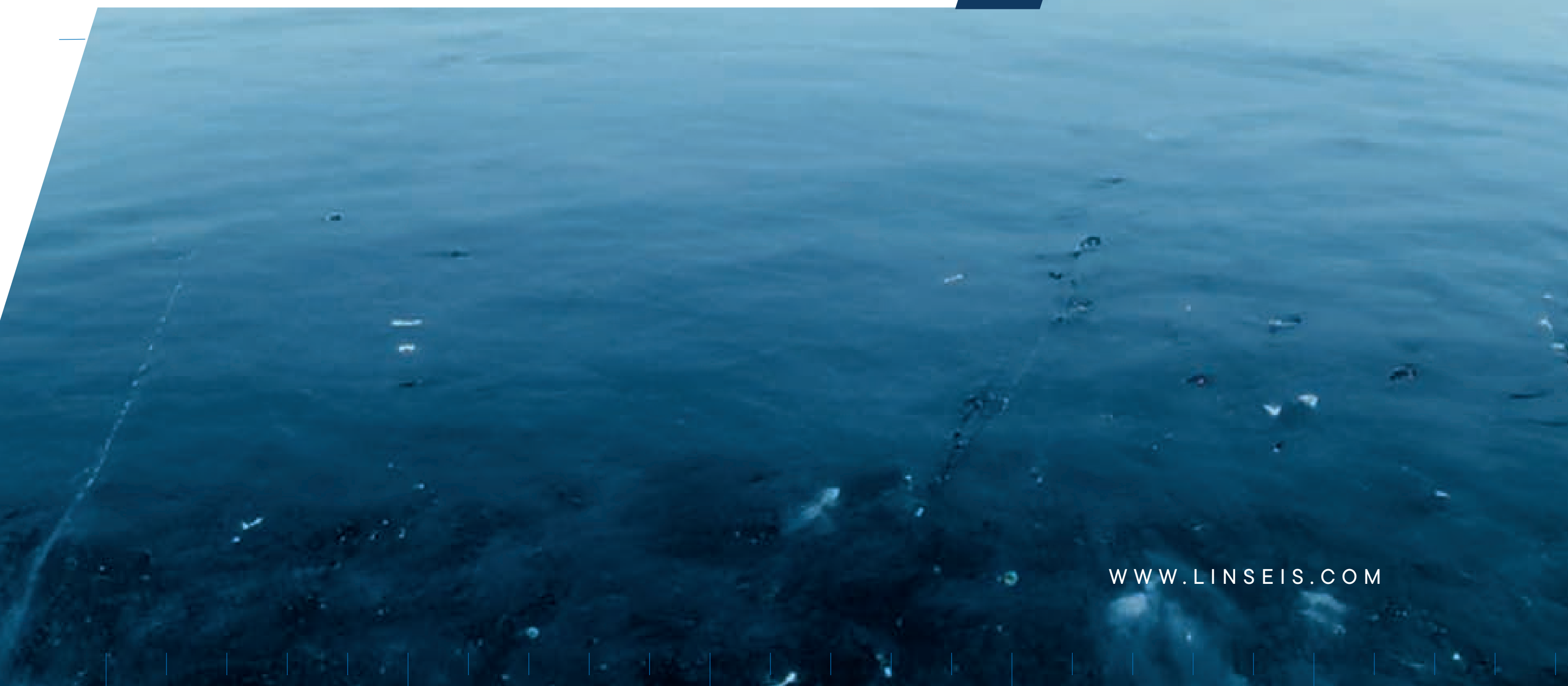
LINSEIS

pushing boundaries

LFA L51/L52
PLH L53
TFA L59
THB L56
HFM L57
TF-LFA L54
TIM-TESTER L58

Thermal **Conductivity**



Since 1957 LINSEIS Corporation has been delivering outstanding service, know-how and leading innovative products in the field of thermal analysis and thermo-physical properties.

Customer satisfaction, innovation, flexibility, and high quality are what LINSEIS represents. Thanks to these fundamentals, our company enjoys an exceptional reputation among the leading scientific and industrial organizations. LINSEIS has been offering highly innovative benchmark products for many years.

The LINSEIS business unit of thermal analysis is involved in the complete range of thermoanalytical equipment for R&D as well as quality control. We support applications in sectors such as polymers, chemical industry, inorganic building materials, and environmental analytics. In addition, thermophysical properties of solids, liquids, and melts can be analyzed.

Rooted in a strong family tradition, LINSEIS is proudly steered into its third generation, maintaining its core values and commitment to excellence, which have been passed down through the family leadership. This generational continuity strengthens our dedication to innovation and quality, embodying the essence of a true family-run business.

LINSEIS provides technological leadership. We develop and manufacture thermoanalytic and thermophysical testing equipment to the highest standards and precision. Due to our innovative drive and precision, we are a leading manufacturer of thermal analysis equipment.

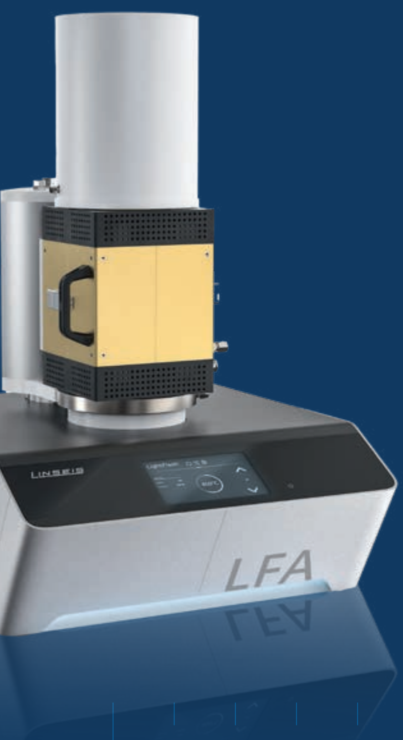
The development of thermoanalytical testing machines requires significant research and a high degree of precision. LINSEIS Corp. invests in this research to the benefit of our customers.

CLAUS LINSEIS

CEO DIPL. PHYS.

To strive for the best due diligence and accountability is part of our DNA. Our history is affected by German engineering and strict quality control.

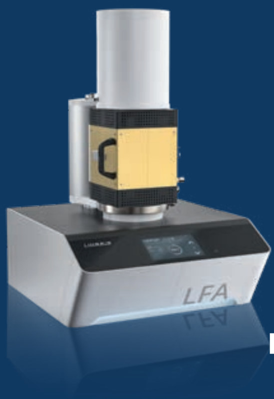
We want to deliver the latest and best technology for our customers. LINSEIS continues to innovate and enhance our existing thermal analyzers. Our goal is to constantly develop new technologies to enable continued discovery in Science.



