LINSEIS

pushing boundaries

TF-LFA FDTR L54

Thin Film **Laser Frequency Analyzer**

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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 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, 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.

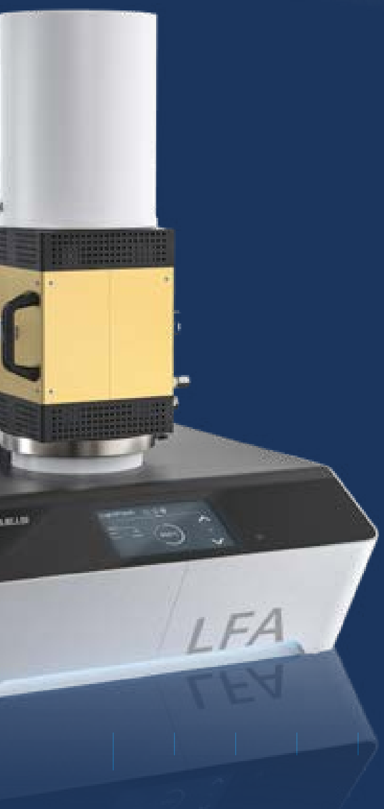
CLAUS LINSEIS

CEO DIPL. PHYS.

Enginering & Innovation

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.

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.



Thin Film Laser **Frequency Analyzer**

Information of the thermo physical 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 non-destructive optical method has developed into the most commonly used technique for the measurement of the thermal diffusivity and thermal conductivity of various kinds of solids, powders and liquids. Thermophysical properties from 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 the semiconductor industry. All these industries deposit a film on a substrate in order to give a device a particular function. Since the physical properties of these films differ from bulk material, these data are required for accurate thermal management predictions.

Thermal properties

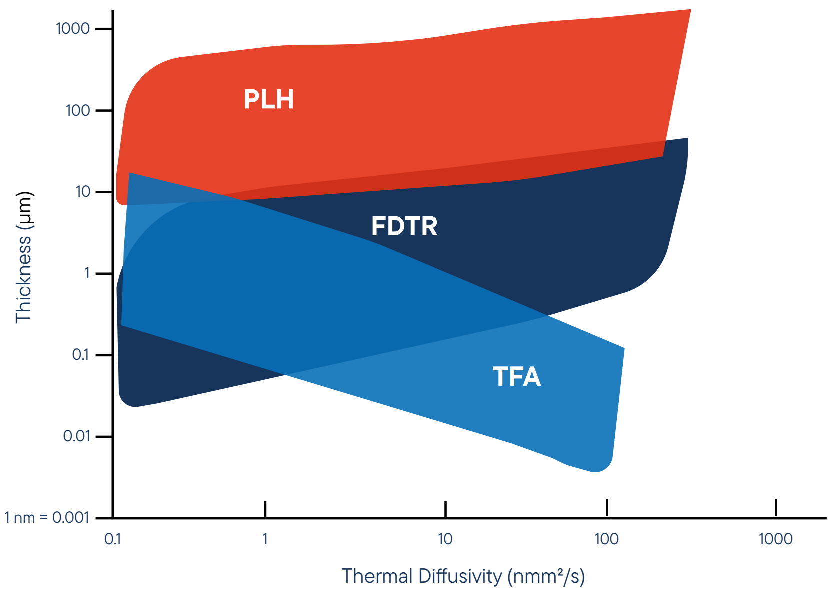
- Thermal Conductivity
- Volumetric Heat Capacitiy
- Thermal Diffusivity
- Thermal Effusivity
- Thermal Boundary Conductance

Thin Films

Thin films are materials with thicknesses from nanometers to micrometers, applied to surfaces. Their thermophysical properties differ significantly from bulk materials and depend on thickness and temperature. Thin films are typically used in semiconductors, LEDs, fuel cells, and optical storage media.

