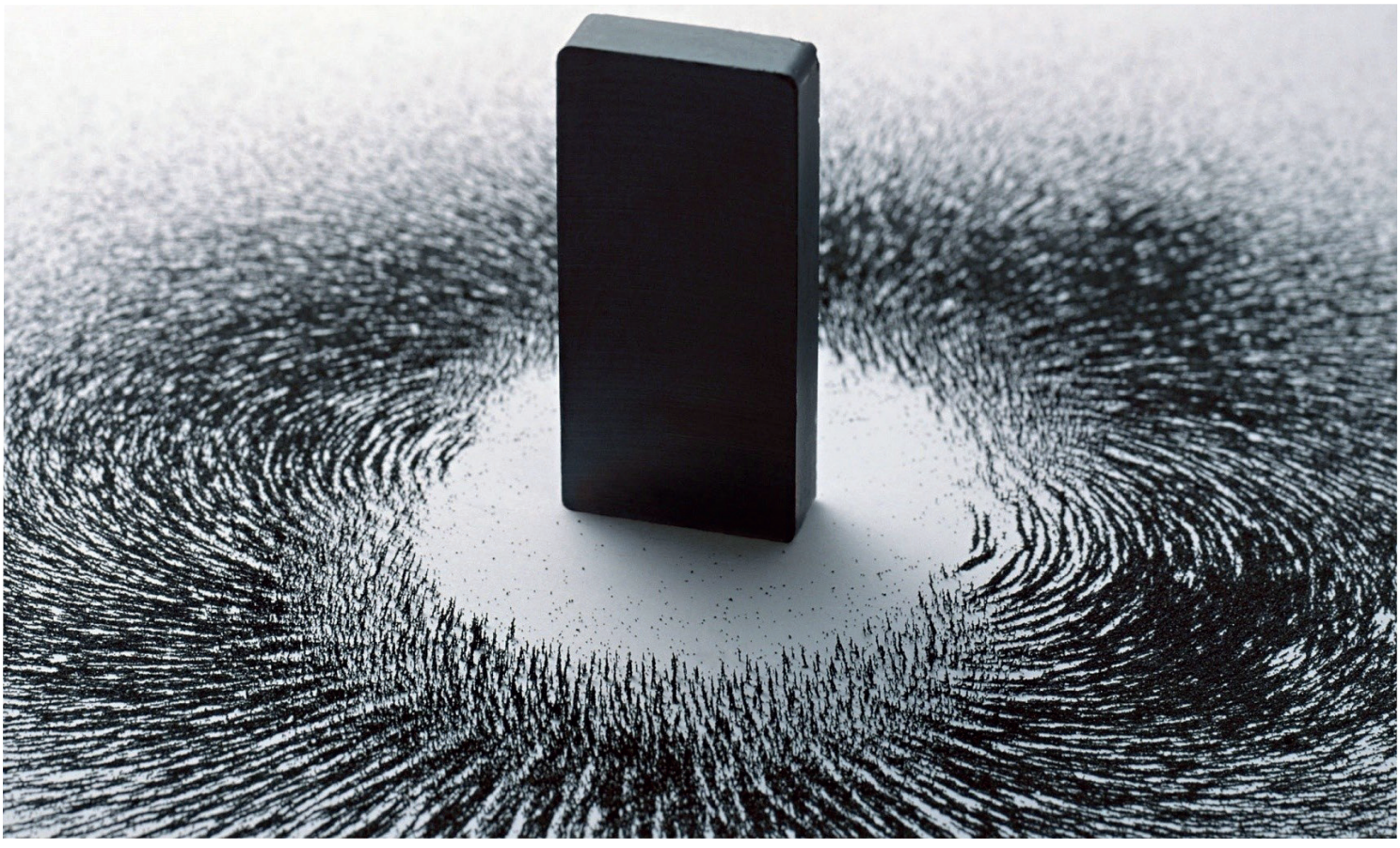
LINSEIS

THERMAL ANALYSIS

HALL-EFFECT Characterization Systems

HCS 1
HCS 10
HCS 100



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.

