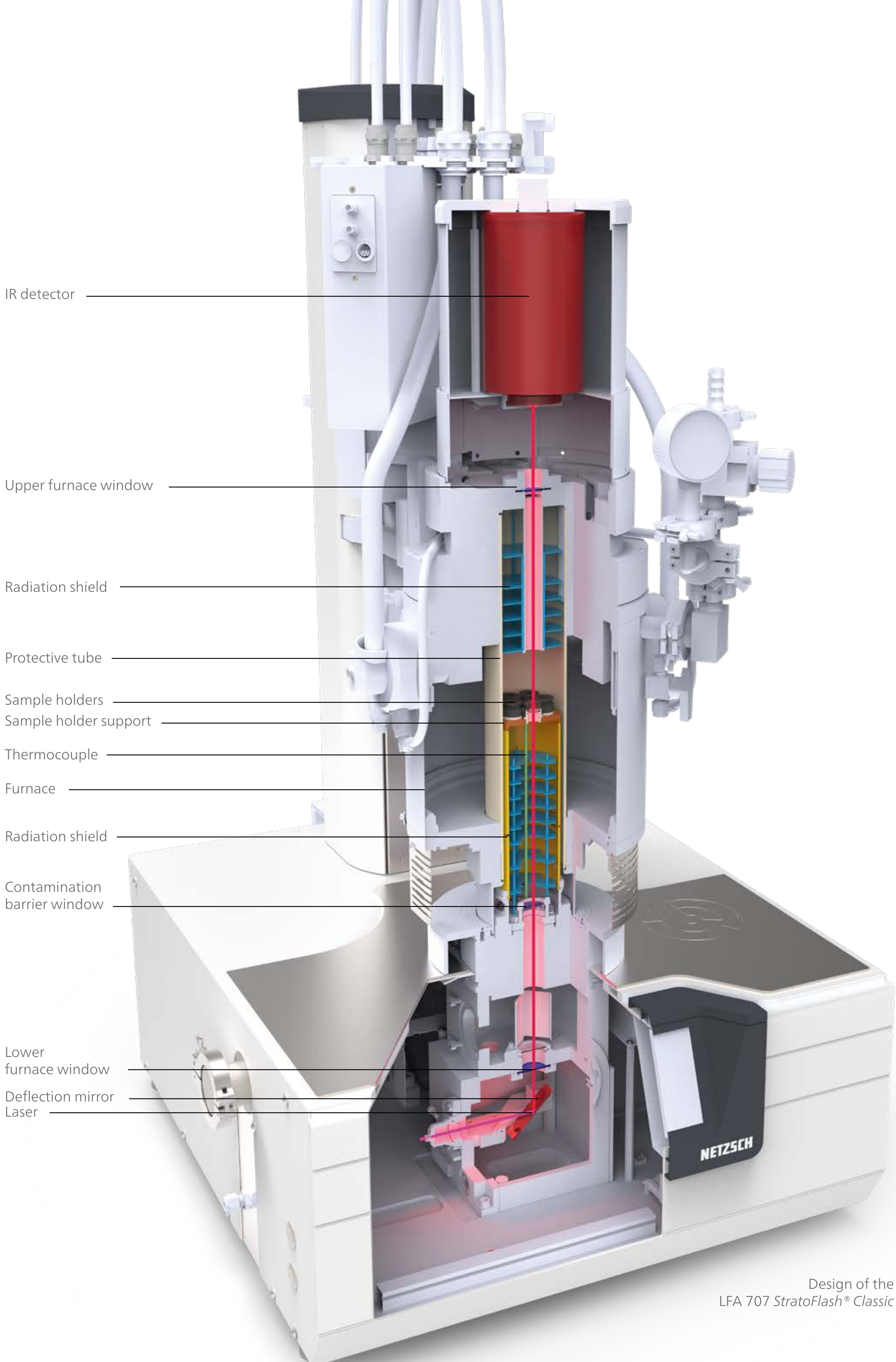
NETZSCH

Proven Excellence.

Laser Flash Apparatus LFA 707 *StratoFlash® Classic*

Thermal Diffusivity and Thermal Conductivity between RT and 1600°C
Method, Techniques and Applications

Analyzing & Testing



Design of the
LFA 707 *StratoFlash® Classic*

LFA 707 *StratoFlash®* *Classic*

Thermal Diffusivity Measurements with Laser Precision

Maximized Efficiency

- **Automatic sample changer** increases sample throughput by enabling the simultaneous measurement of up to five samples.
- Precise, high-resolution measurement curves can be captured with **ultra-fast data acquisition**, delivering exceptional accuracy.

Great Versatility

- Discover a wide range of over **30 sample holders** – available in various sizes and designs – engineered to deliver seamless adaptability for every application.

Easy Maintenance

- Experience **effortless cleaning and maintenance** with easy access to furnace windows and contamination barriers – keeping your instrument performing at its best.

Developed for Your Needs

- **Versatile energy input settings** – analyze a wide range of materials – from thick polymers to ultra-thin metals like copper
- **In-house developed software and NETZSCH laser** – designed and programmed for the job
- **Advanced calculation models** – better performance and reliable results
- **Customizable heating rates** and precise timed intervals

Enhance Process and Product Safety through Precise Laser Pulses

- **Highly accurate c_p determination** by using the comparison method
- **Pulse shape detection and finite pulse correction**, essential for measuring highly conductive metals like silver and copper
- **Captures rapid thermal responses** efficiently – Measure ultra-fast-reacting and energy-sensitive samples accurately with a minimum pulse width of 50 µs

The LFA 707 StratoFlash® Classic

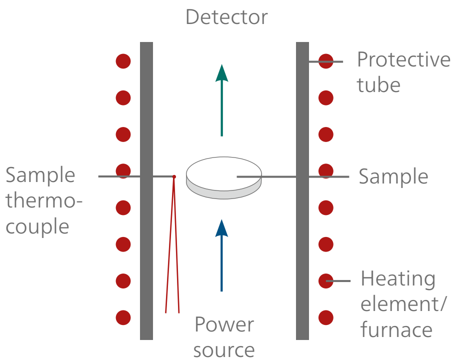
The Universal, Off-the-shelf Laser Flash Analyzer for the Metal, Glass and Ceramics Industry

Laser Flash Analysis (LFA) is a fast, accurate, non-destructive and non-contact method used to measure the thermal properties of materials like ceramics, metals, polymers, and composites over a broad temperature range. It provides essential data on thermal diffusivity and specific heat capacity for characterizing the thermal conductivity of the samples. This is important for applications in insulation, heat exchangers, electronics cooling, and high-temperature process control.

