

LINSEIS

T H E R M A L A N A L Y S I S

THERMAL CONDUCTIVITY

LFA
TFA
THB
HFM
TF-LFA
TIM-Tester



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.

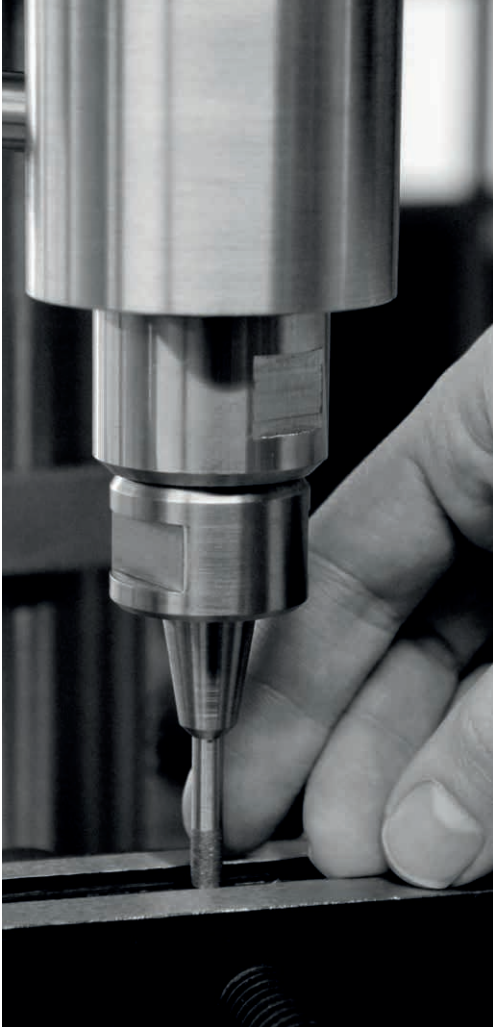
Customer satisfaction, innovation, flexibility and high quality are what LINSEIS represents. Thanks to **these fundamentals**, our company enjoys an exceptional reputation among the leading scientific and industrial organizations. LINSEIS has been offering highly innovative benchmark products for many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

The LINSEIS business unit of thermal analysis is involved in the complete range of thermo analytical 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, thermo physical properties of solids, liquids and melts can be analyzed.

LINSEIS provides technological leadership. We develop and produce the most advanced analytical and thermo physical testing equipment to allow high standards of precision. As a leading manufacturer of thermo analytical equipment, manufacturing thermo analytical equipment for testing machines requires significant research and a high degree of precision. LINSEIS Corp. invests in this research to the benefit of our customers.

