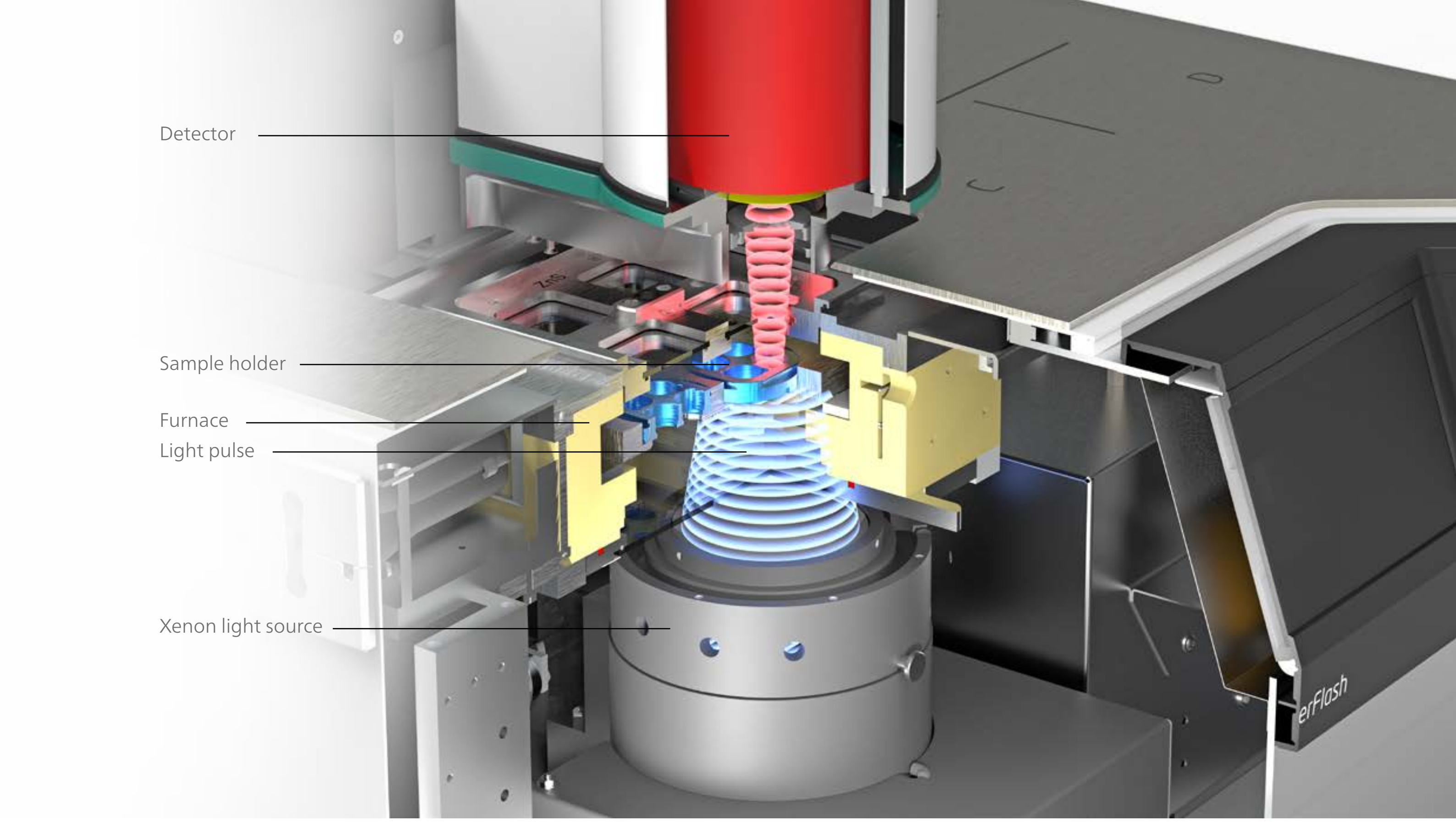
NETZSCH
Proven Excellence.

Light Flash Apparatus LFA 717 *HyperFlash*® Series

Method, Technique, Applications of
Thermal Diffusivity and Thermal Conductivity

Analyzing & Testing



Thermal Conductivity/Thermal Diffusivity

How Fast Is Heat Being Transferred?

Understanding thermal conductivity is essential to material selection in a variety of applications. Insulation materials require low thermal conductivity, while heat sinks require high thermal conductivity to efficiently dissipate heat. In industrial processes such as casting and welding, thermal conductivity influences the movement of heat, affecting process efficiency and quality. Thermal diffusivity is critical in situations where heat transfer changes with time, such as rapid heating/cooling processes.
One accurate, reliable and elegant solution for measuring thermal conductivity and thermal diffusivity is offered by the Flash Method. This method allows to overcoming the challenges of understanding and managing heat transfer. Typical applications include:

- Thermal management for the control of temperature in systems, devices, or materials to ensure proper functioning, longevity, and efficiency
- Preventing overheating in components by selecting materials with appropriate thermal properties
- Designing materials that can withstand extreme temperature changes
- Controlling temperatures in processes like extrusion, molding, and metal working
- Enhancing the efficiency of thermal insulation and heat exchangers

Over the past three decades, NETZSCH has led the way in this technology, extending or capabilities such that we now can accommodate an application range from -125°C to 2800°C. We never stop innovating, anticipating, and meeting our customers' needs. Once again, true to our tradition of excellence, the LFA 717 *HyperFlash*® and the LFA 717 *HyperFlash® HT* set the standard.

THE
FLASH
METHOD

Light Flash

An Efficient Method for Determination of Thermophysical Properties

The Light Flash (LFA) technique is a fast, absolute, non-destructive, and non-contact method for determining thermal diffusivity. Using a reference specimen, the specific heat capacity of materials can also be characterized by LFA.

The front surface of a plane-parallel sample is heated by a short energy light pulse. From the resulting temperature excursion of the rear face measured with an infrared (IR) detector, both thermal diffusivity and specific heat capacity can be determined.

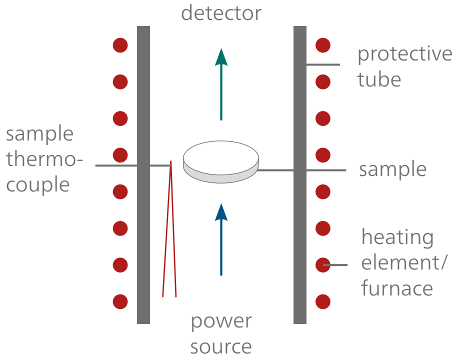
Combining these thermophysical property values with the density value yields in the thermal conductivity value as follows:

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

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

This complete set of thermophysical properties can then be used:

- As input data for numerical simulations
- For material optimization, for example, targeting the desired thermal performance



Flash Technique

MARKET LEADER

LFA 717 *HyperFlash*®

-100°C to 500°C

EXCELLENT EFFICIENCY – SIMULTANEOUS MEASUREMENT OF 16 SAMPLES

The LFA 717 *HyperFlash*® features an automatic sample changer for up to 16 samples, accommodating round and square samples in four holders embedded in one furnace.

ONE-INCH SAMPLE HOLDER FOR LARGE-DIAMETER SAMPLES

Even larger samples can be measured using the 1-inch (ø 25.4 mm) sample holder. Typical sample thickness range from 0.5 to 3 mm.

FLEXIBILITY THROUGH COOLING

Using liquid nitrogen as a coolant, samples can be measured at temperatures as low as -100°C. An optional compressed air unit is available for measurements between 0°C and 500°C.

GENERAL INSTRUMENT FEATURES

THE BROADEST SAMPLE HOLDER AND SAMPLE MATERIAL RANGE

MOST ADVANCED CALCULATION MODELS

Always at the forefront of scientific advances, the LFA 717 *HyperFlash*® accurately reflects a material's thermal diffusivity, offering the most advanced calculation models.

FOR HIGHLY ACCURATE AND RAPID THERMAL DIFFUSIVITY MEASUREMENTS

RT to 1250°C

LFA 717 *HyperFlash® HT*

UP TO 1250°C WITH XENON FLASH LAMP

The LFA 717 *HyperFlash® HT* is based on the already-established LFA 717 *HyperFlash®* technology and requires no laser class due to the innovative light source system. The long lifetime of the xenon lamp provides cost-effective measurements up to 1250°C without costly consumables.

VACUUM-TIGHT FURNACE FOR DEFINED ATMOSPHERES TO PREVENT OXIDATION

An internal pump device supports defined atmospheres via an automatic evacuation function prior to each measurement. Additional connections for external pump devices are available. The vacuum-tight platinum furnace allows for heating rates up to 50 K/min.