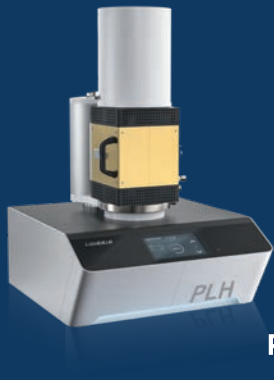
Engineering
& Innovation

Thermal **Conductivity**

Laser-Flash Analyzer, Thermal Interface Materials Tester, Transient Hot Bridge, Heat Flow Meter, Thin Film Laser Flash and Thin Film Analyser



LFA

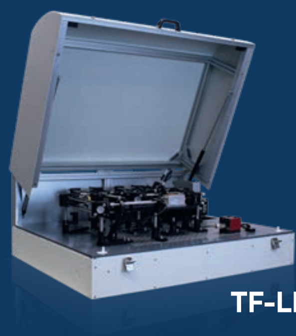


PLH

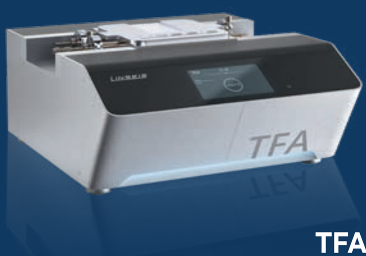
TIM-Tester

THB

HFM



TF-LFA



TFA

Measurments devices: an overview

The following table shall give an orientation concerning measurement devices and their capabilities. For more detailed information please contact our product and application specialists.

Devices	LFA L51/L52	TIM-Tester L58	THB L56	HFM L57	TFA L59	TF-LFA L54
Info	Most universal tool	For thermal interface materials	For fast and easy measurement	For insulating materials	Thin films on LINSEIS chip	For nm to µm films
Measurement						
Thermal Conductivity	probably possible	possible	possible	possible	possible	probably possible
Thermal Diffusivity	possible	not possible	probably possible	not possible	probably possible	possible
Specific Heat Capacity	probably possible	not possible	probably possible	not possible	possible	not possible
Thermal Resistivity	probably possible	possible	not possible	possible	not possible	not possible
Defined Pressure on Sample	probably possible	possible	possible	possible	not possible	not possible
Atmosphere	possible	not possible	possible	not possible	possible	possible
Themperature range	-125°C to 2800°C	-20°C to +300°C	-150°C to +700°C	-40°C to +90°C	-170°C to +300°C	-100°C to +500°C
Price	$$ -$$$	$$	$	$$	$$$	$$$
Sample Type						
Solid	possible	possible	possible	possible	not possible	probably possible
Liquid	possible	probably possible	possible	not possible	not possible	not possible
Powder	probably possible	probably possible	possible	probably possible	not possible	not possible
Paste	probably possible	possible	possible	not possible	not possible	not possible
Pad	probably possible	possible	probably possible	not possible	not possible	not possible
Thinfilm	probably possible	probably possible	not possible	not possible	possible	possible

Measurement is possible

Measurement is probably possible

Measurement is not possible

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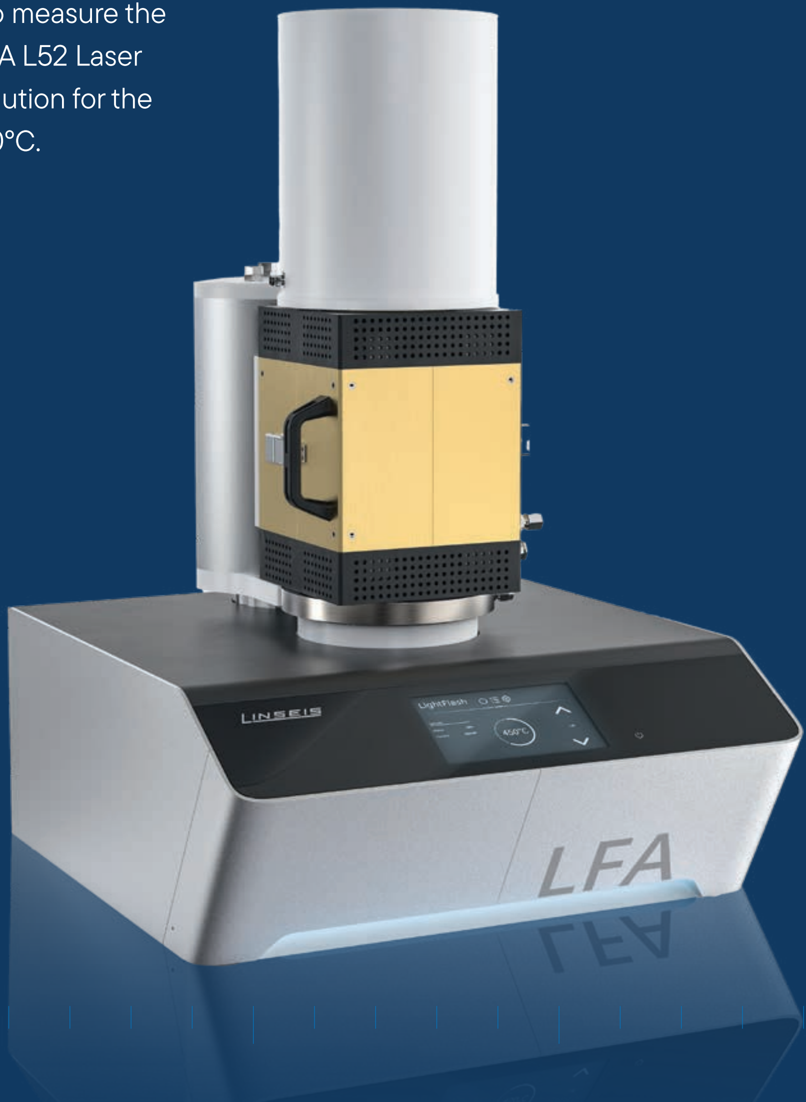
Laser Flash **Analysis**

Bulk

Thin Film

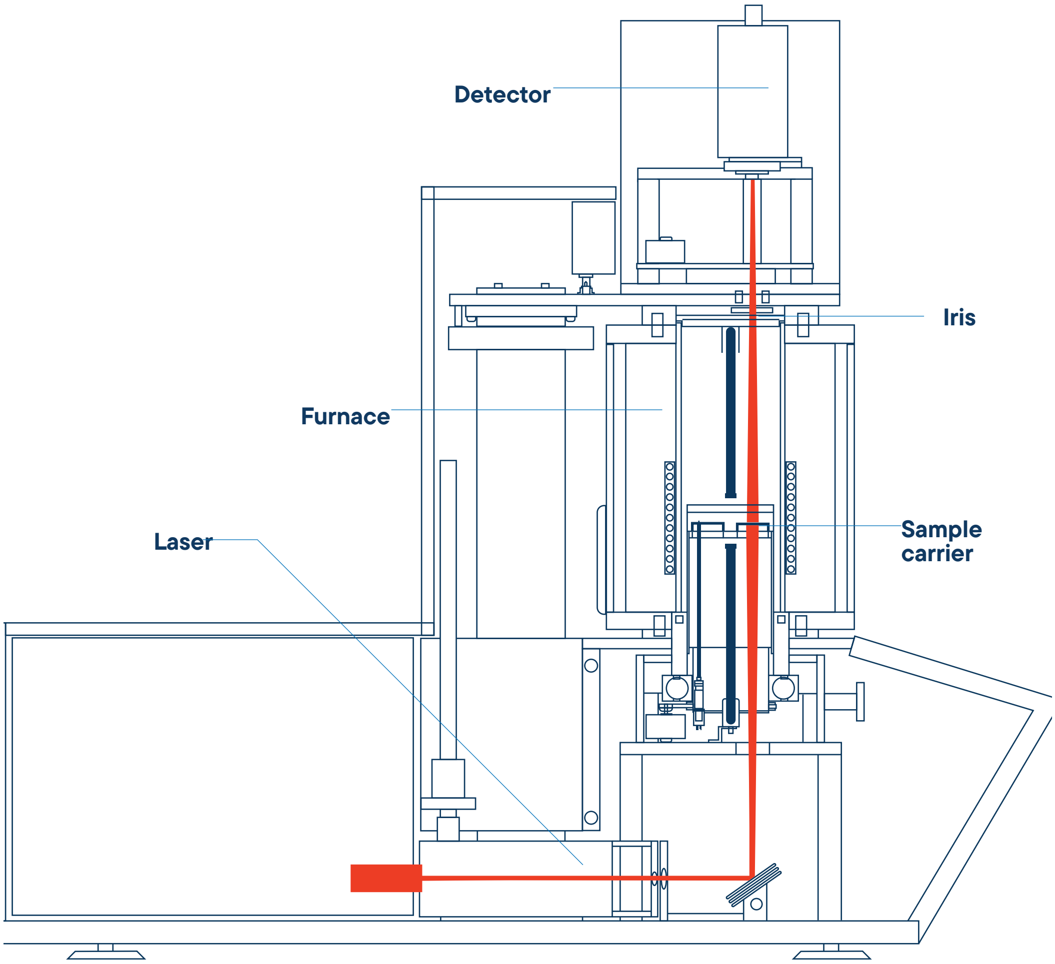
Information about the thermophysical properties of materials and heat transfer optimization of final products is becoming more and more vital for industrial applications. Over the past few decades, the flash method has developed into a commonly used technique for the measurement of the thermal diffusivity and thermal conductivity of various kinds of solids, powders, pastes and liquids. Application areas are electronic packaging, heat sinks, brackets, reactor cooling, heat exchangers, thermal insulators and many others. Trouble-free sample preparation, small required sample dimensions, fast measurement times and high accuracy are only a few of the advantages of this non-contact and non-destructive measurement technique.