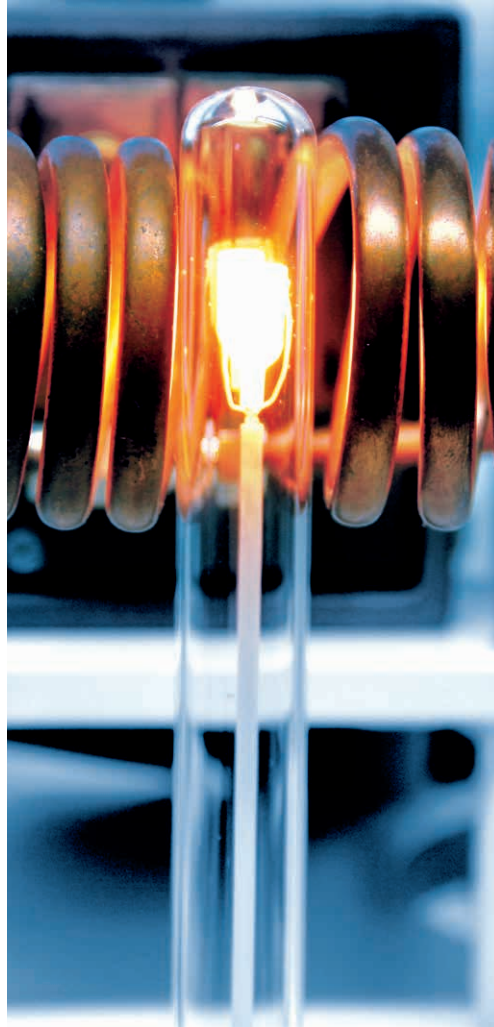


Claus Linseis
Managing Director



German engineering

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

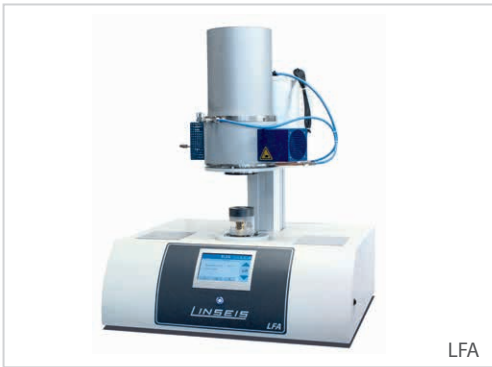


Innovation

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 constantly develop new technologies to enable continued discovery in Science.

PRODUCT OVERVIEW

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



LFA



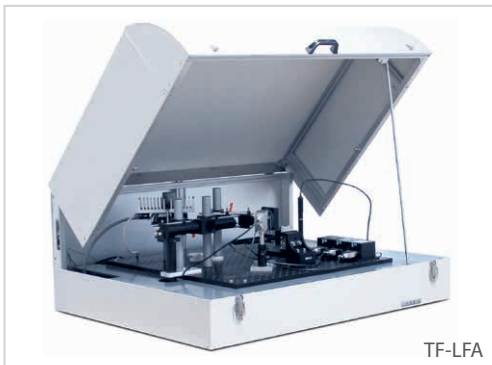
TIM-Tester



THB



HFM



TF-LFA



TFA

MEASUREMENT 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 | TIM-Tester | THB | HFM | TFA | TF-LFA |
|----------------------------|---------------------|----------------------------------|-------------------------------|--------------------------|----------------------------|-------------------------------|
| Info | Most universal tool | For thermal inter-face materials | For fast and easy measurement | For insulating materials | Thin films on LINSEIS chip | For nm to μm films |
| Measurement | | | | | | |
| Thermal Conductivity | | | | | | |
| Thermal Diffusivity | | | | | | |
| Specific Heat Capacity | | | | | | |
| Thermal Resistivity | | | | | | |
| Defined Pressure on Sample | | | | | | |
| Atmosphere | | | | | | |
| Temperature 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 | | | | | | |
| Liquid | | | | | | |
| Powder | | | | | | |
| Paste | | | | | | |
| Pad | | | | | | |
| Thinfilm | | | | | | |



Measurement is possible



Measurement is probably possible



Measurement is not possible

LFA - Laser Flash Analyzer

Information about the thermophysical properties of materials and heat transfer optimization of final products is becoming more and more important 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 in-

ulators and many more. Easy 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.