TIME-SAVING MINI-TUBE FURNACES

Effective sample throughput over the entire temperature range is provided by mini-tube furnaces for unmatched test speed. Each of the four sample positions has its own thermocouple, resulting in short stabilization times. Ten temperature steps up to 1250°C can be measured in one hour.

WIDE TEMPERATURE RANGE WITH SMALL FOOTPRINT

Measurements from either -100°C to 500°C or room temperature to 1250°C can be made with a single instrument setup.

PULSE CORRECTION

Consideration of the pulse length of the light source accurately reflects a material's properties – especially when characterizing highly conductive materials or thin films.

Accessories

SAMPLE HOLDERS – CLEVERLY DESIGNED FOR SPECIAL APPLICATIONS

Accessories Catalogue

Full selection of LFA 717 *HyperFlash*® series accessories, containing sample holders, reference materials and tools

Numerous sample holders for different sample geometries are available for measurements in the complete temperature range of both LFA instruments. These also include those that can be used for special applications.

The design of the sample holder for liquids ensures continuous contact between the liquid and the crucible over the entire temperature range – even at freezing temperatures. The heat transfer through the container wall is minimized.

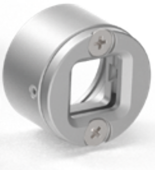
A special sample holder made of cost-effective consumables is available for measurements on resins during the curing process. In addition, sample holders for measurements in the in-plane direction and ones for tests under mechanical pressure are included in our product line. Customized sample holders are available upon request.

LFA 717 *HyperFlash*®

In addition to standard sample holders for solid samples of round and square geometries, we also offer sample holders designed for special applications on specific materials, including:

- Molten polymers and low-viscosity liquids
- Resins during curing
- Pastes and powders
- Fibers
- Laminates

Sample holder for foils (left), standard sample holder for up to 4 round samples (right)

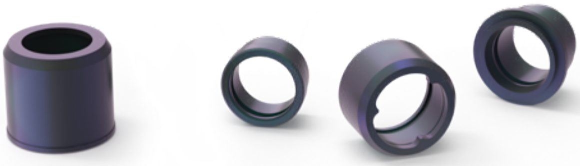


The following applications can be tested using special sample holders:

- Pastes and powders, e.g., metal powders, greases and resins
- Liquid samples, e.g., water, oil, waxes or honey as well as molten polymers and metals
- Anisotropic materials: fiber-reinforced polymers and/or ceramics, carbon prepregs (through-plane and in-plane)
- In-plane measurements on thin and highly conductive metal foils like copper and aluminum
- Polymer thin foils like adhesive tapes or plastic packing films
- Fibers, e.g., carbon fibers

LFA 717 *HyperFlash*® *HT*

Sample holders for liquids, pastes, polymer melts and resins are also available for the LFA 717 *HyperFlash*® *HT*. In addition, special sample holders also allow measurements on "liquid"* and powdery metallic samples.



Special sample holder for "liquid"* and powdery metallic samples (left), standard sample holder for round samples (right)

* In this context, the term “liquid metals” refers to sample holders that facilitate measurements at temperatures exceeding the melting point of metals.

The high-temperature version covers the following materials:

- Pastes and powders, e.g, metal powders, greases and resins
- Liquid samples, like water, oil, waxes of honey as well as molten polymers and metals
- Anisotropic materials: fiber-reinforced polymers and/or ceramics, carbon prepregs (through-plane and in-plane)

Cooling Accessories and Features that Focus on Efficiency and a More Sustainable Laboratory

Handling Critical Materials

Certain materials, such as toxic or oxygen/moisture-sensitive substances, require special handling to ensure operator safety. Exposure to the environment should also be prevented. Our LFA units can be designed in special glove box or hot cell versions that are engineered to meet these unique requirements, including the restricted handling of instruments.

Internal and External Pump Systems

An internal pump together with automatic evacuation control allow measurements in defined atmospheres in the LFA 717 *HyperFlash*®. In the high-temperature version, an external pump can also be connected to improve the purity of the atmosphere.

Analysis in Subambient Temperatures – LN_2 and Compressed Air Cooling

The LFA 717 *HyperFlash*® offers several cooling options. Temperatures down to 0°C can be achieved with compressed air. Liquid nitrogen (LN_2) is required for cooling down to -100°C. LN_2 refill systems allow continuous operation of the LFA by steadily supplying the furnace and detector with liquid nitrogen.

Illustration showing the use of the glovebox with the LFA 717 *HyperFlash*® *HT;* gloves are not shown.

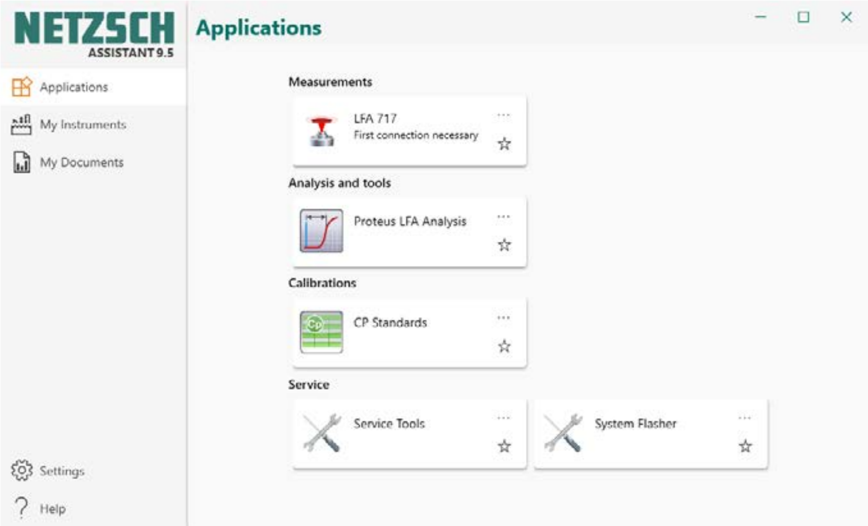
50% LESS ENERGY CONSUMPTION WITH THE LATEST CHILLER TECHNOLOGY

The integration of a chiller in laser flash analysis plays a crucial role in ensuring stable initial temperatures and maintaining a controlled environment, both of which are essential for accurate measurements of thermal diffusivity and the subsequent determination of thermal conductivity. By minimizing temperature fluctuations, chillers enhance the reproducibility and reliability of measurements. However, chillers also consume energy and produce waste heat, which can contribute to operational inefficiencies. Therefore, the use of energy-efficient chillers is important for reducing both energy consumption and operating costs. NETZSCH addresses this need by offering highly efficient chillers in conjunction with its LFA instruments. With advanced chiller technology, energy consumption in the LFA can be reduced by up to 50%, leading to an annual energy savings of approximately 3,400 kWh*.

* For half-day usage of 12h per day, for 52 weeks per year

Proteus® Software

Intelligent Operation – Just a Click Away



NETZSCH Assistant to for managing all instruments and applications

The *Proteus*® 64-bit software is licensed with each instrument and can handle multiple instruments connected via USB in parallel or run on secondary installations on other computer systems.

It is integrated in the NETZSCH Assistant as of version 9.5, which collectively links a wide variety of NETZSCH instruments as well as several third-party applications into one higher-level software management suite.

General Software Features
Determination of the specific heat capacity with the comparative method including c_p graph
Comparative analysis for up to 32 series of shots from the same database
Determination of the contact resistance in multi-layer systems
Definition of numerous temperature setpoints and individual number of shots per setpoint
Existing NETZSCH customers can use any of their data already collected with the LFAs (457, 467, 427) in the new software version
Graph of the measurement curves with up to 3 scalable Y axes
Fast zoom function for X and Y segments
Measurement values shown as a Tool-Tip when hovering the mouse over the measurement points
Thermal diffusivity graphs as a function of temperature or time
Combined graph of raw data and theoretical model

The Latest *Proteus®* Software Version for Highest Stability and Most Reliable Results

A major LFA-specific upgrade was replacement of the previous database format with the new and faster SQL database format. This change in the underlying data structure leads to improved modeling times and yields results up to 2.5 times faster while using less memory space.

This means that users can now store an almost unlimited number of measurements per database. All common database management functions such as import/export and data merging are still available.

