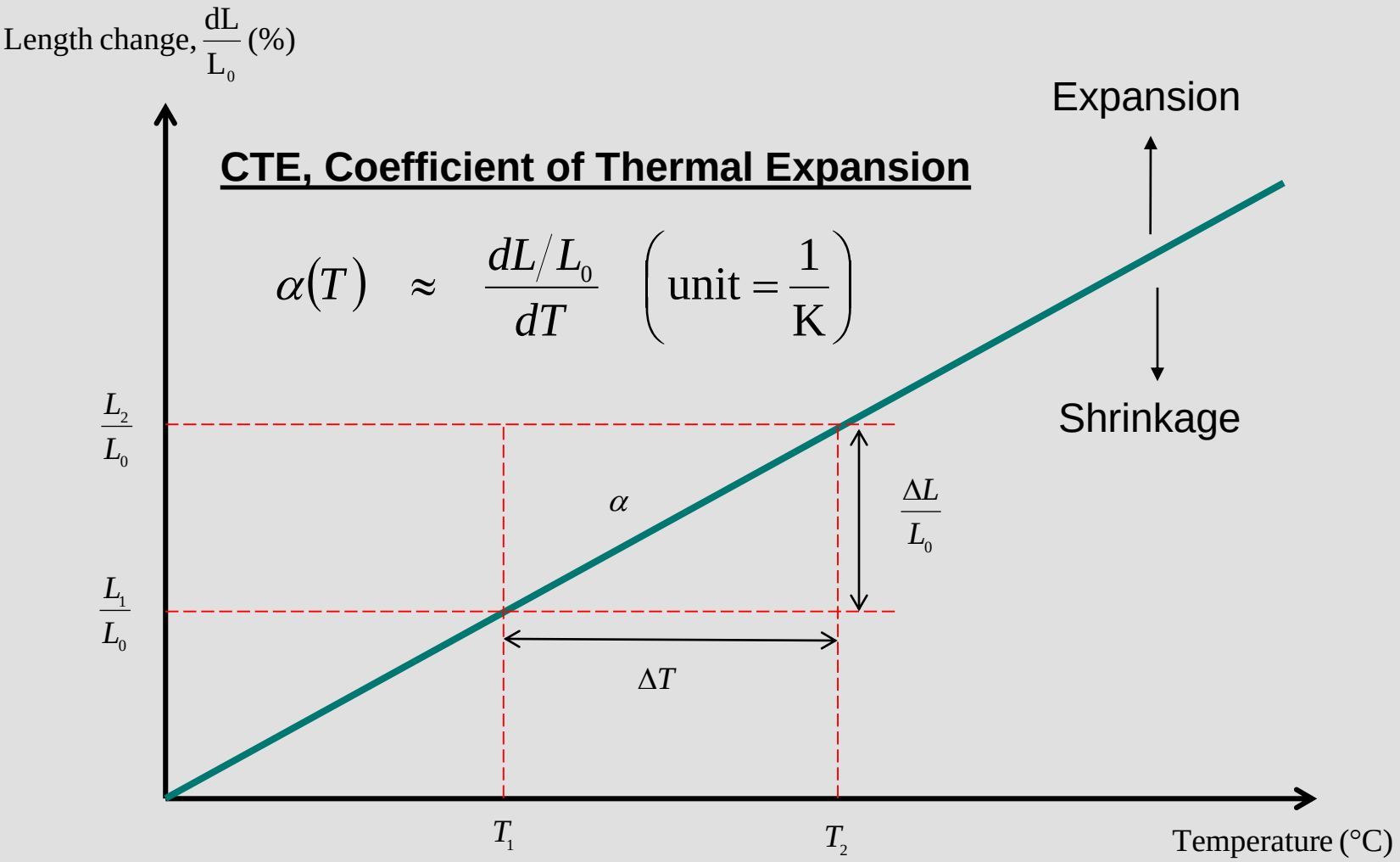
$$Rate-of-Length-Change = \frac{1}{L_0}\cdot\frac{dL(T)}{dt} \quad .$$

The quotient from the difference in length change between two temperatures and the temperature difference is called **the average linear expansion coefficient *α(T)***:

