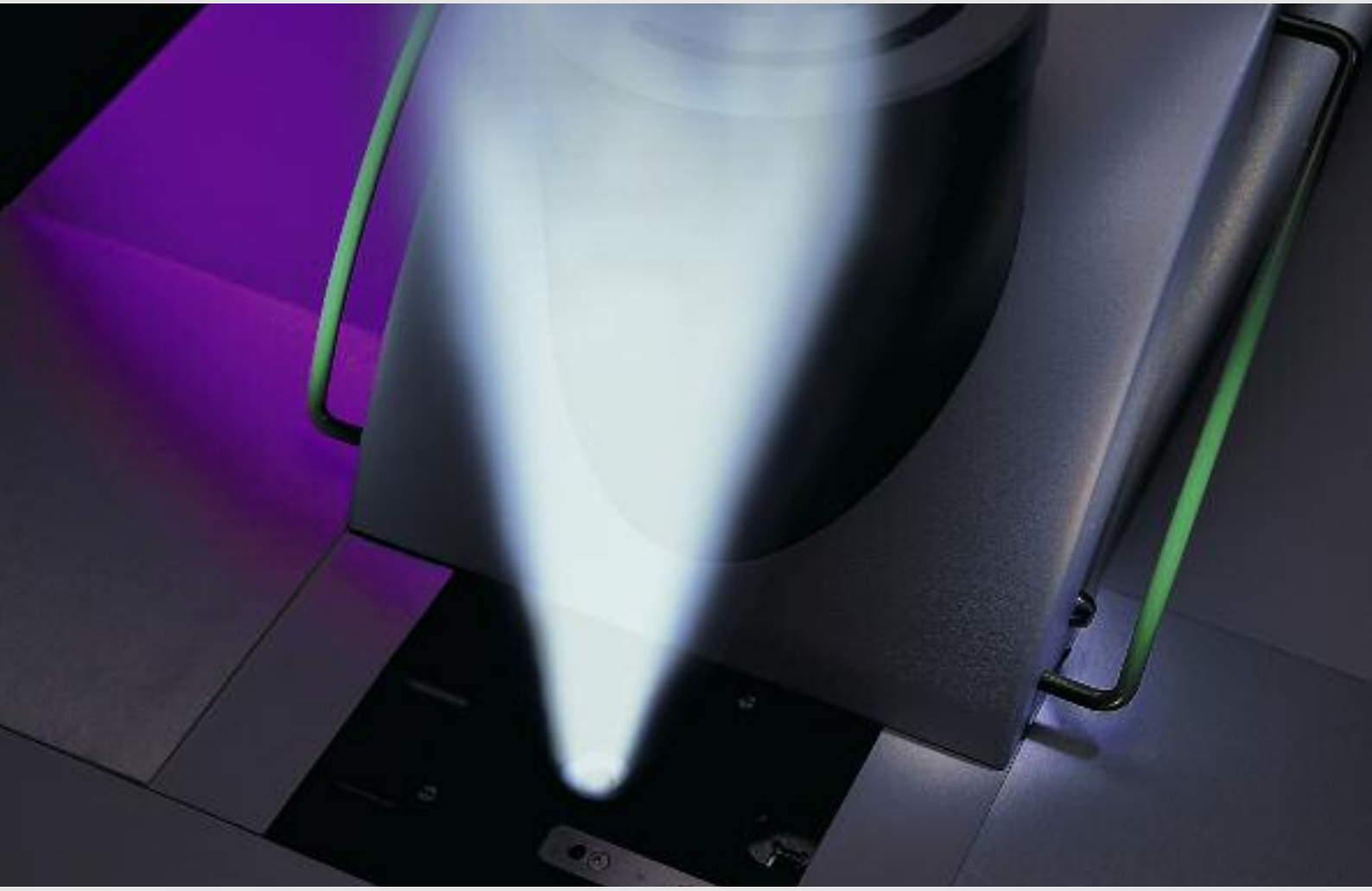
NETZSCH

Thermal Diffusivity - Thermal Conductivity



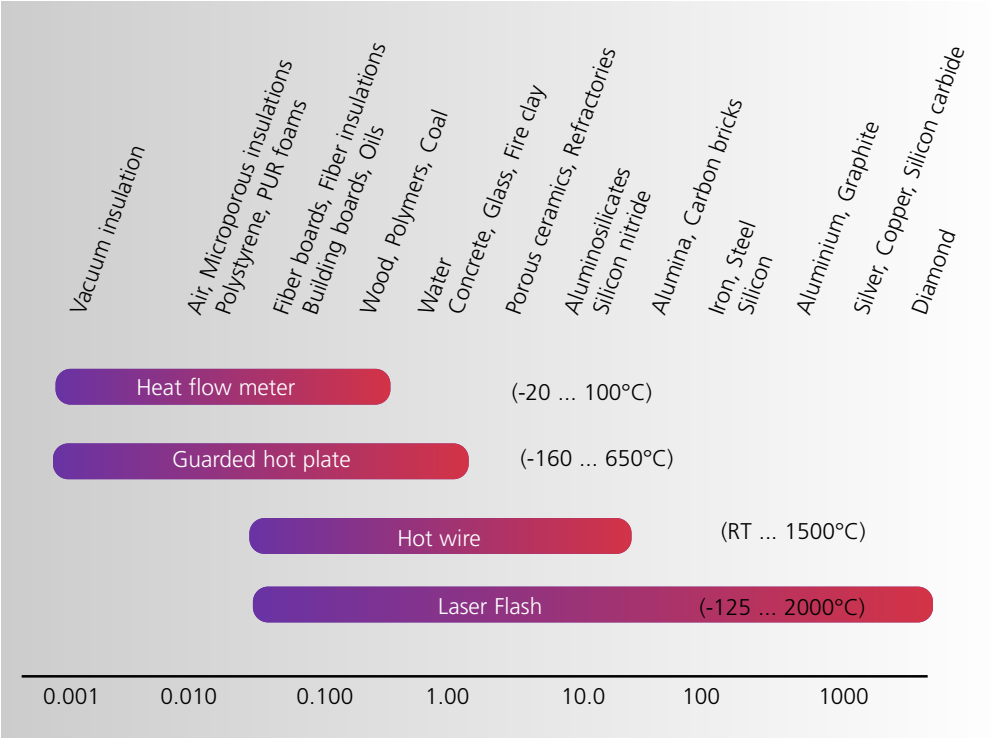
Leading Thermal Analysis.

LFA 447

Nano Flash®

LFA 447 *NanoFlash*®

What is the heating/cooling load of a building as a function of the weather conditions and how can I improve it? How can I improve the heat transfer out of an electronic component? What are the optimum materials and how do I design a heat exchanger system to achieve a required efficiency? In order to answer questions like these, material properties such as thermal diffusivity and thermal conductivity must be known. Engineers must select from a variety of test methods to characterize the diverse array of materials and configurations they employ in their designs. For ceramics, metals, composites, and multi-layer systems, the flash technique is an ideal choice. Easy sample preparation, fast testing times, and high accuracy are only some advantages of this non-contact test method. NETZSCH offers a variety of flash systems to cover a broad range of applications and temperatures from -125 °C up to 2000 °C. The NETZSCH *NanoFlash*® system is designed as a cost-effective, easy-to-operate, highly accurate instrument for testing between room temperature and 300 °C.



Thermal Conductivity at RT in W/(m·K)