Models and Corrections
Classic and state-of-the-art models for simultaneous data evaluation
▪ Standard Model based on improved Cape-Lehman ▪ Transparent Model for transparent and translucent specimens (considering radiative heat transfer within the sample) ▪ Penetration Model for porous samples
▪ Adiabatic ▪ Cowan (front-back heat loss) ▪ 2-/3-Layer Models (consideration of heat loss) ▪ In-Plane Model (isotropic and orthotropic)
Heat-loss
Baseline corrections
Accurate pulse length correction by pulse mapping
Multiple-shots averaging
Temperature-dependent thermal properties approximation via various mathematical functions (polynomials, splines, etc.)
Optimization of gain and measurement duration
Improvement of robustness of individual models and quality criteria to cover latest user requirements

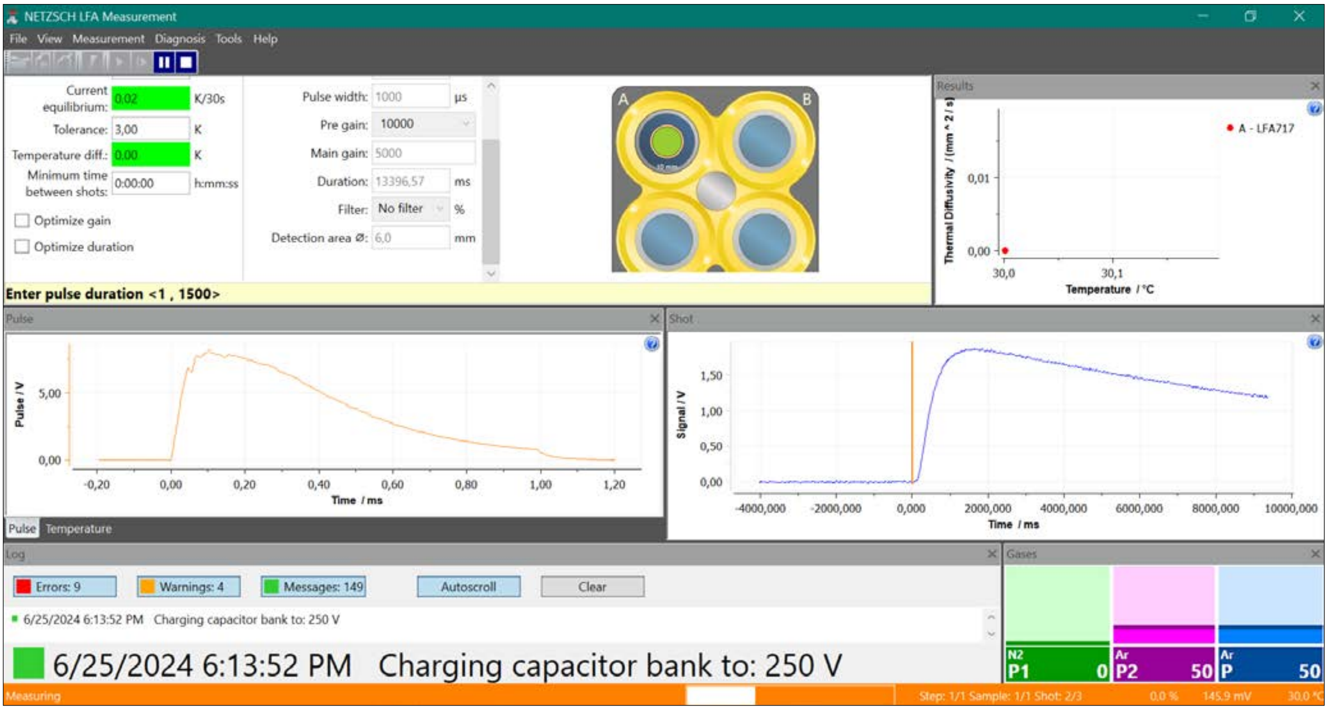
All models allow for the combination of heat loss, pulse correction and various baseline types.

For more information, see page 16.

The latest *Proteus®* LFA software is divided into two components: the measurement software and the analysis software. A key advantage of this setup is that the analysis can be performed on a separate computer that is not connected to the instrument, providing greater flexibility and convenience in data processing.

Measurement Software

The measurement software is self-contained software for connecting and controling the instrument and hardware accessories, as well as for defining and monitoring each measurement. The measurement software achieves a high level of automation with features such as gain and duration optimization. However, all of these options are fully customizable to provide the user with maximum flexibility.



Current equilibrium: 0,02 K/30s

Tolerance: 3,00 K

Temperature diff.: 0,00 K

Minimum time between shots: 0:00:00 h:mm:ss

☐ Optimize gain

☐ Optimize duration

Pulse width: 1000 µs

Pre gain: 10000

Main gain: 5000

Duration: 13396,57 ms

Filter: No filter %

Detection area Ø: 6,0 mm

Enter pulse duration <1 , 1500>

🟥 Errors: 9 🟧 Warnings: 4 🟩 Messages: 149

```
6/25/2024 6:13:52 PM   Charging capacitor bank to: 250 V
```

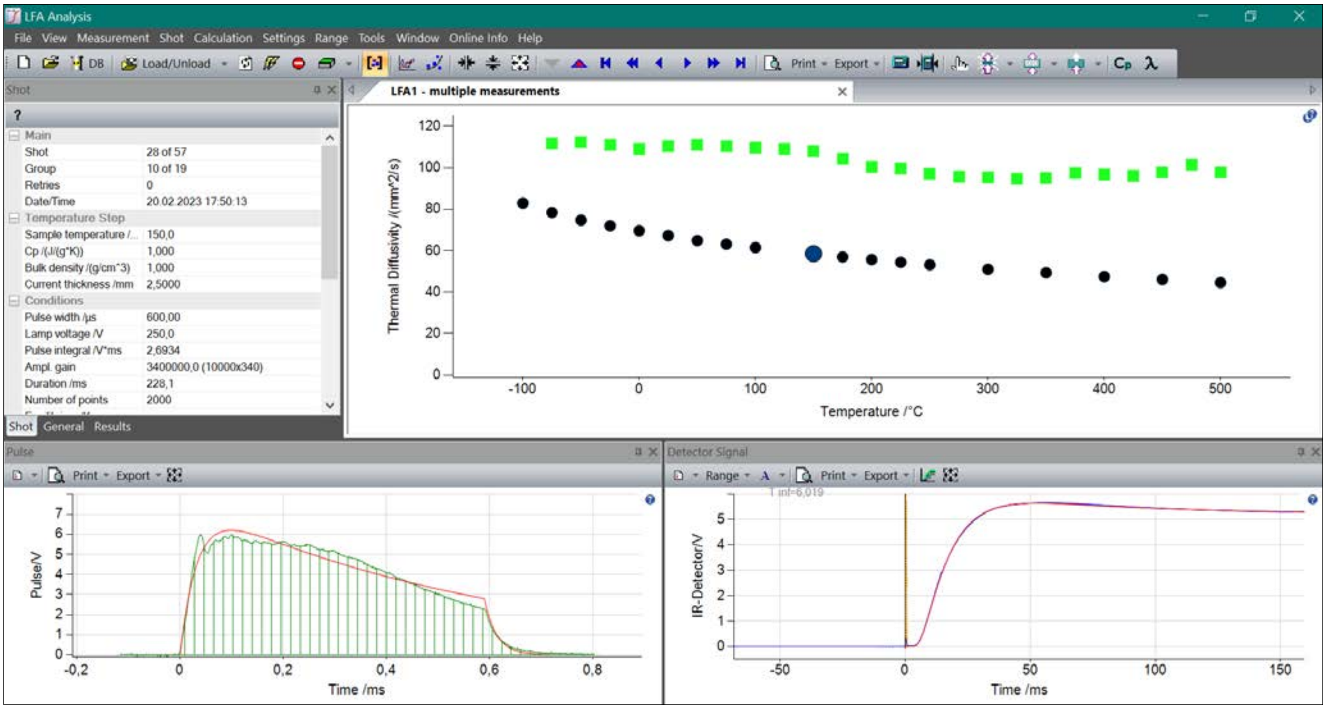
🟩 6/25/2024 6:13:52 PM Charging capacitor bank to: 250 V

Measuring   Step: 1/1 Sample: 1/1 Shot: 2/3   0,0 %   145,9 mV   30,0 °C

Graphical user interface of the measurement software while measurement is performed.

Analysis Software

The second independent component of the *Proteus*® LFA software is dedicated to data analysis based on analytical models and the detailed export of documentation and results.
Several measurements can be analyzed and compared in one plot as well as exported to common image and text based data formats. No subsequent data processing is required. Analysis states can be saved to make subsequent evaluation as convenient as possible.



Main	
Shot	28 of 57
Group	10 of 19
Retries	0
Date/Time	20.02.2023 17:50:13
Temperature Step	
Sample temperature /...	150,0
Cp /(J/(g*K))	1,000
Bulk density /(g/cm^3)	1,000
Current thickness /mm	2,5000
Conditions	
Pulse width /µs	600,00
Lamp voltage /V	250,0
Pulse integral /V*ms	2,6934
Ampl. gain	3400000,0 (10000x340)
Duration /ms	228,1
Number of points	2000

Graphical user interface for analysing the measurement results.