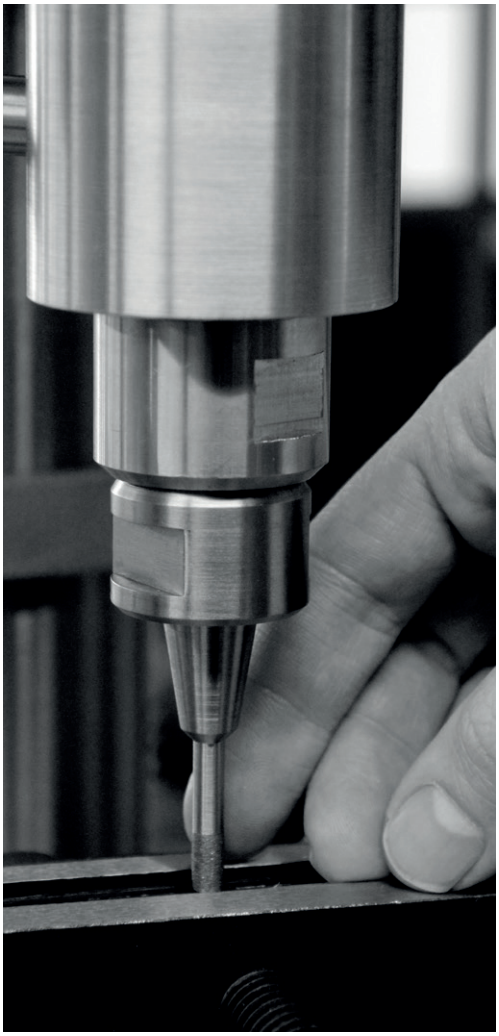
Customer satisfaction, innovation, flexibility and high quality are what LINSEIS represents. Thanks to these fundamentals, our company enjoys an exceptional reputation among the leading scientific and industrial organizations worldwide and has been offering highly innovative benchmark products for many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

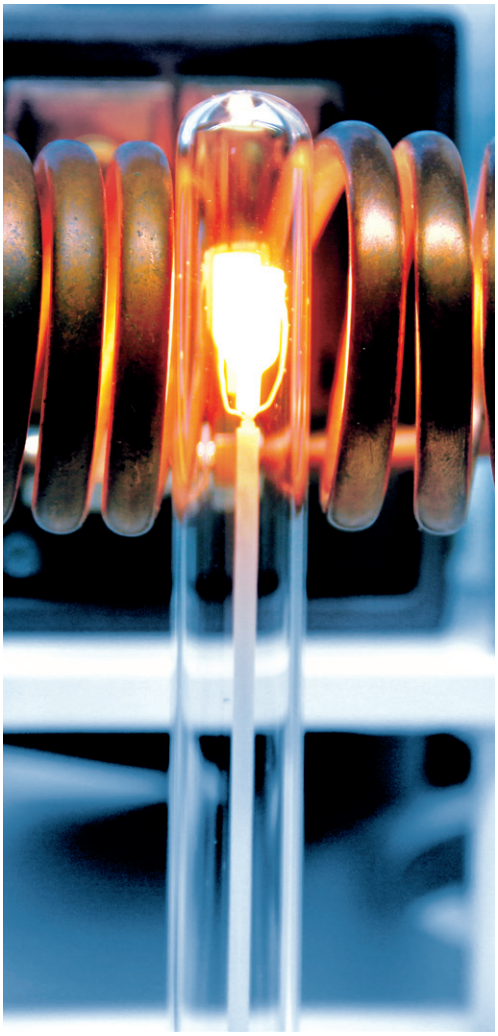
LINSEIS provides technological leadership. We develop and manufacture thermo analytic and thermo physical testing equipment to the highest standards and precision. Due to our innovative drive and precision, we are a leading manufacturer of thermal Analysis equipment.

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.

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

Claus Linseis
Managing Director





German engineering

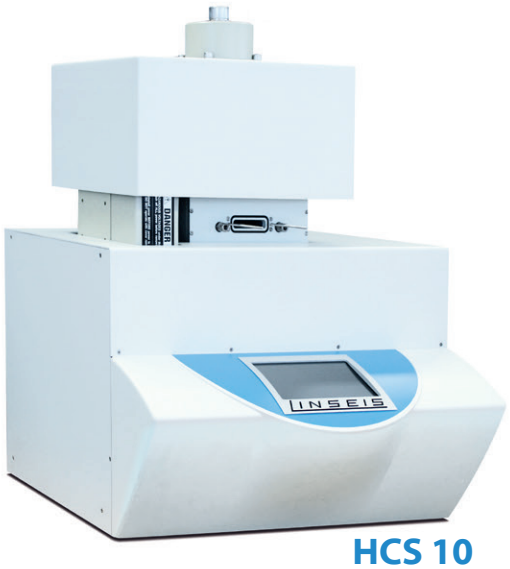
The strive for the best due diligence and accountability is part of our DNA. Our history is affected by German engineering and strict quality control.