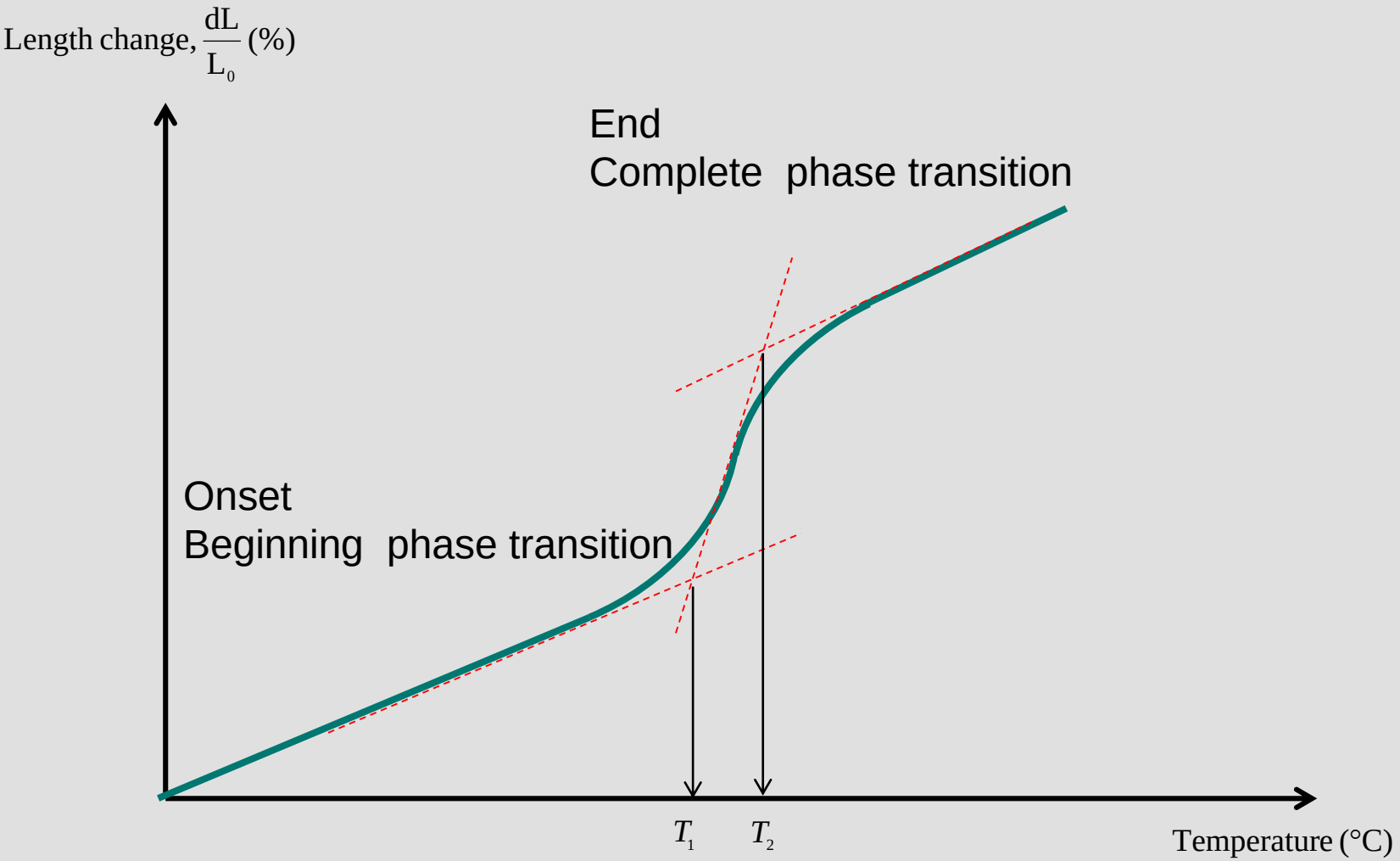
$$\alpha(T) \approx \frac{1}{L_0}\cdot\frac{L(T_2)-L(T_1)}{T_2-T_1} \quad .$$

$$\alpha_{phys}(T) \approx \frac{1}{L_0}\cdot\frac{dL}{dT} \quad . \qquad \alpha_{phys}(T) \approx \frac{dL/L_0}{dT} \quad \left(\text{unit} = \frac{1}{\text{K}}\right)$$