Thermal Conductivity/ Thermal Diffusivity

Key Benefits

- Rapid and precise characterization of thermal properties
- High-temperature measurements up to 1600°C
- Exceptional measurement precision due to monochromatic, coherent, and collimated beam
- Multiple sample geometries (between 6 and 25.4 mm)
- Non-destructive testing, preserving samples for further analysis or use
- Versatile for many materials: solids, liquids, pastes, powders, and composites including anisotropic and multilayered structures
- Easy to use advanced calculation models for best curve fit and results

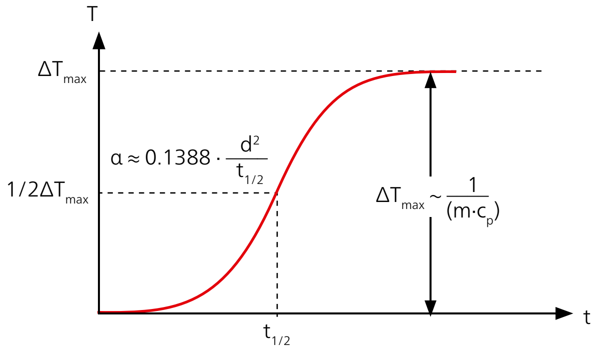


Flash Technique

Principle

A thin, plane-parallel sample is mounted on a carrier system and placed inside a furnace. Once the sample reaches a predefined temperature, a short, laser pulse is applied to its front surface. Following this heat pulse, thermal energy diffuses through the sample, leading to a time-dependent temperature rise on the rear surface. This temperature change is recorded by an infrared detector.

By analyzing this temperature response of the detector signal, the material's thermal diffusivity can be calculated. In addition, the specific heat capacity of the sample can be determined using a reference sample. Finally, the thermal conductivity λ can be calculated using the measured thermal properties in combination with the sample density.



Schematic representation of an LFA signal

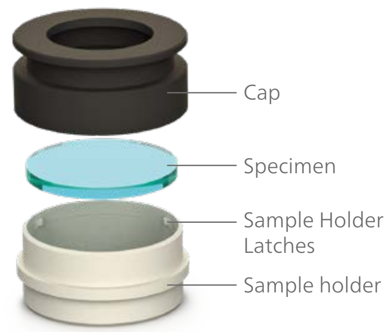
Thermal Conductivity

$$\lambda(T) = \alpha(T) \cdot c_p(T) \cdot \rho(T)$$

where
λ = thermal conductivity [W/(m·K)]
α = thermal diffusivity [mm^2/s]
c_p = specific heat [J/(g·K)]
ρ = bulk density [g/cm^3].

The thermal diffusivity (α) of a sample can be quickly estimated using its thickness (d) and the time ($t_{1/2}$) it takes for the rear face to reach half of its maximum temperature rise. To accurately determine the thermal diffusivity, the *Proteus*® software performs a thorough analysis of the thermogram using advanced LFA models.

Sample Holders for Standard and Special Applications



Sample holder setup for round samples
(similar set up for square samples)

Over 30 Sample Holders for Different Specimen Types and Dimensions

Various sample holders made of graphite and aluminum oxide (Al_2O_3) are available for solid circular or square specimens between 6 mm and 25.4 mm. These include sample holders for in-plane measurements and pressure sample holder for powder samples, as well as ones for special geometries. Sample holders for testing laminates, pastes, liquids, fibers and specimens that crumble or shrink upon heating complete the wide sample holder selection.

Special Sample holder:
for metal melts and laminats

Sample Holder Systems – Easily Handled

The specimen is in a horizontally stable, well-defined position. Once the furnace has been raised, all samples are directly accessible and can be easily inserted or removed. A sample carrier tube mounted in a metallic adjusting socket carries the sample holder support, sample holder and cap. The sample holder is mounted directly into the round openings of the sample holder support.

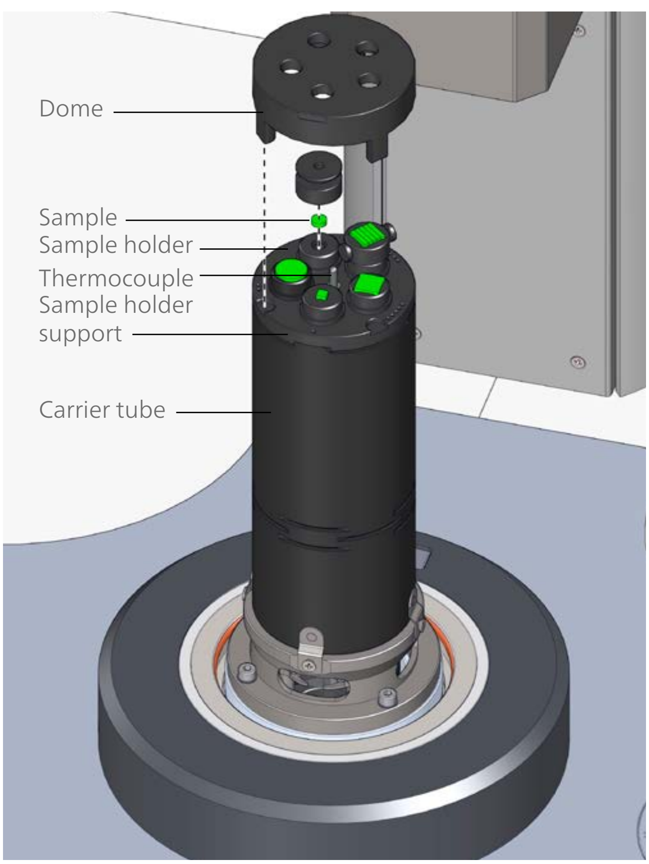
Standard sample holders for square and round specimens and different dimensions (available in Al_2O_3 and graphite)

Sample Holder Latches for Minimized Contact

The sample holder secures and centers the specimen with small latches. This design minimizes the contact between the specimen and the holder, reducing heat loss and enabling uniform laser irradiation of the entire specimen surface. The inside diameter of the sample holder acts as a limiting diaphragm below the specimen and fits it perfectly.

Integrated Sample Placement Area

The top cover of the instrument is often used for preparing or storing samples. It is now designed with visually distinct areas that correspond to sample positions in the furnace. This simplifies sample identification and pre-assembly, reduces delays, and is especially useful when multiple users work with the instrument.