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.

LINSEIS HCS-SERIES

HCS 100



HCS 10

HCS 1

HCS-
HALL CHARACTERIZATION SYSTEM

The HCS System permits the characterization of semiconductor devices regarding their electric transport properties, in particular Hall-mobility, Charge Carrier Concentration, Resistivity and Seebeck Coefficient.

The integrated desktop setups offer a complimentary product line-up from a basic, manual operated, Hall Characterization stage to an automized high temperature stage up to the innovative Halbach configuration for the characterization of most challenging samples.

The systems can be equipped with different sample holder for various geometries and temperature requirements. An optional low temperature (LN_2) attachments is available as well as a high temperature version up to 800°C, to ensure that all fields of application can be covered. Depending on the system configuration, either a permanent magnet, a water cooled electromagnet or a Halbach magnet provide magnetic field strength of up to 1 Tesla.

The comprehensive Windows based software offers an easy to use graphical user interface to control the system parameters, define measurement procedures and temperature profiles as well as allows for an easy data evaluation, presentation and storage.

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 ration of resistance)
- Megneto resistance
- Seebeck Coefficient [µV/K]

System features

- Gas tight measurement chamber which allows measurements under defined atmospheres or vacuum conditions
- 120 mm diameter magnets for highest field homogenity and maximum accuracy as well as biggest measureable sample sizes
- Modular and upgradeable system design
- High temperature version up to 800°C / 1073 K
- Lock-in amplifier upgrade for lowest noise measurements
- Connector for use of external electronics
- Integrated software package for easy handling
- Seebeck Coefficient opition to apply on board temperature gradients up to 20K

HALL CONSTANT

HIGH TEMPERATURE

MOBILIITY

EASY HANDLING

CHARGE CARRIER CONCENTRATION

SEEBECK COEFFICIENT ADDON

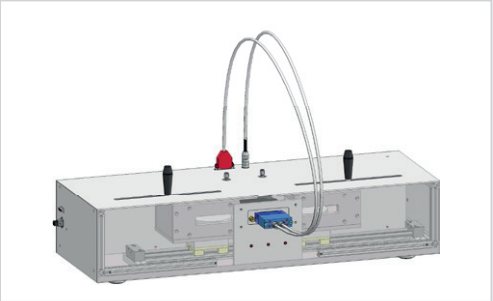
FEATURES

MEASUREMENT SYSTEM

The sample holder handle closes the measurement chamber vacuum tight. The measurement chamber is provided with a gas in and outlet, so measurements can be taken under controlled and changeable atmospheres. Different sample holders are available to take measurements from RT up to 500°C / LN_2 up to 800°C.

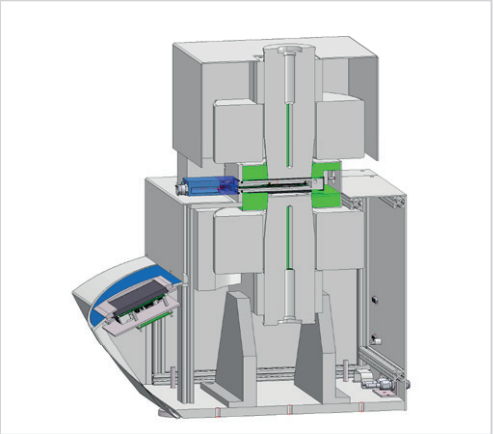
Permanent Magnet Option (HCS 1)

The HCS 1 stage is equipped with two magnetic circuits (Neodymium), assembled on a moveable sledge, which optionally can be automized. The system can be equipped with a low temperature as well as high temperature extension.