Different kinds of Thin Films

- Thin film: layer of few nm to µm
- Films are grown on specific substrate
- Typical growing techniques include
  - PVD (e.g. Sputtering, thermal evaporation)
  - CVD (PECVD, LPCVD, ALD)
  - Drop casting, Spin coating & Printing
- Many different kind of films, including:
  - Semiconducting films (e.g. thermoelectric, sensors, transistors)
  - Metallic films (used as contacts)
  - Thermal barrier coatings
  - Optical coatings



Mulitlayer sample

5nm to 20µm — Thin film (e.g. semiconductor, metal, organic, oxide)

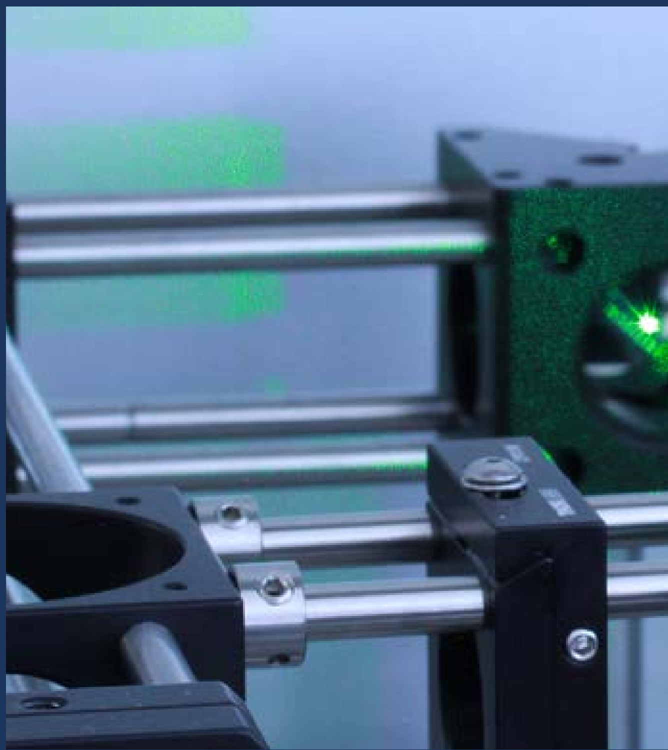
> 100µm to mm — Substrate (e.g. Si, Si3N4,Fused Silica)

Unique features

Complete thermal characterization of thin films

- Thermal conductivity
- Thermal diffusivity
- Thermal effusivity
- Volumetric heat capacity

No more assumptions of heat capacity and density of thin films.



Determination of the thermal contact resistance/conductance

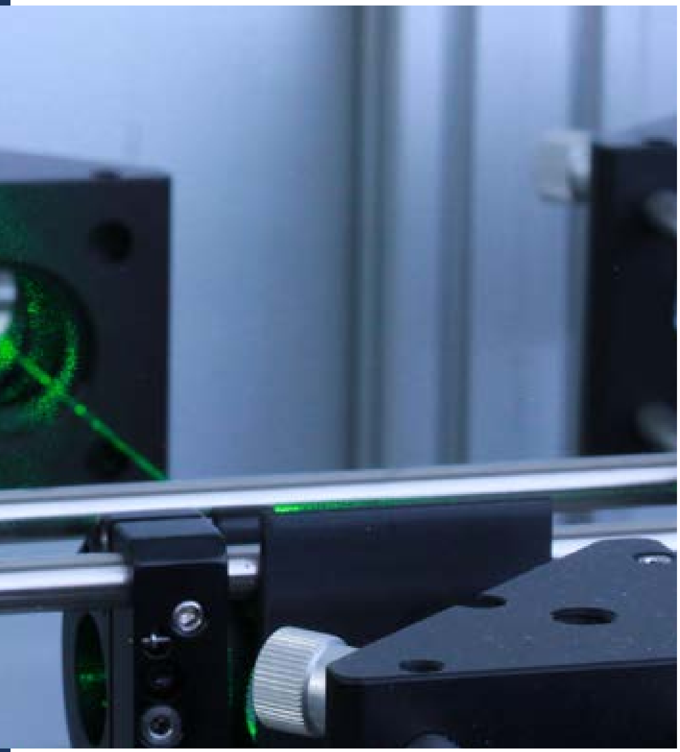
Measure the thermal contact between two adjacent layers (e.g. sample to surface or sample to transducing layer)

Anisotropy measurements

Optional anisotropy function which allows the measurement of the thermal conductivity in the cross-plane (through the material) and in-plane (perpendicular to the laser excitation) direction.

