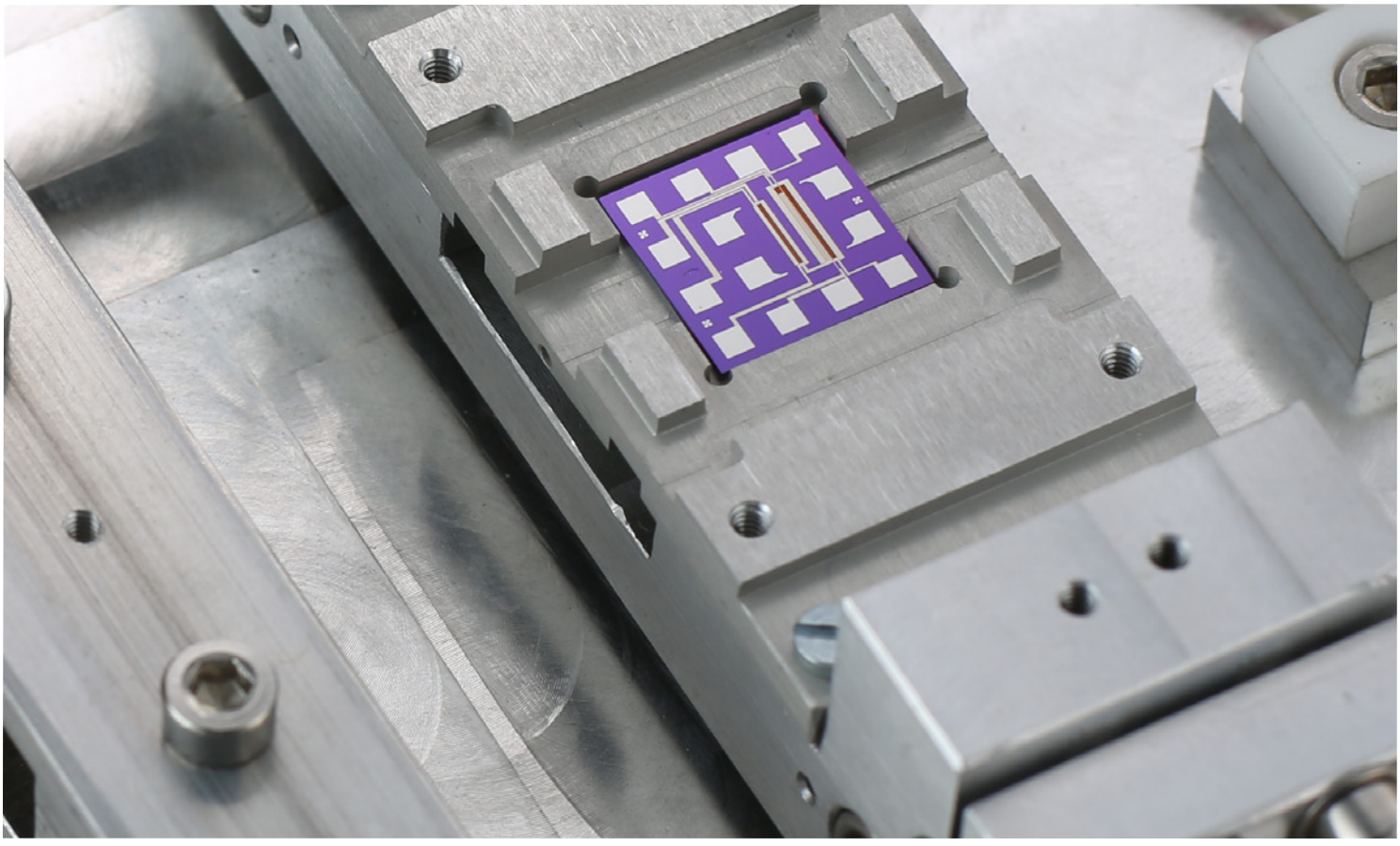
LINSEIS

THERMAL ANALYSIS

THIN FILM ANALYZER | TFA



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.