For the measurement of low conductivity materials such as insulations, NETZSCH offers a broad selection of Heat Flow Meters and Guarded Hot Plate Instruments. For the analysis of refractory materials, a hot wire system (TCT 426) is available. Differential scanning calorimeters (DSC 404 *Pegasus*®) for the measurement of specific heat, and dilatometers (DIL 402 C series) for the analysis of density and length changes up to high temperatures, are also available.

Flash Apparatus LFA 447 *NanoFlash*®

The NETZSCH LFA 447 *NanoFlash*® is based on the well-known flash method. In this method, the front side of a plane-parallel sample is heated by a short light pulse. The resulting temperature rise on the rear surface is measured using an infrared detector. By analysis of the resulting temperature-versus-time curve, the thermal diffusivity can be determined.

The LFA 447 *NanoFlash*® is a powerful research tool for making accurate, rapid thermal diffusivity tests on small specimens. It can complete tests on dozens of samples at room temperature in a single morning or, with the optional furnace, make measurements at temperatures up to 300 °C automatically.

Fast test times

The speed and repeatability of thermal diffusivity measurements have made this technique the method of choice among researchers worldwide, replacing traditional steady-state methods that are difficult, costly, and much slower. By measuring thermal diffusivity (a) of a material, its thermal conductivity (λ) can be determined if specific heat (c_p) and density (ρ) are known.