Broad temperature range

The instrument is capable to measure the thermal properties of thin films from room temperature up to 500°C.



Thermal mapping

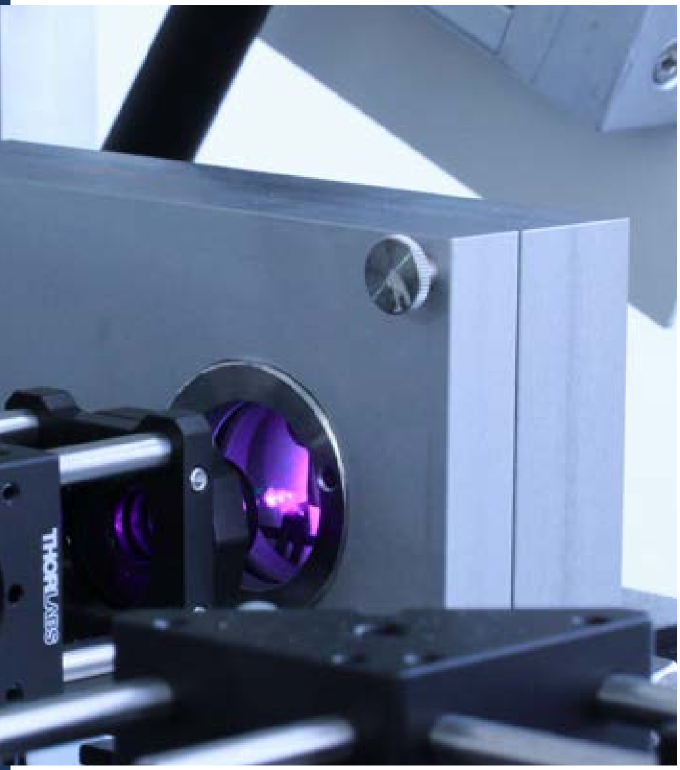
With the optional sample mapping option, it is possible to track down the thermal properties of the sample over a specific area or points of the surface. Perfect for homogeneity checks.

Automatic optimization

Stressless optimization of the laser beam focusing to improve the measurement results.

Camera option

Additional camera option simplifies life by giving additional visual information. This allows the user to actually see the sample surface and therefore decide, where interesting spots are located on the sample.



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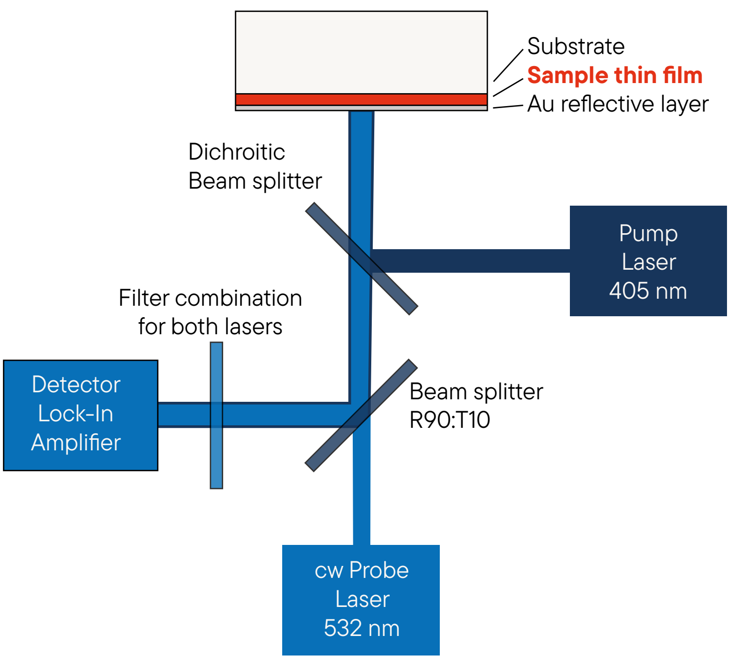
FDTR
Frequency Domain