Sample holder system

Automatic Sample Changer for Three or Five Samples

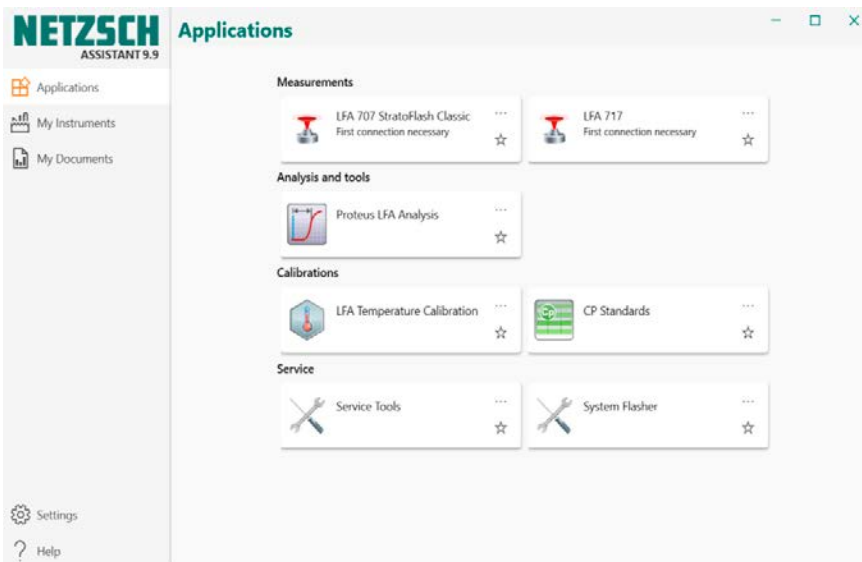
The LFA 707 *StratoFlash®* *Classic* is equipped with an automatic sample changer and enables the analysis of multiple samples under identical conditions. This greatly boosts throughput for research & development and quality control.

Reference Materials

A number of different reference materials can be supplied in various shapes and diameters. Single reference materials and sets are available. A certificate is included for each material class.

Software *Proteus*®

Easily Obtainable Results – A Quick Overview



NETZSCH Assistant – all instruments and applications at a glance

The new NETZSCH LFA software combines highest automation with maximum flexibility. Thanks to its modern user interface, powerful 64-bit architecture, and SQL database, it offers short loading times, low memory requirements, and intuitive operation.

The NETZSCH Assistant

The latest software generation introduces the NETZSCH Assistant. This tool provides a clear overview of connected instruments and available software features to ensure a smooth, efficient workflow from the beginning.

Decentralized Data Management

Thanks to our database-driven storage of measurements and evaluations, teams can access, analyze, and continue working on projects from different computers and locations. This enables seamless collaboration, improves traceability, and ensures that everyone is always working with the latest data.

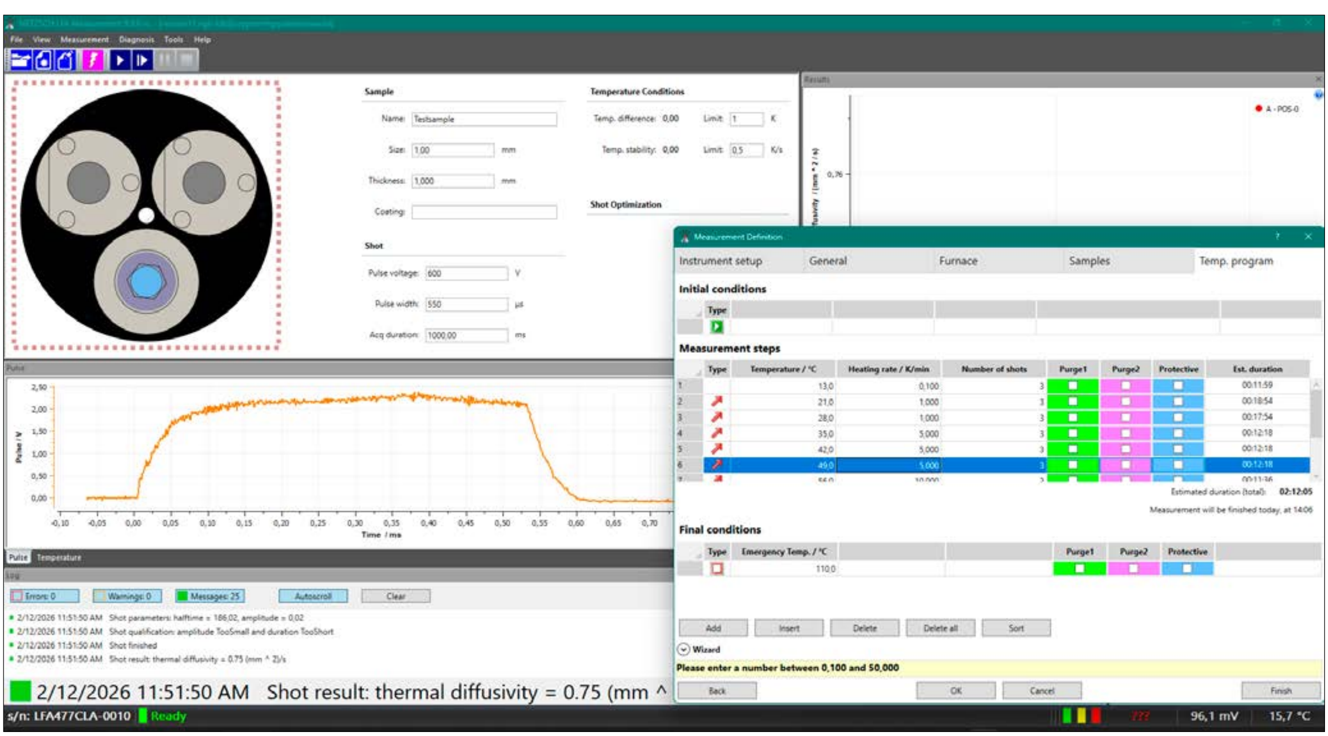
Software Advantages

Separate measurement and analysis software so that the analysis can be performed away from the instrument

- Modern user interface with intuitive navigation
- Powerful SQL database for fast processing
- Compatible with historic NETZSCH LFA data
- Advanced calculation models
- High flexibility through a combination of automation and manual control
- Automated Measurement Evaluation
- Export to common formats for seamless further processing