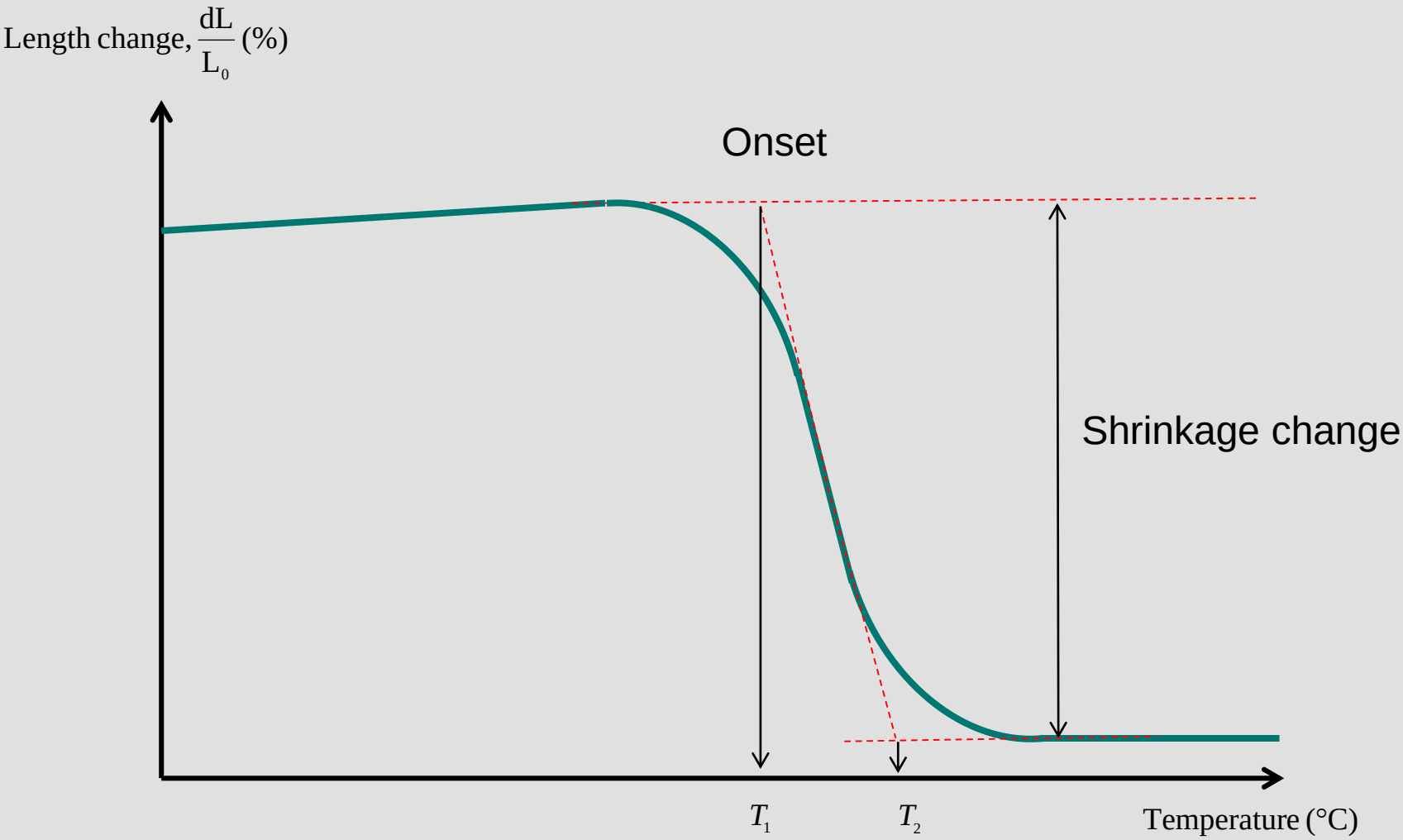
Expansion/Shrinkage behavior



Expansion/Shrinkage behavior



Expansion/Shrinkage behavior

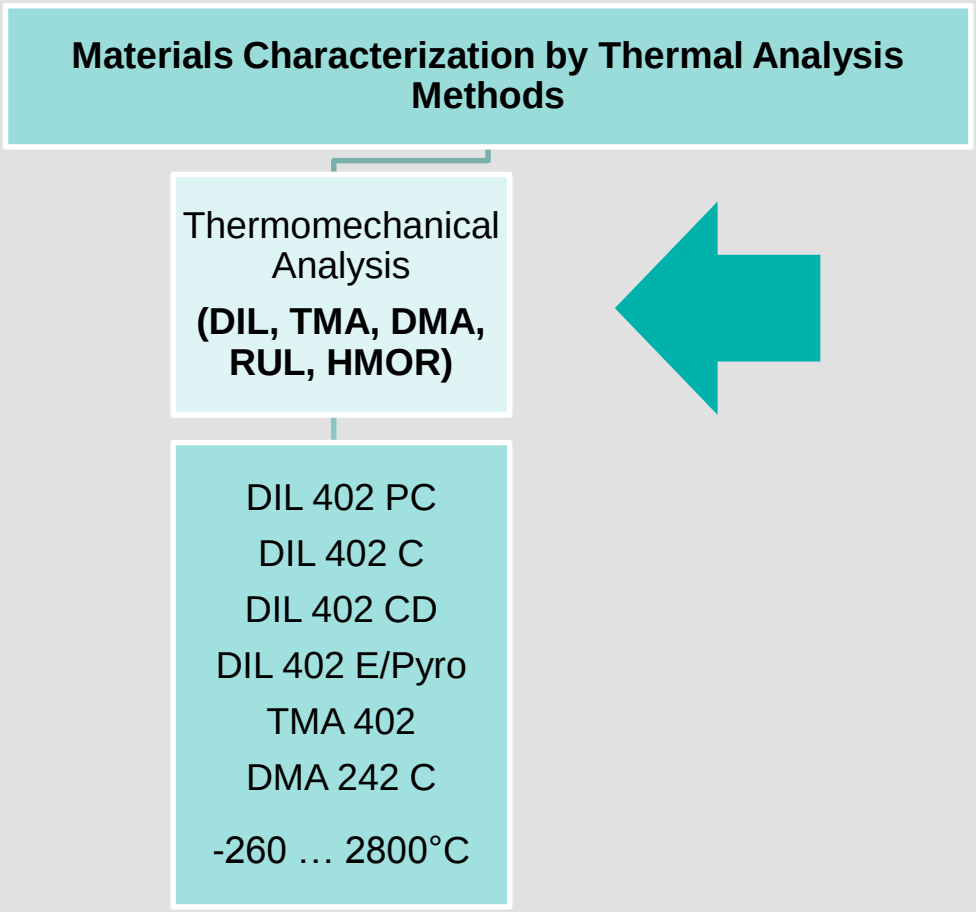


Expansion/Shrinkage behavior

Substance	CTE value (10^{-6} /K at RT)
Fused silica	0.5
Invar	2
Glass (Pyrex)	3
Silicon carbide	3.5
Porcelain	4
Glass (ordinary)	9
Platinum	9
Zirconia	10
Iron/steel	12

Substance	CTE value (10^{-6} /K at RT)
Concrete	12
Copper	17
Brass	19
Aluminum	23
Zinc	26
Lead	29
Ice	51
Plexiglass	70

The NETZSCH Product Range – Optimized Instruments with Outstanding Features



Thermomechanical Analysis – Definition

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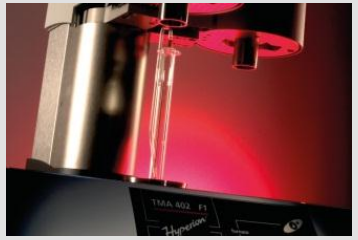
Dilatometry

A technique in which a dimension of a substance under **negligible load** is measured as a function of temperature while the substance is subjected to a controlled temperature program.
(ICTA, ASTM E 473-85)

(The force applied on the sample during a measurement results in a just negligible small length change.).

Thermomechanical Analysis

A technique in which the deformation of a substance under a **defined load** is measured as a function of temperature while the substance is subjected to a controlled temperature program.
(DIN 51005; ASTM E 831)



Dilatometry – Principle Horizontal

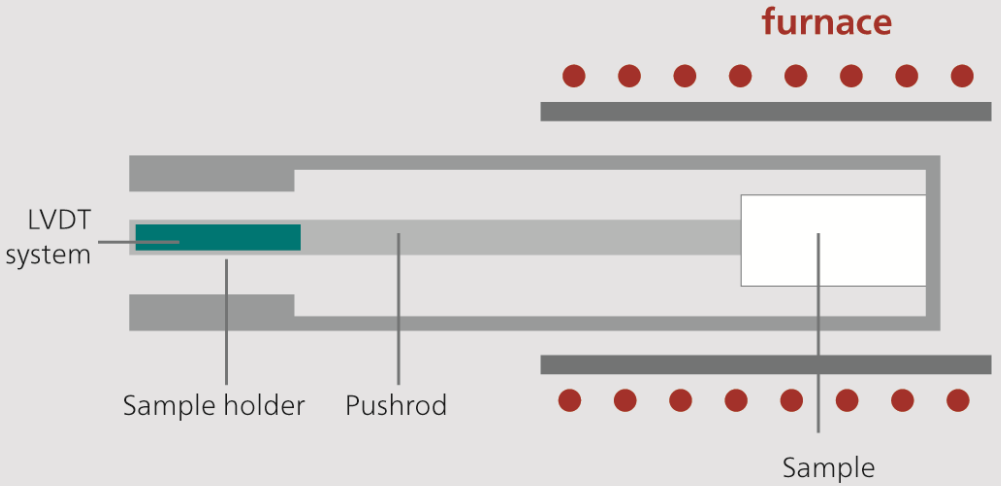
Advantages:

Wide temperature range

Easy handling

High accuracy

Flexible sample geometry



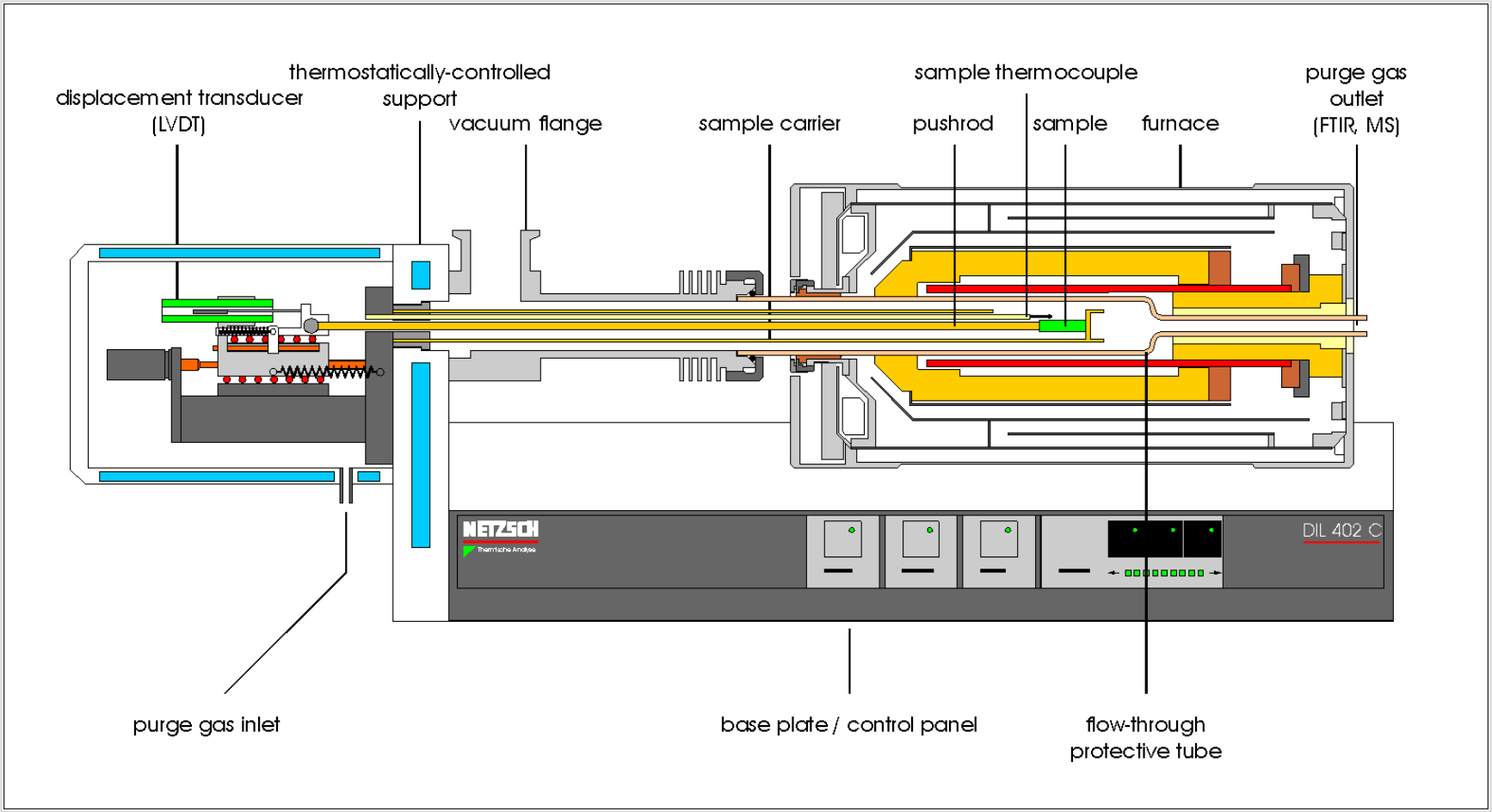
Disadvantages:

Limited load range

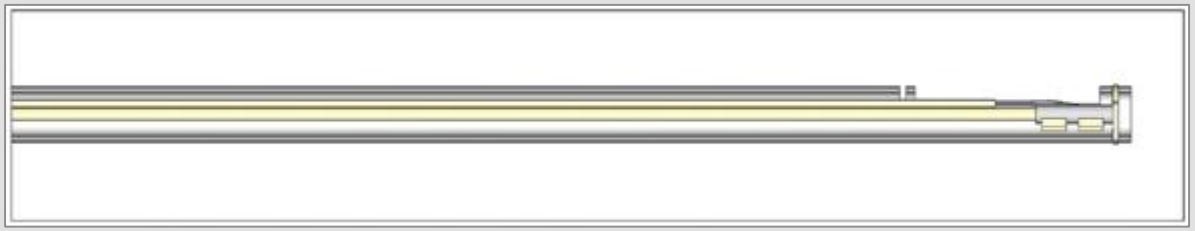
No tension mode

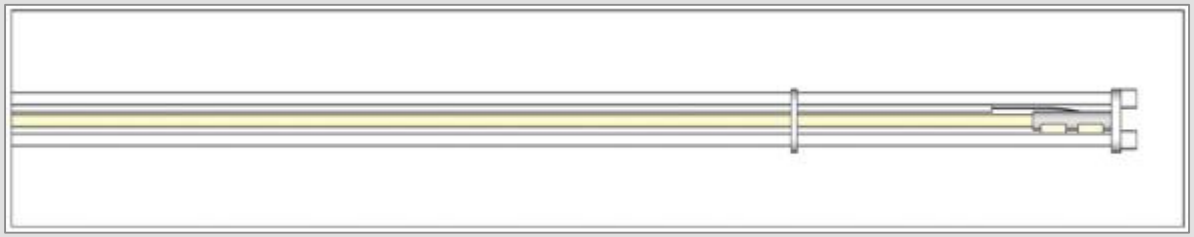
DIL 402 C

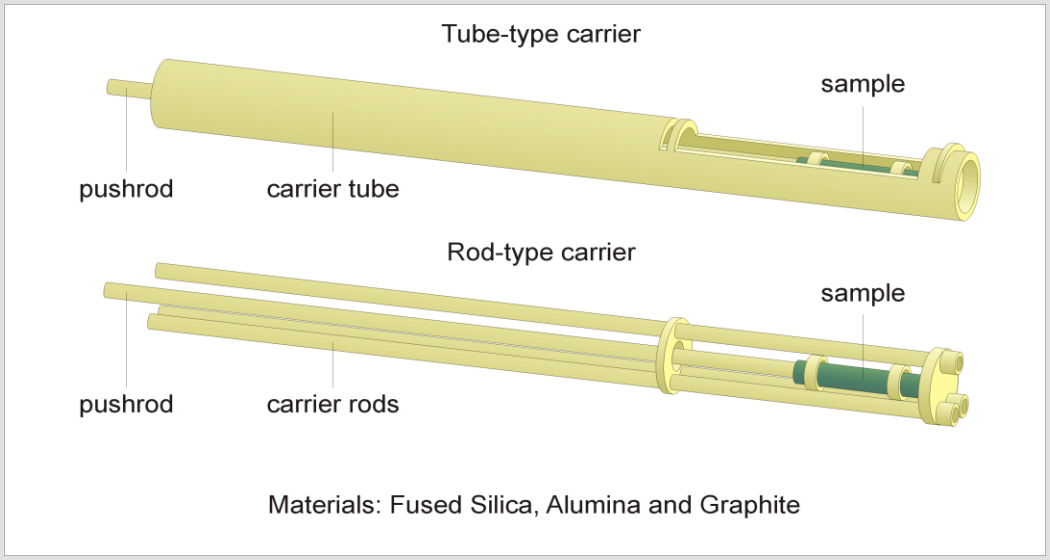
NETZSCH DIL 402 C - Measurement Part



DIL402C - Sample Carrier



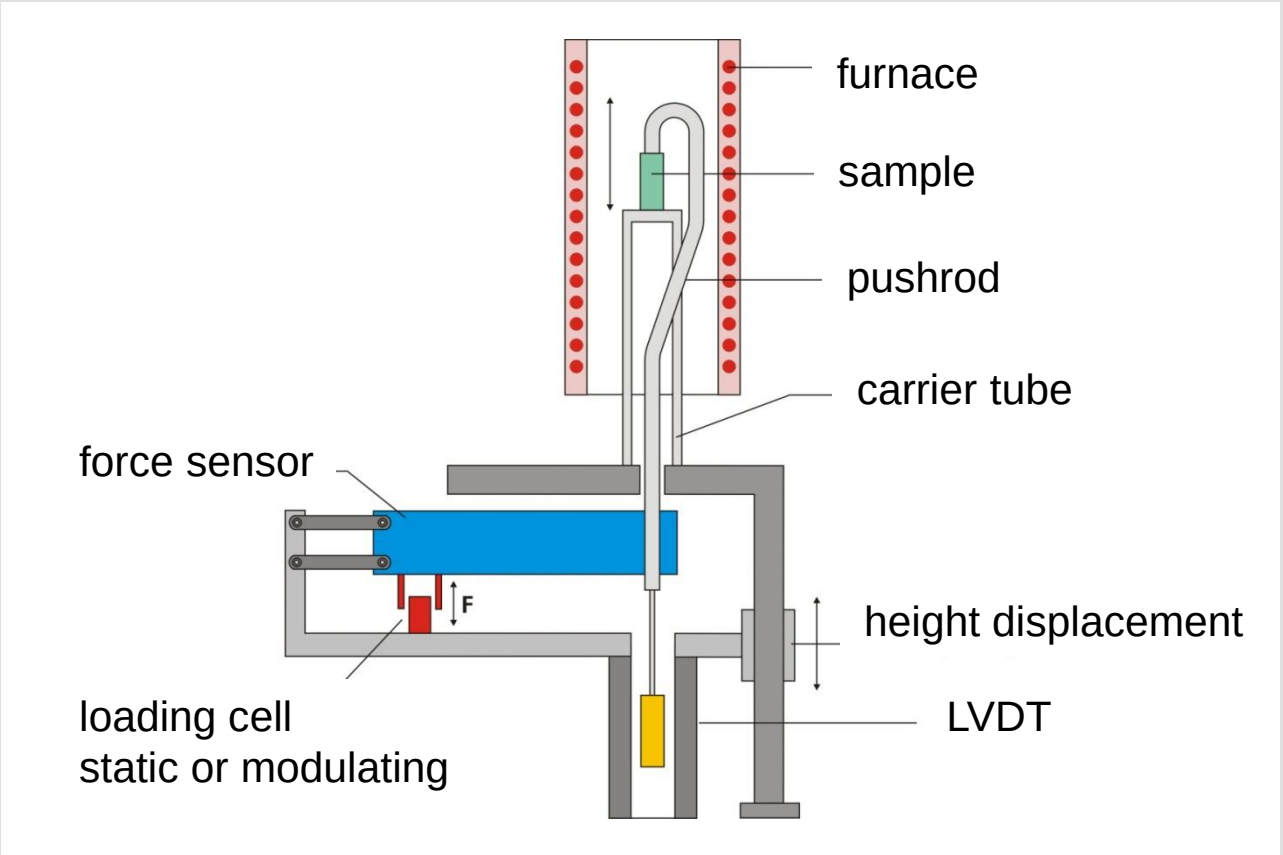




TMA 402 **F1/F3** *Hyperion*®

Platform concept – interchangeable furnaces

TMA 402 **F1/F3** *Hyperion*®
Principle of Operation



Sample length: up to 30 mm

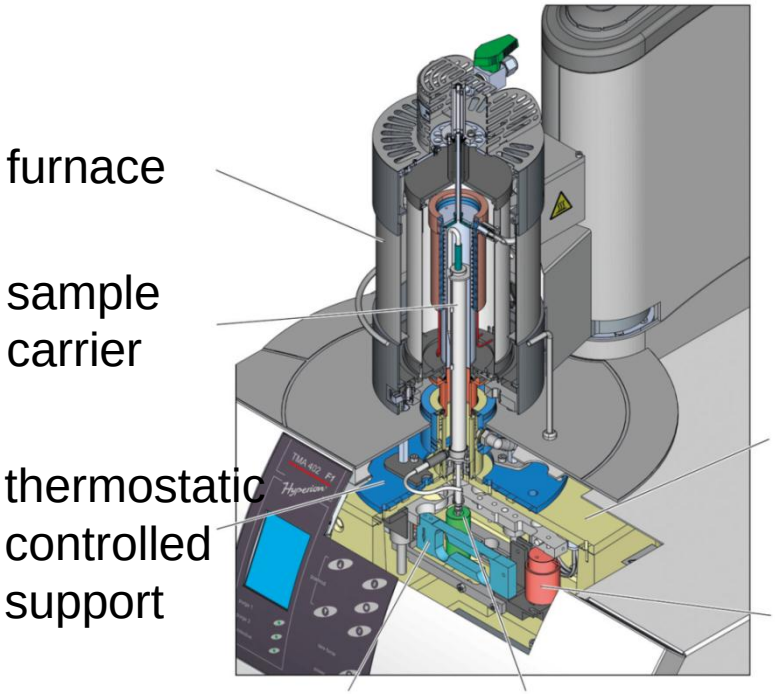
Digital resolution of 0.125 nm in a ± 2.5 mm measuring range

Force range: 0.001 N … 3 N