Features of the Analysis Software
Simultaneous measurement and evaluation
One-click analysis for routine tasks as well as expert level analysis with sample pre-knowledge available
Combined analysis: Consideration of c_p and thermal expansion via import of DSC, DIL and TMA measurements in a single plot with multiple curves/temperature segments from the same or different measurements
Data export as well as export graphics with evaluation results to clipboard or to common formats such as EMF, PNG, BMP, JPG, TIF, PDF, ASCII, CSV
Generated fit data as well as measured raw data for pulse and response signal as output option
History of analyzed measurements accessible upon start of software for fast continuation

Advances in Pulse Correction Routines

IMPACT ON ALL MODELS

In the latest version of the analysis software, you will find a refined and highly accurate analysis pulse correction that allows access to samples where exceptional time resolution is required. This is beneficial for thin or high conductivity samples, or simply whenever the light pulse overlaps with the thermal response of the sample. The user can choose from the following correction techniques in the Calculation dialog:

- Equivalent square
- Gravity center
- Double exponential pulse correction

Application of the pulse correction will notably impact the appearance of the model function as well as its associated "Goodness of fit", as seen in the following simulation of a high-diffusivity material (see below).

The example evaluation comprises a simulated detector signal with α = 800 mm²/s, which superposes a pulse signal of 1 ms duration. It can be observed that the exponential impulse correction is essential in the thermal diffusivity calculation, as deviations without this correction can exceed 20%.

Calculate Diffusivity

Use	View	Model	Heat Loss Front	Heat Loss Back	Heat Loss Side	Bas
☑	☑	In-plane Isotropic + p.c.	☑	☑	☑	Lin
☐	☐	In-plane Orthotropic + p.c.	☑	☑	☑	Lin
☑	☐	In-plane Isotropic + p.c.	☑	☑	☑	Lin

Correction Pulse	Therm. Diffusivity /mm²/s
Exponential	800.134
Equiv. Squ...	
None	653.095

Deviation: 18.36 %

Goodness of fit 0-33%	33-66%	66-100%	Total	Calc. Rng
0.998164	0.998891	0.998405	0.998522	0.998524
0.960424	0.987964	0.986944	0.977349	0.977383

Patterns: In-plane Isotropic + p.c.

☑ Extended mode

Measurement: inplanesim (simulation)

Shot 1/1

Temp. /°C: 19.2

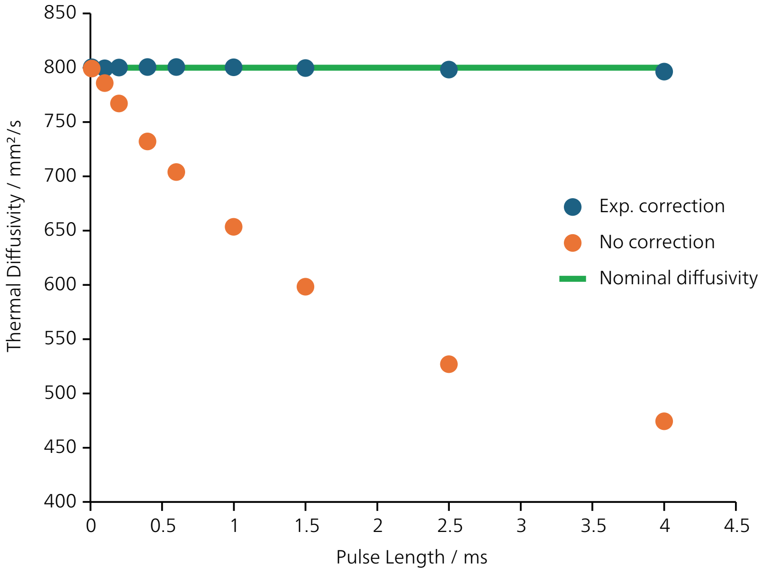
☑ In-plane Isotropic(I,ana.,1.00,0.00)
☑ In-plane Isotropic(I,-,1.00,0.00)

☐ Change Calculation Range

○ Input values
10 Half Time
● Full

☑ Residuals

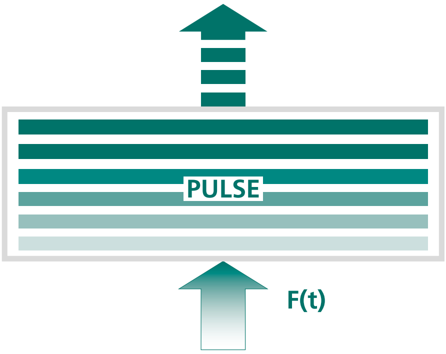
Imported simulation fed into the LFA software



Effect of pulse correction on evaluated simulation data

The importance of the pulse correction becomes more significant when looking at a range of pulse lengths simulated into this single set of data (see above).

For uncorrected data, the calculated thermal diffusivity decreases with increasing pulse length. When an exponential pulse correction is applied, however, the diffusivity remains almost constant over the simulated range of pulse lengths. This amendment enables any user to rapidly evaluate the real diffusivities of samples with the vast majority of our provided sample holders.



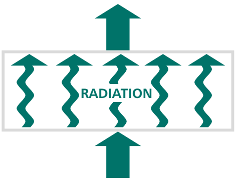
Calculation Models, Corrections and Mathematical Operations

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. These materials completely absorb the energy of the light pulse at the front surface of the sample. The Standard Model takes the two-dimensional (z-axis and radial) heat loss and the illuminated area as well as the detection area into account.

Transparent Model

For transparent and translucent materials, in addition to the conductive heat flow, a direct radiative heat transfer occurs between the front and rear face of the specimen. This results in an instantaneous increase of the thermal curve. The Transparent Model takes these effects into account to determine the thermal diffusivity.

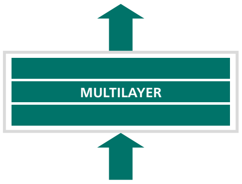


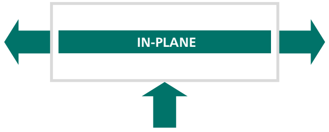
Penetration Model

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 are available for the user. These models cover a wide range of geometries and anisotropic specimens, and round out the complete LFA analysis software.



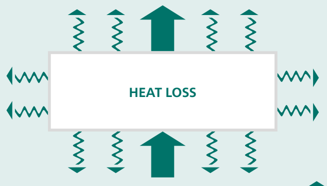


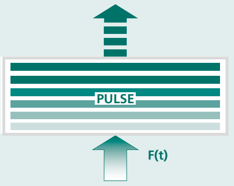
Orthotropic Model for the In-Plane Sample Holder for Non-Transparent One-Layer Samples

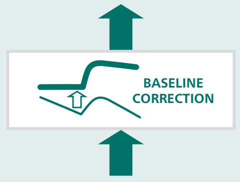
In addition to the isotropic model, there is also another model available for the in-plane sample holder. The Orthotropic Model assumes transverse isotropy, e.g., a sample at constant temperature will have isotropic thermal diffusivity in its entire xy plane (radial heat diffusion), and only the diffusivity in the z direction (axial heat diffusion) will be uniformly different.
The In-Plane Model can be applied to data from such samples in either its inward or outward heat flow variation.

Corrections

For a better fit and best results, all models come standard 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.







Rugged yet Adaptable Instrument Design

The design of the LFA 717 *HyperFlash*® focuses on utilizing specific materials around the sensor components to ensure robustness, durability, and maximum measurement precision. For easy access to the interior of the instrument, the top and bottom cover of each furnace can be opened with one hand. If required, the detector can easily be exchanged by the user in a matter of minutes (e.g., for special applications or maintenance).

Status Information at a Glance

The front of the device features several visual elements that provide live information once the instrument is turned on. For example, the illuminated information panel communicates basic instrument information, such as "instrument locked, gas flow active". The integrated LED bar indicates the status of a running measurement, such as the progress of the measurement or whether any user interaction is required.

Multi-User Design

The top cover of the instrument is regularly used as a sample preparation or storage area. It is now designed with four visually separated areas that correspond to sample positions in the furnace. This simplifies sample identification or pre-assembly, reduces delays, and is especially useful when the instrument is emplyed by multiple users.