Theory Frequency Domain Thermoreflectance

FDTR is a contactless characterization technique for thin film thermal material properties in the frequency domain, where is a contactless characterization of thin films thermal properties in the frequency domain, where the effect of thermoreflectance is used to establish a highly sensitive thermometer to sense the surface temperature of the sample, by monitoring the reflectivity. For this a continuous wave laser (Probe laser) with 532 nm wavelength is used, while heating with a harmonically modulated pump laser at a different wavelength (405 nm). Local heating induces changes in the reflectivity and the phase lag between the thermal excitation and the detection is measured using a lock-in amplifier. Modelling the response in the frequency domain with a diffusive heat transport model allows us to determine the thermal conductivity, volumetric heat capacity, thermal diffusivity, thermal effusivity and thermal interface conductance. A thin metallic transducer layer (60 -70 nm in thickness) is deposited on top of the surface of the samples to enhance the temperature coefficient of reflectance, dR/dT, and at the same time to reduce the optical penetration depth in the material.

Simplified schematic setup

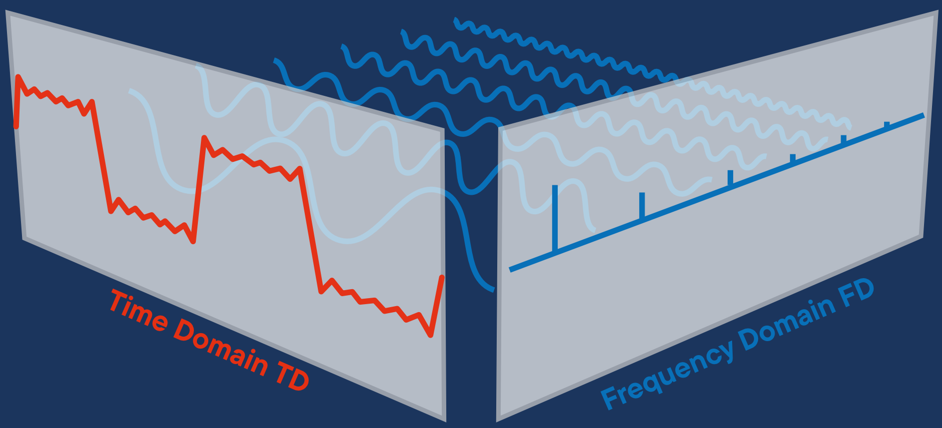


Comparison of FDTR and TDTR Methods

Our advanced FDTR (Frequency-Domain Thermoreflectance) system offers significant advantages over the traditional TDTR (Time-Domain Thermoreflectance) method, optimizing the setup and enhancing measurement stability.