Measurement Software

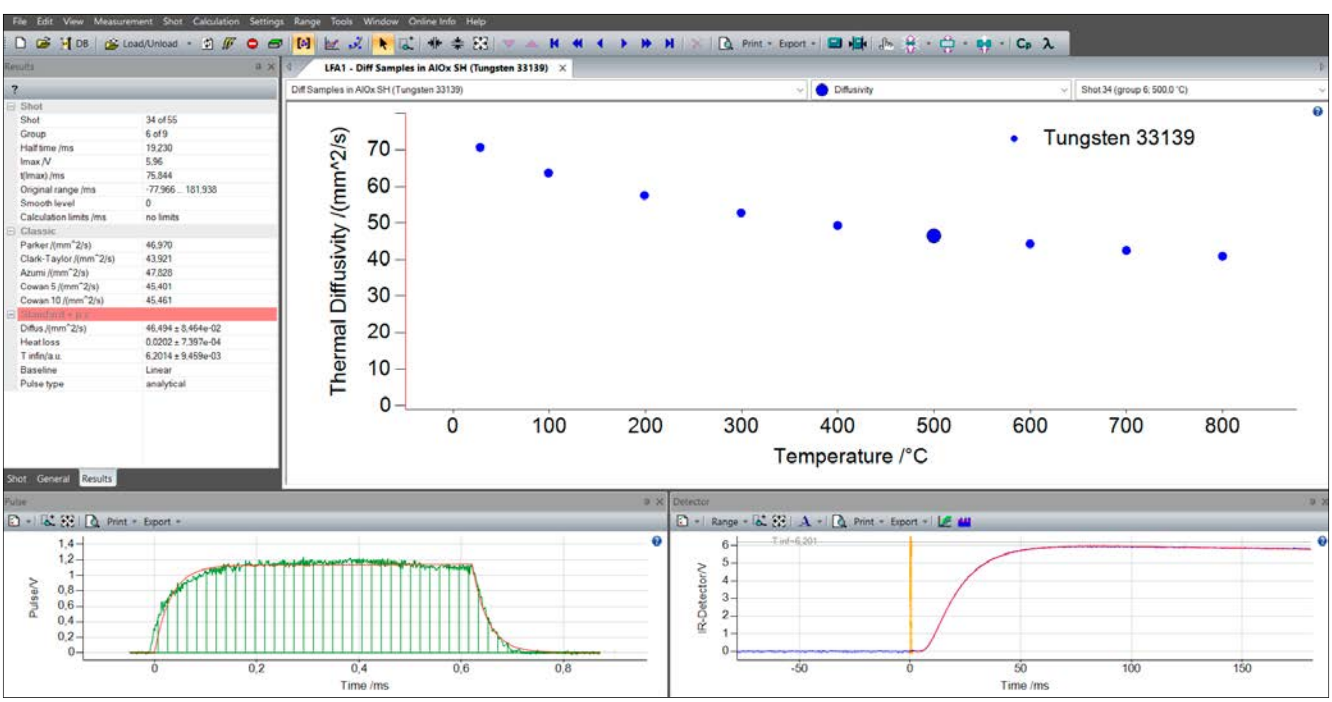
Measurement Software Features
Fully automated optimization of amplification and measurement time
Comprehensive instructions regarding live instrument and safety statuses
Visualization of pulse and detector signals during the measurement
Initial estimation of the thermal diffusivity during the measurement
Definition of any number of temperature steps and the number of shots per step
Visualisation of the sample position in the furnace
Temperature calibration for maximum accuracy across the entire temperature range
Defined temperature program featuring customizable heating rates
Intuitive measurement definition on modern, easy to use interface



Graphical user interface of the measurement software during measurement definition.

Analysis Software

Features of the Analysis Software
Simultaneous analysis of multiple measurements within a database
Option to evaluate data from previous LFA generations
Calculation of the specific heat capacity (c_p) using the comparison method
Determination of the thermal conductivity by importing c_p and thermal expansion data
Display of pulse and detector signals, as well as corresponding curve fitting
Simultaneous display of multiple measured variables, such as thermal diffusivity, thermal conductivity, and specific heat capacity as a function of temperature
Averaging of multiple shots at the same temperature
Description of the temperature dependence of thermal properties using common mathematical functions (polynomials, splines, 1/T)
Visual processing with extended detector signal smoothing functionality
Display of all relevant shot parameters and results in an extended info grid
"Goodness-of-fit" calculation for selecting the best calculation model
Export functions to common file formats, such as csv
Zoom function for precise data analysis

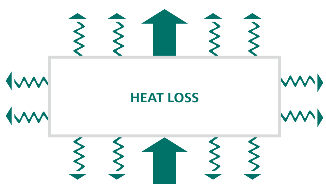


Graphical user interface for analyzing the measurement results.

Calculation Models, Corrections and Mathematical Operations

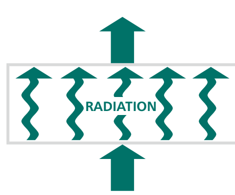
Standard Model

For opaque, homogeneous and isotropic samples, the so-called improved Cape-Lehman Model is the all-in-one solution for about 90% of all LFA applications. The standard model is a two-dimensional heat transfer model. It takes into account axial and radial heat losses. It also considers the illuminated and detection areas.



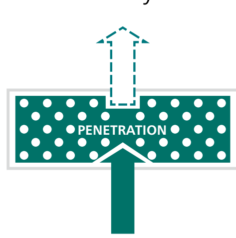
Transparent Model

In the case of a transparent, optically thin and diathermic material with opaque boundaries, a direct radiative heat flux will occur between the front and rear face of the specimen. Because of the low optical thickness, in addition to the conductive heat transfer, radiative heat transfer will occur. This results in an instantaneous increase of the thermal curve. The transparent model considers these effects, to determine the thermal diffusivity.



Penetration Model

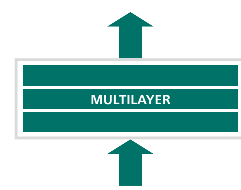
In the case of porous materials, the absorption of the energy pulse is no longer limited to the front face, but extends over a thin layer into the specimen thickness. The Penetration Model takes this into account to improve the thermal diffusivity results of such specimens.

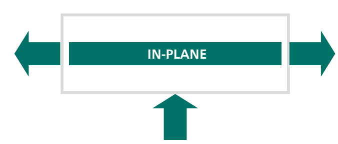


Special Models

For special applications, 2- and 3-layer models as well as in-plane heat flow models (orthotropic and isotropic) are available for the user. These models cover a wide range of geometries and directional anisotropic compositions of specimen and rounds up the LFA analysis software.

More Information

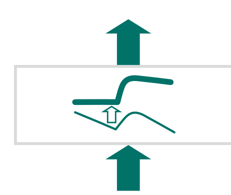


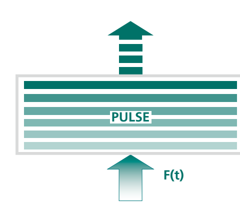


Corrections

For improved fits and best results all models will by default be available with light pulse correction and baseline correction. The user is free to turn off those corrections to measurement signals. In addition all models take heat loss into account.

More Information





Applications

Metals

Thermophysical Properties of Stainless Steel

Understanding temperature-dependent thermal conductivity is essential for designing and simulating thermally stressed components, particularly those made of metallic materials such as austenitic stainless steel 1.4301 (X5CrNi18-10). This knowledge determines the cooling rate and solidification, and thus the microstructure and mechanical properties. Accurate understanding of heat conduction can prevent defects, distortion and material damage, thereby ensuring process quality.