LINSEIS offers a variety of instruments to measure the Thermal Diffusivity/Conductivity. The LFA L52 Laser Flash series provides a cost effective solution for the temperature range from -125 up to 2800°C.



System Design

The vertical arrangement with sensor on top, sample in the middle and heat pulse source (Laser/Xenon Lamp) on the bottom, ensures easy handling and best possible measurement results. The pulse energy and duration are adjuDetector stable in the range of 0.05 to 25 Joule/pulse and 0.05 to 5 ms. Due to this flexibility all kinds of demanding samples (even thin film or ultra-low thermal conducting samples) can be analyzed.



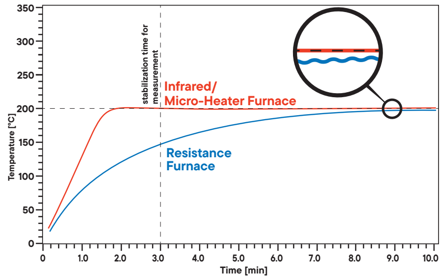
Absolute Method

The used method is an absolute measurement technique (for thermal diffusivity), hence there is no need to calibrate the system. The LINSEIS Flash Analyzers operate in agreement with national and international standards, such as ASTM E-1461, DIN 30905 and DIN EN 821.

High speed furnace

The LFA unit is either equipped with a high speed infrared furnace (LFA L51 500/1000) or with an advanced microheater (LFA L51 500/1250). This technology enables unmachted heating and cooling speed, unmatched temperature control, homogenity and precision.

Because time matters

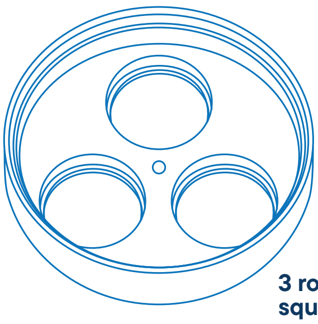


Comparison: time to reach the temperature stability. A high speed IR-micro-heater furnace reaches the set temperature much faster and delivers a superior isothermal temperature stability

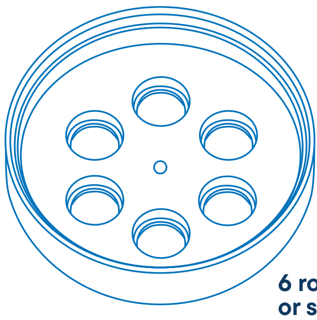
High speed furnace

The system can be either equipped with an InSb or with a MCT detector, covering the complete temperature range from sub-ambient temperature up to 2800°C. Both are easily user exchangeable. An available automatic LN_2 refilling accessory with Dewar flask allows prolonged measurement cycles.

Sample carriers



3 round (25.4 mm) or square (20 mm x 20 mm) samples

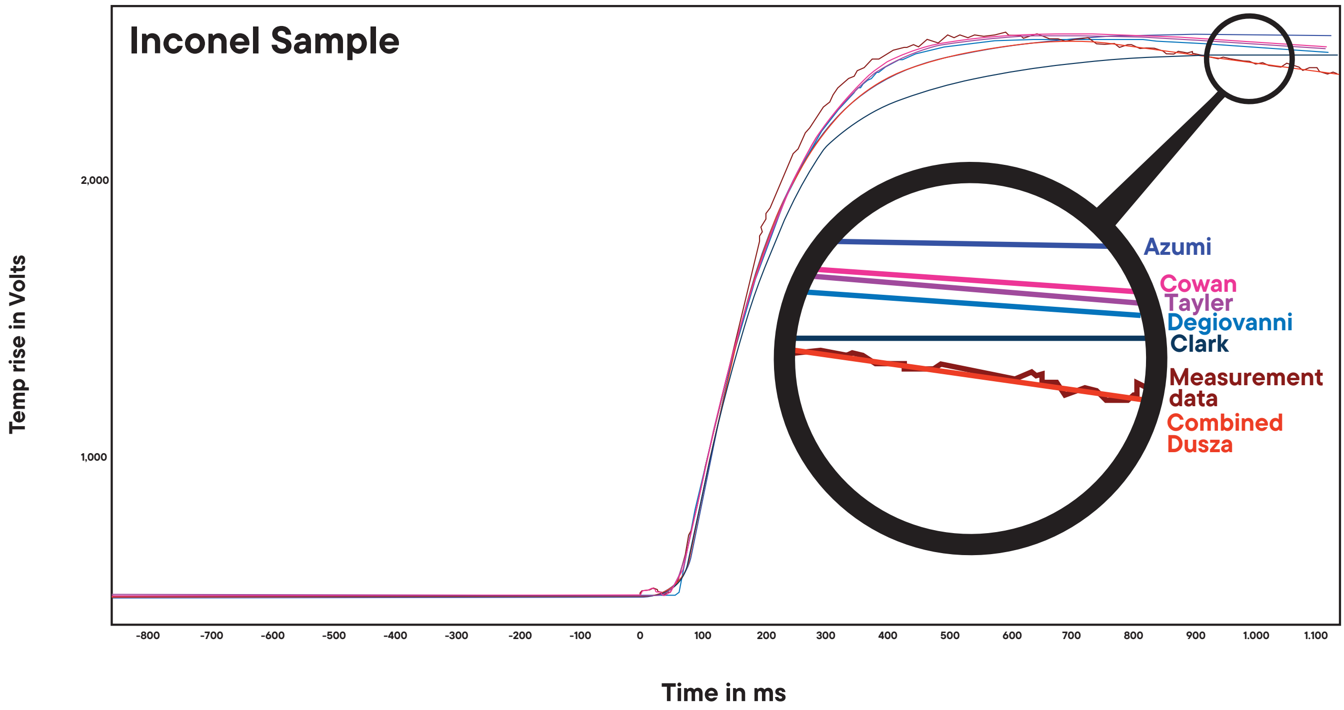


6 round (3, 5, 6, 8, 10, 12.7 mm) or square (3, 5, 5, 10 mm) samples

Software: Combined Model according to DUSZA

Combining simultaneous heat loss and finite pulse-time corrections in a single evaluation model provides highest measurement accuracy.