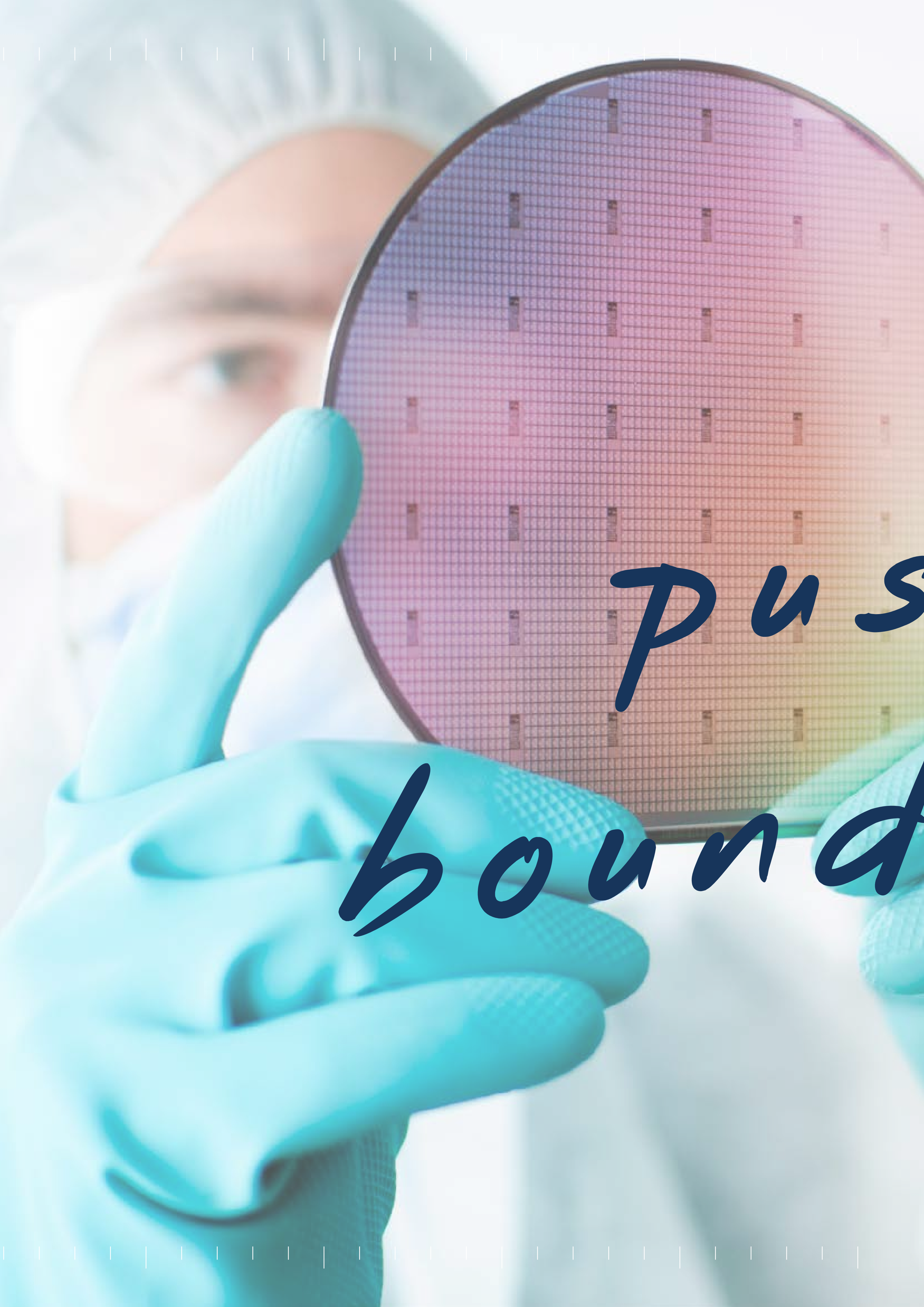
No need for probe laser adjustment: Unlike the TDTR arrangement, where the probe laser must be adjusted relative to the sample due to slight changes in reflection when the sample is altered, our FDTR system eliminates this necessity. Our system includes automatic focusing, which continuously adjusts the probe laser's focus to accommodate any changes in the sample, ensuring optimal measurement conditions without manual intervention

Aligned lasers: With perfectly aligned lasers in our FDTR system, there is no need to adjust the probe laser beam, resulting in a simpler sample setup and more stable measurements.



Advantages:

- Broader measuring range
- Easier handling
- Higher stability
- More precise results
- Possibility to measure thermal contact resistance between two layers
- No more assumptions of heat capacity and density of thin sample films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Software

All thermo analytical devices of LINSEIS are PC controlled, the individual software modules exclusively run under Microsoft® Windows® operating systems. The complete software consists of 3 modules: temperature control, data acquisition and data evaluation. The LINSEIS software encounters all essential features for measurement preparation, execution and evaluation, just like with other thermo analytical experiments. Due to our specialists and application experts LINSEIS was able to develop this easy understandable and highly practical software.