Figure 1 shows the thermophysical properties of a stainless steel sample; both the thermal diffusivity and thermal conductivity increase steadily with rising temperature. After that, a local minimum becomes apparent, indicating the start or completion of melting of the sample. This is confirmed by DSC measurements, which reveal a peak in the apparent specific heat capacity upon melting. For the calculation of the thermal conductivity, the energetic effect of melting was interpolated to determine the true specific heat capacity.

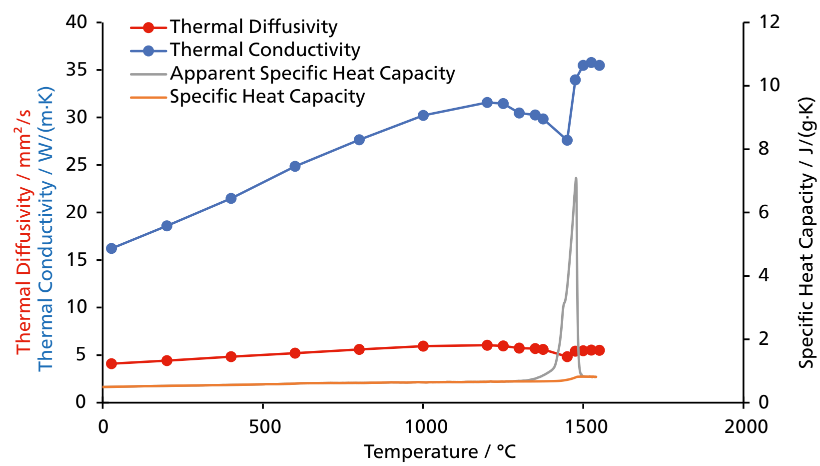
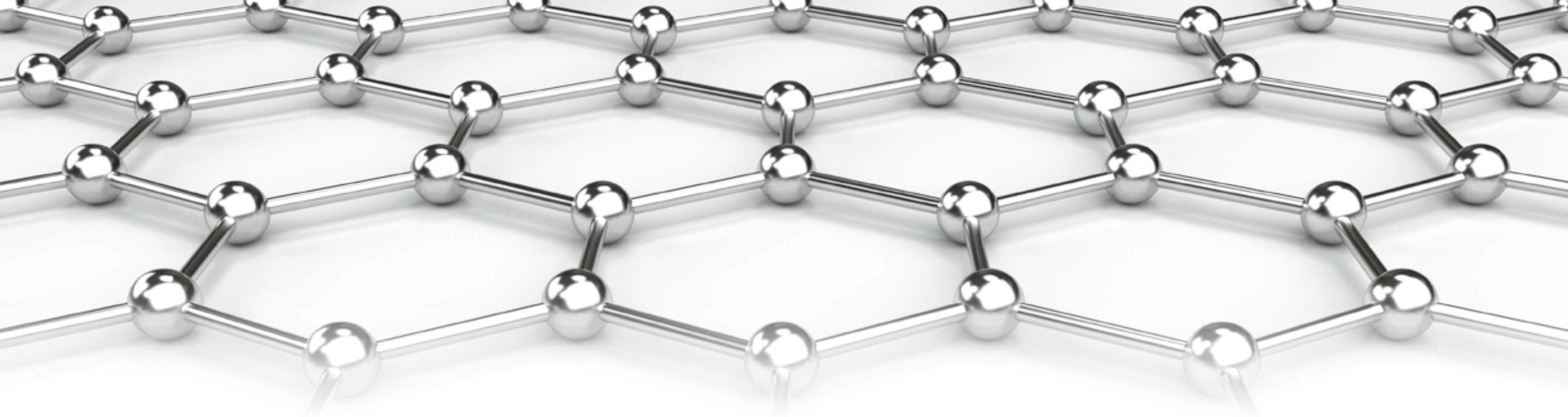


Fig. 1: Thermophysical properties of 1.4301 stainless steel, RT to 1550°C. Specific heat capacity measured with the DSC 500 *Pegasus*®.

Sample:	1.403 austenitic stainless steel
Sample size:	Ø 10.34 mm; ↕ 1.41 mm; plane-parallel surfaces
Sample holder:	Sapphire for metal melts
Temperature range:	RT to 1550°C
Atmosphere:	Argon
Heating rate:	Variable up to 20 K/min
Model:	Standard



Pure Iron

Pure iron is used in industrial applications, such as the manufacture of electromagnetic components, where heat transfer is crucial. Laser flash analysis (LFA) can be used to accurately determine its thermal conductivity, providing a reliable basis for designing and simulating industrial processes.

Figure 2 shows the typical behavior of the thermal diffusivity and specific heat capacity during the Curie transition (approximately at 770°C). However, the thermal conductivtiy does not show a significant effect in this range. After the Curie transition, the thermal conductivity and diffusivity behave similarly, decreasing in the melt due to dissolution of the lattice structure during the phase transition at temperatures greater than 1525°C. These properties behave similarly and decrease in the melt due to the dissolution of the lattice structure during the phase transition at >1525°C (when there is no heat transfer from phonons in the melt). The Curie transition is clearly visible in both the thermal diffusivity and the specific heat capacity. However, the thermal conductivity shows no effect in this range.

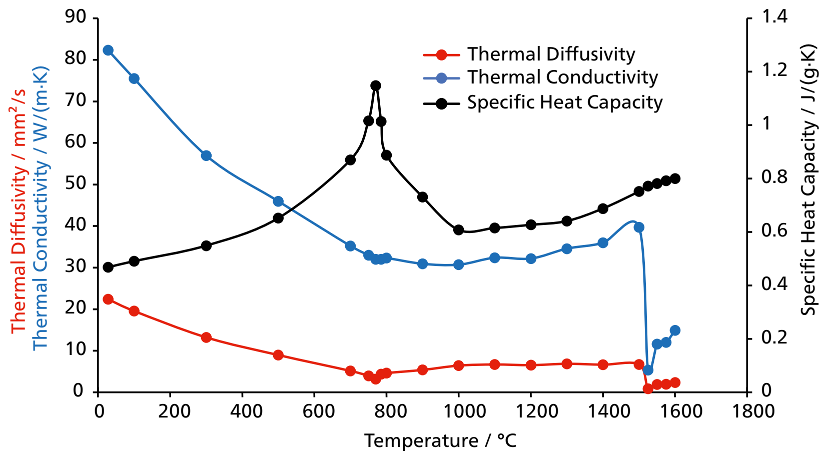


Fig. 2: Thermophysical properties of pure iron

Sample:	Pure Iron
Sample size:	Ø 10.39 mm; thickness ~ 1.4 mm; plane-parallel surfaces
Sample holder:	Sapphire for metal melting
Temperature range:	RT to 1600°C
Atmosphere:	Argon
Heating rate:	Variable up to 20 K/min
Model:	Standard

Tests on Metals within the Liquid Phase

Thin Samples with High Thermal Conductivity

Accurate measurement of thin, highly conductive samples requires a highly sensitive system, short pulse widths, fast data acquisition, and advanced data evaluation. The main challenge is the extremely short measurement time, which demands low pulse widths and high sampling rates.