One fits all **Easy controlling** **No uncertainty**



The plot illustrates a measurement on an Inconel sample. The raw data was evaluated using different common models. It can clearly be observed, that the combined model provides the best f it, resulting in the most accurate measurement result.

The combined model with non-linear parameter estimation has been proven for hundreds of samples. In all cases it worked reliably and its results gave the correct adiabatic, finite pulsetime and heat loss corrected values. The two main advantages of the method are that no operator choice between the different models and corrections is necessary, and that it can be applied to any type of sample. The quality of the f it can be checked by plotting the model curve and also as a numeric value.

Technical Specifications

	LFA L51	LFA L52
Temperature range	–100°C up to 500°C RT up to 500 / 1000 / 1250°C (Boost function: 1450°C)	–125/–100°C up to 500°C RT up to 1250 / 1600 / 2000 / 2400 / 2800°C
Heating rate	0.01 up to 300 K/min (depending on model)	0.01 up to 50 K/min
Thermal Diffusivity	0.01 up to 1000 mm^2/s	0.01 up to 1000 mm^2/s
Thermal Conductivity	0.1 up to 2000 W/(m•K)	0.1 up to 2000 W/(m•K)
Accuracy	Thermal diffusivity ± 2.4% Specific Heat ± 5%	Thermal diffusivity ± 2.4% Specific Heat ± 5%
Repeatability	Thermal diffusivity ± 1.9% Specific Heat ± 3%	Thermal diffusivity ± 1.9% Specific Heat ± 3%
Flash source	Light flash: up to 15 J/pulse variable (software controlled)	Laser Nd:YAG 28 J/pulse variable (software controlled)
Pulse width	0.05 up to 2 ms	0.05 up to 5 ms
IR-detector	InSb: RT up to 1450°C MCT: –100°C up to 500°C	InSb: RT up to 2800°C MCT: –125°C up to 500°C
Atmosphere	inert, oxidizing, reducing, vacuum	inert, oxidizing, reducing, vacuum
Vacuum	up to 10^{-5}mbar	up to 10^{-5}mbar
Data aquisition	10 MHz	10 MHz
Sample holders	round or square - solid samples, powders, pastes, liquids, laminates - special holder for measurement under mechanical pressure	round or square - solid samples, powders, pastes, liquids, laminates - special holder for measurement under mechanical pressure
Sample numbers	sample robot up to 3, 6 or 18 samples (depends on model)	up to 3, 6 or 18 samples

Periodic
Laser Heating

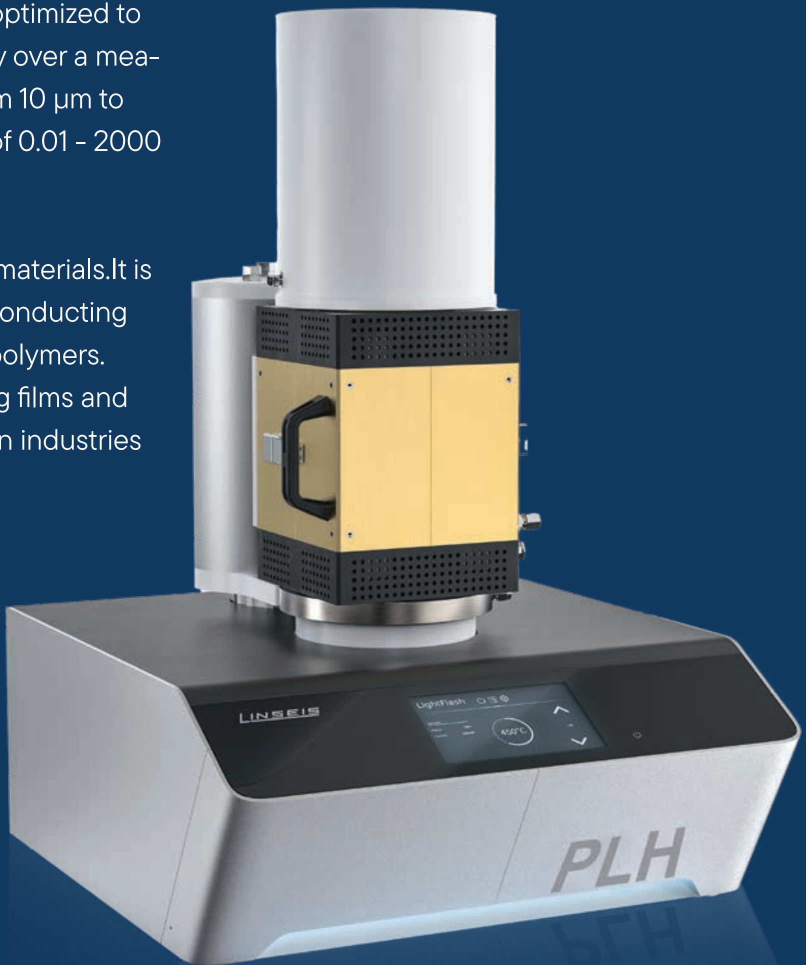
Thin Film

The characterization of micrometer materials is a critical issue today due to ongoing R&D for new technologies, such as battery and hydrogenapplications, as well as miniaturization efforts.
Due to the large surface to volume ratio, these types of materials need to be studied separately from bulk materials, but sample preparation and measurements can be very challenging.

In addition to our well-established laser flash technique, the PLH L53 setup allows us to extend the measurement range of our non-destructive optical instruments in terms of thickness and thermal transport properties.

The PLH L53 has been developed and optimized to characterize samples with high accuracy over a measurement range of sample thickness from 10 µm to 500 µm and a thermal diffusivity range of 0.01 - 2000 mm^2/s.

The system can handle a wide range of materials.It is possible to measure samples with semiconducting behavior as well as metals, ceramics or polymers. Typical applications include freestanding films and membranes for the battery and hydrogen industries