High Degree of Automation

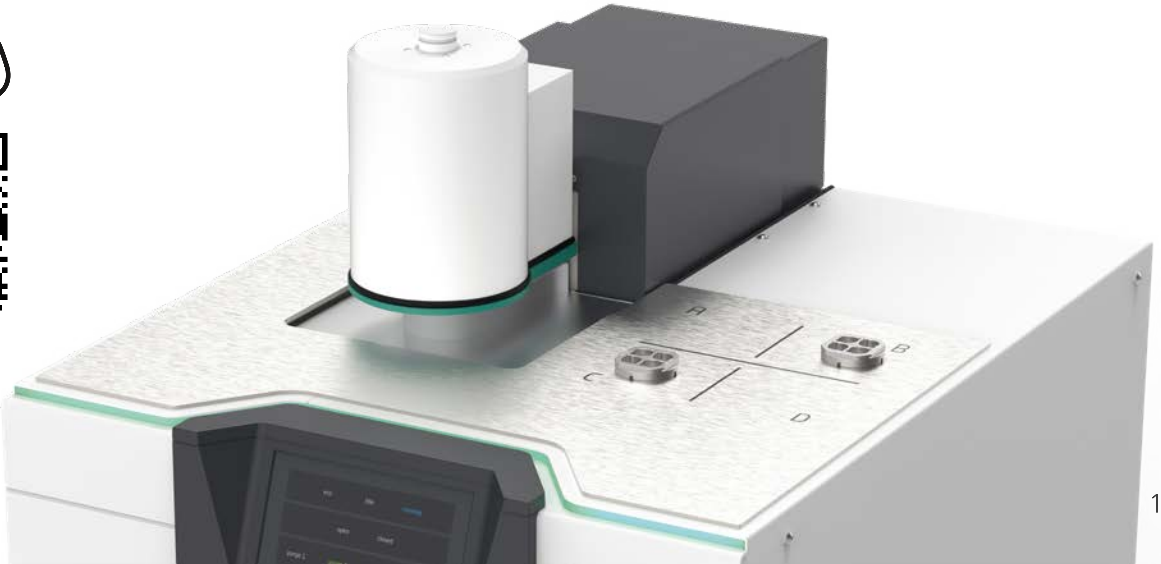
Once a fully defined measurement is started in the software, no further user interaction is generally required. The instrument takes care of typical tasks such as sample repositioning, automatic temperature control, and synchronization of vacuum or gas supply. Automatic LN_2 refill also reduces the need for user intervention. Once a measurement is defined, it can be stored and reused, resulting in highly reproducible results.

Safety Features

In addition to the benefits of a fully protective enclosure that shields electrostatic and electromagnetic fields, the design incorporates several other safety features, such as two-handed opening and closing of the furnaces to prevent entrapment. Sudden cooling or gas leakage is detected by the firmware and a running measurement is automatically stopped.
For work with hazardous samples, sample racks can be handled in a non-contact manner with the use of special tools and special tweezer sets. Depending on the application, the instrument is suitable for glove box and hot cell use.

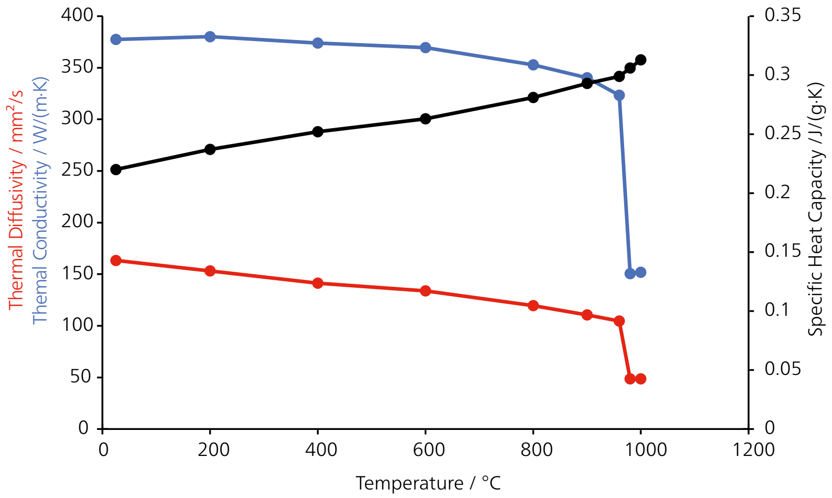
User-Friendly Design and Safe Operation

360°



Applications

Thermal Conductivity of Molten Metals



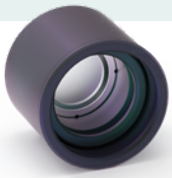
Thermophysical properties of an Ag alloy from room temperature up to the melting range

Sample:	Ag alloy
Instrument:	LFA 717 *HyperFlash® HT*
Detector:	InSb
Sample holder:	Molten metals sapphire
Model:	Standard
Heating rate:	10 K/min
Temperature range:	25°C to 1050°C
Sample dimension:	Ø 10.4 mm, ⇕ 1.42 mm

The thermal conductivity of elemental silver is one of the highest amongst all metals known today. In the electronic industry, silver and its alloys are widely used due to their ability to dissipate heat from sensitive parts. Therefore, the thermal conductivity in these applications is of high interest.

Using the sapphire sample holder, measurements on a silver alloy in the solid as well as in the liquid state are possible; see plot on the left. The specific heat capacity was determined using a DSC 500 *Pegasus®*.

Both thermal diffusivity and thermal conductivity decrease continuously with increasing temperature. The dissipation of the lattice structure is observed by a sharp decrease in thermal diffusivity and thermal conductivity at about 960°C, indicating melting of the Ag alloy. The real specific heat capacity overlaps with the endothermic effect during the melting and is therefore interpolated.



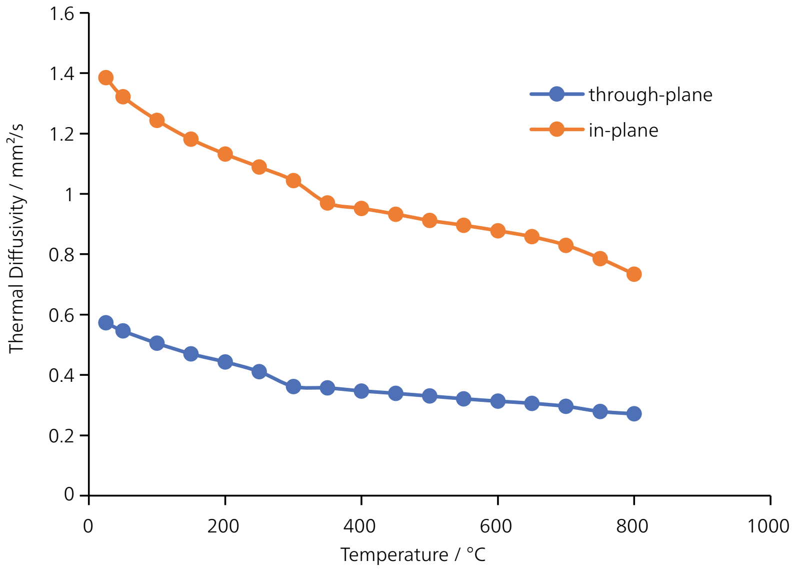
Thermal Diffusivity of Anisotropic Ceramics

Anisotropic ceramics are engineered to increase thermal conductivity in specific directions, which is valuable for thermal management in electronic devices, high-temperature applications, and thermal barrier coatings. Understanding and controlling anisotropy is essential for optimizing performance in various industries.

Anisotropy in thermal diffusivity and conductivity caused by embedded fibers can be determined using an SiC laminate sample holder.

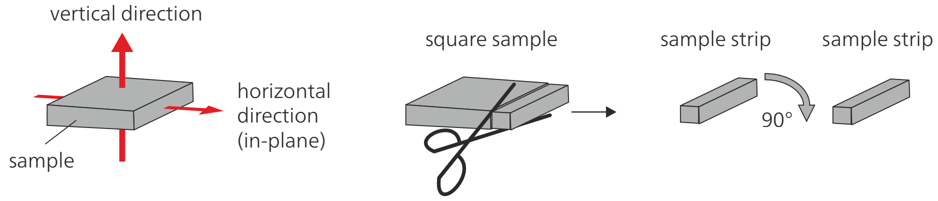
A sintered ceramic specimen was cut into strips, placed in the holder, and measured in the through-plane and in-plane direction from room temperature to 800°C in an argon atmosphere.

This example shows the thermal diffusivities in two perpendicular directions. The in-plane measurement shows the highest thermal diffusivity due to unidirectional fibers in the sample.