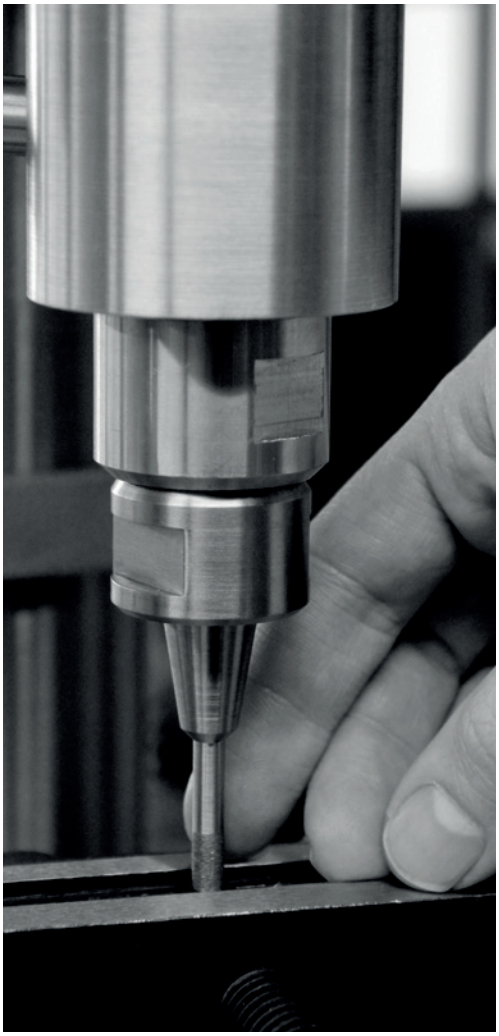
We are driven by innovation and customer satisfaction.

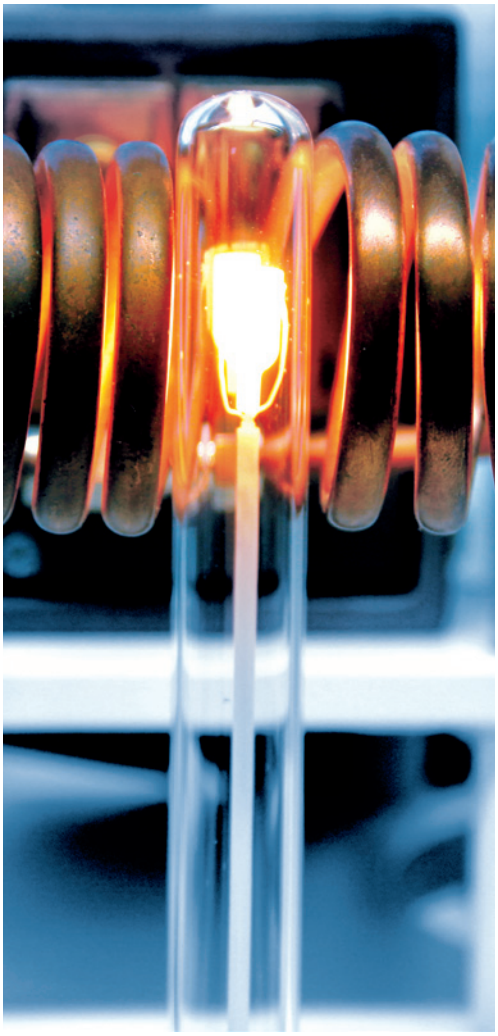
Customer satisfaction, innovation, flexibility and high quality are what LINSEIS represents. Thanks to these fundamentals our company enjoys an exceptional reputation among the leading scientific and industrial organizations. LINSEIS has been offering highly innovative benchmark products for many years.

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 manufacture thermo analytic and thermo physical 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 thermo analytical 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.

THIN FILM ANALYZER

The LINSEIS Thin Film Analyzer 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 Firmware 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 to learn more about their structure and conduction mechanism but also important for technical applications.

Measurement Setup

The LINSEIS TFA 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 300°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 semocinducting behaviour as well as metalls, ceramics or organics. Therefore many different deposition methods like PVD or Spin coating and drop casting are possible to use.