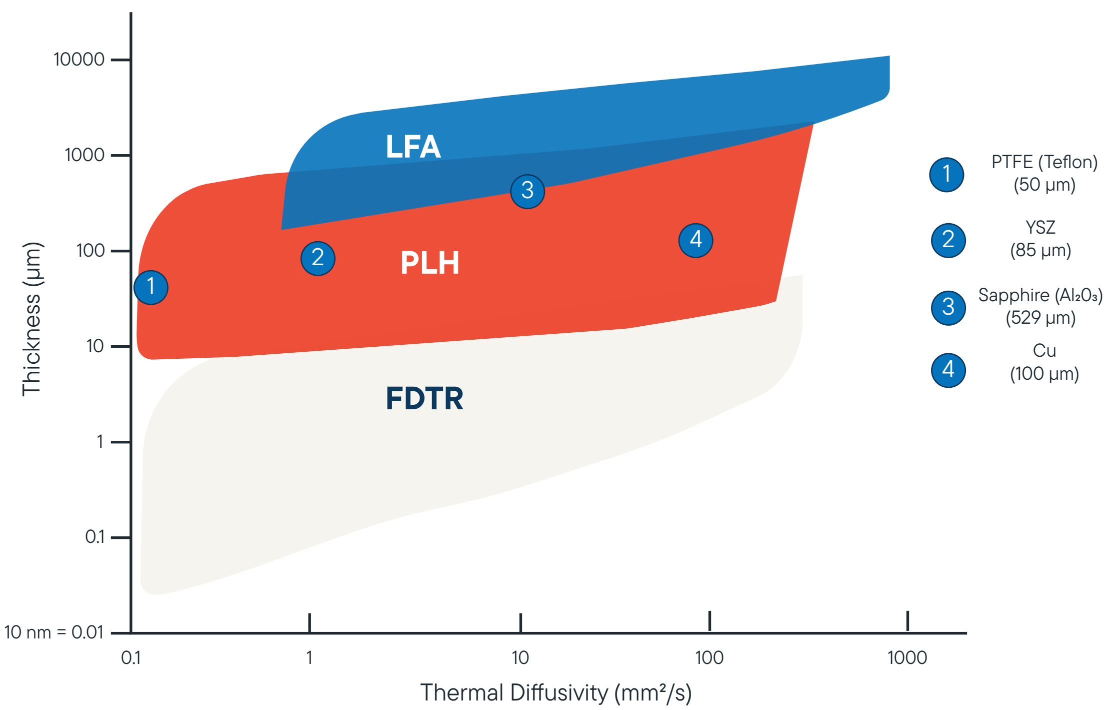


Technical Specifications

	PLH L53
Temperature range	RT upt o 300°C
Heating range	0.01 up to 20 °C/min
Sample dimensions	Ø 3, 6, 10, 12.7 or 25.4 mm square 5x5, 10x10 or 20x20 mm
Sample thickness	10 - 500 µm
Sample robot	robot with 3 or 6 samples
Laser source	CW diode laser up to 5 W wavelength: 450 nm
Thermal diffusivity	0.01 to 2000 mm²/s (thickness depended)
Accuracy	±5%
Repeatability	±5%
Footprint	550 x 600 x 680 mm 21,6 X 23,6 X 26,7 inch

ASTM Normen LFA: ASTM E-1461, DIN 30905 and DIN EN 821

ASTM Normen PLH: JIS R 7240:2018 & ISO: 20007:2017



Thermal Interface Materials **Testing**

Bulk

Thin Film

Waste heat management and thermal runaway protection in batteries and electronic packaging is becoming more and more important as power densities of these devices increase. Thermal management of these complex systems is not trivial and requires a fundamental understanding of how components and interface materials work together to shed heat. Our LINSEIS Thermal Interface Material Tester (TIM-Tester TIM L58) is the perfect solution for thermal management optimization of these complex systems.

The TIM-Tester TIM L58 measures the thermal impedance of sample materials and identifies an apparent thermal conductivity for a wide range of materials from liquid compounds and pastes to hard solid materials. The **approach is consistent with the ASTM D5470 standard.** Thermal interface materials such as thermal f luids, thermal pastes or greases, phase change materials (PCM), solders or resilient thermal conductors are tested automatically by applying a pressure of up to 10 MPa (for ø 25mm sample) and temperature of up to 300°C at the hot side. The software interface allows the instrument to be operated automatically over a wide temperature and pressure range, while all test parameters are recorded in real time. Different instrument configuration for square or round shaped samples of different size can be analysed under variable load in order to optimize materials for a specific application.

Exchangeable meter bars

Technical Specifications

	TIM L58
Sample temperature rangen (max)	-30°C to 300°C*
Standard sample size	Round: ø 20 mm, 25 mm, 40 mm Rectangular: 20 mm x 20 mm, 25 mm x 25 mm, 40 x 40 mm Other sizes on request
Sample thickness	0.01 mm to 8 mm (up to 20 mm)
Sample measurement range	0.1 – 50 W/mK
Sample resistance range	0.01 – 8.0 K/W
Contact pressure range	0 to 16 MPa (depending on sample size and shape) From round ø 20mm (up to 16 MPa) to ø 40 mm (up to 4 MPa) and rectangular 20mm x 20mm (up to 8 MPa)
Force options	1000 N, 2000 N, 5000 N (also possible: 1 kN, 2 kN, 5 kN)
Meter bar material	Aluminium, Copper, Brass (others on request)
Software Plugins	Thickness modulation Temperature cycling Quality management tool
Cooling options	Standard water cooling unit, intracooler 600 (-20°C cold side)**, intracooler 1000 (-30°C cold side)**
Power supply	110/115/220/230 VAC 50/60 Hz

* Under optimum conditions

** Lowest cold side meter bar temperature under optimum conditions

Transient Hot
Bridge

Bulk

Instrument for rapid measurement of thermal conductivity, thermal diffusivity and specific heat

A flexible sensor is sandwiched between two f lat surfaces of the specimens to assure a good thermal contact without air inclusions. Either the delivered sample holder or a weight can be used in order to optimize the contact resistance. The shapes of the faces, which are not in contact with the sensor, are of no importance, which helps to reduce the sample preparation to a mini mum. There are no limitations regarding the maximum sample size, where else the minimum thickness depends on the samples thermal diffusivity. The measurement and evaluation are completely software controlled, run automatically and can be post-processed if needed. Measurements take only some seconds up to a few minutes. The sensors are automatically identified by the software. Multiple measurements with automatic calculation of the mean values are possible as well as the storage of results.

Measurements can be done either at room temperature (no further equipment required), elevated or sub-ambient temperatures. The setup, including the sensor, can be placed in a normal lab furnace or climatic chamber, which are often available in laboratories. LINSEIS also offers specially adapted furnaces covering temperatures from -150°C up to 700°C.

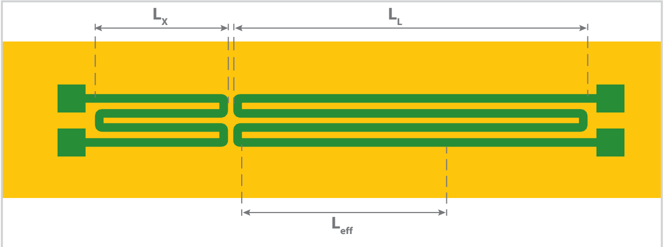
The measurement set-up

Advantages

- Short measurement times (seconds to few minutes)
- High accuracy due to patented sensor design
- Easy set-up and sample preparation
- Non-destructive measurement
- Absolut method - no calibration required
- Suitable for solids, liquids, powders, pastes etc.
- Temperature range -150°C to 700 °C
- Measurements at different atmospheres, vacuum and pressures up to 150 bar
- Broad thermal conductivity range from 0.005 to 1800 W/m·K
- Modular design

Transient Hot Bridge Method

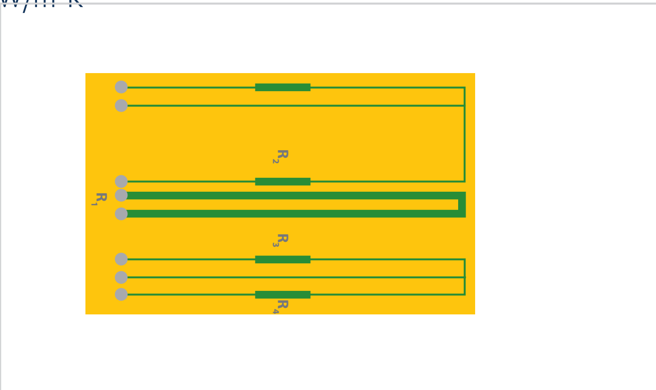
The THB measurement method, initially developed by the National Metrology Institute of Germany(PTB), is an optimized hot wire technique to measure all relevant thermal transport properties (thermal conductivity, thermal diffusivity and volumetric specific heat) with the highest possible accuracy.