In-plane and through-plane thermal diffusivity of a ceramic with embedded fibers, between room temperature and 800°C

Sample:	Ceramic with fiber content
Instrument:	LFA 717 *HyperFlash® HT*
Detector:	InSb
Sample holder:	Holder for laminates made of SiC
Model:	Standard
Heating rate:	10 K/min
Temperature range:	25°C to 800°C in 50 K steps
Sample dimension:	5 strips of 10 mm x 2 mm x 2 mm



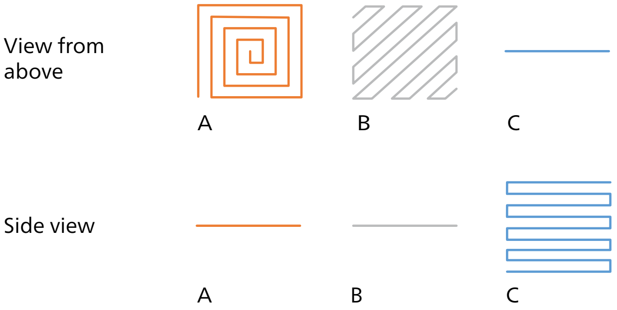
Preparation of specimen for the laminate sample holder, SiC, for high temperatures (RT to 1250°C)

Thermal Diffusivity Measurement of PLA Filament

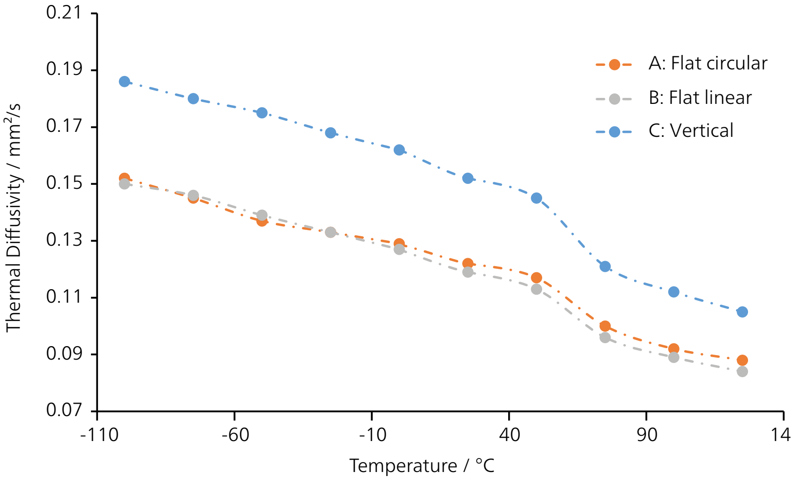
Additive manufacturing, or 3D printing, has grown exponentially over the past few decades. In the early 2020s, the expiration of several FDM 3D printer patents made 3D printing accessible to mainstream users for DIY projects.

Fused Deposition Modeling (FDM) is particularly popular among enthusiasts because of its high quality and affordability. For example, when using thermoplastic polyesters, the deposition process creates objects with directional properties.

This example shows the thermal diffusivity of polylactic acid (PLA), a common 3D printing polymer, printed at 60 mm/s in three different orientations. Two data sets represent single-filament layers printed flat on the bed (linear and circular), while the third data set, with the highest diffusivity, represents a layer printed perpendicular to the bed with vertical filament fusion. The notable step at around 60°C in all diffusivity data sets indicates the glass transition (T_g) of PLA. The higher diffusivity in the blue data set indicates better intrafilament fusion achieved by vertical layering, likely due to rapid cooling on a bed with higher thermal conductivity.



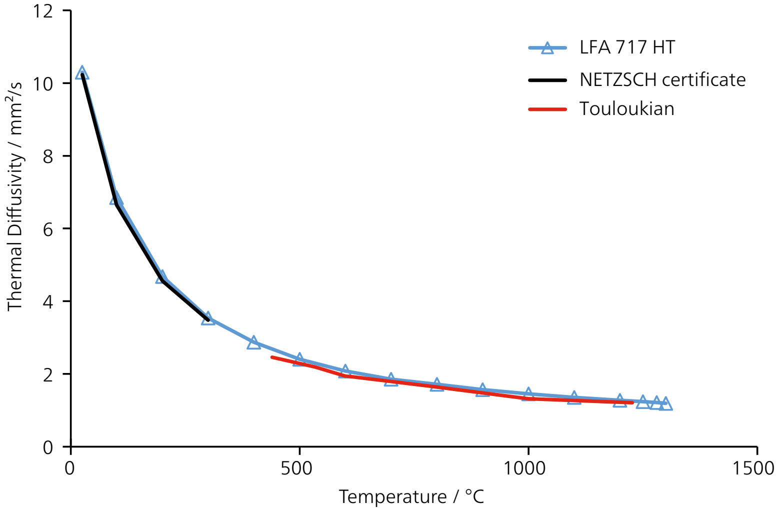
PLA printed in three different orientations: A) flat on bed circular, B) flat on bed linear, C) perpendicular on bed with vertical filament fusion



Thermal diffusivity of PLA filament printed in horizontal plane onto a non-heated printing bed and vertical on top of recently extruded and cooled PLA

Sample:	Polylactic acid (PLA)
Instrument:	LFA 717 *HyperFlash*®
Detector:	MCT
Sample holder:	4 sample squares
Heating rate:	10 K/min
Temperature range:	-100°C to 125°C
Sample dimension:	10 mm x10 mm x 0.9 mm (square)
Model:	Standard

Thermal Diffusivity of Al_2O_3



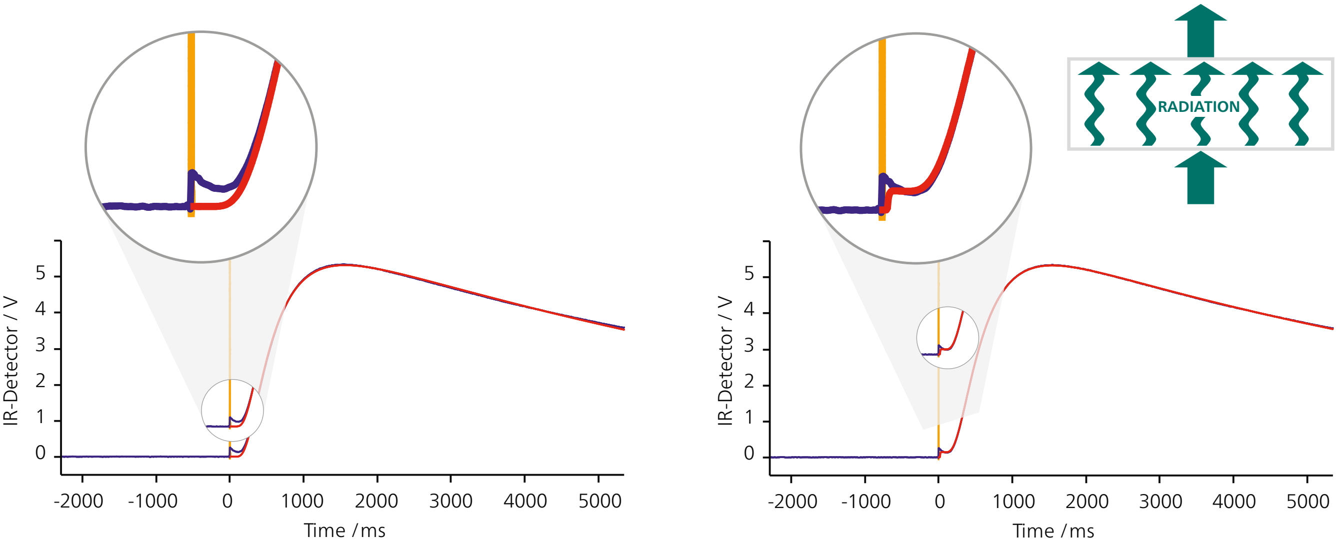
Thermal diffusivity measurement of Al_2O_3 in comparison to literature values.

Sample:	Alumina, Al_2O_3
Instrument:	LFA 717 *HyperFlash®* *HT*
Detector:	InSb
Sample holder:	Single, Ø 12.7 mm
Heating rate:	20 K/min
Temperature range:	25°C to 1250°C
Sample dimension:	Ø 12.5 mm, ↕ 2.49 mm
Model:	Standard and Transparent

Alumina (Al_2O_3) is a versatile translucent ceramic used in electronics, catalysts, medical devices, glass, chemicals, coatings and batteries. The diagram on the left shows the thermal diffusivity of Al_2O_3 from room temperature to 1250°C, measured with the LFA 717 *HyperFlash® HT*. The measurement results are in good agreement with literature values.