Dig. force resolution: <0.01 mN

TMA 402 **F1/F3** *Hyperion*®

Static and Dynamic Forces up to 3 N



- Electronically controlled forces – down to the mN-range
- Programmable from -3 N up to +3 N
- Stepwise or linear altering of forces
- For ***F1***: force modulation (rectangular, sinusoidal etc.) with freely selectable frequencies (up to 1 Hz); determination of viscoelastic properties

TMA – Versatile Force Options

Constant Force

Ramp

Can be changed with every segment within the temperature program

Step

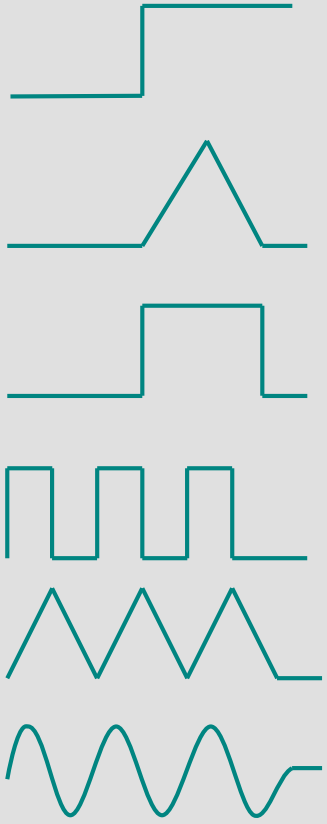
Triangular pulse (sym.)