Advanced data analysis

The evaluation of the measured data can be done using the well known half-time method:

$$a=0.1388 \cdot \frac{d^2}{t_{1/2}}.$$

The *NanoFlash*® additionally allows the consideration of radial and facial heat losses and finite pulse effects using advanced mathematical regression routines.

Using the multiproperty measurement capabilities of the *NanoFlash*®, both thermal diffusivity and specific heat can be determined simultaneously – on the same specimen – thus yielding thermal conductivity if the density is known:

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

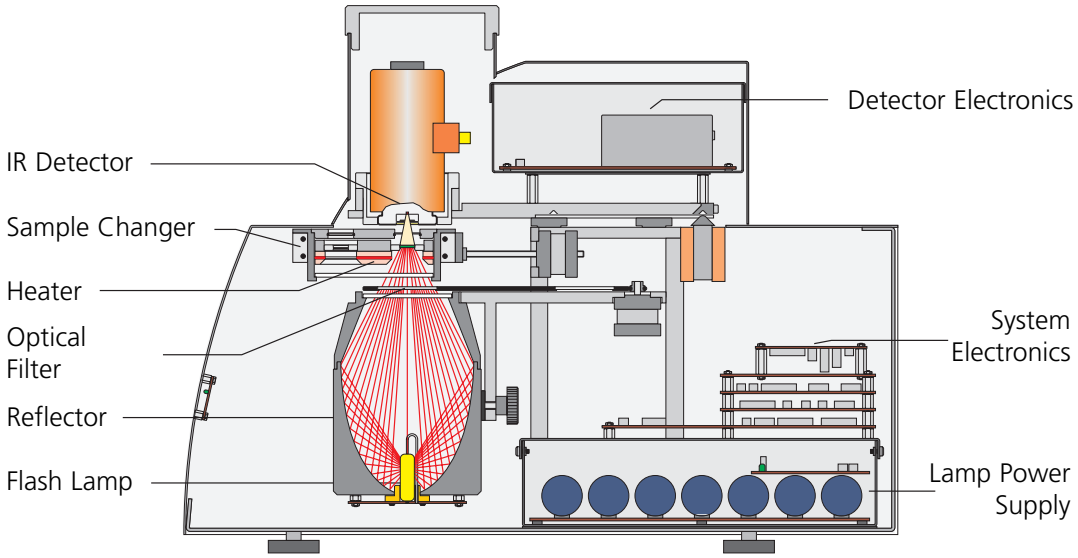
Standardized test method

The *NanoFlash*® works according to national and international standards such as ASTM E-1461 or DIN EN 821.

MTX-version

A special version (LFA 447/2-4/MTX) allows scanning of surfaces (50 mm x 50 mm) for analysis of the thermal diffusivity over the area. This enables the detection of structural inhomogeneities or defects under the surface.

LFA 447 *NanoFlash*® – Setup System



In the LFA *NanoFlash*®, a state-of-the-art technology is integrated in a compact measuring system. The flash lamps, sample, and detector are vertically arranged. Therefore the use of mirrors is not necessary. Short signal pathways and a good signal-to-noise ratio are thereby warranted.

The Flash Lamp:

A high-performance Xenon flash lamp is applied to produce the heat pulse on the front of the sample. The lamp is placed in a parabolic mirror, whereby a large part of the radiation given off is focused on the sample. The assembly of the mirror and the position of the lamp are conceived such that a homogenous illumination of the entire sample surface is warranted. The energy released from the flash lamp can be adjusted using the software (voltage and pulse length). The length of the heat pulse can be varied in three stages from 0.1 ms through 0.5 ms by the software.

Sample Placement:

The samples are placed in an automatic sample changer which can test up to four samples in one test. The samples are thereby brought into a special sample carrier which can be adjusted according to the user's wishes. There are standard carriers for testing of round samples with 10 mm, 12.7 mm or 25.4 mm diameter. Sample receptacles for the testing of square samples (8 mm x 8 mm and 12.7 mm x 12.7 mm) also exist. The measurement of the sample temperature is done with a temperature sensor which is integrated into the system's sample holder plate. Special sample holders are available for the measurement of liquids and pastes with unmatched accuracy and test speed.

The Furnace:

The system can optionally be equipped with a furnace for temperature-dependent measurements up to 300 °C. The furnace is directly integrated into the sample changer of the system, whereby a small thermal mass and thereby fast heating and cooling times are secured.

The Detector:

The measurement of the temperature increase on the rear of the sample is carried out with a liquid-nitrogen-cooled InSb (Indium-Antimonide) infrared detector. The non-contact measurement of the temperature increase guarantees an easy sample change and a short response time for the signal acquisition system. Both the detector and amplifier components are designed for measurements with data acquisition rates of up to 500 kHz.