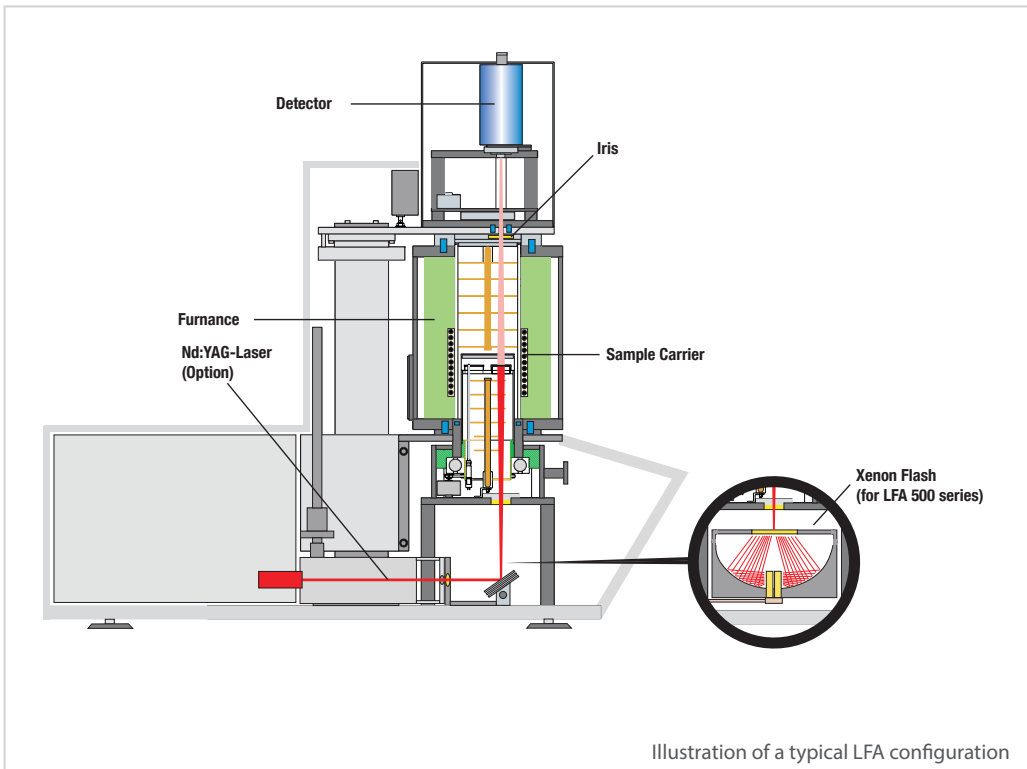
LINSEIS offers a variety of instruments to measure the thermal diffusivity/conductivity. The LFA L51/L52 Flash Analyzer series provides a cost effective solution for the temperature range from -125°C up to 2800°C .



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 adju-

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

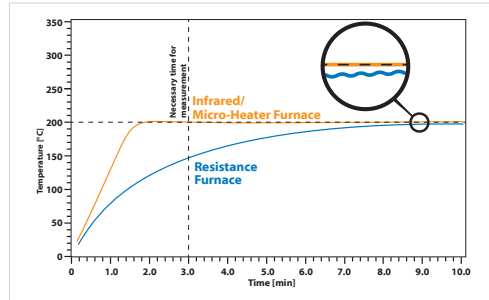
The used method is an absolute measurement technique (for thermal diffusivity), hence there is no need to calibrate the system. The LINSEIS

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/LFA L51 1250). This technology enables unmatched heating and cooling speed, unmatched temperature control, homogeneity 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

DETECTORS

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 exchan-

geable. An available automatic LN₂ refilling accessory with Dewar flask allows prolonged measurement cycles.