Copper, which is typically 0.3 to several millimeters thick, is a common example. It is widely used as a heat spreader, substrate, or cooling plate in power electronics and battery systems, where efficient heat dissipation and compact design are essential.

The LFA 707 *StratoFlash® Classic* meets these requirements by offering adjustable pulse widths and voltages, which allow for optimized energy input. Its 2 MHz data acquisition rate ensures sufficient data points, even at very short measurement times. Thermal diffusivity measurements of copper samples ranging in thickness from 0.32 to 4 mm showed results within ±2.5% of the literature value of 117 mm^2/s at room temperature. The pulse lengths ranged from 100 µs to 600 µs, and half-times ($t_1/_2$) varied from 0.21 ms to 24 ms.

In addition to controlled energy input, accurate data evaluation, especially robust pulse correction, is essential for very short measurement times. Without pulse correction, errors significantly increase for thinner samples due to pulse overlapping.

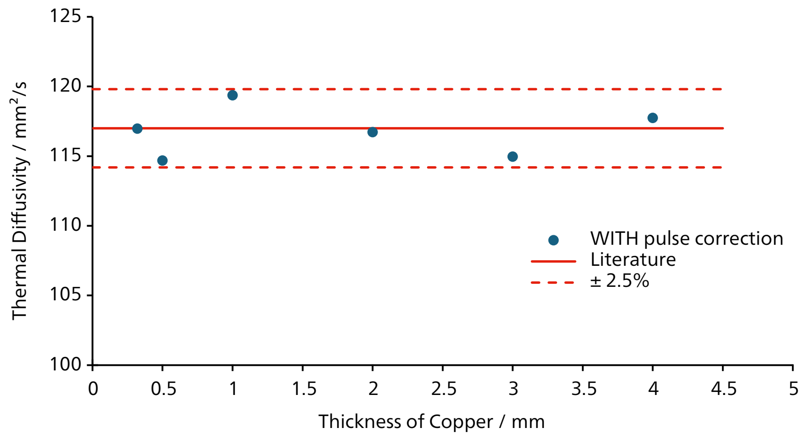


Fig.1: Thermal diffusivity of Copper with different thickness at room temperature compared to literature values.

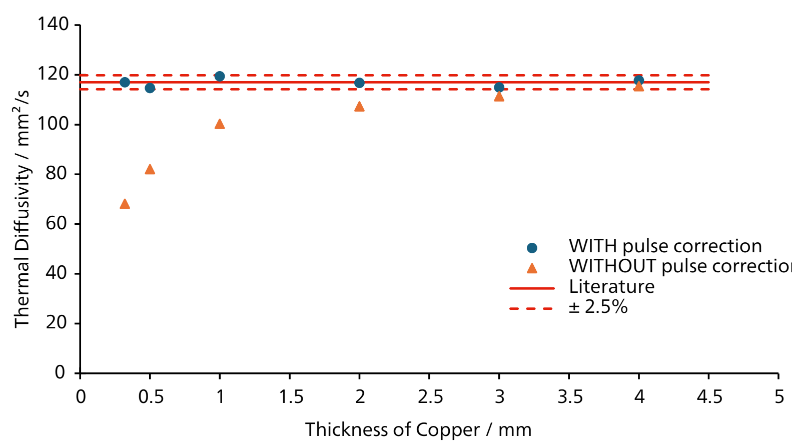


Fig. 2: Thermal diffusivity of Copper evaluated with and without pulse correction.

Sample:	Pure copper (Cu)
Sample size:	Ø 12.7 mm. ↕ 0.32 mm - 4.0 mm
Sample holder:	Graphite
Sample holder size:	12.7 mm
Temperature range:	RT
Atmosphere:	Argon
Model:	Standard

[1] Touloukian, Y. S., et al. "Thermophysical properties of matter-The TPRC data series". Volume 10. Thermal Diffusivity. 1974

Refactories

Representative Samples for Non-homogeneous Materials

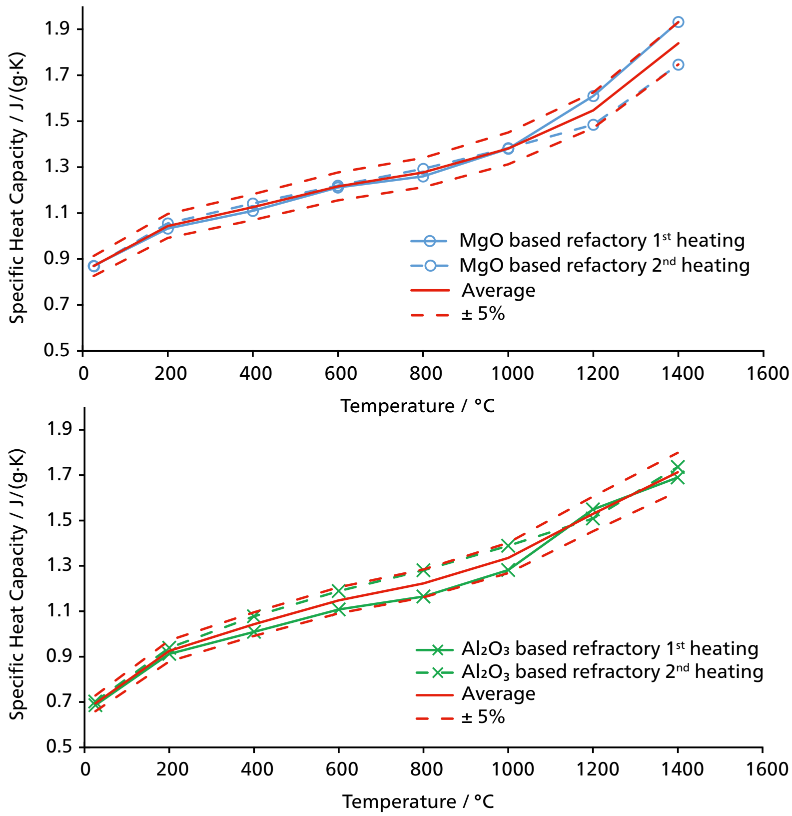


Fig. 3: Specific heat capacity of two refractory materials during the first and second heating cycles