General Software

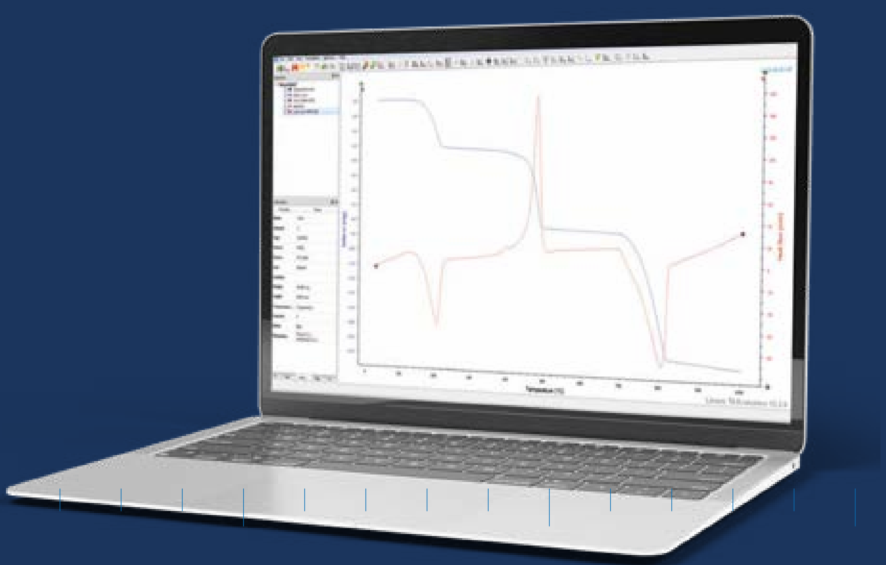
- Fully compatible MS® Windows™
- Data security in case of power failure
- Evaluation of current measurement
- Curve comparison
- Storage and export of evaluations
- Export and import of data ASCII
- Data export to MS Excel

Measurement Software

- Easy and user-friendly data input for temperture segments, gases etc.
- Fully automated measurement

Evaluation Software

- Determination of contact resistance
- Multilayer heat transport model to extract the thermal conductivity, thermal diffusivity, thermal effusivity and volumetric heat capacity at once
- Measurement feasibility check
- Sensitivity Plot



Technical Specifications

Product Overview

Sample dimensions	Any shape between 2mm x 2mm and 25mm x 25mm lateral size		
Thin film samples	10nm up to 20µm* (depends on sample)		
Temperature range	RT, RT up to 200/500°C Sample holder for 4“ Wafer (only RT)		
Measured properties	Thermal conductivity Thermal diffusivity Thermal interface resistance Volumetric specific heat capacitiy Thermal effusivity		
Options	**Anisotrophy**	**Sample mapping**	**Camera**
	Measurement of cross-plane and in-plane thermal properties	Scanning multiple positions of the sample pointwise or clusterwise. Map-ping area: 10 mm² Stepsize: 50 µm	Allows the user to view the present sample surface and the position of the laser beams to record the actu-al measurement position.
Atmosphere	inert, oxidizing or reducing vaccuum up to 10E-4		
Diffusivity measuring range	0.01mm²/s up to 1200mm²/s (depends on sample)		
Pump laser	CW Laser (405 nm, 300 mW, modulations frequency up to 200 MHz)		
Probe laser	CW Laser (532 nm, 25 mW)		
Photodetector	Si Avalanche Photodetector, active diameter: 0.2 mm, bandwidth: DC - 400MHz		
Power supply	AC 100V ~ 240V, 50/60 Hz, 1 kVA		
Software	Included. Software package using multi-layer analysis for calcula-tion of thermophysical properties		