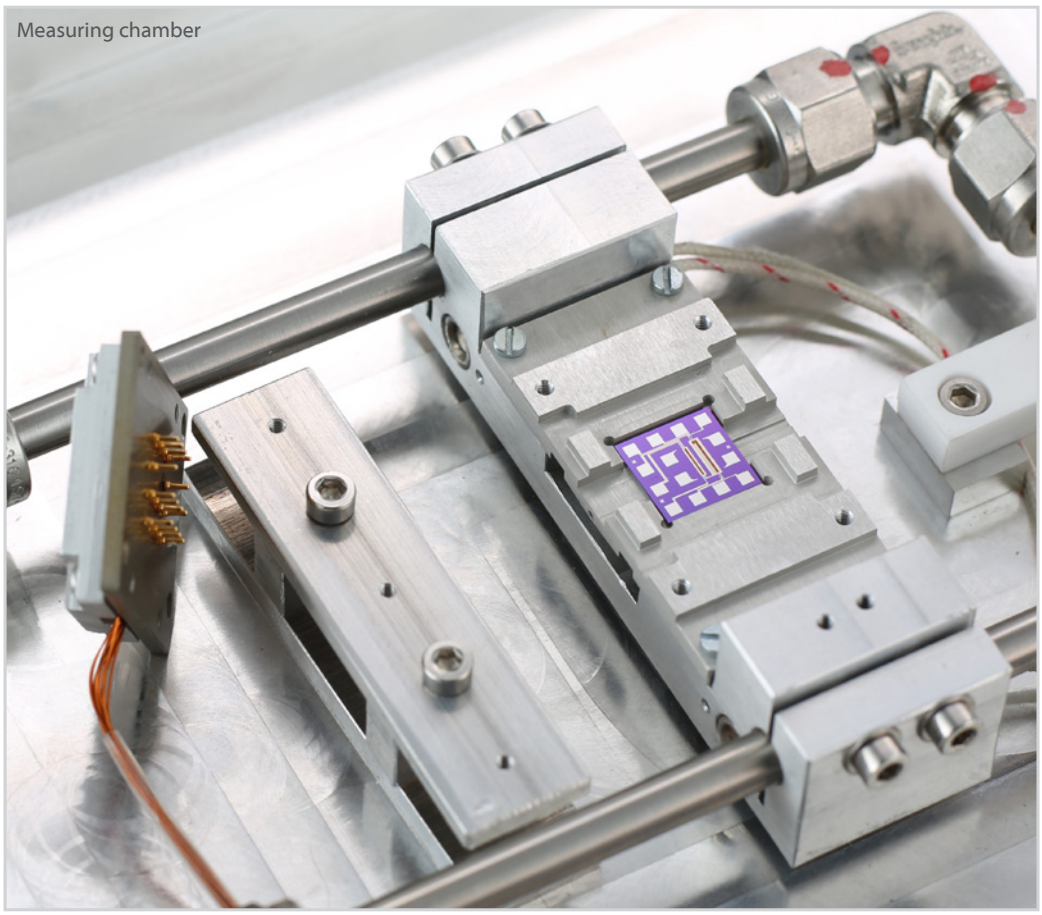
MEASURING SETUP

Components

The basic setup consists of a measurement chip on which the sample can be easily deposited and the measurement chamber to provide the required environmental conditions. Depending on the application, the setup can be utilized with a Lock-In amplifier and / or a strong electric magnet. The measurements are usually taken under UHV and the samples temperature can be controlled between -170°C and +300°C during the measurement using LN2 and powerful heaters.

Modular design

Starting with a basic setup to measure, the System can be upgraded easily with either the transient upgrade kit to measure the thermal conductivity and specific heat with the 3w Method or the magnetic upgrade kit to take Hall constant, mobility and charge carrier concentration measurements.



Measuring chamber

PACKAGING OPTIONS

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, measurement electronics, PC and LINSEIS Software package. The design is optimized to measure following physical properties:

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

2. Transient package

Consisting of system integrated lock-in amplifier, electronics and evaluation software for 3ω-method. The design is optimized for measuring the following parameters:

- λ - Thermal Conductivity
- c_p - Specific Heat
- ε - Emissivity (depends on material)

3. Magnetic package

The design is optimized for measuring the following parameters:

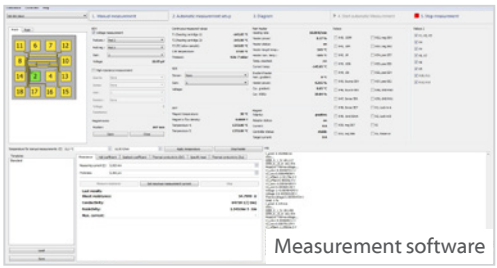
- A_H - Hall Constant
- μ - Mobility
- n - Charge carrier concentration

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

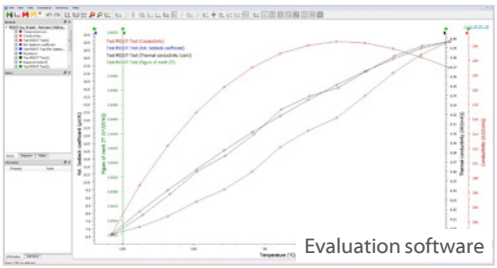
- TFA/KREG controlled cooling unit
- TFA/KRYO Dewar 25l

Software

The TFA software package consists of two parts. A measurement software which displays the actual values as well as 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 chip is combining the 3 Omega 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 Van-der-Pauw electrodes. For an easy sample preparation either a strip off foil mask or a metal 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.