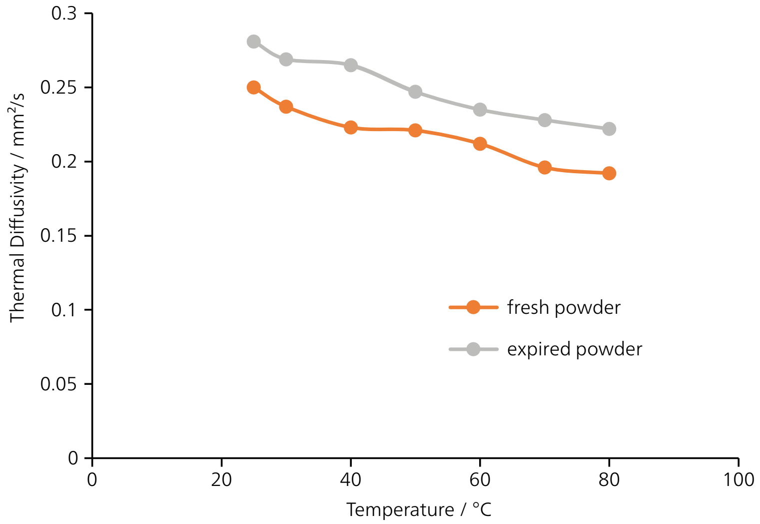
Measurements on translucent samples require a sample coating. The graphite coating makes the Al_2O_3 surface opaque, improving signal detection at low temperatures using the Cape-Lehman Standard Model. At higher temperatures, radiative heat transfer within the material becomes dominant, causing a steep jump in diffusivity known as the radiative step. The Transparent Model is required to accurately fit this step.

The signals below illustrate the difference between using the Standard Model and the Transparent Model, highlighting the importance of selecting the appropriate model for accurate results.



Evaluation of a measurement signal with radiation step using different models (Standard Model left; Transparent Model right)

Thermal Diffusivity of Lactose Monohydrate



Thermal diffusivity results for two different lactose monohydrate pellets measured from 25°C to 80°C under an argon atmosphere

Sample:	Lactose monohydrate
Instrument:	LFA 717 *HyperFlash*®
Detector:	MCT
Sample holder:	Ø 12.7 mm/standard
Heating rate:	10 K/min
Temperature range:	25°C to 80°C
Sample dimension:	Ø 12.6 mm, ↕ 3 mm
Model:	Standard

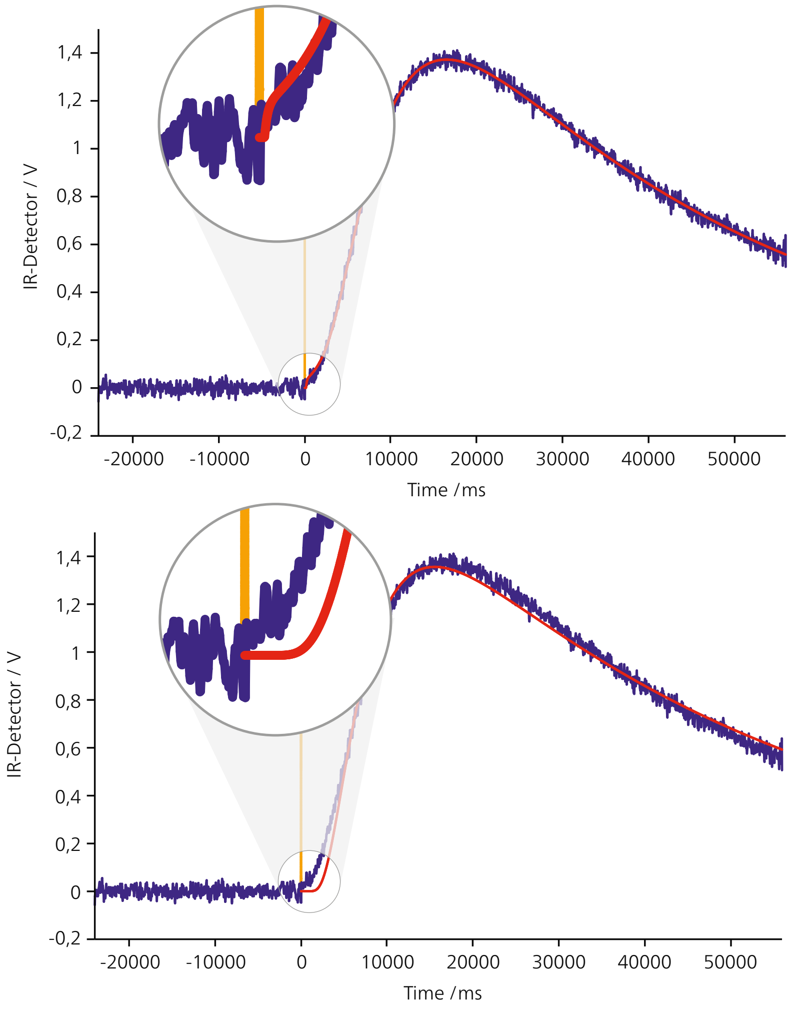
Lactose monohydrate is widely used in various industries, especially in the pharmaceutical industry, as a filler or diluent in tablets and capsules due to its good compressibility, flowability and ease of handling. Two lactose monohydrate powders (one fresh and one expired) were pressed into pellets under identical conditions (20 min at 20 kN).

This example exhibits the thermal diffusivity of both samples. The thermal diffusivity decreases with increasing temperature due to higher phonon-phonon interaction. The fresh powder (orange curve) has a thermal diffusivity up to 16% lower than the expired powder, which is probably due to a higher proportion of amorphous material than the crystallized part.

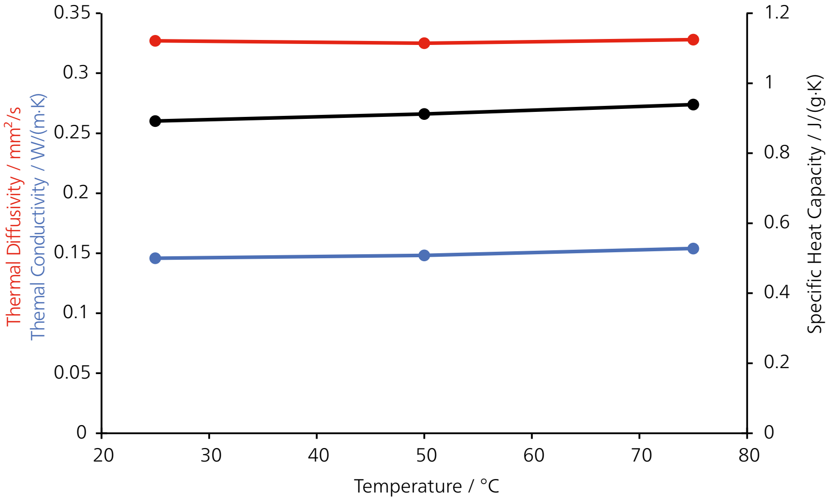
Autoclaved Aerated Concrete

Aerated concrete is commonly used in construction due to its low density and excellent thermal insulation, making it ideal for energy-efficient buildings. In the development of new construction materials, knowledge of thermal conductivity is essential for quality control. The *Proteus*® software's Penetration Model allows thorough investigation of porous materials with rough surfaces. The current sample, with visible pore sizes down to 0.5 mm, describes the thermophysical properties of autoclaved aerated concrete (AAC) between 25°C and 75°C. The thermal diffusivity was evaluated using the Penetration Model, which yields more reliable results than the Standard Model. This can be seen in the better fit of the signal, especially in the beginning; see the first and second image on the right side.

The measurement plot on the right shows the thermophysical properties of aerated concrete. The specific heat capacity was determined by the DSC 204 *Phoenix*®. The thermal conductivity increases with increasing temperature, as expected for porous materials, due to the higher radiative heat transfer at higher temperatures.



Measurement signal of concrete evaluated with different models (Penetration top, Standard bottom)



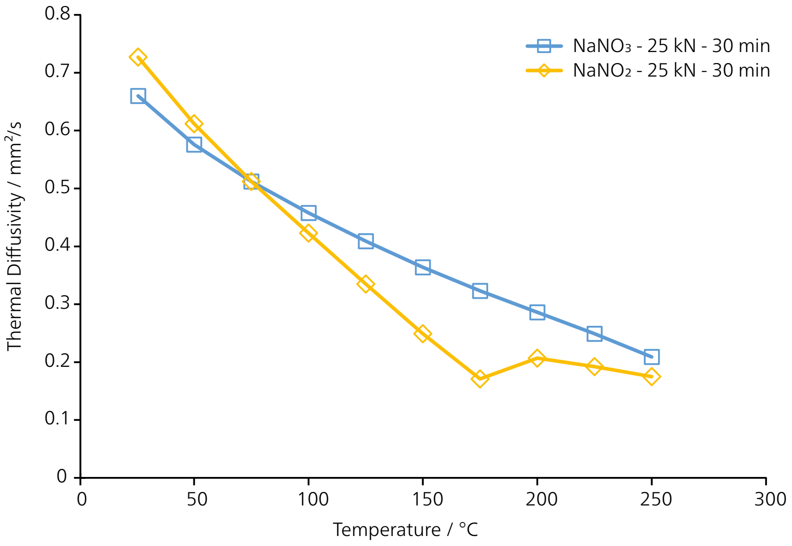
Thermophysical properties of concrete between 25°C and 75°C.