SAMPLE CARRIERS



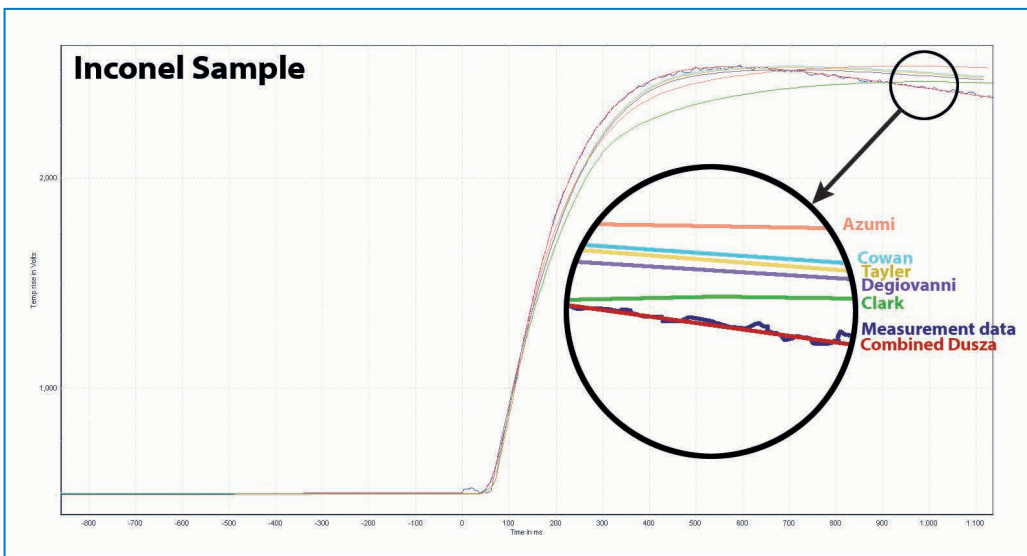
SOFTWARE: COMBINED MODEL ACCORDING TO DUSZA

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 were evaluated using different common models. It can clearly be observed, that the combined model according to Dusza provides the best fit, 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 pulse-time 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 fit can be checked by plotting the model curve and also as a numeric value.

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 acquisition | 10 MHz | 10 MHz |
| Sample holders | round or square - solid samples, powders, pastes, li- quids, laminates - special holder for measurement under mecha- nical pressure | round or square - solid samples, powders, pastes, li- quids, laminates - special holder for measurement under mecha- nical pressure |
| Sample numbers | sample robot up to 3, 6 or 18 samples (depends on model) | up to 3, 6 or 18 samples |

PLH L53 - Periodic Laser Heating

The characterization of micrometer materials is a critical issue today due to ongoing R&D for new technologies, such as battery and hydrogen-applications, 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 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 semi-conducting behavior as well as metals, ceramics or polymers. Typical applications include free-standing films and membranes for the battery and hydrogen industries.

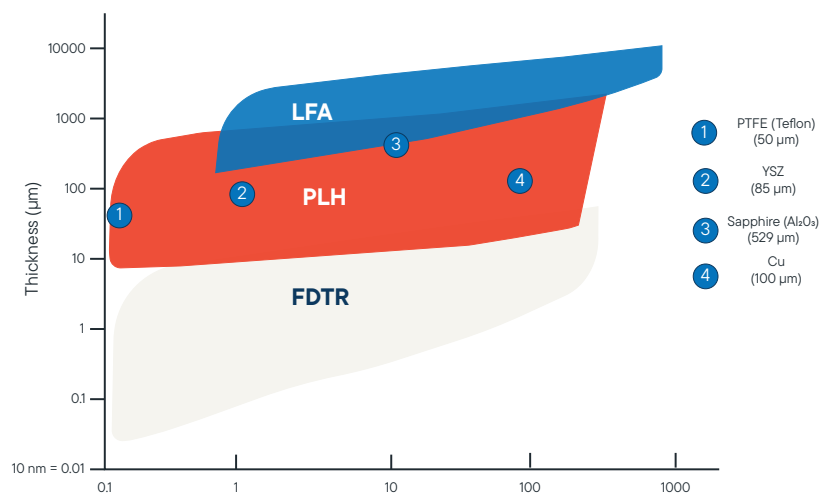


SPECIFICATIONS

| | PLH L53 |
|---------------------|--|
| Temperature range | RT up to 300°C |
| Heating range | 0.01 up to 20 °C/min |
| Samples 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 mm ² /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



TIM-TESTER TIM L58

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) is the perfect solution for thermal management optimization of these complex systems.

The TIM-Tester 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 fluids, 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 \varnothing 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.



TIM L58



Exchangeable meter bars

SPECIFICATIONS

| | TIM L58 |
|--------------------------------|---|
| Sample temperature range (max) | -30°C to 300°C* |
| Standard sample size | Round: \varnothing 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 bis 16 MPa (je nach Probengröße und -form) Von rund \varnothing 20mm (bis zu 16 MPa) bis \varnothing 40 mm (bis zu 4 MPa) und rechteckig 20mm x 20mm (bis zu 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

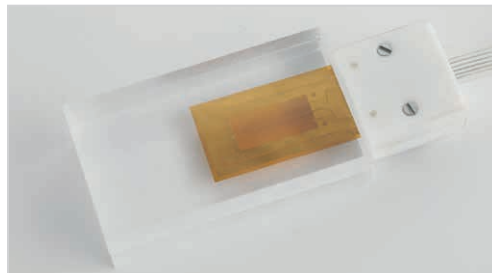
THB L56 – TRANSIENT HOT BRIDGE

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

A flexible sensor is sandwiched between two flat 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 minimum. 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 .