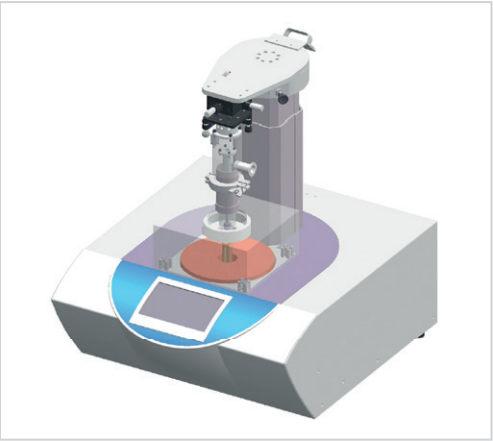
Electromagnet Option (HCS 10)

Optional to the permanent magnet, an electromagnet kit is available. The water cooled electromagnet is working in combination with a programmable power supply and a current reversal switch. The power supply can apply currents of up to 75 A, resulting in a variable magnetic field strength of up to +/-1 T.

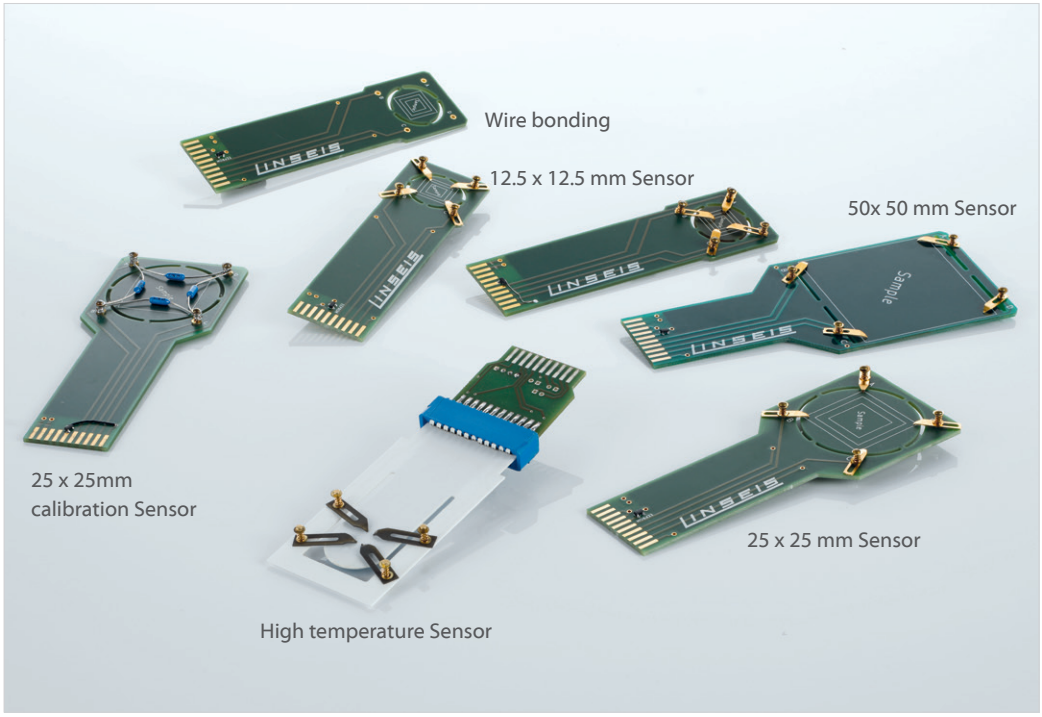


Halbach option (HCS 100)

The HCS 100 uses a magent in Halbach configuration (permanent magnet in donut configuration), in order to apply either a DC or an AC magnetic field to the sample. In combination with an AC current, provided by a Lock-in amplifier, this setup is a powerful tool for the investigation of challenging samples, as occuring offsets as well as noise can be suppressed in most cases.



SENSORS

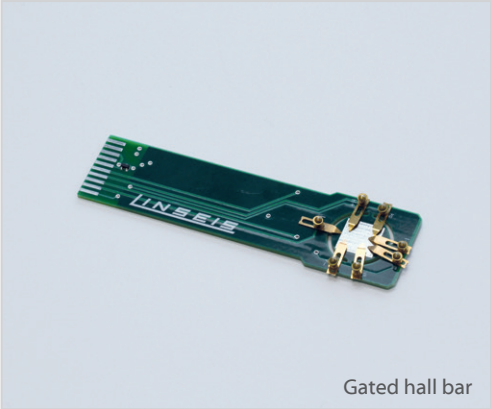


Exchangeable Sensors with an EPROM on it for easy plug and play usage.

