LINSEIS

pushing boundaries

Thermoelectric **Materials Characterization**

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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

Linseis **Service**

Customized Solutions - The Linseis Advantage

At Linseis, we believe that every measurement challenge is unique — and so should be your instrument.
While many suppliers rely on standardized configurations, Linseis distinguishes itself through exceptional flexibility and the capability to deliver customer-specific adaptations in record time.

Our experienced engineering teams work hand in hand with you to design and implement fully customized solutions that meet your precise application requirements — whether that means a unique sensor configuration, an extended temperature range, or a specialized software integration.

With decades of experience and a modular product architecture, we turn customization into a standard service — fast, efficient, and reliable.
Choose Linseis and experience what true flexibility in thermal analysis and material characterization means.

Contact form

Service & Support

Redefining Ownership

When investing in analytical instrumentation, long-term value matters just as much as precision. That's why Linseis systems are engineered to deliver the lowest **Total Cost of Ownership** in their class — combining reliability, efficiency, and flexibility in every detail.

Our instruments are built with robust, high-quality components designed for longevity and minimal maintenance. This means fewer service interventions, shorter downtimes, and reduced operating costs over the entire product lifetime. Intelligent software updates and remote support further ensure that your system remains state-of-the-art, even years after installation.

Thermoelectrics

Thermoelectricity describes the interaction between temperature and electricity, and their conversion into each other. There are three effects that describe this reversible interaction: the Seebeck effect, the Peltier effect and the Thomson effect. These effects almost always appear together.

Field of Application

In recent years, thermoelectricity has become increasingly prevalent in applications such as portable refrigerators, beverage coolers, electronic component coolers and metal alloy sorting devices.

Furthermore, it is used in thermoelectric generators for waste heat recovery, for example in cars to reduce CO_2 emissions, and in solid-state cooling or Peltier elements.

Thermoelectric generators (TEGs) have been available since the early 1960s, with a power output ranging from 10 to 550 W.

Advantages of TEGs include high reliability, long service intervals, low maintenance requirements, and long durability. One of the most commonly used materials for such applications is bismuth telluride (Bi_2Te_3), a chemical compound of bismuth and tellurium.

Figure of Merit

Altenkirch (1909, 1911) showed that good thermoelectric materials should possess large Seebeck coefficients, high electrical conductivity and low thermal conductivity. The thermoelectric efficiency of a material is therefore given by the dimensionless figure of merit ZT, which combines these three values and is defined as follows:

$$ZT = \frac{S^2 \cdot \sigma \cdot T}{\lambda}$$

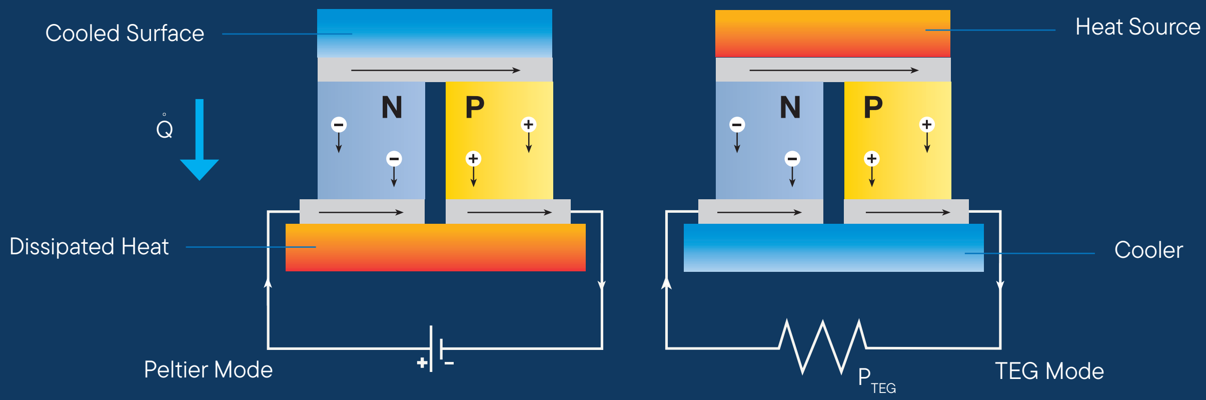
Seebeck coefficient $[S]=\mu V/K$

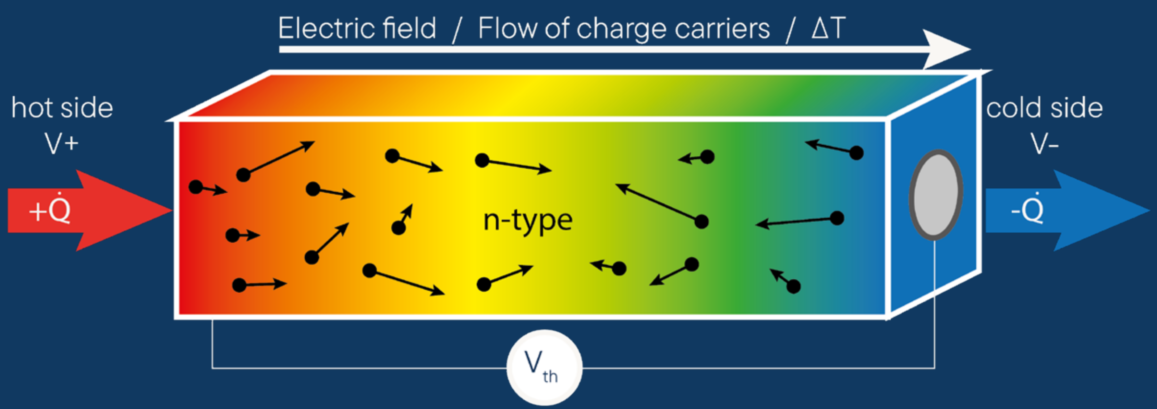
Electrical conductivity $[\sigma]= 1/\Omega m$

Thermal conductivity $[\lambda]= W/mK$

The figure of merit is an important value for the materials science community as well as industry, as it is used to compare the thermoelectric efficiency of materials and modules.

In fact, the highest ZT value is between 2 and 3, while the range of 3 to 4 is considered competitive with mechanical energy generators.