LFA 447 *NanoFlash*® – Software

The LFA 447 *NanoFlash*® comes with a 32 bit Windows® software package, especially tailored to the needs of our users. It combines easy handling and complex evaluation routines, thus offering a solution to almost every problem the user might face.

More than 15 different evaluation models are available for the user. These have been developed with leading experts from science and industry and correspond to current requirements and state-of-the-art technology.

Software Features

- 32 bit Windows®-software: fully compatible with other Windows® programs
- multitasking: simultaneous measurement and evaluation
- full network compatibility
- easy printout and export of measuring curves and data (ASCII)
- selectable screen design by means of docking windows
- multi-moduling: operation of several different instruments with one computer
- integrated data base

Measuring Task

- Full control of the sample changer
- easy and user-friendly input of test parameters
- free selection of temperature programs
- optimization of the system parameters (measuring time, amplification, etc.)
- automatic evaluation of the measurement after each shot with one or several evaluation models

Evaluation Task

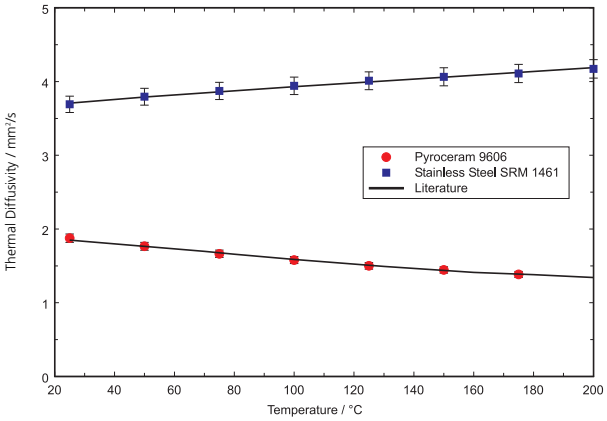
- presentation of an individual response curve, the entire result as well as test parameters and measured values in one presentation
- free input or import of density and specific heat values for determination of thermal conductivity
- simultaneous presentation of thermal diffusivity and conductivity data in one plot
- storage and restoration at any point of the analysis
- presentation and new evaluation of data from previous measurements

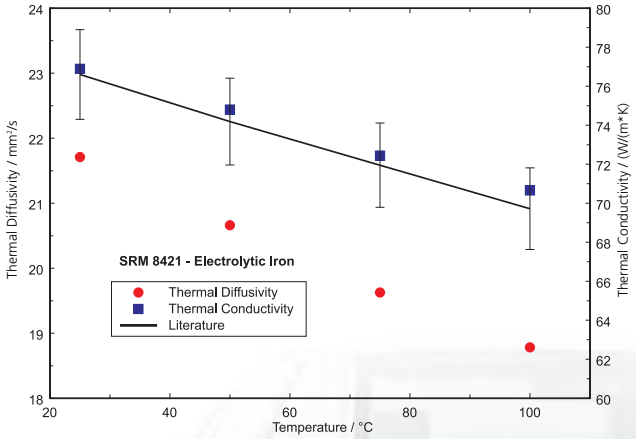
Evaluation Models

- accurate finite pulse correction
- standard heat-loss corrections: correction models according to Cowan and Clark and Taylor, known from literature are integrated
- Cowan-Fit: non-linear regression based on the original publication by Cowan (optionally with or without finite pulse correction)
- Cape-Lehmann-model is improved. Non-linear regression with consideration of radial and facial heat losses (optionally with or without finite pulse correction)
- correction of radiation effects: a new model that considers radiation effects is integrated for accurate analysis of tests on oxide ceramics or glasses (simultaneously with heat-loss and finite pulse corrections)
- 2- or 3-layer systems: analysis of multi-layer systems with consideration of the heat loss based on non-linear regression (optionally with or without finite pulse corrections)
- contact resistance: determination of the contact resistance in a layer system
- model wizard: simultaneous evaluation of a response curve with several models; determination of the optimum model using statistic criteria
- determination of specific heat by means of a comparative method

LFA 447 *NanoFlash*® – Performance

Performance – Stainless Steel and Pyroceram 9606
The thermal diffusivities of two well-known standard materials (NIST SRM 1461 Stainless Steel and Pyroceram 9606) were measured versus temperature with the LFA 447 *NanoFlash*®: The figure shows the measurement results as compared to literature values (Touloukian et al., 1970, Henderson et al., 1998) up to 200 °C. It can clearly be seen that the deviations between the literature values and the measurement results are less than 3% (error bars). This demonstrates the high accuracy of this flash unit in the field of metals and ceramics.