1. Van-der-Pauw measurement

To determine the electrical conductivity (s) and Hall coefficient (AH) 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.

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

By applying a magnetic field and measuring the corresponding change of the diagonal Van-der-Pauw resistance, the Hall coefficient 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 measurment of the thermovoltage at different temperature gradients wich can be used in order to calculate the Seebeck Coefficient S=-Vth/ΔT.

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

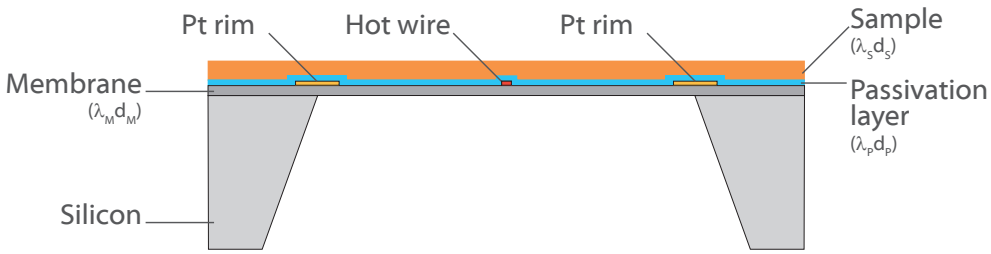
2. Hot stripe measurement

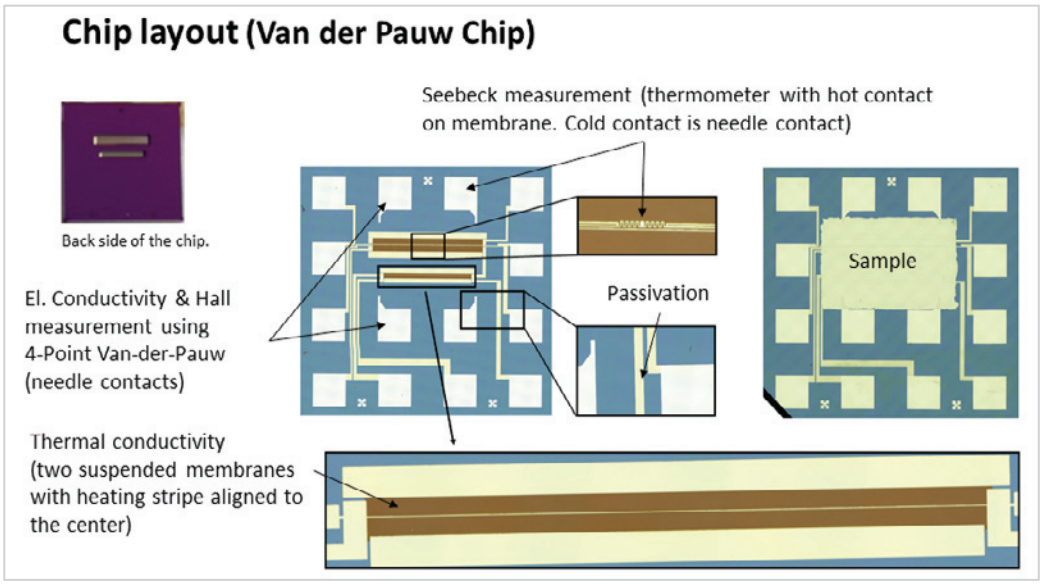
For the deterimation of the in-plane thermal conductivity, a patend pending hot-stripe suspended membrane setup is used. In this setup, a very small wire is used as heater and temperature sensor in one. The sample of interrest will be deposited directly on this membrane.