Cooled Surface
Q̇
Dissipated Heat
N
P
Peltier Mode
Heat Source
Cooler
P TEG
TEG Mode


Electric field / Flow of charge carriers / ΔT
hot side
V+
+Q̇
n-type
cold side
V-
-Q̇
V th

LSR

Bulk

Thin Film

LSR L31

With the Linseis LSR platform, thermoelectric materials in the form of bulk materials and thin films can be characterized in a simple and convenient way.
In the basic version – LSR L31- both the Seebeck coefficient and the electrical resistivity can be measured fully automatically and simultaneously from -160°C to 200°C.
This system enables the characterization of metallic and semiconducting samples using the well-known Van der Pauw (resistance) and slope Seebeck coefficient measurement techniques.
The compact table-top design enables fully automatic and software-controlled operation.

LSR L33

The Linseis LSR platform can be used to characterise almost all thermoelectric materials, whether they are solid or thin film materials. The LSR L33 can measure the Seebeck coefficient and electrical conductivity (resistivity) of solid materials fully automatically and simultaneously at temperatures of up to 1500°C.

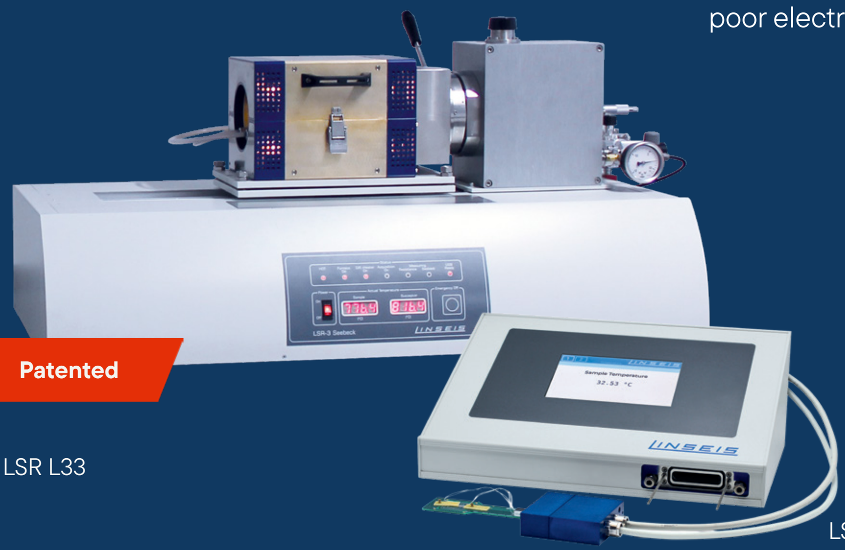
This version can be combined with various options to extend its range of applications. For instance, the low-temperature option enables fully automated measurements using LN_2 cooling down to -100°C, as well as the use of a special thin-film adapter for measuring films and thin layers.

An optional camera enables electrical conductivity to be determined with the highest accuracy, while the high-resistance option significantly extends the measuring range for characterising samples with poor electrical conductivity.

Electrical Resistivity

Seebeck

Direct ZT



Patented

LSR L33

LSR L31

Features

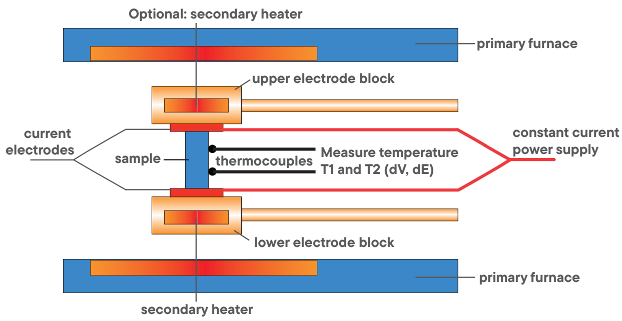
The LSR can simultaneously measure the Seebeck coefficient and electrical resistivity, and optionally the thermal conductivity and ZT using the Harman method.

- Bar-shaped and cylindrical samples with a length between 6 and 23 mm can be analysed.
- Disc-shaped samples with a diameter of 10, 12.7 or 25.4 mm
- Thin films and foils can be analysed using a unique measurement adapter.
- The design of the sample holder guarantees the highest measurement reproducibility (nearly perfect 1-D heat flux through the sample).
- State-of-the-art software enables automatic measurement procedures.
- Direct ZT measurements of bar-shaped and cylindrical samples

Four different exchangeable furnaces cover the temperature range from -100 to 1500°C. The commonly used infrared furnace enables very fast heating and cooling rates, as well as the most accurate temperature regulation according to the set temperature profile.

Method

A sample is positioned vertically between two electrodes. The lower electrode block contains a heater, and the entire measuring arrangement is located within a primary furnace. The furnace surrounding the measuring arrangement heats the sample to a specified temperature. At this temperature, the secondary heater in the electrode block creates a temperature gradient along the sample. Two contacting thermocouples then measure the temperature gradient ($\Delta T = T_{hot} - T_{cold}$) and the electromotive force (dE) at one wire of each thermocouple. The DC four-terminal method is used to measure the electric resistance by applying a constant current (I) to both ends of the sample and measuring the corresponding voltage drop between the wires of each of the two thermocouple pairs. A unique thermocouple contact mechanism enables the highest measurement accuracy.



Technical **Specifications**

	LSR L31
Temperature range	Basic unit: RT to 200°C Cryo option: -160°C to +200°C
Measurement method	Seebeck coefficient Electrical resistivity
Atmosphere	Inert, reducing, oxidising, vacuum Helium gas with low pressure, recommended
Sample holder	Integrated PCB board with primary and seconda-ry heater
Sample size (Seebeck)	L: 8 mm to 25 mm; W: 2 mm to 25 mm; T: Thin film up to 2 mm
Optional round samples (only for resistance)	L: 18 mm to 25 mm; W: 18 mm to 25 mm; D: thin film up to 2 mm
Vacuum pump	optional
Heating rate	0.01 – 100 K/min
Temperature accuracy	±1,5 °C oder 0,0040 · | t |
Electrical conductivity	0.01 to 2x10^5 S/cm
Seebeck coefficient	Measuring range: 0 to 2.5 mV/K - temperature gradient up to 10K Voltage measurement range: ± 8 mV