Rectangular pulse

Rectangular modulation

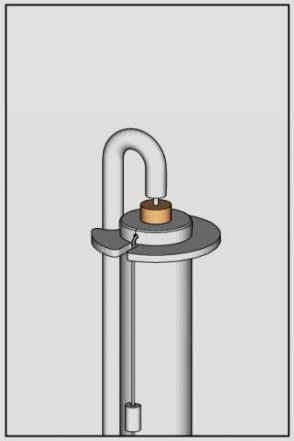
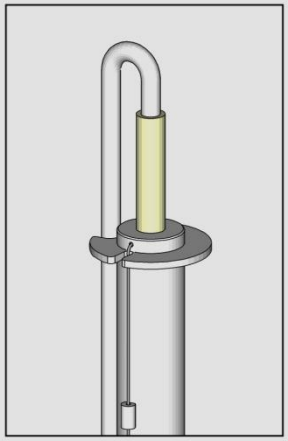
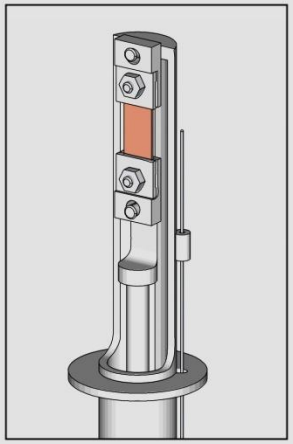
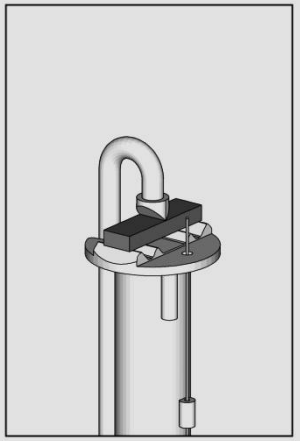
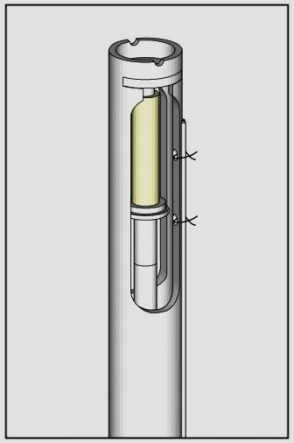
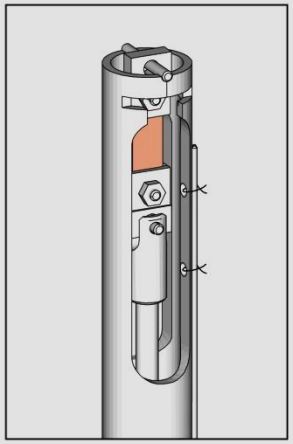
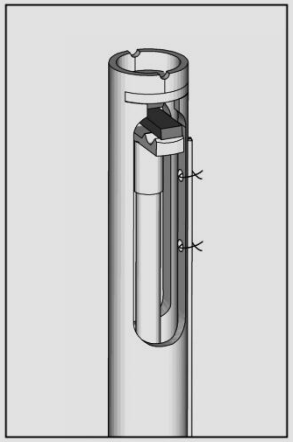
Triangular modulation

Sinusoidal modulation



TMA 402 ***F1*** only

TMA 402 *Hyperion*® – Sample Holder Types

Penetration	Expansion	Tension	3-point bending
			
Fused silica -150°C … 1000°C			
Al_2O_3 → RT … 1550°C			

Application Ranges on DIL

Expansion/Shrinkage Behavior

- Expansion
- Shrinkage
- CTE, Coefficient of Thermal Expansion
- Volumetric Expansion

Typical Materials

- Metals and Alloys
- Green Bodies and Clays
- Ceramics
- Refractories
- Glasses
- Polymers
- Liquids, Solids, Powders

Phase transition

- Sintering Temperatures
- Shrinkage Steps
- Phase Transition Temperatures
- Glass Transition Temperatures
- Softening Points
- Decomposition Temperature

Advanced Techniques

- Caloric Effects
- Density Changes
- Sintering Kinetics

Application Ranges on TMA

Expansion/Shrinkage Behavior

- Expansion under pressure
- Shrinkage under pressure
- CTE, Coefficient of Thermal Expansion
- Volumetric Expansion

Typical Materials

- Metals and Alloys
- Green Bodies and Clays
- Ceramics
- Refractories
- Glasses
- Polymers
- Liquids, Solids, Powders

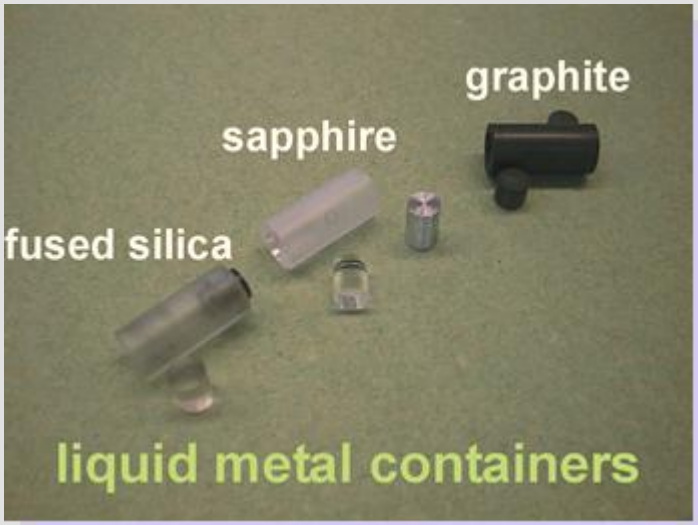
Phase transition

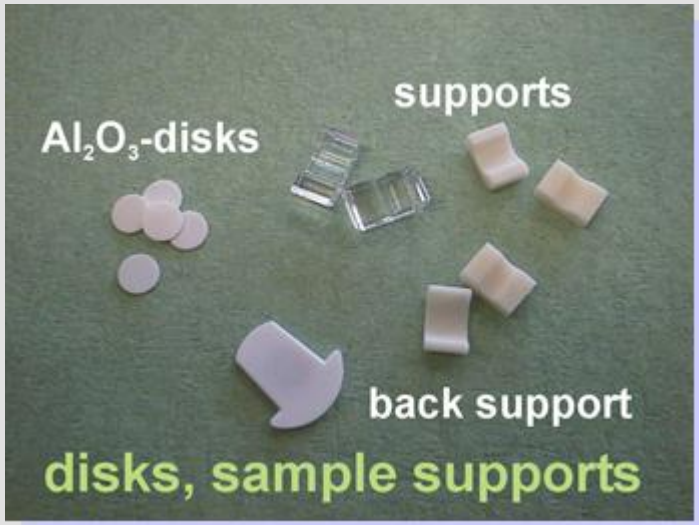
- Sintering Temperatures
- Shrinkage Steps
- Phase Transition Temperatures
- Glass Transition Temperatures
- Softening Points
- Decomposition Temperature
- Elastic-Visco Properties