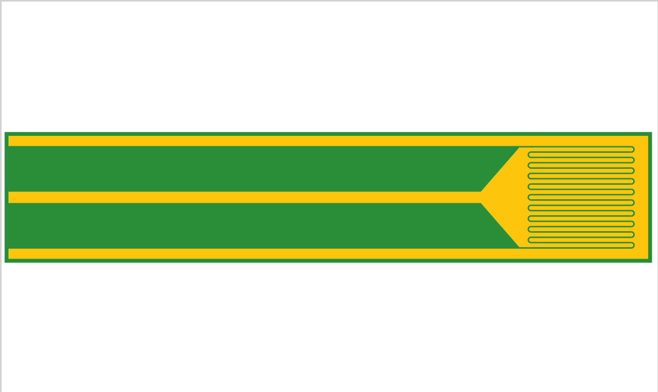
Patented meander-shaped tandem hot wire

For the THB-Advance and THB-Ultimate additional hot wire measurement techniques are available, based on innovative and patented sensors:

The Quasi-Steady-State (QSS) sensors have been developed for the measurement of high thermal conductivities. It combines the advantages of steady-state and transient measurement techniques and enables measurements in the range up to1800 W/m*K



The LINSEIS Hot Point Sensors (HPS) work according to the transient plane method. They are suitable to measure small samples with dimensions down to 3 x 3 mm². The thermal conductivity range of 0.01 to 30 W/m*K is covered by the Hot Point Sensor.

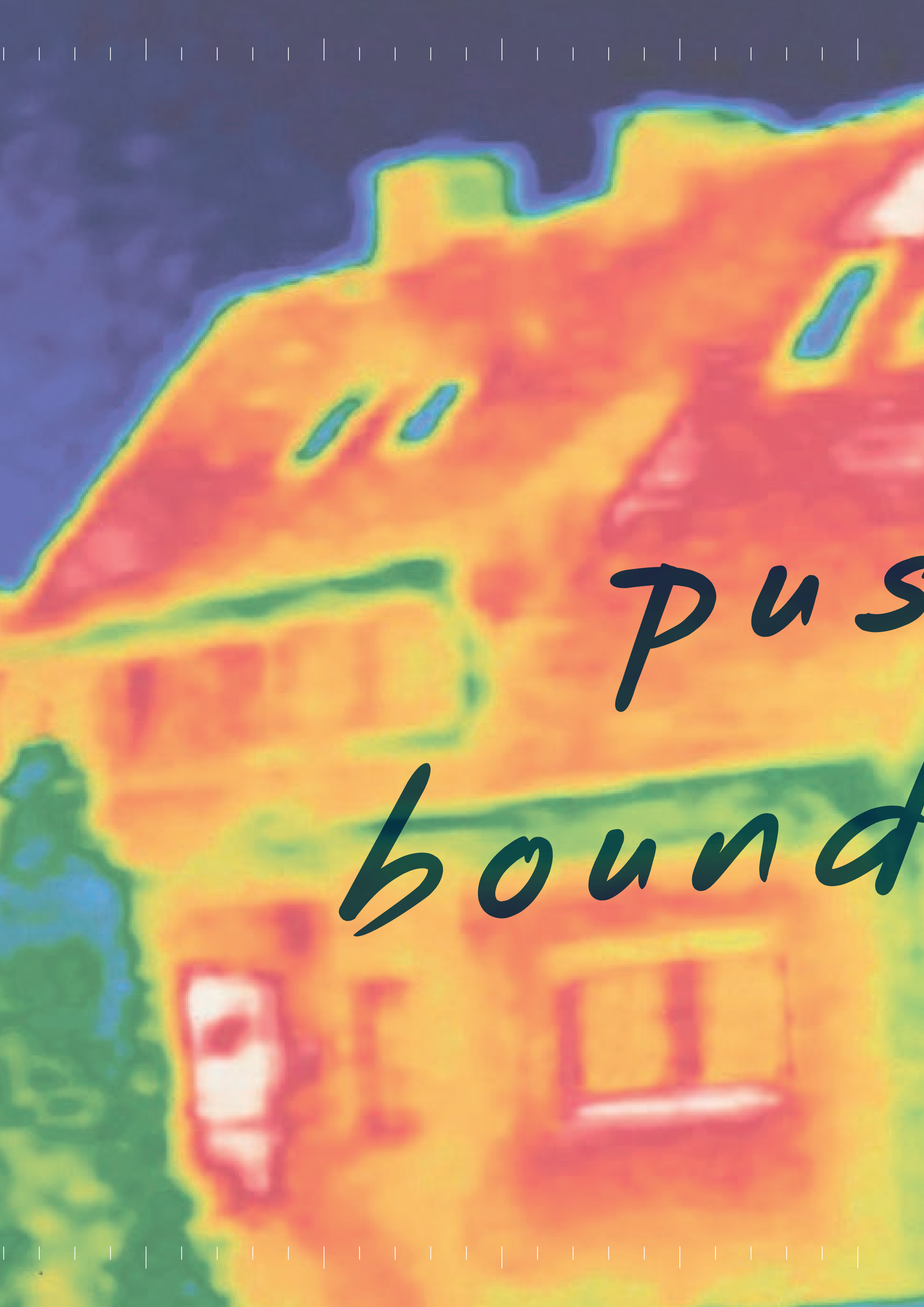


Technical Specifications

All sensor types are available as Kapton-foil-sensors and resist to temperatures from -150°C up to 200°C. Ceramic sensors are available covering a temperature range up to +700°C (THB Basic and THB Advance).

	THB L56 Basic	THB L56 Advance	THB L56 Ultimate
THB Sensors	✓	✓	✓
OSS Sensors	✗	✓	✓
Hot Point Sensors	✗	✓	✓

	THB L56 Basic	THB L56 Advance	THB L56 Ultimate
Measurement ranges			
Thermal Conductivity	0.01 to 5 W/(m·K)	0.005 to 500 W/(m·K)	0.005 to 1800 W/(m·K)
Thermal Diffusivity	0.05 to 50 mm^2/s	0.05 to 300 mm^2/s	0.05 to 1200 mm^2/s
Special thermal capcity	100 to 5000 $kJ/(m^3 \cdot K)$	100 to 5000 $kJ/(m^3 \cdot K)$	100 to 5000 $kJ/(m^3 \cdot K)$
Measurement uncertainties			
Thermal Conductivity	better than 1%	better than 1%	better than 1%
Thermal Diffusivity	better than 4%	better than 4%	better than 4%
Specific Heat	better than 4%	better than 4%	better than 4%
Duration of the measurement	typically < 1 min	typically < 1 min	typically < 1 min
Service temperature			
Sensor	-150°C to 200°C	-150°C to 700°C	-150°C to 700°C
Sensor type	Kapton and Ceramic	Kapton and Ceramic	Kapton and Ceramic
Sample size			
Smallest sample	10 x 20 x 3 mm	3 x 3 x 2 mm	3 x 3 x 2 mm
Sample consistency	solid, liquid, gel	solid, liquid, gel	solid, liquid, gel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Heat Flow
Meter

Bulk

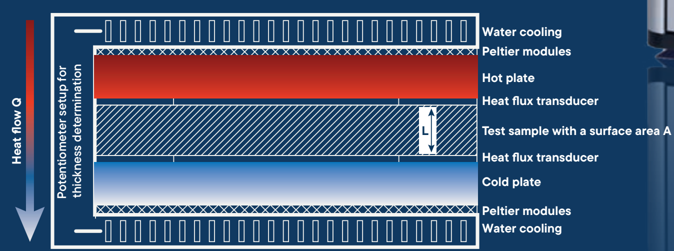
The Heat Flow Meter (HFM L57) provides a rapid and easy to use method to determine the thermal conductivity properties of low thermal conductivity materials (e.g. like insulating materials) with a high level of accuracy. The instrument is designed for ASTM C518, JIS A1412, ISO 8301 and DIN 12667. The principle of measurement is to position a sample between a hot and a cold plate, and to measure the heat flow. Peltier heating and cooling technology enables high-precision temperature control while reducing maintenance and downtime.
The excellent long-term stability enables accurate long-term aging studies.