Sample:	Refactory
Sample size:	25.4 mm; ↕ ~ 3 mm; plane-parallel surfaces
Sample holder:	Graphite
Sample holder size:	25.4 mm
Temperature range:	RT to 1400°C
Atmosphere:	Argon
Heating rate:	Variable up to 20 K/min
Model:	Standard

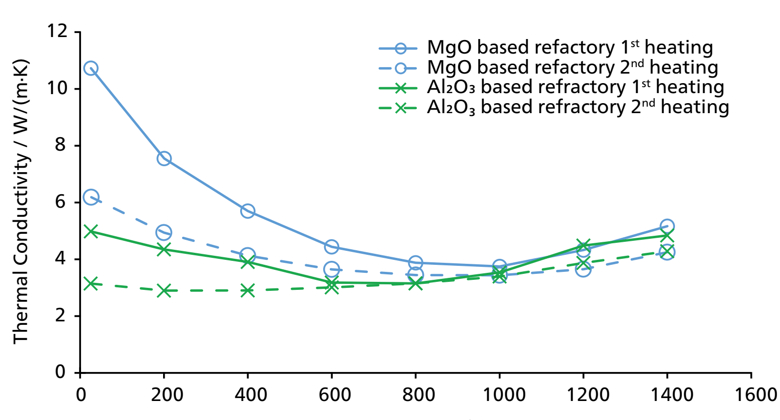


Fig. 4: Thermal conductivity of two refractory materials during the first and second heating cycles

Refractory materials are inhomogeneous composites that are essential for high-temperature applications. Accurately determination of their thermal conductivity requires large representative samples, which the LFA 707 *StratoFlash® Classic* can assess in specimens up to 25.4 mm in diameter at high temperatures.

In the measurement example, the specific heat capacity was determined using the LFA via the comparison method. A representative sample size was chosen. Figures 3 and 4 show the results for the specific heat capacity and thermal conductivity, which were measured with two heating cycles each. Unlike the thermal conductivity, the specific heat capacity does not significantly change with the second heating cycle. This indicates that the samples are thermally stable up to 1400°C, with no significant change in chemical composition.

Conversely, the thermal conductivity shows significant differences between the first and second heating cycles for the two materials. These differences, which are likely caused by changes in the sample structure, must be considered when designing high-temperature applications.

Ceramics

Ceramic Fiber Composite

In modern high-temperature technology, there is an increasing demand for materials that can withstand extreme thermal loads. Ceramic fiber composites are primarily used for the thermal protection of critical components, for example, as linings in combustion chambers or as structural components in the process industry.

The layered fiber structure of these materials causes them to exhibit anisotropy, meaning that knowledge of heat transport by the fiber rientation is crucial for designing high-temperature components.

Investigating this using laser flash analysis (LFA) up to a temperature of 1100°C thus reflects the real operating environment. The differences in the resulting thermal diffusivity are clearly visible. At room temperature, the values measured in the fiber direction are about 16% higher than those measured perpendicular to the fiber. As temperature increases, this difference decreases to around 13%.

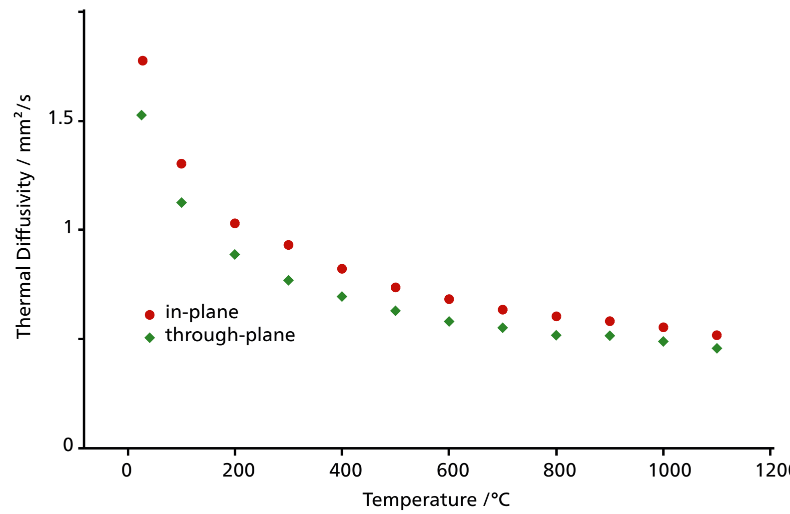


Fig.1: Thermophysical properties of an ansisotropic material, RT to approx. 1100°C, comparing in-plane and through plane.

Sample:	Ceramic fiber composite
Sample size:	Ø 12.5 mm, ↕ 0.50 mm
Sample holder:	Standard (through-plane direction), Laminate (in-plane direction)
Sample holder size:	Through-plane; Ø 12.64 mm; ↕ ~ 2.03 mm; in-plane; □ 10 mm; ↕ ~ 2.30 mm; plane-parallel surfaces on both
Temperature range:	RT to 1100°C
Atmosphere:	Argon
Heating rate:	Variable up to 20 K/min
Model:	Penetration

Accurate Analysis of Transparent and Translucent Materials

Alumina (Al_2O_3) is a key ceramic material renowned for its exceptional hardness, chemical inertness and thermal and mechanical stability. These properties make it a popular choice for structural components, cutting tools, wear-resistant coatings, electronic substrates, catalyst supports, biomedical devices and energy storage technologies.

Although polycrystalline alumina appears opaque, it is translucent in the infrared region, influencing the detector response during LFA measurements. Consequently, alumina samples require an appropriate surface coating to make both the front and rear faces opaque to infrared radiation. The analyzed samples were exclusively coated with graphite spray. The quality of the detector signals obtained demonstrates the capabiity of the LFA 707 *StratoFlash*® *Classic* to characterize this sample type without the need for additional coatings.

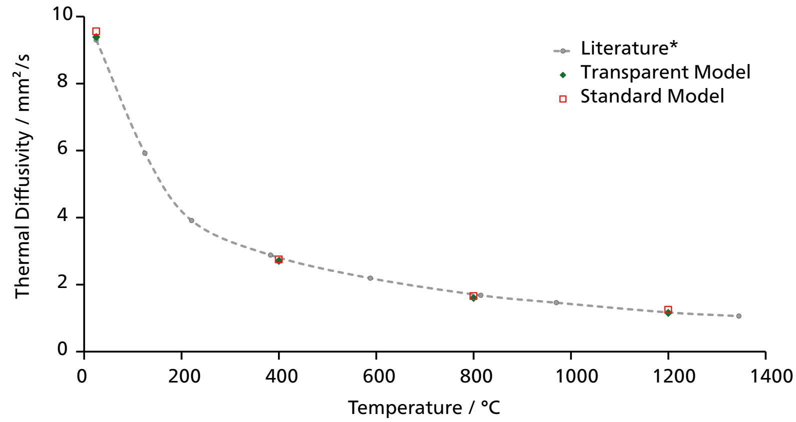


Fig. 2: Thermal diffusivity of alumina between room temperature and 1200°C. Analysis performed using the Transparent Model.