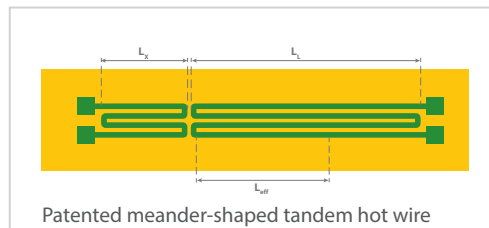
THE MEASUREMENT SET-UP

Advantages

- Short measurement times (seconds to few minutes)
- High accuracy due to patented sensor design
- Easy set-up and sample preparation
- Non-destructive measurement
- Absolute 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

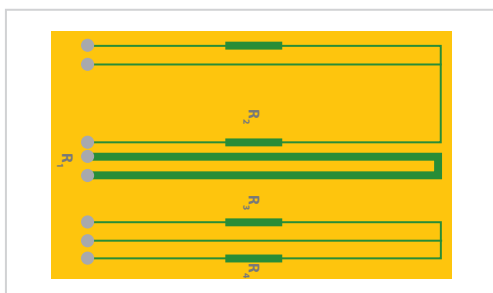
Transient Hot Bridge Method

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.

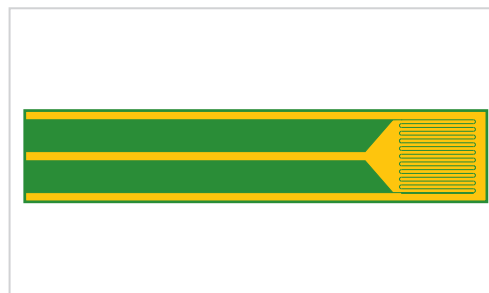


For the THB-Advance and THB-Ultimate additional hot wire measurement techniques are available, based on innovative and patented sensors:

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 to 1800 W/m²·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/m²·K is covered by the Hot Point Sensor.



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 Advanced | THB L56 Ultimate |
|-------------------|---------------|------------------|------------------|
| THB Sensors | ✓ | ✓ | ✓ |
| QSS Sensors | ✗ | ✓ | ✓ |
| Hot Point Sensors | ✗ | ✓ | ✓ |

| Measuring ranges | THB L56 Basic | THB L56 Advanced | THB L56 Ultimate |
|----------------------------------|------------------------------------|------------------------------------|------------------------------------|
| 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 capacity | 100 to 5000 kJ/(m ³ ·K) | 100 to 5000 kJ/(m ³ ·K) | 100 to 5000 kJ/(m ³ ·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 |

HFM L57 - HEAT FLOW METER

The Heat Flow Meter 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 po-

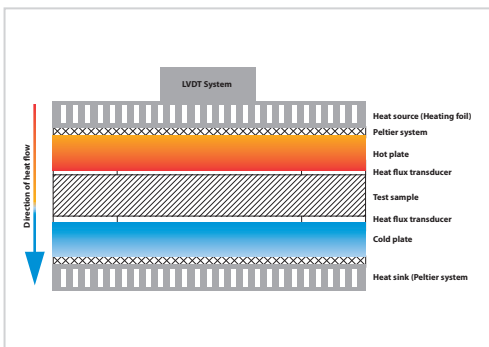
sition a sample between a hot and a cold plate, and to measure the heat flow.

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 flux sensors then measure the heat flow from which the thermal resistance and thermal conductivity are calculated.