Product Overview

Product Overview

	LSR L33
Temperature range	Infrared oven: RT up to 800°C/1100°C Resistance oven: RT up to 1500°C Low temperature oven: -100°C to 500°C
Measurement method	Seebeck coefficient: Static DC method / Slope method Electrical resistance: four-point measurement; Resistivity Options: • High resistance option for sample resistance up to 200 MOhm • Low current option optimized for thin film applica-tions
Atmosphere	Inert, reducing, oxidizing, vacuum Helium gas with low pressure recommended
Sample holder	Vertical clamping between two electrodes Optional adapter for films and thin layers
Sample size (cylinder or retangle)	2 to 5 mm base area and max. 23 mm long up to a diameter of 6 mm and a length of max. 23 mm long
Sample size round (disc shape)	10, 12.7, 25.4 mm
Measuring distance of the thermocouples	4, 6, 8 mm
Water cooling	required
Measuring range Seebeck coefficient	1µV/K to 5000 µV/K (static direct current method) Accuracy ±7% / repeatability ±3.5%
Measuring range Electrical conductivity	0.01 to 2×10 5 S/cm ; Accuracy ±10% / repeatability ±5%
Current Source	Low drift current source from 0 to 160 mA (optional 220 mA)

LZT L32

Bulk

Thin Film

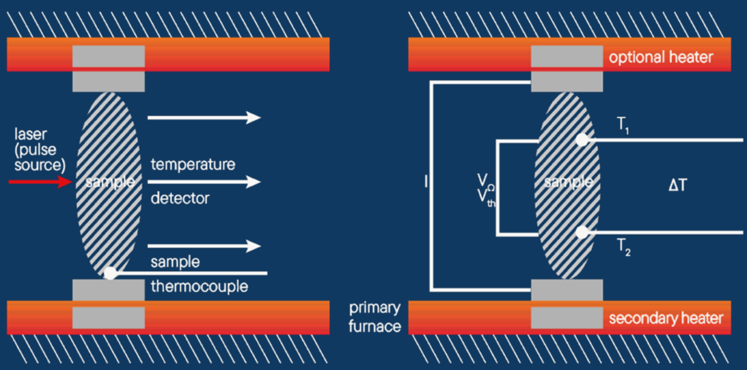
This is the first commercial instrument that can measure all the parameters required for calculating the figure of merit in a single measurement **(combining LSR and LFA)**. The instrument combines three types of measurement: thermal conductivity, electric resistivity and Seebeck coefficient.
This means it can perform the functions of both an LSR and an LFA.
The analyzer is available with different furnace types. These include an advanced infrared furnace for the most accurate temperature control at very high heating and cooling rates; a low-temperature furnace for sub-ambient temperature measurements, a high-temperature furnace for measurements up to 1100 °C in the horizontal configuration, and, upon request, a vertical high-temperature configuration for measurements up to 1500 °C. The included software package provides an easy-to-use interface for evaluating all measured data.

Electrical Resistivity

Seebeck

Thermal Conductivity

LZT L32



LFA-Mode

LSR-Mode

Main advantages of all in one measurement

- Same sample
- Same geometry
- Same stoichiometry
- Absolutely identical environmental conditions (humidity, atmosphere)
- Identical temperature profile
- Possible measurement of high ohmic resistance samples

Product Overview

Technical **Specifications**

	LZT L32
Temperature range	-100°C up to 500°C RT up to 1100°C (horizontal configuration) RT up to 1500°C (on request: vertical configuration)
Specimen holder	Sandwiched between two electrodes optional thin film adapter (for LSR part only)
Atmosphere	inert, oxid., red., vac. (typically helium)
Seebeck (LSR)	
Seebeck coefficient	Static DC method / slope method
Electric resistance	Four-point measurement; Resistivity Options: • High resistance option for sample resistance up to 200 MOhm • Low current option optimized for thin film applications
Sample size (LSR only)	2 to 4 mm diameter x 6 to 23 mm long
Thermal conductivity (LFA)	
Sample size (LFA and LSR)	ø 10, 12.7, 25.4 mm
Lead interval	4, 6, 8 mm
Pulse source	Nd: YAG laser with up to 25 J/pulse
Pulse duration	0.01 up to 5 ms
Detector	InSb
Thermal diffusivity	
Measuring range	0.01 up to 1000 mm^2/s