For the measurment, a current is applied to the hotwire which is heated up due to Joule heating. Because of the temperature rise, the resistivity of the wire is changing and can be measured easily. From this resistivity change and the knowledge of the exact geomtrie of the setup, it is possible to calculate back to the thermal conductivity of the sample.

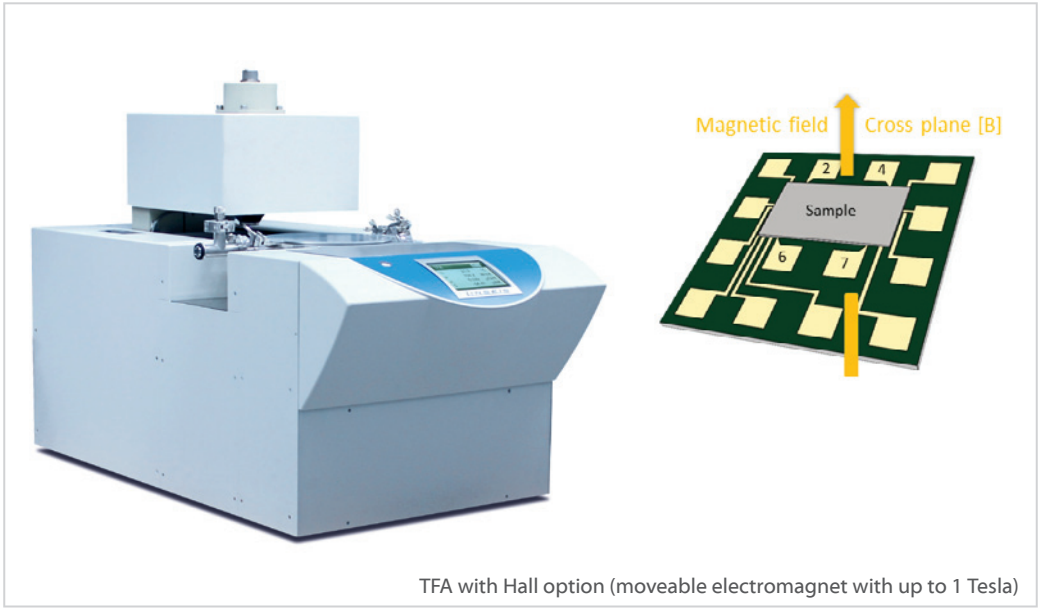
Depending on the sample, it is also possible to measure the emissivity and specific heat.

In order to get high quality results, the sample thickness times sample thermal conductivity should be equal or bigger than 2 x 10^{-7} W/K.





Hall option



TFA with Hall option (moveable electromagnet with up to 1 Tesla)

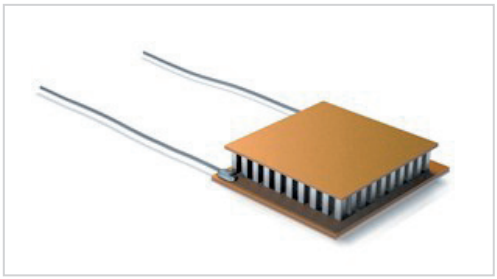
TECHNICAL SPECIFICATIONS

General	
Temperature range	RT up to 200°C -170°C up to 300°C
Sample thickness	from nm to µm range (depends on sample)
Measurement principle	chip based (pre structured measurement chips, 15 pcs. per box)
Desposition techiques	include: PVD (sputtering, evaporation), ALD, spin coating, ink-jet printing and more
Measured parameters	Electrical Resisitivity / Conductivity Seebeck Coefficient
Optional	Hall Constant / Mobility / Charge carrier conc. Electromagnet up to 1 T Thermal Conductivity (3 Omega) Specific Heat
Vacuum	up to 10^{-5}bar
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	5 up to 2500 µV/K
Repeatability & Accuracy	
Thermal Conductivity	± 10% (for most materials)
Electrical Resistivity	± 6% (for most materials)
Seebeck Coefficient	± 7% (for most materials)

APPLICATIONS

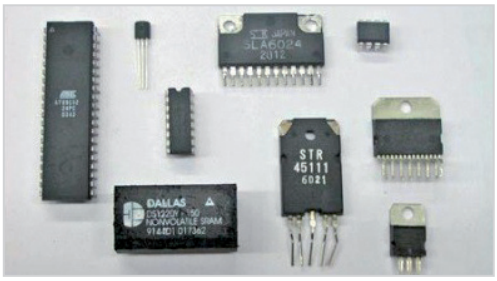
Thermoelectric devices

A typical application is the characterization of thin films made out of thermoelectric materials. A lot of research is done to improve the efficiency of thermoelectric devices.