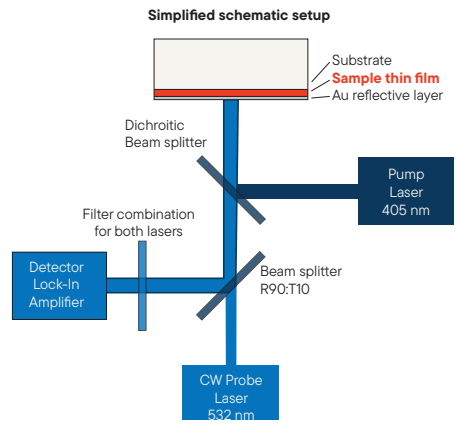
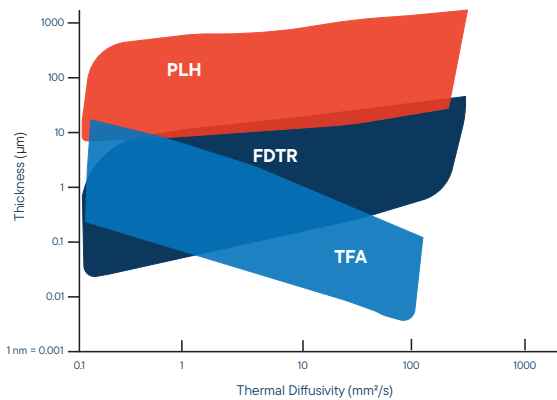


TF-LFA L54 - FDTR

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, flat 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 .

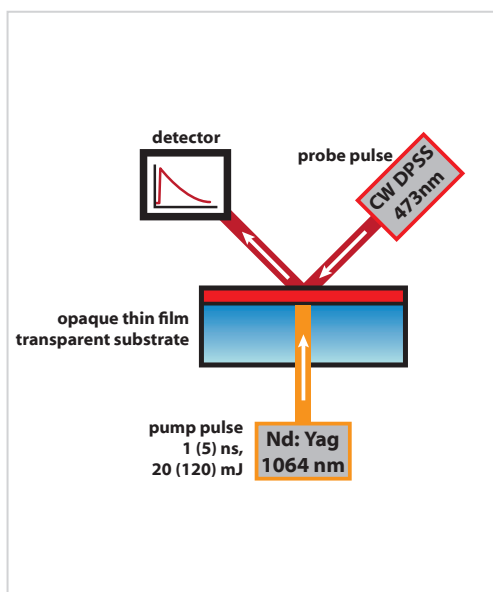


THE HIGH SPEED LASER-FLASH TECHNIQUE

High Speed Laserflash Method

Rear heating Front detection (RF)

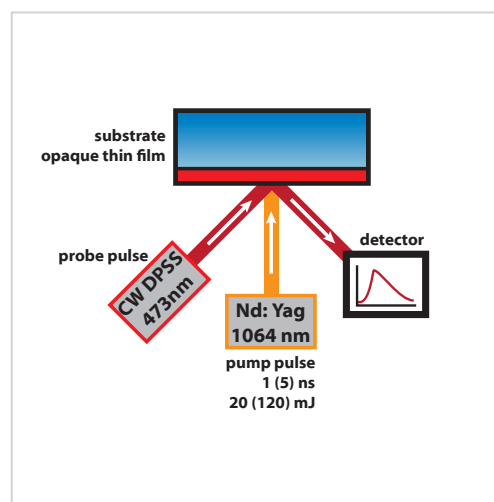
The measurement arrangement is the same as for the standard laser flash technique: detector and laser are on opposite sides of the sample. Because IR-detectors are too slow for the measurement of thin layers, the detection is done by the so called thermoreflectance method. The idea behind this technique is, that once a material is heated up, the change in the reflectance of the surface can be utilized to derive the temperature change and thus the thermal properties. The reflectivity is measured with respect to time, and the data received can be matched to a model which contains coefficients that correspond to thermal properties.



Time Domain Thermoreflectance Method

Front heating, Front detection (FF)

The measurement geometry is called "front heating front detection (FF)" because detector and laser are on the same side of the sample. This method can be applied to thin layers on various substrates (e.g. non transparent substrates or very thin films) for which the RF technique is not suitable. For the measurement, a heating pulse is applied to the front side of the sample and the temperature rise at this spot is measured with a detection laser coming from the same side. The thermal diffusivity of the sample layer can be calculated by using the falling edge of the normalized temperature rise in combination with a multilayer model developed by LINSEIS in cooperation with Prof. David G. Cahill of the University of Illinois.