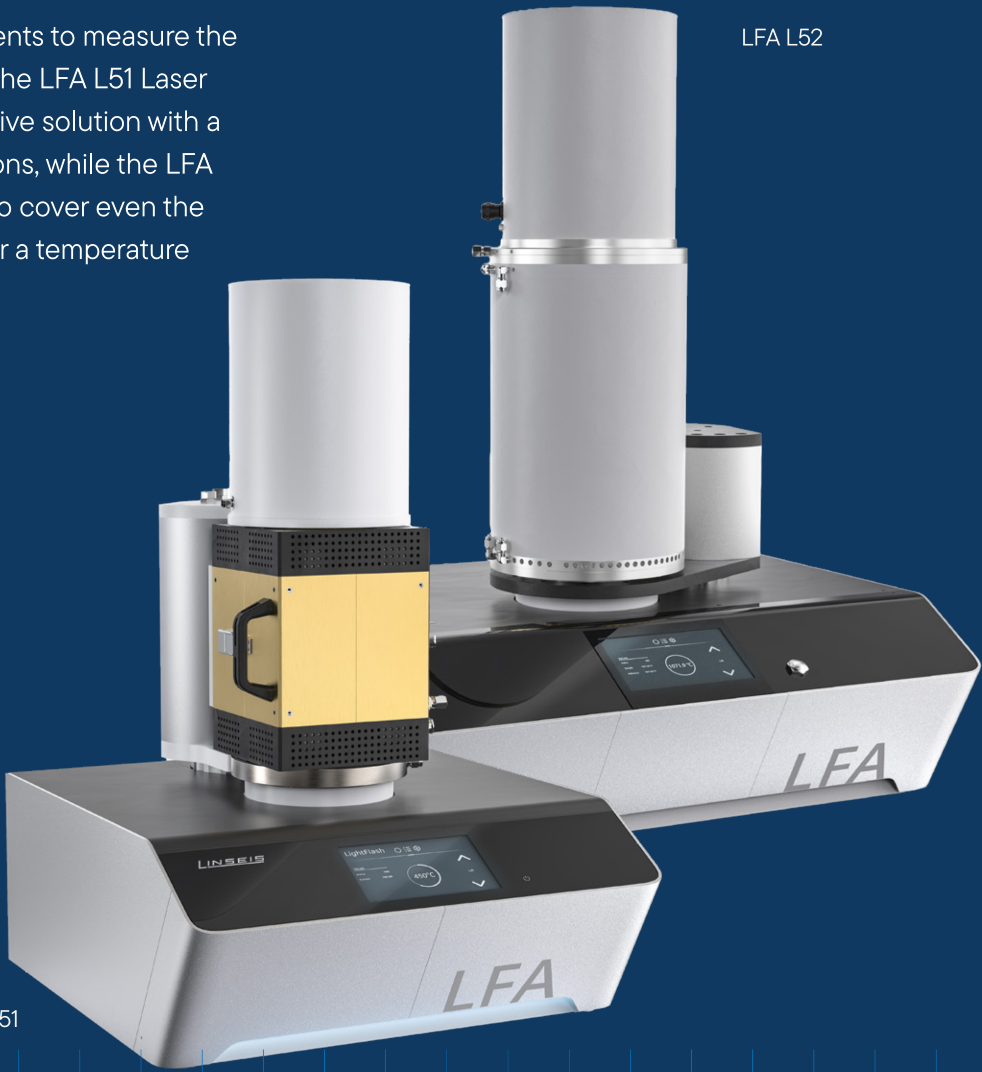
Laser Flash
Analysis

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 L51 Laser Flash series provides a cost-effective solution with a xenon lamp for standard applications, while the LFA L52 uses a powerful laser source to cover even the most challenging applications over a temperature range from -125°C to 2800°C.

LFA L52



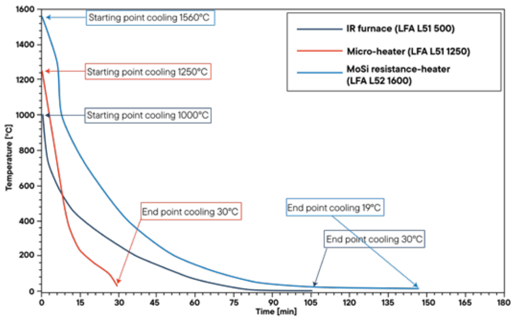
LFA L51

High speed furnace

The LFA unit is equipped either with a high-speed infrared furnace (LFA L51 500/1000) or with an advanced micro-heater (LFA L51 500/1250), while the LFA L52 uses powerful $MoSi_2$ or graphite heaters to cover the broadest temperature and application range. This technology enables unmatched heating and cooling rates, excellent temperature control, high temperature homogeneity, and outstanding precision.

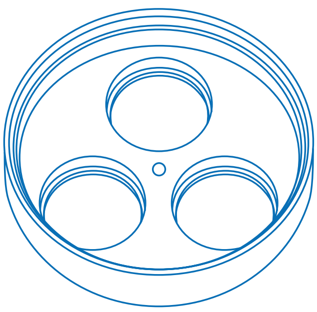
The system can be either equipped with an InSb or with a MCT detector, covering the complete temperature range from sub-ambient temperature up to 2800°C. Both are easily user exchangeable. For LN_2-free operation, the system can be equipped with a Peltier-cooled detector. For configurations requiring LN_2 cooling, an automatic refilling accessory with Dewar flask ensures prolonged measurement cycles.

Because time matters

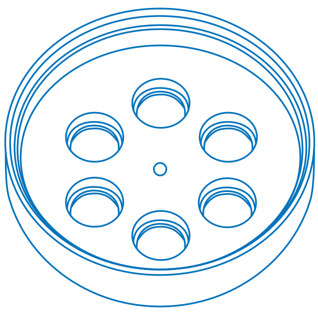


Cooling comparison of IR furnace, micro-heater, and MoSi resistance-heater clearly demonstrates the advantage of short cool-down times. This allows multiple measurements in quick succession and improves sample throughput. The IR furnace cools from 1000°C to 30°C in 105 minutes, while the micro-heater takes only ~26.5 minutes. Even when cooling from 1250°C, it stays below 30 minutes. The MoSi-heater, used for comparison, cools from 1560°C to 19°C in approximately 147 minutes.