The Linseis HCS systems are modular in design, so that the application areas can be easily expanded with a wide range of options. These include, for example, the Seebeck option, the gated hall bar setup and the illumination option. The plug-and-play system of the sample boards allows the measurement mode to be changed in a simple and fast way.

Gated hall bar

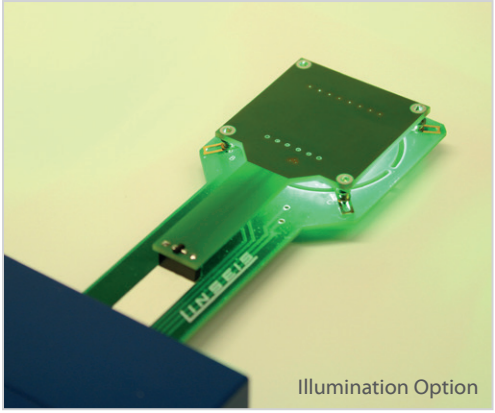
The sample holder for Hall Bar or Gated Hall Bar measurements allow for example the characterization of nanowires and transistors. It can be used to determine the electrical conductivity, the Hall mobility and all quantities derived from those. Furthermore, it allows the investigation of the properties in dependence on an additional applied electric field, the gate. It should be noted that the structure of the sample, i.e. the contact scheme, in the gated Hall bar setup differs from the Van-der-Pauw setup and thus the sample must be prepared accordingly.



Gated hall bar

Illumination Option

The illumination option allows to perform Hall effect investigations under illumination of the sample. This allows effects to be analyzed by irradiation of different wavelengths in the blue, green and red range of light, and as a function of illuminance. This means that the additional sample holders can also be used to investigate the photoelectric effect. Consequently, this option is particularly interesting for example, for materials that are also used in photovoltaic systems.



Illumination Option

SOFTWARE

All LINSEIS devices are PC controlled, where the individual software modules exclusively run under Microsoft® Windows® operating systems. The integrated software allows for an easy handling, temperature control, data acquisition and data evaluation.

General features

- NIST routine to find optimum measurement settings and get highest accurate results
- Extended connection test
- Possible integration of external electronics
- Optional Database storrage
- Optional Lock-in amplifier integration
- Automatic sensor recognition (EEPROM)
- Automatic evaluation
- Fully automatic cooling regulation
- HCS 10 online access to fit data

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Hall effect measurement report

Parameters

Date:	Fri Nov 8 13:58:25 2019
Sample name:	ITO 200
Temperature:	80.02 °C
Res. current:	10 mA
Hall current:	10 mA
Thickness:	0.185 µm

Measurement data

AB [mV]	BC [mV]	AC [mV]	+MAC [mV]	-MAC [mV]
13.83	12.72	-1.109	-1.274	-0.9542

CD [mV]	DA [mV]	BD [mV]	+MBD [mV]	-MBD [mV]
13.82	12.71	1.111	0.9547	1.275

Results

Sheet resistance:	6.011 Ω	Mobility:	-38.5362 cm²/(V s)
Resistivity:	0.0001112 Ω cm	Conductivity:	8.99e+3 /(Ω cm)
CCC (Sheet):	-2.694e+16 /cm²	CCC (bulk):	-1.456e+21 /cm³
AC cross Hall coefficient:	-0.004281 cm³/C	BD cross Hall coefficient:	-0.00429 cm³/C
Ratio of Vertical/Horizontal:	0.919626	Average hall coefficient:	-0.004285 cm³/C
Magneto-Resistance:	0 Ω		

LINSEIS

Hall effect measurement report

Parameters

Date:	Fri Nov 8 13:06:40 2019
Sample name:	ITO 200
Temperature:	20.09 °C
Res. current:	10 mA
Hall current:	10 mA
Thickness:	0.185 µm