Integrated devices

For the development and design of new and robust integrated devices like sensors or microchips, the semiconducting industry needs to know a lot about the physical properties of the used films. For example for the heat management or the electric insolation of such devices.



Thermal barrier coatings

Another interesting field for thin films are thermal barrier coatings as they are used in aircraft engines. Many new materials have been developed and characterized, especially in regard to their thermal behavior.



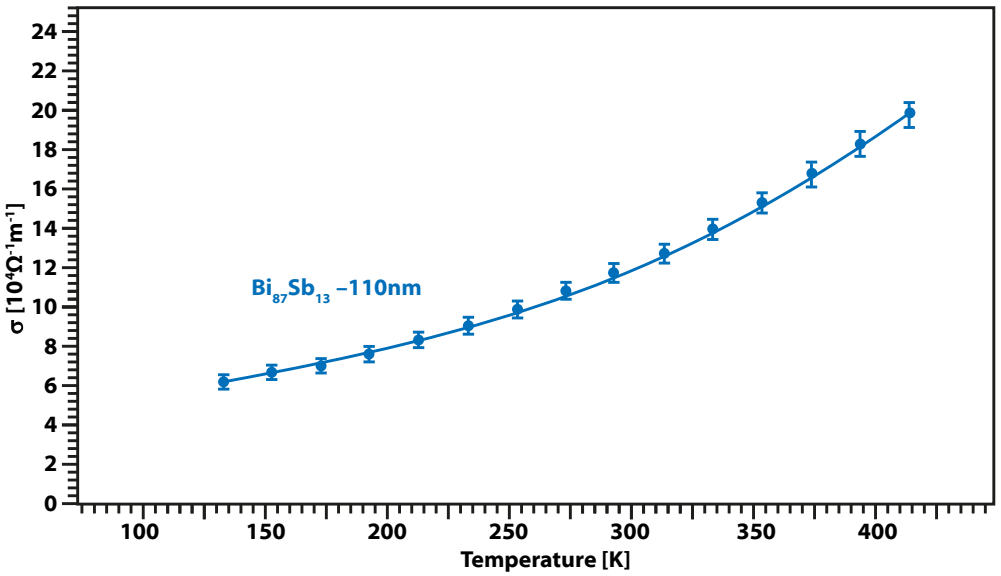
Tribological stress

The last application example is the determination of material parameters for thin films used in tools. The understanding is very important to avoid wear due to tribological stress to ensure an extended product life cycle.