Sample:	Autoclaved aerated concrete (AAC)
Instrument:	LFA 717 *HyperFlash*®
Detector:	InSb
Sample holder:	Ø 12.7 mm/standard
Heating rate:	10 K/min
Temperature range:	25°C to 75°C
Sample dimension:	Ø 12.5 mm, ↕ 4 mm
Model:	Penetration

Salts

In order to design energy storage systems, the molten as well as the solid-state properties of ionic compounds (e.g., salts) are of high interest. Particularly in the molten state, however, the chemical reactivity is highly increased. Therefore, the material compatibility between the salt to be tested and the intended sample holder material must be tested at elevated temperatures.

LFA measurements were performed on two salt powders, $NaNO_3$ and $NaNO_2$*. The powders were pelletized at 25 kN for 30 min. This example shows the thermal diffusivity of both samples as a function of temperature from 25°C to 250°C. The thermal diffusivity decreases with increasing temperature, as expected for most materials, due to higher phonon-phonon interactions (lattice vibrations) at higher temperatures. $NaNO_2$ shows a local minimum at 175°C, corresponding to a solid phase change in the lattice structure.



Thermal diffusivity of $NaNO_3$ and $NaNO_2$ as a function of temperature

Sample:	Molten salts
Instrument:	LFA 717 *HyperFlash*®
Detector:	InSb
Sample holder:	Ø 12.7 mm/standard
Heating rate:	10 K/min
Temperature range:	25°C to 250°C
Sample dimension:	Ø 12.5 mm, ↕ 2 mm
Model:	Standard

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* Standard LFA measurements can be performed on $NaNO_3$ and $NaNO_2$; no special requirements are necessary.

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STANDARDS

Standard	Description
In accordance with	
ASTM E1461	Standard Test Method for Thermal Diffusivity by the Flash Method
ASTM E2585	Standard Practice for Thermal Diffusivity by the Flash Method
DIN EN 821-2	Monolithic ceramics – Thermophysical properties – Part 2: Determination of thermal diffusivity by the laser flash (or heat pulse) method
ISO 22007-4	Plastics – Determination of thermal conductivity and thermal diffusivity – Part 4: Laser flash method
ISO 18755	Fine ceramics (advanced ceramics, advanced technical ceramics): Determination of thermal diffusivity of monolithic ceramics by laser flash method
ISO 13826	Metallic and other inorganic coatings – Determination of thermal diffusivity of thermally sprayed ceramic coatings by laser flash method
JIS R 1611	Measurement methods of thermal diffusivity, specific heat capacity, and thermal conductivity for fine ceramics by flash method
JIS R 1667	Determination of Thermal Diffusivity of Continuous Fiber-Reinforced Ceramic Matrix Composites by the Laser Flash Method
JIS H 7801	Method for measuring thermal diffusivity of metals by the laser flash method
JIS R 1650-3	Method for measurement of fine ceramics, thermoelectric materials, Part 3: Thermal diffusivity, specific heat capacity, and thermal conductivity
JIS H 8453	Measurement method for thermal conductivity of thermal barrier coatings
JIS R 1689	Determination of thermal diffusivity of fine ceramic films by pulsed light heating thermoreflectance method
GB/T 22588	Determination of thermal diffusivity or thermal conductivity by the flash method
GB/T 35807	Rubber, vulcanized – Determination of thermal diffusivity – Flash method
GB/T 42919.4	Plastics – Determination of thermal conductivity and thermal diffusivity, Part 4: Laser flash method
GJB 1201.1	Test method for thermal diffusivity of solid materials at high temperature by a laser pulse method
Based on	
DIN EN 1159-2	Advanced technical ceramics – Ceramic composites; Thermophysical properties – Part 2: Determination of thermal diffusivity; German version EN 1159-2:2003
BS EN 1159-2	Advanced Technical Ceramics. Ceramic Composites. Thermophysical Properties. Determination Of Thermal Diffusivity (British Standard)
ASTM C714	Standard Guide For Thermal Diffusivity Of Carbon And Graphite By Thermal Pulse Method

Technical Specifications

	LFA 717 *HyperFlash*®	**LFA 717 *HyperFlash*® *HT***
Temperature range	-100°C to 500°C (RT version available)	RT to 1250°C
Heating rate (max.)	50 K/min	50 K/min
Cooling device	External chiller (RT to 500°C), optional: ▪ Liquid nitrogen cooling (-100°C to 500°C) ▪ Pressurized air (0°C … 500°C)	External chiller (RT to 1250°C)
Thermal diffusivity	0.01 mm^2/s ... 2000 mm^2/s	0.01 mm^2/s ... 2000 mm^2/s
Thermal conductivity	0.1 W/(m·K) ... 3000 W/(m·K)	0.1 W/(m·K) ... 3000 W/(m·K)
Accuracy	▪ Thermal diffusivity[1]: ± 3% ▪ Specific heat capacity[2]: ± 5%	▪ Thermal diffusivity[1]: ± 3% ▪ Specific heat capacity[2]: ± 5%
Repeatability	▪ Thermal diffusivity[1]: ± 2% ▪ Specific heat capacity[2]: ± 3%	▪ Thermal diffusivity[1]: ± 2% ▪ Specific heat capacity[2]: ± 3%
Xenon flash lamp	▪ Pulse energy: up to 10 Joules/pulse (variable), software-controlled ▪ Pulse width: 10 ... 1500 µs	▪ Pulse energy: up to 10 Joules/pulse (variable), software-controlled ▪ Pulse width: 10 ... 1500 µs
ZoomOptics	Patented; optimized field of view (optional, requires no mask)	Patented; optimized field of view (optional, requires no mask)
Pulse mapping	For finite pulse correction and improved c_p determination	For finite pulse correction and improved c_p determination
IR detectors	▪ InSb: RT ... 500°C ▪ MCT: -100°C ... 500°C ▪ Detector refill (option)	▪ InSb: RT ... 1250°C ▪ Detector refill (option)
Atmosphere	Inert, oxidizing, static and dynamic	Inert, oxidizing, static and dynamic
Vacuum	< 150 mbar	10^{-4} mbar (with turbo pump)
Data acquisition	2 MHz ▪ Min. measurement time (10 half times) down to 1 ms → for highly conducting and/or thin samples (e.g., Al, Cu plates, thin films, etc.) ▪ Max. measurement time up to 120 s → for low-conducting and/or thick samples (e.g., polymers, refractories, etc.)	2 MHz ▪ Min. measurement time (10 half times) down to 1 ms → for highly conducting and/or thin samples (e.g., Al, Cu plates, thin films, etc.) ▪ Max. measurement time up to 120 s → for low-conducting and/or thick samples (e.g., polymers, refractories, etc.)
Gas control	Frits or optional MFC; measurements under reduced pressure possible	MFC + internal pump
Sample holders	▪ Round and square samples ▪ Liquids, pastes, resins, powders, fibers, laminates, anisotropic samples ▪ Tests under mechanical pressure	▪ Round and square samples ▪ Liquids, pastes, resins, powders, lamellar samples ▪ Tests under mechanical pressure
Integrated automatic sample changer	4 insets for up to 4 samples each: ▪ Ø 6 mm, 8 mm, 10 mm, 12.7 mm ▪ 4x Ø$_{max.}$ 25.4 mm ▪ 16x up to Ø$_{max.}$ 12.7 mm ▪ 16x up to □$_{max.}$ 10 mm	4 insets for 1 sample each: ▪ Ø 10 mm, 12.7 mm ▪ Ø 6 mm and 8 mm on request ▪ □ 10 mm

1 Accuracy of thermal diffusivity amounts to ±1.5% and repeatability to ±1%, based on 900 tests on Cu (high diffusivity) and Pyrex (low diffusivity) specimens (Ø 12.7mm, thickness 2.0 mm) with at least 3 different devices at room temperature.

2 Accuracy of the specific heat capacity amounts to ±4% and repeatability to ±2% when using 4 different reference materials, 550 shots, averaging for 5 shots, RT, recommended dimension, recommended shot parameters.

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