Service and maintenance

The robust system design and the unique “zero maintenance” Peltier heating and cooling cycle ensures a minimum of cost.

Test cycles

The double heat flux sensor configuration ensures shortest possible measurement cycles. A typical measurement can take as little as 15 minutes until the temperature stabilizes. Two heat f lux sensors then measure the heat flow from which the thermal resistance and thermal conductivity are calculated.



NEW

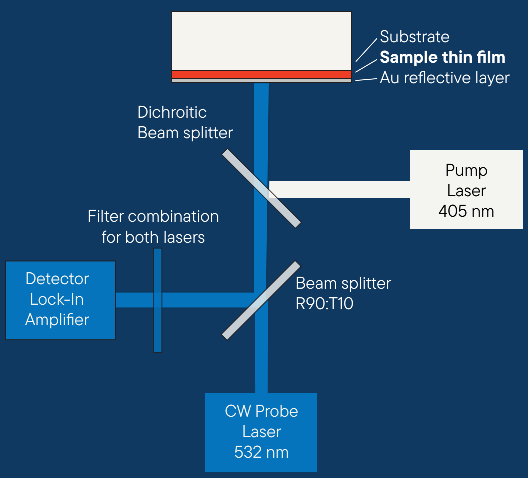
Thin Film

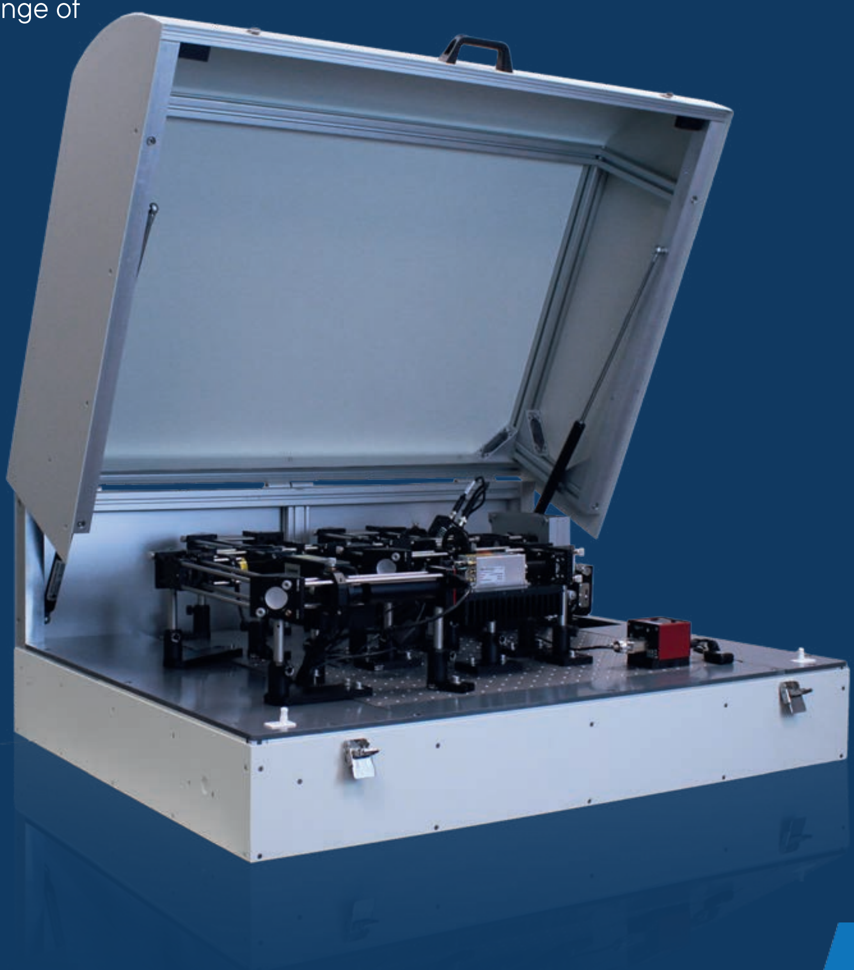
Frequenvy Domain **Thermoreflectance**

Thermophysical properties of thin films are becoming more and more important in industries such as phase-change optical disk media, thermo-electric materials, light emitting diodes (LEDs), phase change memories, f lat panel displays, and semiconductors. In all these applications thin films are deposited on substrates in order to give a device a particular function. Since the physical properties of these films significantly differ from bulk material, data of thin films are required for accurate thermal management predictions.

Therefore we developed the LINSEIS TF-LFA L54 (Thin-Film-Laser-Frequency-Analyser), allowing to measure the thermo-physical properties thermal conductivity, thermal diffusivity, thermal effusivity, the volumetric heat capacity and the thermal boundary conductance of thin films in the thickness range of 80 nm to 20 µm.

Simplified schematic setup





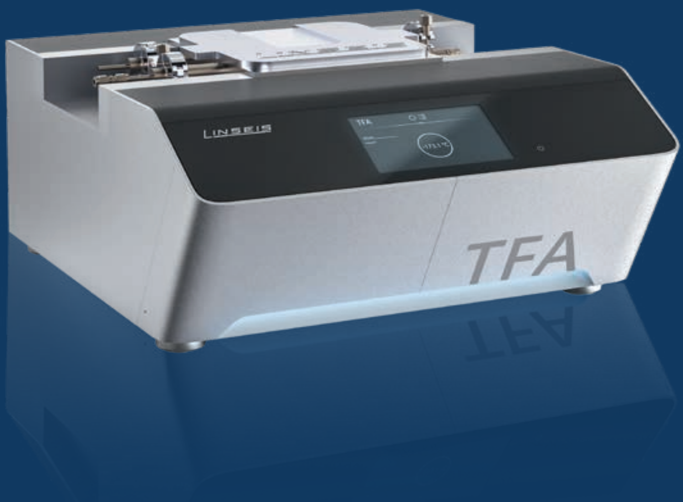
Thin Film **Analysis**

Thin Film

The LINSEIS Thin Film Analyzer TFA L59 is the perfect solution to characterize a broad range of thin film samples in a very comfortable and quick way. It is an easy to use, single stand alone system and delivers high quality results using an optimized measurement design as well as the proven LINSEIS firm- and software package.

Motivation

Due to new research efforts in the field of semiconducting materials, with a focus on size effects, there is a growing need for measurement setups dedicated to samples with small geometrical dimensions like thin films and nanowires, with considerably different physical properties than bulk material. The characterization of these samples is important in order to learn more about their structure and conduction mechanism and also important for technical applications.