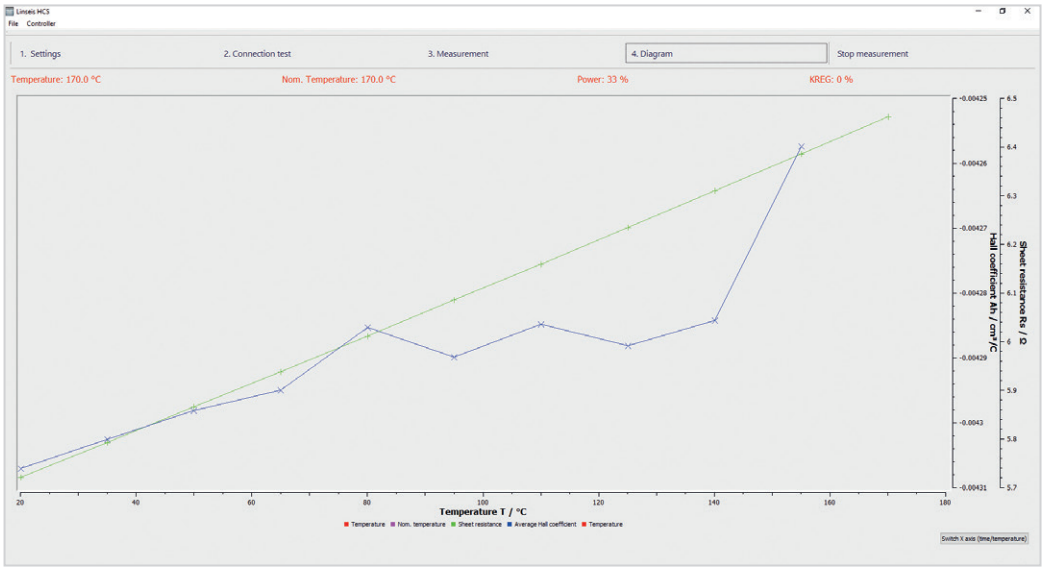
Measurement data

AB [mV]	BC [mV]	AC [mV]	+MAC [mV]	-MAC [mV]
13.16	12.1	-1.061	-1.226	-0.9049

CD [mV]	DA [mV]	BD [mV]	+MBD [mV]	-MBD [mV]
13.16	12.1	1.061	0.9056	1.227

Results

Sheet resistance:	5.721 Ω	Mobility:	-40.6961 cm²/(V s)
Resistivity:	0.0001058 Ω cm	Conductivity:	9.45e+3 /(Ω cm)
CCC (Sheet):	-2.681e+16 /cm²	CCC (bulk):	-1.449e+21 /cm³
AC cross Hall coefficient:	-0.004304 cm³/C	BD cross Hall coefficient:	-0.00431 cm³/C
Ratio of Vertical/Horizontal:	0.919333	Average hall coefficient:	-0.004307 cm³/C
Magneto-Resistance:	0 Ω		