*actual thickness range depends on sample

Applications
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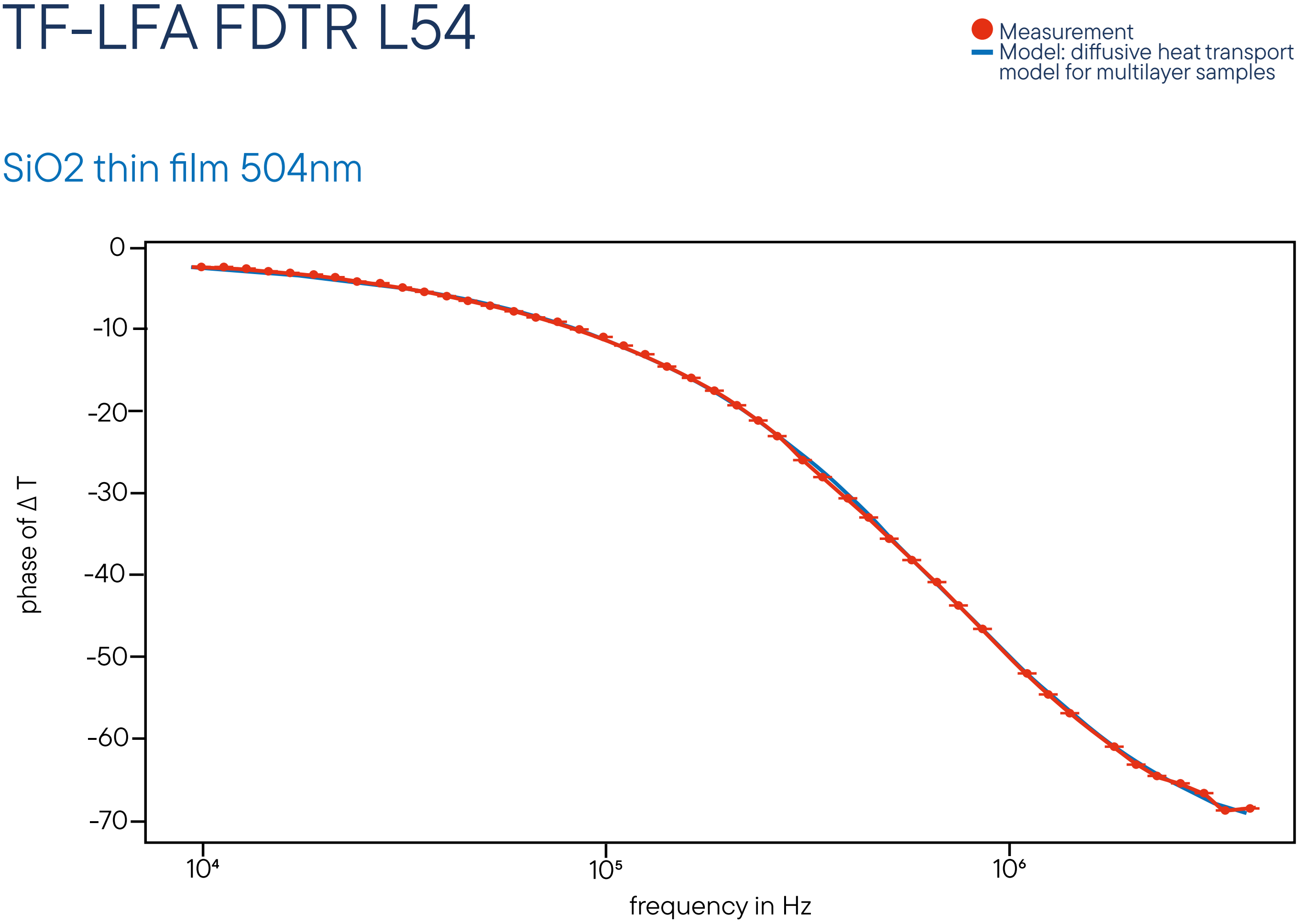
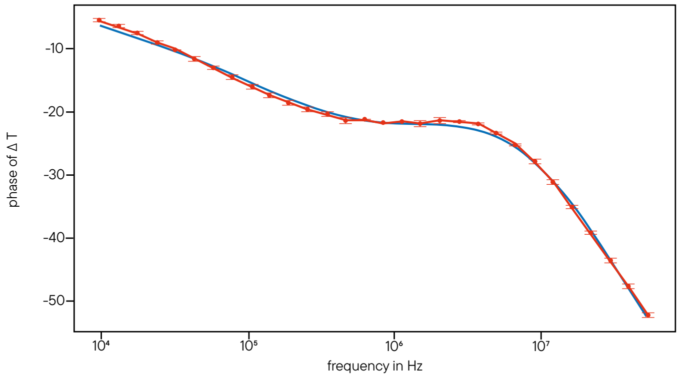