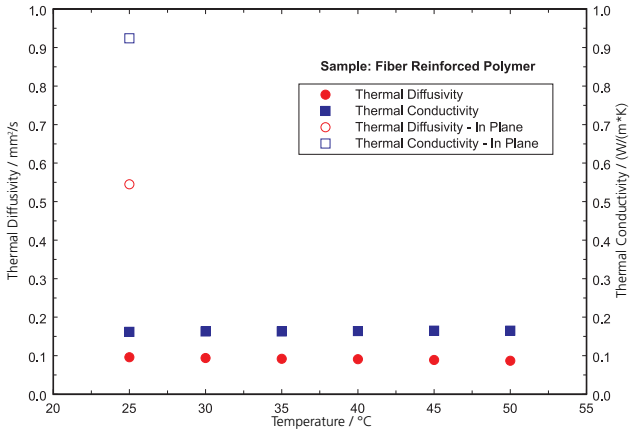


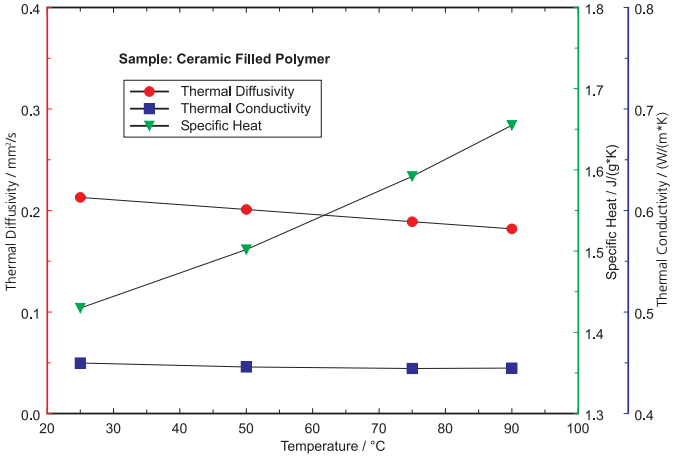


Accuracy - NIST SRM 8421 Electrolytic Iron
A certified NIST thermal conductivity reference material (SRM 8421) was measured between room temperature and 100 °C. Additionally shown are the NIST values for the thermal conductivity for this material together with the stated accuracy (3%). As expected, both the thermal diffusivity and thermal conductivity decrease with temperature. It can be seen that the determined thermal conductivity values are close to the NIST values. The measured deviations are within the stated uncertainty range for this certified standard reference material.

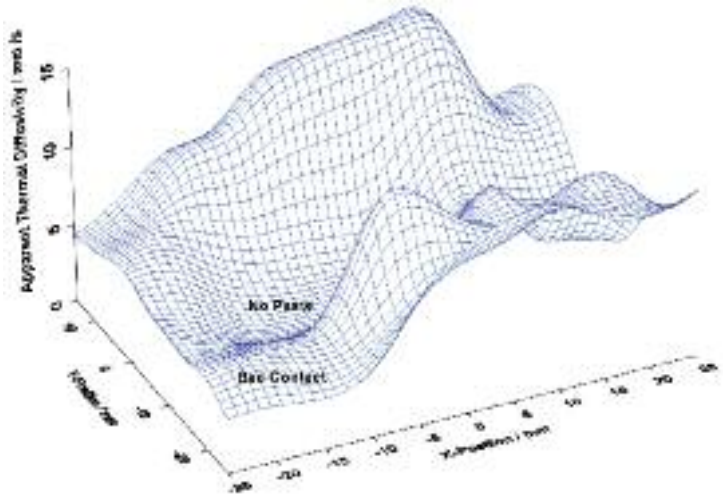
LFA 447 *NanoFlash*® – Applications

In-Plane Tests – Fiber-Reinforced Epoxy
More and more polymers, metals or ceramics are being reinforced with fibers to improve their bending strength and to adjust them to special applications. In many cases, the fiber reinforcement results in a high degree of anisotropy to the mechanical and thermal transport properties. By employing special sample holders, the flash technique allows analysis of this anisotropy in the thermal diffusivity and thermal conductivity. The measurement example clearly demonstrates that the values for both the thermal diffusivity and thermal conductivity, perpendicular to the fiber direction are significantly lower than the results of the in-plane test (in the fiber direction).