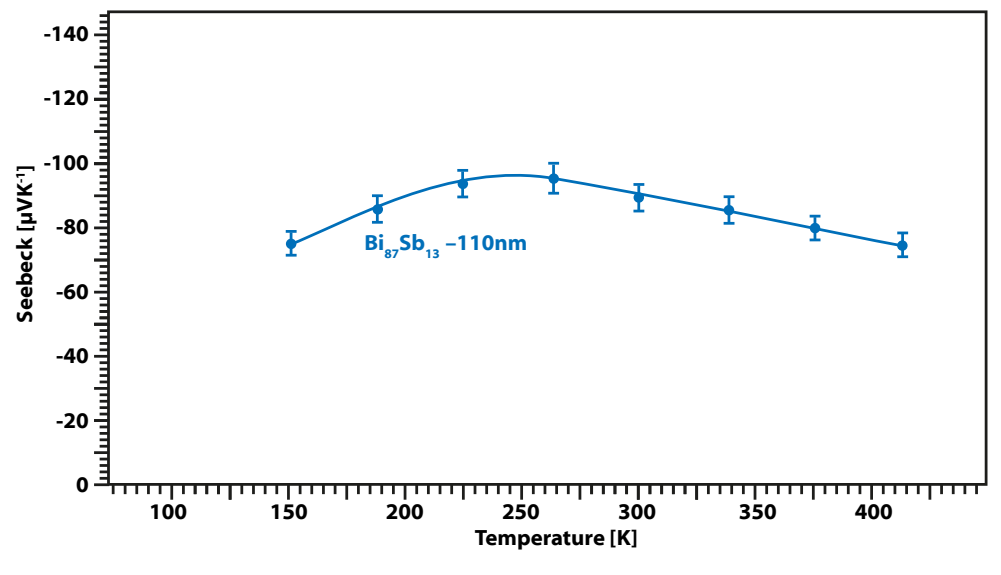
APPLICATIONS

Electrical conductivity



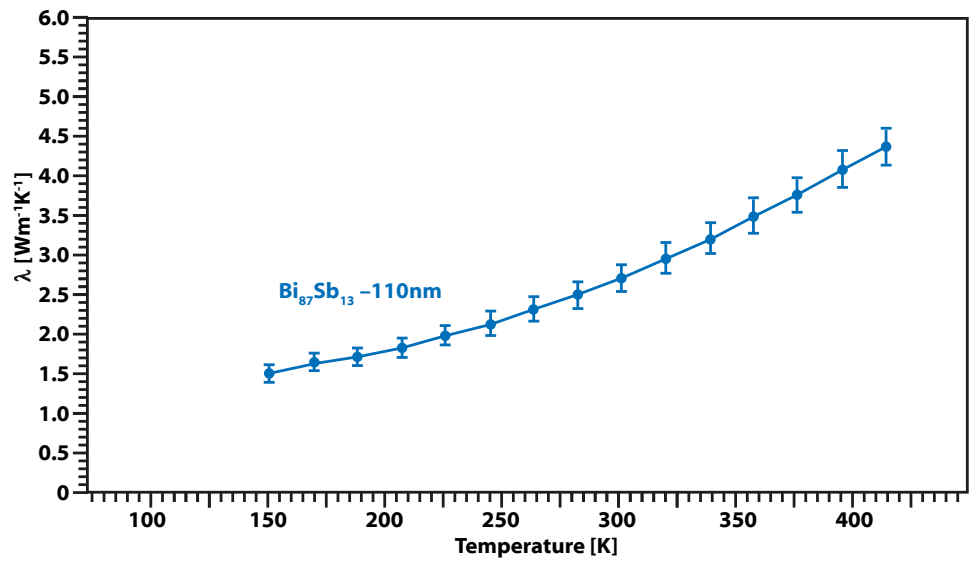
Electrical conductivity of a 110 nm bismuth antimony layer in the temperaure range from 120 to 450K.

Seebeck coefficient



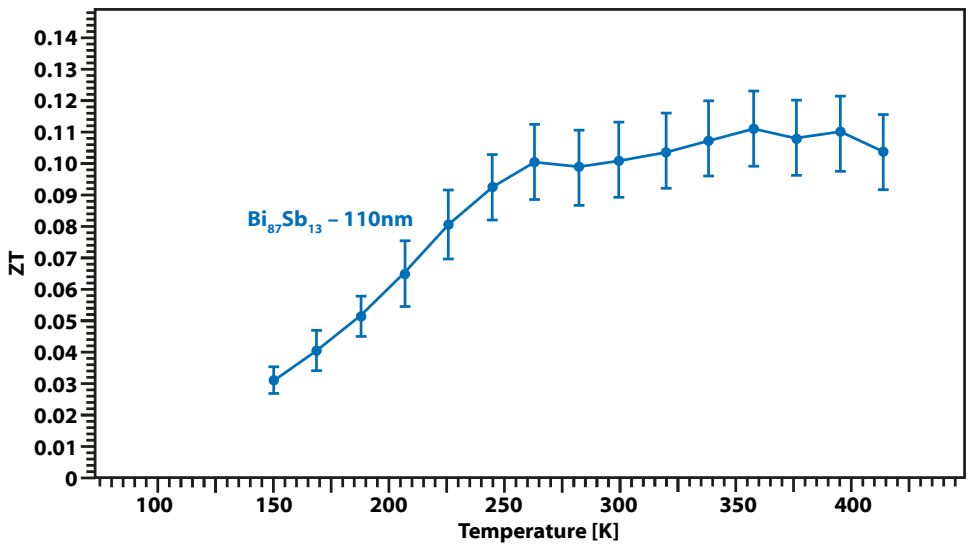
Seebeck coeficient of a 110 nm bismuth antimony layer in the temperaure range from 120 to 450K.

Thermal conductivity



Thermal conductivity of a 110 nm bismuth antimony layer in the temperaure range from 120 to 450K..

Figure of Merit



ZT-value of a 110 nm bismuth antimony layer in the temperaure range from 120 to 450K..

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