Measurement Setup

The LINSEIS TFA L59 is a chip-based platform to simultaneously measure the in-plane electrical and thermal conductivity, the Seebeck coefficient as well as the Hall constant of a thin film sample in the temperature range from -170°C up to 280°C and in a magnetic field of up to 1 T. Due to the design of the setup, time consuming preparation steps can be omitted and a nearly simultaneous measurement of the sample properties is achieved. Typical errors caused by different sample compositions, varying sample geometries and different heat profiles are avoided with this measurement method. The system can handle a broad range of different materials. It is possible to measure samples with semiconducting behaviour as well as metals, ceramics or organic materials. Therefore many different deposition methods like PVD, CVD, spin coating or drop casting can be used.

TFA L59 Options

The following packaging options are available for the LINSEIS Thin Film Analyzer (TFA L59):

1. Basic device

Consists of measurement chamber, vacuum pump, basic sample holder with included heater, system integrated lock-in amplifier for the 3w-method, PC and LINSEIS software package including measurement and evaluation software. The design is optimized to measure following physical properties:

- λ - thermal conductivity
- c_p - specific heat

2. Thermoelectric package

Consisting of extended measurment electronics (DC) and evaluation software for thermoelectric experiments. The design is optimized for measuring the following parameters:

- σ- electrical conductivity / electrical resistivity
- S - Seebeck coefficient

3. Magnetic package

The design is optimized for measuring the following parameters:

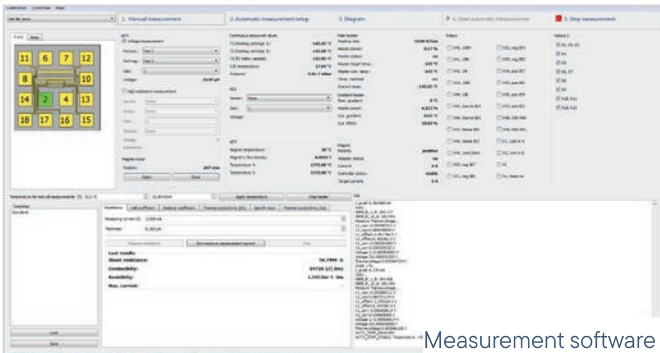
- A_H - Hall constant
- μ - Mobility
- n - charge carrier concentration

4. Low temperature option for controlled cooling down to 100 K

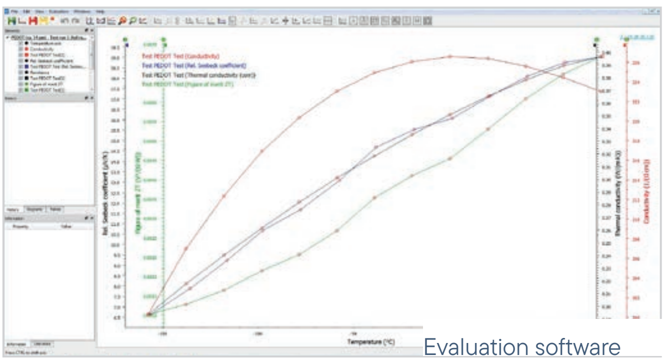
- TFA/KREG controlled cooling unit
- TFA/KRYO Dewar 25l

Software

The TFA software package consists of two parts. A measurement software which displays the actual values and which allows to define a measurement routine and the dircet control of the setup. And an additional evaluation software for the post processing of the measured raw data.



Measurement software



Evaluation software

Measuring principles

Pre-structured measuring chips

The thin film to be analyzed has to be deposited on a pre-structured disposable chiip available from LINSEIS. All necessary sensing arrangements are integrated in this chip. The chip is combining the 3w measurement technique for the thermal conductivity measurement with a 4-point Van-der-Pauw setup for the determination of the electrical transport properties. The Seebeck coefficient can be measured using additional resistance thermometers located near the sample. For an easy sample preparation either a strip-off foil mask or a metallic shadow mask can be used. This configuration allows for a nearly simultaneous characterization of a sample which has been prepared by either PVD (e.g. thermal evaporation, sputtering, MBE), CVD (e.g. ALD), spin coating, drop casting or ink-jet printing in one step.

Van-der-Pauw measurement

To determine the electrical conductivity (s) and Hall constant (AH) of the sample, the Vander-Pauw method is used. After depositing the sample on the chip, it is already connected to four electrodes A, B, C & D at their edge. For the measurement, a current is applied between two of the contacts and the corresponding voltage between the remaining two is measured. By clockwise changing of the contacts and repeating of the procedure, the resistivity of the sample can be calculated using the Van-der-Pauw equation.

$$\exp(- \quad \cdot R_{AB,CD}) + \exp(- \quad \cdot R_{BC,DA}) = 1$$

By applying a magnetic field and measuring the corresponding change of the diagonal Van-derPauw resistance, the Hall constant of the sample can be calculated.

$$A_H = \quad \cdot \Delta R_{AC,BD}$$

For the determination of the Seebeck coefficient, an additional thermometer and heater is placed on the chip near the sample. This configuration allows for the measurment of the thermovoltage at different temperature gradients wich can be used in order to calculate the Seebeck coefficient S=-Vth/ΔT.

$$S = -V_{th} / \Delta T$$

Technical Specifications

	TFA L59
Temperature range	RT up to 280°C -160°C up to 280°C
Sample thickness	from only a 5 nm to 25 µm (range depends on sample)
Measurement principle	chip based (pre-structured measurement chips, 24 pcs. per box)
Desposition techniques	include: PVD (sputtering, evaporation), ALD, spin coating, ink-jet printing and more
Measured parameters	Thermal conductivity (3ω) Specific heat
Optional	Seebeck coefficient Electrical resisitivity / conductivity Hall constant / Mobility / Charge carrier concentration Permanent magnet 0.5 T or Electromagnet up to 1 T
Vacuum	up to 10^{-5} mbar
Electronics	integrated
Interface	USB
Measurement range	
Thermal Conductivity	0.05 up to 200 W/m·K
Electrical Resistivity	0.05 up to $1 \cdot 10^6$ S/cm
Seebeck Coefficient	1 up to 2500 µV/K
Hall mobility	1 up to 10^7 (cm² /Volt sec)
Charge carrier concentration	10^7 up to 10^{21} (1/cm³)
Repeatability & accuracy	
Thermal Conductivity	± 10% (for most materials)
Electrical Resistivity	± 6% (for most materials)
Seebeck Coefficient	± 7% (for most materials)
Hall constant	± 9 % for most materials

LINSEIS

pushing boundaries

LINSEIS GmbH Germany

Vielitzerstr. 43
95100 Selb

Tel.: (+49) 9287 880 0
E-mail: info@linseis.de

LINSEIS Inc. USA

109 North Gold Drive
Robbinsville, NJ 08691

Tel.: (+1) 609 223 2070
E-mail: info@linseis.de

LINSEIS China

Linseis Shanghai Scientific
Room 120, Building T3, No.1220
Yuqiao Road, Pudong, Shanghai

Tel.: (+86) 61 90 12 03
Tel.: (+86) 50 55 06 42
E-mail: info@linseis.com.cn

LINSEIS India

Plot 65, 2nd Floor, Sai Enclave,
Sector 23, Dwarka05-800
110077 New Delhi

Tel.: +91-11-42883851
E-mail: sales@linseis.in

WWW.LINSEIS.COM

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