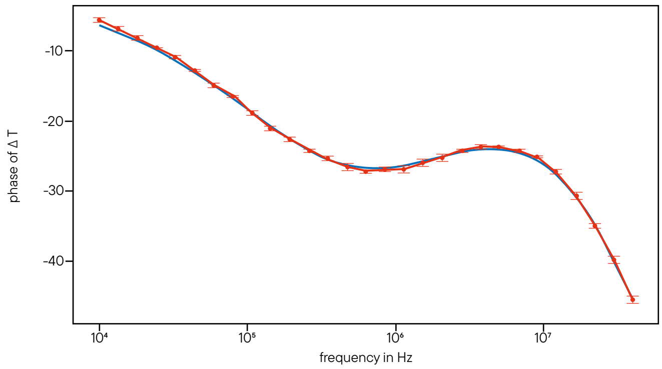
SiO2 thin film 504nm

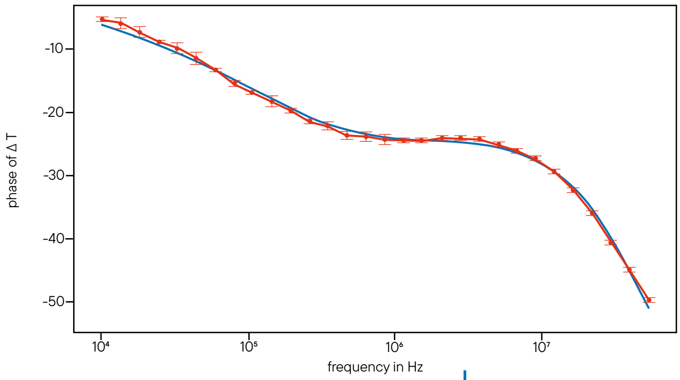
Thermal conductivity λ / $\frac{W}{mK}$	1.48 ± 0.02
Thermal diffusivity α / $\frac{m^2}{s}$	8.75e-07 ± 1.1e-08
Thermal effusivity e / $\frac{Ws^{1/2}}{m^2K}$	1582 ± 22.0
Volumetric heat capacity $c_p\rho$ / $\frac{MJ}{m^3K}$	1.69 ± 0.03

Linseis Service Lab

Aluminum nitride AlN







	200nm	800nm	1600nm
Thermal boundary conductivtiy $\lambda_{TBC} / \frac{W}{mK}$	0.069 ± 0.007	0.049 ± 0.001	0.044 ± 0.0
Thermal boundary conductance $TBC / \frac{MW}{m^2K}$	68.549 ± 6.922	48.783 ± 1.245	44.368 ± 0.468
Thermal conductivity $\lambda / \frac{W}{mK}$	13.73 ± 1.56	38.57 ± 2.58	41.43 ± 0.85
Thermal diffusivity $\alpha / \frac{mm^2}{s}$	5.15 ± 0.73	11.26 ± 1.45	10.26 ± 0.39
Thermal effusivity $e / \frac{Ws^{1/2}}{m^2K}$	6049.0 ± 534.0	11493.0 ± 205.0	12930.0 ± 100.0
Volumetric heat capacity $c_p\rho / \frac{MJ}{m^3K}$	2.67 ± 0.3	3.42 ± 0.23	4.04 ± 0.08

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