Sample carriers



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

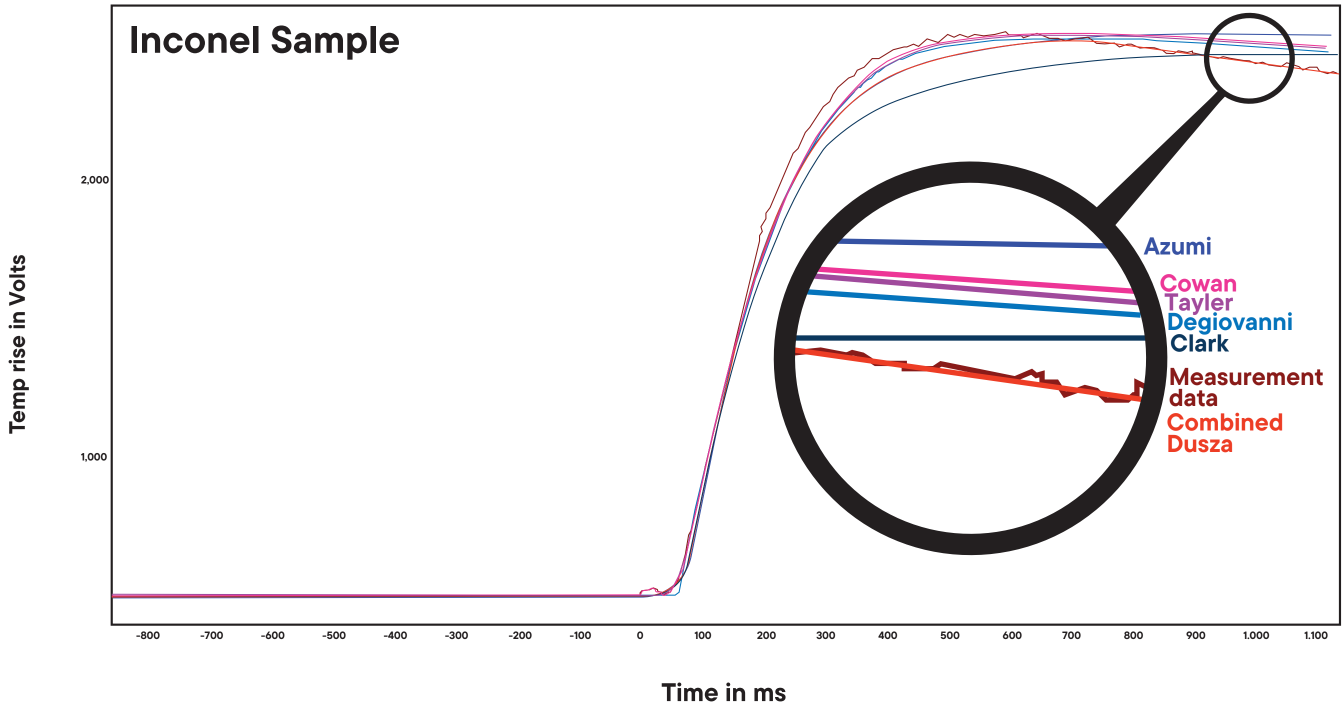


6 round (3, 5, 6, 8, 10, 12.7 mm) or square (3, 5, 5, 10 mm) samples

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**

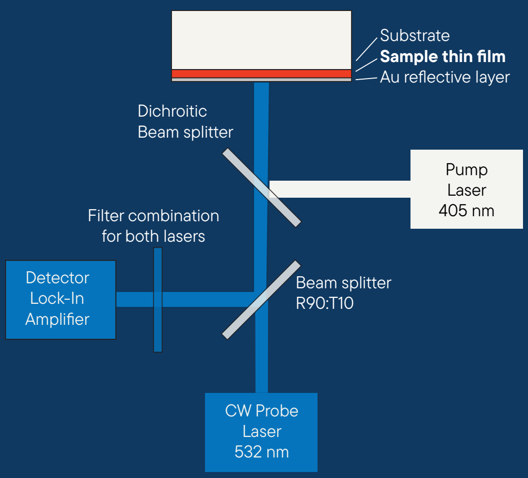
	LFA L51	LFA L52
Temperature range	–100°C up to 500°C RT up to 500 / 1000 / 1250°C	–100°C up to 500°C RT up to 1250 / 1600 / 2000 / 2400 / 2800°C
Heating rate	0.01 up to 100 K/min (depending on model)	0.01 up to 50 K/min (LT/1250/1600) 0.01 up to 100 K/min (2000/2400/2800)
Thermal Diffusivity	0.01 up to 1000 mm^2/s	0.01 up to 1000 mm^2/s
Thermal Conduc-tivity	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 25 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 1250°C MCT: –100°C up to 500°C	InSb: RT up to 2800°C MCT: –100 °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	2.5 MHz	2.5 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

Frequency 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, 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 a few nm up to µm range.

Simplified schematic setup



TF-LFA L54

Product Overview

Technical **Specifications**

<table>
<tr><td>Sample dimensions</td><td colspan="3">Any shape with lateral dimensions between 2 mm x 2 mm and 25 mm x 25 mm</td></tr>
<tr><td rowspan="2">Thin film samples</td><td colspan="2">Standard version*</td><td>With measurement range extension*</td></tr>
<tr><td colspan="2">Low conductive material:
From 30 nm to 20 µm

Moderate conductive material:
From 200 nm to 20 µm

High conductive material:
From 1 µm to 20 µm</td><td>Low conductive material:
From 10 nm to 20 µm

Moderate conductive material:
From 10 nm to 20 µm

High conductive material:
From 80 µm to 20 µm</td></tr>
<tr><td>Temperature range</td><td colspan="3">-100 °C up to 500 °C
Sample holder for 4“ Wafer (only RT)</td></tr>
<tr><td>Measured properties</td><td colspan="3">Thermal conductivity: 0.01 W/mK - 2000 W/mK
Thermal diffusivity: 0.01 mm^2/s - 1200 mm^2/s
Thermal interface resistance: 0.1 MW/m^2K - 100 MW/m^2K
Volumetric specific heat capacitiy: 0.1 MJ/m^3K - 10 MJ/m^3K
Thermal effusivity: 1000 $Ws^{1/2}/m^2K$ - 100000 $Ws^{1/2}/m^2K$</td></tr>
<tr><td rowspan="2">Options</td><td>Anisotrophy</td><td>Sample mapping</td><td>Flexible Probe Laser</td></tr>
<tr><td>Hardware and Software extension to extend the capbabilities of the system to measure the in-plane thermal transport properties. Thus anisotropy investigations can be performed.</td><td>Scanning multiple positions of the sample pointwise or clusterwise. Mapping area: 10 mm^2
Stepsize: 50 µm</td><td>Selectable transducer material (e.g., gold, aluminium, molybdenum, etc.) with optimized probe laser wavelengths to ensure reliable signal detection. An optional dual-laser setup provides maximum flexibility by supporting both transducer materials within one system.</td></tr>
<tr><td>Atmosphere</td><td colspan="3">inert, oxidizing or reducing
vaccuum up to 10 E^{-4}</td></tr>
<tr><td>Integrated Camera</td><td colspan="3">Allows the user to view the present sample surface and the position of the laser beams to record the actual measurement position</td></tr>
<tr><td>Pump laser</td><td colspan="3">CW Laser (405 nm, 300 mW,
modulations frequency up to 200 MHz)</td></tr>
<tr><td>Probe laser</td><td colspan="3">CW Laser (532 nm, 25 mW)</td></tr>
<tr><td>Photodetector</td><td colspan="3">Si Avalanche Photodetector, active diameter: 0.2 mm, bandwidth: DC - 400 MHz</td></tr>
<tr><td>Power supply</td><td colspan="3">AC 100 V ~ 240 V, 50/60 Hz, 1 kVA</td></tr>
<tr><td>Software</td><td colspan="3">Included. Software package using multi-layer analysis for calculation of thermophysical properties</td></tr>
</table>