SPECIFICATIONS

| | Thin Film Laser Flash Analyzer TF-LFA L54 |
|-------------------------------------|---|
| Sample dimensions | Round or rectangular between of 10mm and 20mm |
| Film thickness | 80 nm up to 20 μ m (depends on sample) |
| Temperature range | RT, RT up to 500°C or -100°C to 500°C |
| Heating and cooling rates | 0.01 up to 20K/min |
| Vacuum | up to 10 ⁻⁴ mbar |
| Atmosphere | inert, oxidizing or reducing |
| Thermal diffusivity measuring range | 0.01 mm ² /s up to 1000 mm ² /s |
| Pump-Laser | Nd: YAG Laser: 1064nm, max. 90mJ/Impulse (software controlled), Pulse width: 5ns (1ns on request) |
| Probe-Laser | DPSS CW-Laser (473nm or 532nm), 50mW (optimized for Au coating – other wavelengths on request) |
| Photoreceiver | Si-Photodiode, active diameter: 0,8mm, bandwidth DC 400MHz, rise time: 1ns, Acquisition rate: 1 Gigasample/s (faster acquisition rate on request) |

TFA - THIN FILM ANALYZER

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 semi-conducting 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.



PACKAGING OPTIONS

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

1. Basic device

Consists of measurement chamber, vacuum pump, basic sample holder with included heater, system integrated lock-in amplifier for the 3ω -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 measurement 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:

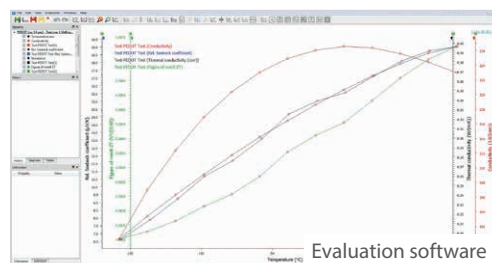
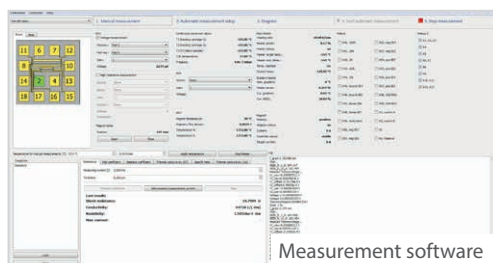
- A_H - Hall constant
- μ - Mobility
- n - charge carrier concentration

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 direct control of the setup. And an additional evaluation software for the post processing of the measured raw data.



MEASURING PRINCIPLES

Pre-structured measuring chips

The thin film to be analyzed has to be deposited on a pre-structured disposable chip available from LINSEIS. All necessary sensing arrangements are integrated in this chip. The chip is combining the 3ω 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 (σ) and Hall constant (A_H) of the sample, the Van-der-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.

$$\exp\left(-\frac{\pi d}{\rho} R_{AB,CD}\right) + \exp\left(-\frac{\pi d}{\rho} R_{BC,DA}\right) = 1$$

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

$$A_H = \frac{d}{B} \cdot \Delta R_{AC,BD}$$

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 measurement of the thermovoltage at different temperature gradients which can be used in order to calculate the Seebeck coefficient $S = -V_{th} / \Delta T$.

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



SPECIFICATIONS

| | TFA L59 |
|-------------------------------------|--|
| Temperature range | RT up to 280°C -170°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 techiques | include: PVD (sputtering, evaporation), ALD, spin coating, ink-jet printing and more |
| Measured parameters | Thermal conductivity (3 ω) Specific heat |
| Optional | Seebeck coefficient Electrical resisitvity / 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 · 10 ⁶ S/cm |
| Seebeck Coefficient | 1 up to 2500 µV/K |
| Hall mobility | 1 up to 10 ⁷ (cm ² /Volt sec) |
| Charge carrier concentration | 10 ⁷ up to 10 ²¹ (1/cm ³) |
| 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 |



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