Sample:	Al_2O_3
Sample size:	Ø 12.5 mm, ↕ 0.50 mm
Sample hoder:	Grafit
Probenhaltergröße:	Ø 12.7 mm
Temperature range:	25°C to 1200°C
Atmosphere:	Argon
Heating rate:	Variable to 20 K/min
Model:	Standard and Transparent

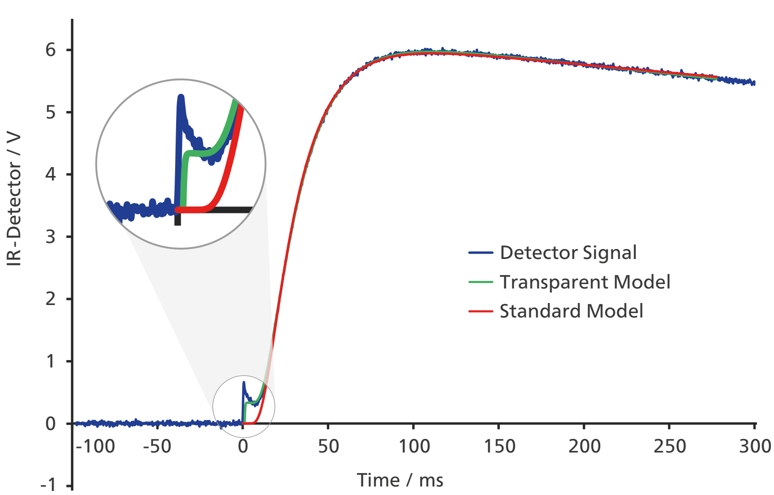


Fig. 3: Comparison of the analysis of a detector signal acquired at 1200 °C evaluated with the Standard Model and the Transparent Model.

At room temperature, the standard Cape-Lehman model can adequately fit the detector signal. However, at high temperatures, radiative heat transfer within the translucent ceramic introduces a radiative step in the signal. This requires the use of the Transparent Model to accurately fit the detector signal. Figure 3 demonstrates the critical importance of selecting the appropriate fitting model. The table below highlights that choosing the correct model is essential for achieving reliable LFA measurements on alumina across a wide temperature range.

Tab. 1: Results for Al_2O_3 at 1200°C using different models

Model	Thermal Diffusivity	Goodness of Fit	Deviation from Literature Values*
Standard	1.274	0.984	+8.88%
Transparent	1.175	0.991	+0.4 %

* Touloukian, Y. S., et al. "Thermophysical properties of matter-The TPRC data series", Volume 10. Thermal Diffusivity (1974)

	LFA 707 *StratoFlash® Classic*
Temperature range	RT to 1600°C
Heating rates	0.01 K/min to 50 K/min
Laser system	Pulsed Nd: Glass ▪ Wavelength 1054 nm ▪ Software-controlled pulse width and voltage between < 0.05 ms and 1.5 ms in steps of 0.01 ms ▪ Adjustable energy: 0.25 - 25 Joules/pulse ▪ Patented pulse mapping for finite pulse correction (patent no.: US20040079886)
Automatic Sample Changer (ASC)	▪ Sample holder support for 3 insets for samples ≤25.4 mm ▪ Sample holder support for 5 insets for samples ≤12.7 mm
Sensors	InSb (RT to 1600°C), optional LN_2 refill system including 35 liter dewar
Measuring range	▪ Thermal diffusivity: 0.01 mm^2/s to 2000 mm^2/s ▪ Thermal conductivity: 0.1 W/(m·K) to 4000 W/(m·K)
Accuracy*	▪ Thermal diffusivity: ± 2.5% ▪ Specific heat capacity: ± 5%
Repeatability**	▪ Thermal diffusivity: ± 1% ▪ Specific heat capacity: ± 3%
Measurement atmospheres	Inert or vacuum (<2x 10^{-5} mbar; turbomolecular pump)
Specimen dimensions and shapes***	Ø: 6 mm, 8 mm, 10 mm, 12.7 mm, 20 mm, 25.4 mm; thickness: 0.1 mm to 6 mm □: 10 mm x 10 mm, 20 mm x 20 mm; thickness: 0.1 mm to 6 mm
Sample holder material:	Al_2O_3 , graphite
Special sample holder systems	▪ Molten polymers/low-viscosity liquids (incl. low-viscosity materials such as water) ▪ Sample holder, especially for tests on resins during curing ▪ Pastes, powders, fibers ▪ Laminates ▪ In-plane ▪ Mechanical pressure
Reference materials	Various sets and individual reference materials in different dimensions and shapes
Software including calculation and correction models	Each model can be combined with 4 different baseline corrections (incl. shifted baseline) and w/o pulse correction; display of detector signal and model fit, data export; various special and extended models
Display of detector signal and model fit	▪ Quality check of the model fit (same plot) ▪ Automatic storage of both curves for each shot

* Deviation of the measured value from the "true value" (literature value) according to validation with reference materials.
** Deviation using the same operator and equipment over a short time according to validation with reference materials.
*** Additional sample holders upon request.

Technical Specifications

LFA in a mockup glove box

LFA for Special Applications

For applications requiring special atmospheres (O_2- or H_2O-free) or special handling of materials (e.g., radiation or nuclear), NETZSCH continues to offer the well-established LFA glovebox version. This vacuum-tight LFA version can be used in a glovebox with slight negative pressure or low overpressure.

Additionally, the LFA can also be placed in a hot cell. In these cases, the LFA's electronics are in a separate housing, allowing for easy handling with gloves or manipulators. Feedthroughs allow for the connection of cables, water and gas supply, vacuum pump, etc.

Contact your NETZSCH sales representative to discuss customizing the LFA glovebox version for your application.

The owner-managed NETZSCH Group is a leading global technology company specializing in mechanical, plant and instrument engineering.

Under the management of Erich NETZSCH B.V. & Co. Holding KG, the company consists of the three business units Analyzing & Testing, Grinding & Dispersing and Pumps & Systems, which are geared towards specific industries and products. A worldwide sales and service network has guaranteed customer proximity and competent service since 1873.

When it comes to Thermal Analysis, Calorimetry (adiabatic & reaction), the determination of Thermophysical Properties, Rheology and Fire Testing, NETZSCH has it covered. Our 60 years of applications experience, broad state-of-the-art product line and comprehensive service offerings ensure that our solutions will not only meet your every requirement but also exceed your every expectation.

Proven Excellence.

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