*actual thickness range depends on sample

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

System Configurations

Basic system / Thermoelectric kit / Magnetic kit / Cooling option

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

Basic device (incl. transient package)
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

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

- ρ – Electrical Resistivity / σ – Electrical Conductivity
- S – Seebeck Coefficient

Magnetic package
Two different configurations for the magnetic package are available. Either a movable electromagnet (EM) with power supply, field switch, safety circuit and water cooling or a movable configuration with two permanent magnets (PM). The electromagnet allows the user to apply a variable field strength between +/- 1 Tesla perpendicular to the sample. The permanent magnet setup can only be used to apply three defined field points (+0.5 T, 0T and -0.5T) to the sample. Both design are optimized for measuring the following parameters:

- AH – Hall Constant
- μ – Mobility (calculation depending on model)
- n – Charge carrier concentration (calculation depending on model)

Low temperature option for controlled cooling

- LN_2 cooling down to -160°C
- TFA/KREG controlled cooling unit
- TFA/KRYO Dewar 25l

Integrated Thin Film Characterization

The TFA L59 combines multiple measurement techniques on a single pre-structured chip. Depending on the configuration, thermal conductivity, electrical conductivity, Seebeck coefficient and Hall properties can be determined on the same thin-film sample. This enables highly comparable results under identical measurement conditions and in the same in-plane direction.

The sample can be deposited directly onto the chip using PVD, CVD, ALD, spin coating, drop casting or ink-jet printing. Measurements are typically performed under UHV conditions, while the sample temperature can be controlled from –160 °C to 280 °C. Thanks to its modular design, the system can be extended with thermoelectric and magnetic measurement capabilities.

Van der Paul & Hall
Electrical transport properties

Seebeck Coefficient
Thermoelectric characterization

Thermal Conductivity
In-plane thin film analysis

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

Bulk

Thin Film

Hall-Effect
Characterization System

The LINSEIS HCS (Hall-Effect Characterization System) enables the characterization of semiconductor devices in terms of their electrical transport properties, particularly Hall mobility, charge carrier concentration, resistivity and Seebeck coefficient.

The integrated desktop setups offer a complementary range of products, from a basic manually operated Hall characterization stage to an automated high-temperature set-up with an electromagnet (HCS L36 Ultimate) and an innovative Halbach configuration (HCS L36 Advanced) for characterising the most challenging samples.

HCS L36 *Ultimate*

HCS L36 *Basic*

HCS L36 *Advanced*

Measurement features

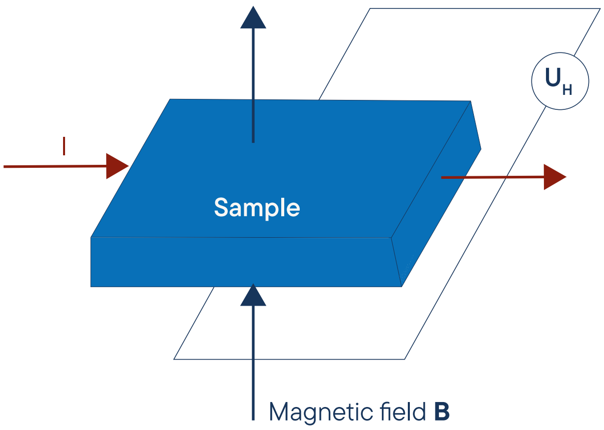
- Charge Carrier Concentration (Sheet [1/cm²]/ Bulk [1/cm³])
- Hall-Constant [cm³/C]
- Hall-Mobility [cm²/Vs]
- Sheet resistance [Ω]
- Resistivity [Ωcm]
- Conductivity [S/cm]
- Alpha (horizontal/vertical ratio of resistance)
- MAGNETO resistance
- Seebeck Coefficient [µV/K]

Hall Effect

The **Hall effect** provides the physical basis for determining key transport parameters in solids. The Hall voltage, which is induced by a perpendicular magnetic field, is directly related to the type, density, and mobility of the charge carriers, thereby enabling the comprehensive characterization of materials.

The voltage is called **Hall voltage U_H**

Measuring Principle



The Hall voltage U_H is measured perpendicular to the direction of current flow. The sign of U_H allows the dominant charge carrier type (*n-type* or *p-type*) to be determined.

$$U_H = A_H \cdot \frac{I \cdot B}{d}$$

A_H:	Material dependent Hall constant
I:	Current through the conductor
B:	Magnetic flux density
d:	Thickness of the conductor parallel to the magnetic field direction

Derived parameters

Charge Carrier Concentration *(n or CCC)*

$$n = \frac{1}{A_H \cdot e}$$

e: *elementary charge*

Hall mobility (μ)