Advanced Techniques

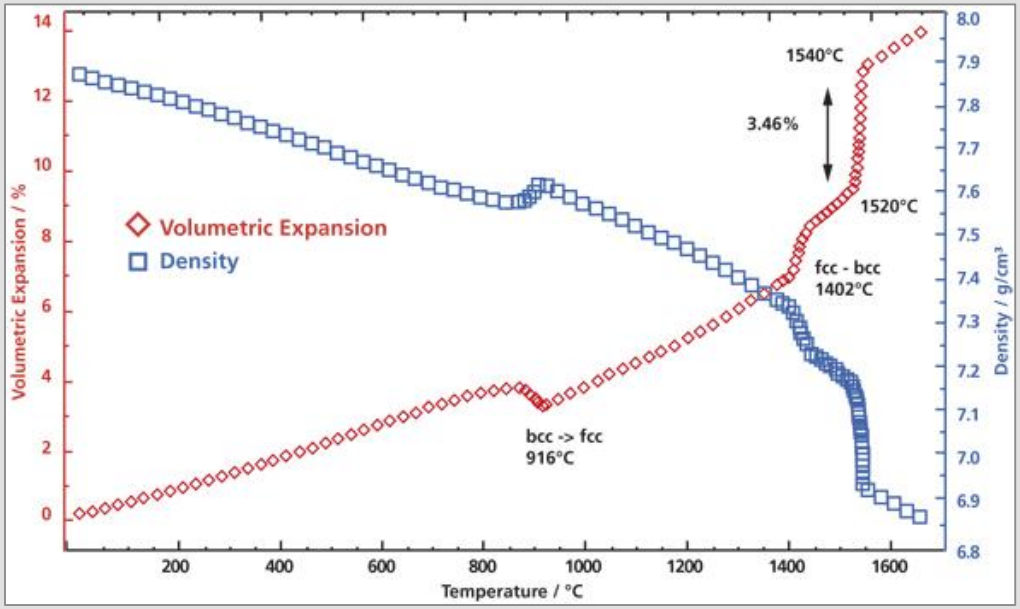
- Caloric Effects
- Density Changes
- Sintering Kinetics

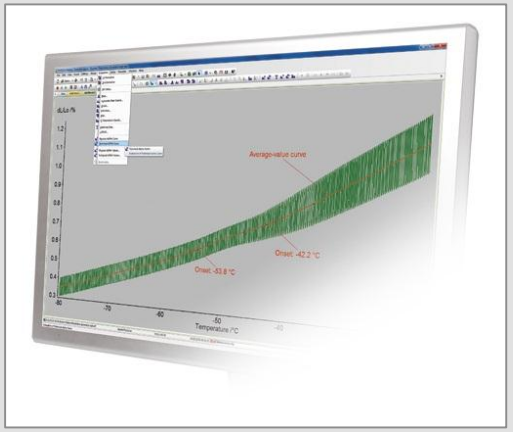
Accessories for Dilatometry

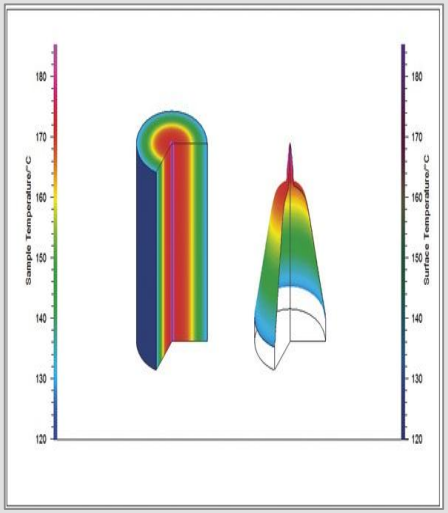


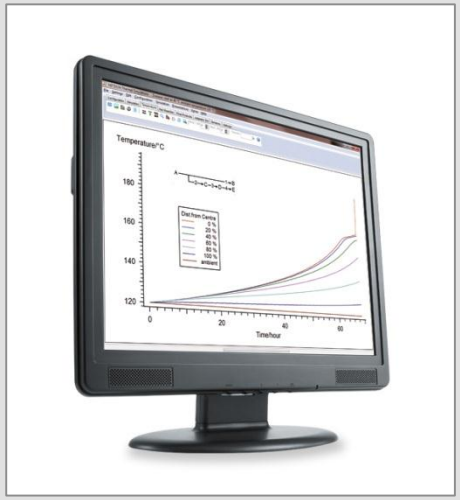


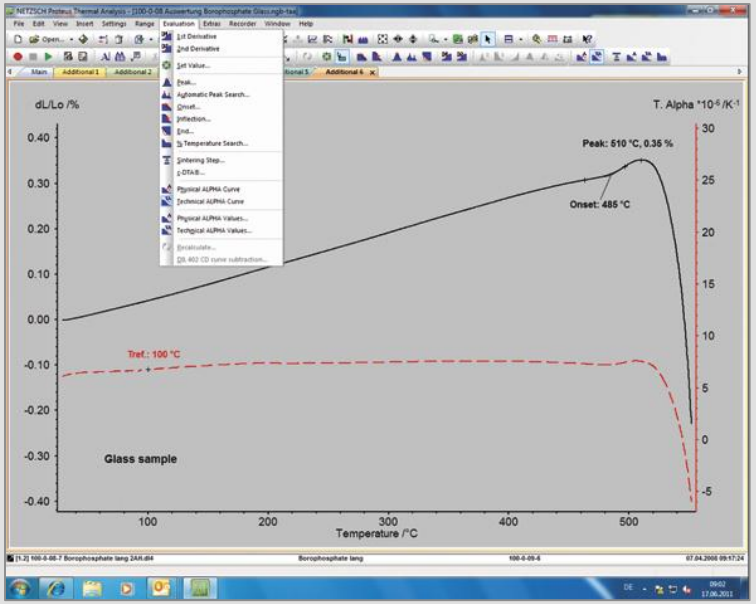
Analysis Software - Proteus











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Thank you for your attention

Inkoo Kim
Laboratory Assistant Manager

Research Center, Analzing & Testing
NETZSCH KOREA Co., Ltd.
Inkoo.Kim@netzsch.com, +82 3193 123 13, + 82 10 7167 7637