Thermal Conductivity Determination – Polymer Tape
The LFA 447 *NanoFlash*® allows easy and fast temperature-dependent measurement of the thermal diffusivity. Additionally, the specific heat can be determined by employing a comparative method. A direct determination of the thermal conductivity is possible, if the bulk density of the material is known. This method was used for the thermophysical properties charaterization of a polymer tape between room temperature and 90 °C. The calibration standard for the specific heat determination was Pyroceram 9606. It can clearly be seen that both the thermal diffusivity and specific heat changed significantly versus temperature. The resulting thermal conductivity depicts nearly no temperature dependence.



MTX-Results
The result shows the influence of a thermal conductivity paste between two aluminum plates. In the areas of poor contact or missing paste, values were obtained in the apparent thermal diffusivity, which were very low. The areas of good contact appear as high values in the apparent thermal diffusivity. Such an analysis can be carried out without disassembling of the composite system.

Technical Specifications

Standard Sample Size	up to 25.4 mm (1“) diameter, or 8 mm / 10 mm / 12.7 mm square, up to 3 mm (0.12“) thick
MTX Version	Scanning range: 50 mm x 50 mm, resolution: down to 0.1 mm
Temperature Range	
LFA 447/0 *NanoFlash*® RT	Ambient, or as controlled by external fluid source
LFA 447/1 *NanoFlash*® 300	Ambient to 300 °C
MTX Version	Test temperature: ambient (up to 300 °C with standard sample carrier)
Thermal Diffusivity Range	0.01 mm²/s to 1000 mm²/s
Thermal Coinductivity	0.1 W/(m·K) to 2000 W/(m·K)
Repeatability *)	Thermal Diffusivity: +/-2 %, Specific Heat: +/-3 %
Accuracy	Thermal Diffusivity: +/-3 %, Specific Heat: +/-5 %
Flash Source	Xenon Flash Lamp, wavelength: 150 nm to 2000 nm Pulse Energy: up to ≈10 Joules (selectable)
Sensor Type	InSb IR Detector with integral dewar
Utilities	230 V - 50/60 Hz, 15 A - Controller Distilled Water (approx. 1L / week) Liquid Nitrogen (approx. 1L / 8 hrs.)
Instrument Dimensions (LxWxH)	61 cm x 56 cm x 43 cm

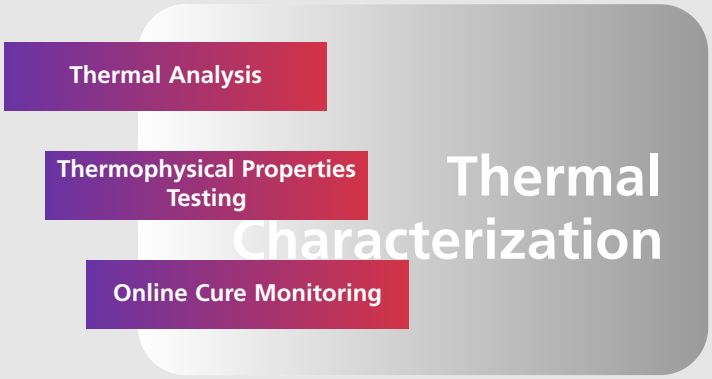
***)** based on tests on standard materials

Testing Services

Are you interested in the thermal characterization of your material but don't want to invest in an instrument? NETZSCH has the solution. NETZSCH contract testing services offers an unmatched range of instruments and methods for the analysis of your materials. We offer a wide range of thermal characterization services conducted by our experienced staff of scientists and engineers. You receive sound advice, accurate data, and real solutions for your thermal design problems from an unbiased, independent source. Contact us for further details.

State-of-the-Art Thermal Characterization with NETZSCH

Knowledge of the thermal characteristics of materials is critical to material development and design in every modern industry. Researchers who need reliable thermal analysis, thermophysical property data or cure monitoring turn to the state-of-the-art instruments and services offered by NETZSCH. Our DSC, TG, STA, DIL, DMA, DEA and TMA instruments form the core of the NETZSCH Thermal Analysis instruments, allowing measurement of dielectric properties, dimension or mass changes and transformation energetics between -260 °C and 2800 °C.
The DSC 404 *Pegasus*®, DIL 402 C and the different LFA models, as well as the thermal conductivity instrument family (TCT, HFM, and GHP) are well established components of the NETZSCH thermophysical properties world.



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