$$\mu = \frac{A_H}{\rho}$$

ρ: *electrical resistivity*

Technical **Specifications**

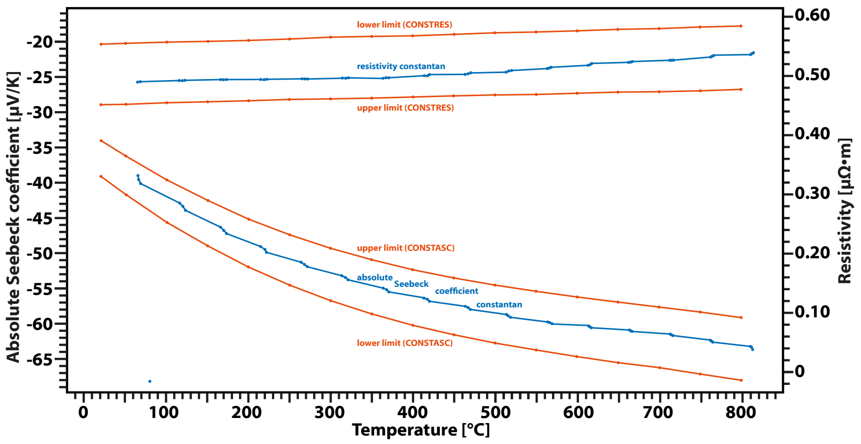
	HCS L36 ***Basic***	HCS L36 ***Advanced***	HCS L36 ***Ultimate***
Temperature range	LN_2 up to 600 °C in different versions (continuously from LT to HT) -160 °C (controlled co-oling) -196 °C (quench cooling)	-150 °C up to 200 °C (controlled cooling) and RT up to 600 °C	LN2 up to 600 °C in different versions (continuously from LT to HT) -160 °C (controlled co-oling) -196 °C (quench cooling)
Magnet	Permanent magnets up to 0.70 T DC field Pole diameter 120 mm Two magnet setup for bi-polar measurement.	Multisegment cylindrical Halb-ach array up to 0.5 T, inner diameter 60 mm AC field up to 0.5 Hz or DC field	Electromagnet with 76 mm of pole diameter. AC power supply for measu-rements up to 0.1 Hz at up to +-40 A
Current source	**DC** 1 nA up to 125 mA (8 decades / Compliance +/- 12 V)		
Voltage measurement	**DC** low noise / low drift 1 µV up to 2500 mV 4 decades amplification Digital resolution: 300 pV	**DC** low noise / low drift 1µV up to 2500mV 4 decades amplification Digital resolution: 300pV **AC** 20 nV up to 1V Features: GΩ range input impedance, variable integration times and amplfication	
Sensors / Sample geometry	Seebeck Sensor, Illumination Sensor, Gated hall bar From 5 x 5 mm^2 to 12.5 x 12.5 mm^2 Maximum sample height 3 mm From 17.5 x 17.5 mm^2 up to 25 x 25 mm^2 Maximum sample height 5 mm From 42.5 x 42.5 mm^2 up to 50 x 50 mm^2 Maximum sample height 5 mm High Temperature board from 10 x 10 mm^2, max. sample height 3 mm	Seebeck Sensor, Illumination Sensor, Gated hall bar From 5 x 5 mm^2 to 12.5 x 12.5 mm^2 Maximum sample height 3 mm High Temperature board from 10 x 10 mm^2, max. sample height 3 mm From 17.5 x 17.5 mm^2 up to 25 x 25 mm^2, max. sample height 3 mm	Seebeck Sensor, Illumination Sensor, Gated hall bar From 5 x 5 mm^2 to 12.5 x 12.5 mm^2 Maximum sample height 3 mm From 17.5 x 17.5 mm^2 up to 25 x25 mm^2 Maximum sample height 5 mm From 42.5 x 42.5 mm^2 up to 50 x 50 mm^2 Maximum sample height 5 mm High Temperature board from 10 x 10 mm^2, max. sample height 3 mm
Resistivity Range	10^{-4} up to 10^7 (Ωcm)	10^{-4} up to 10^7 (Ωcm)	10^{-4} up to 10^7 (Ωcm)
Carrier concentration	10^7 up to $5x10^{22}$ cm^{-3}	10^7 up to 10^{23} cm^{-3}	10^7 up to 10^{23} cm^{-3}
Mobility range	0.1 ~ 10^7 cm^2/Vs	10^{-2} up to $10^7 cm^2/Vs$	10^{-2} ~ 10^7 $cm^{2/}$ Vs
Atmospheres	Vacuum, inert, oxidizing, reducing	Vaccum, inert, oxidizing, reducing	Vaccum, inert, oxidizing, reducing
Temperature resolution	0.001 °C	0.001 °C	0.001 °C

*The actual measurement range depends on the properties of the sample and the geometry

Applications

Measurement of the constantan reference sample

LSR LZT

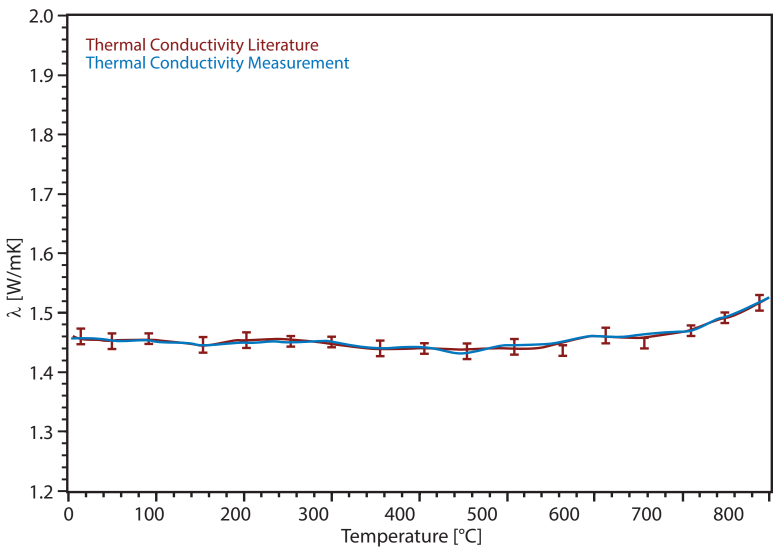


In contrast to the Bi2Te3 reference sample provided by NIST (SRM 3451)™, which is only useable in the low temperature range up to 390 K, our constantan reference sample can be used as a high temperature reference sample up to 800°C.

The measurment shows a typical result which fits perfectly in the specified tolerances.

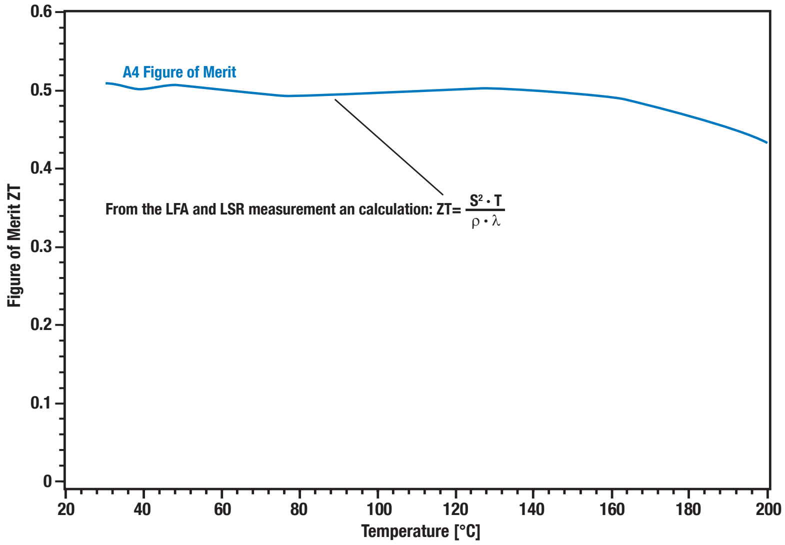
Measurement of thermal conductivity of a ceramic sample using LFA

LFA LZT



With the LFA, the thermal conductivity of a SiO-containing ceramic sample was measured over temperature. The results show a slightly increasing thermal conductivity over temperature in the range of up to 1.5 W/mK.

Figure of Merit (Calculation) over temperature of $(BiSb)_2Te_3$

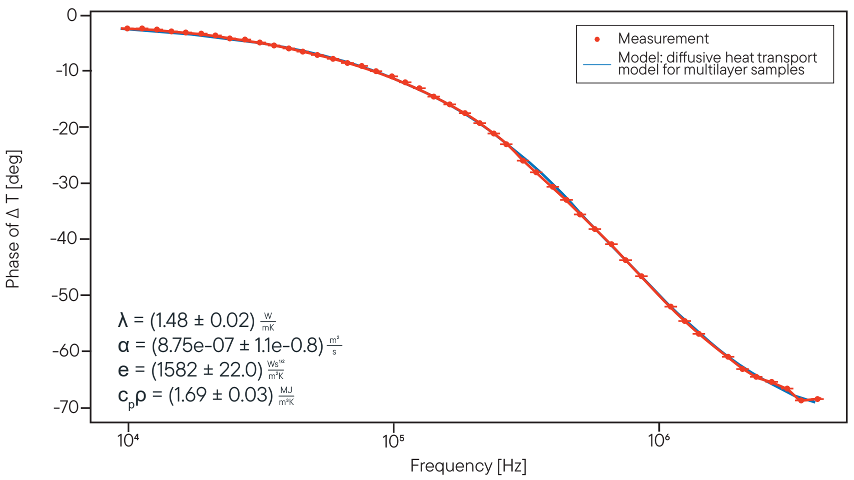


LFA

LZT

LSR

Measurement of a SiO2 thin film 504 nm

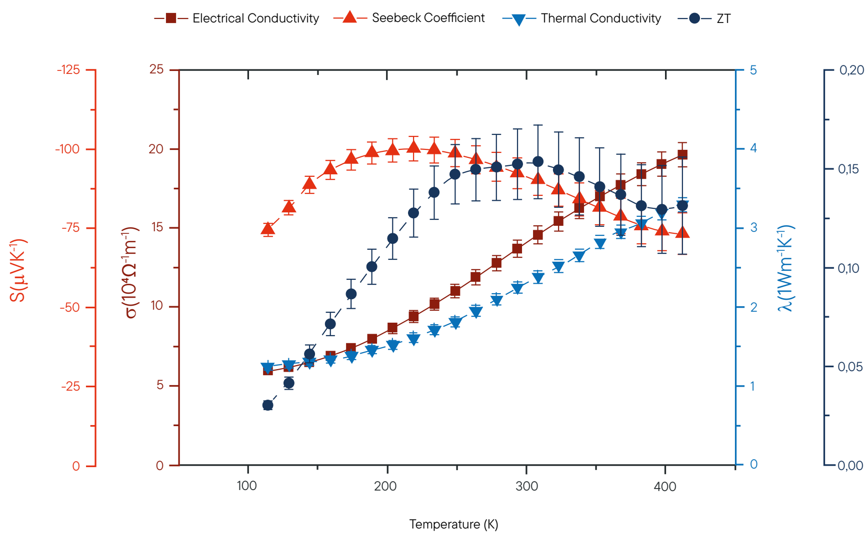


TF-LFA

Thin film glass layers out of pure silicon dioxide (Quartz) are frequently used in semiconductor and electronic industries as protective layer or thermo or electronical insulation layers. In this example SiO2 layer was investigated using the Linseis TF-LFA device to fully characterize its thermal properties.

Full ZT characterization of a 142 nm $Bi_{87}Sb_{13}$ thin film

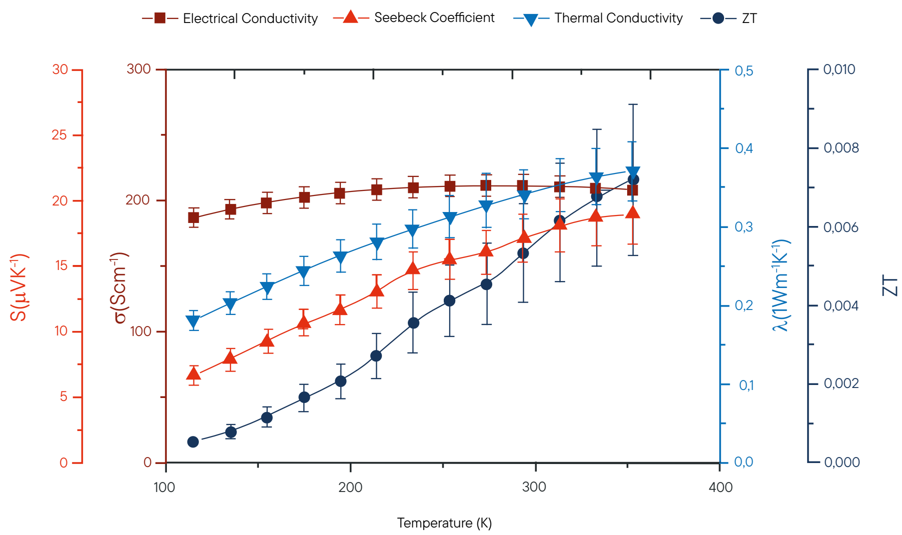
TFA



Measured electrical conductivity, thermal conductivity and Seebeck coefficient as well as calculated ZT value of a 142 nm thick Bi87Sb13 nanofilm, prepared by thermal evaporation in the temperature range from 120 K up to 400 K.

Full ZT Characterization of a PEDOT: PSS layer

TFA



Measured electrical conductivity, thermal conductivity and Seebeck coefficient as well as calculated ZT value of a 15 µm thick PEDOT:PSS thin film, prepared by drop casting in the temperature range from 110 K up to 350 K.

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pushing boundaries

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