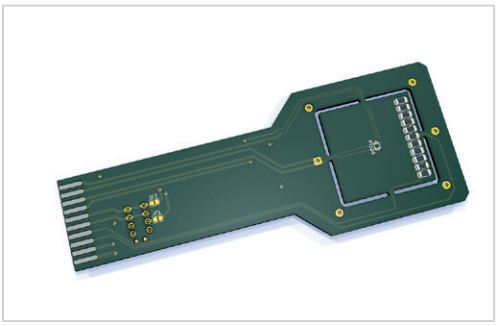


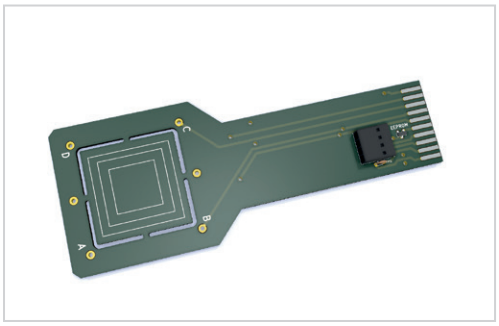
SPECIFICATIONS

	HCS 1	HCS 10	HCS 100
Temperature range	LN2 up to 600°C in different versions (continuously from LT to HT) -160°C (controlled cooling) -196°C (quench cooling)	LN2 up to 600°C in different versions (continuously from LT to HT) -160°C (controlled cooling) -196°C (quench cooling)	RT up to 500°C
Magnet	Permanent magnets up to 0.70 T DC field Pole diameter 120 mm Two magnet setup for bipolar measurement.	Electromagnet up to +/-1 T variable DC field Pole diameter 76 mm Power supply 75A / 40V. Current reversal swith for bipolar measurement.	Magnet up to 0.5 T (AC or DC field) Multisegment Halbach configuration Inner diameter: 40mm Height: 98mm
Current source	**DC** 1nA up to 125mA (8 decades / Compliance +/- 12V) **AC** 16 µA up to 20 mA and output impedance: >100 GigaOhm from 1 mHz to 100 kHz		
Voltage measurement	**DC** low noise / low drift 1µV up to 2500mV 4 decades amplification Digital resolution: 300pV	**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	from 5 x 5 mm to 12.5 x 12.5 mm Maximum sample height 3 mm from 17.5 x 17.5 mm up to 25 x25 mm Maximum sample height 5 mm from 42.5 x 42.5 mm up to 50 x 50 mm Maximum sample height 5 mm High Temperature board 10x10mm, max. sample height 2mm		up to 10 x 10mm Maximum sample height 2.5 mm
Resistivity Range	10^{-4} up to 10^{7} (Ωcm)	10^{-4} up to 10^{7} (Ωcm)	10^{-5} up to 10^{7} (Ωcm)
Carrier concentration	10^{7} up to $10^{21}cm^{-3}$	10^{7} up to $10^{21}cm^{-3}$	10^{7} up to $10^{22}cm^{-3}$
Mobility range	0.1 ~ 10^{7} $cm^{2}V^{-1}s^{-1}$	10^{-3} ~ $10^{7}cm^{2}V^{-1}s^{-1}$	1 ~ $10^{7}cm^{2}V^{-1}s^{-1}$
Atmospheres	Vaccum, inert, oxidizing, reducing	Vaccum, inert, oxidizing, reducing	Vaccum, inert, oxidizing, reducing
Temperature precision	0.05°C	0.05°C	0.05°C

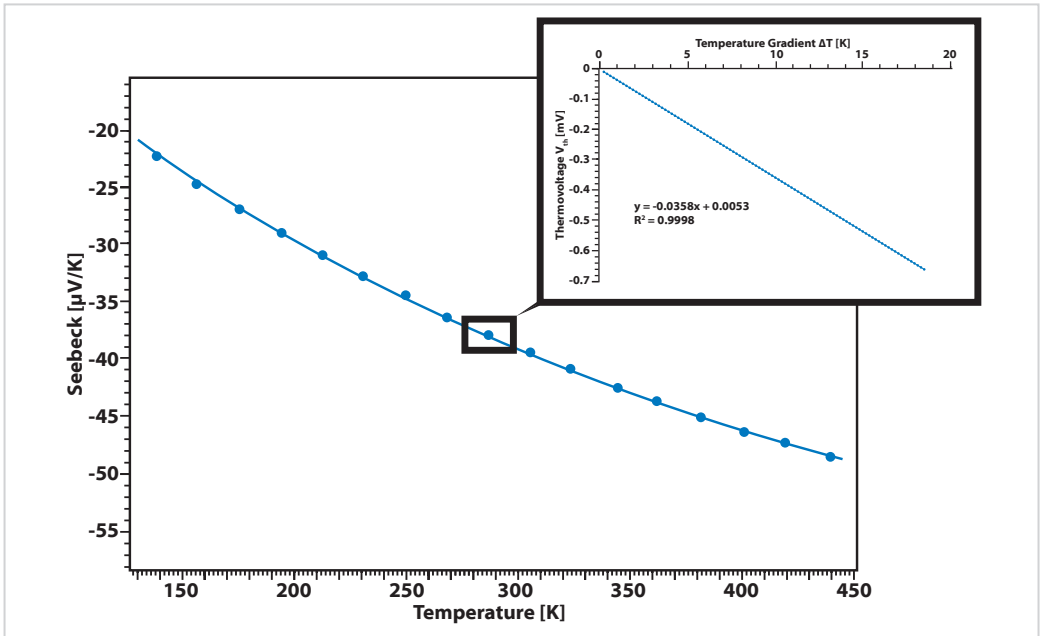
Seebeck Option

	HCS 1	HCS 10
Sample Geometry	length 6 mm to 15 mm, width 1 mm to 10 mm, height thin film to 2 mm	length 6 mm to 15 mm, width 1 mm to 10 mm, height thin film to 2 mm
Seebeck Coefficient	from 1 µV/K up to 2500 µV/K	from 1 µV/K up to 2500 µV/K
Measurement	Slope technique with 10 Readings/Sec	Slope technique with 10 Readings/Sec
Gradient heater	from 0.1 K up to 20 K	from 0.1 K up to 20 K
Thermocouples	Type K	Type K





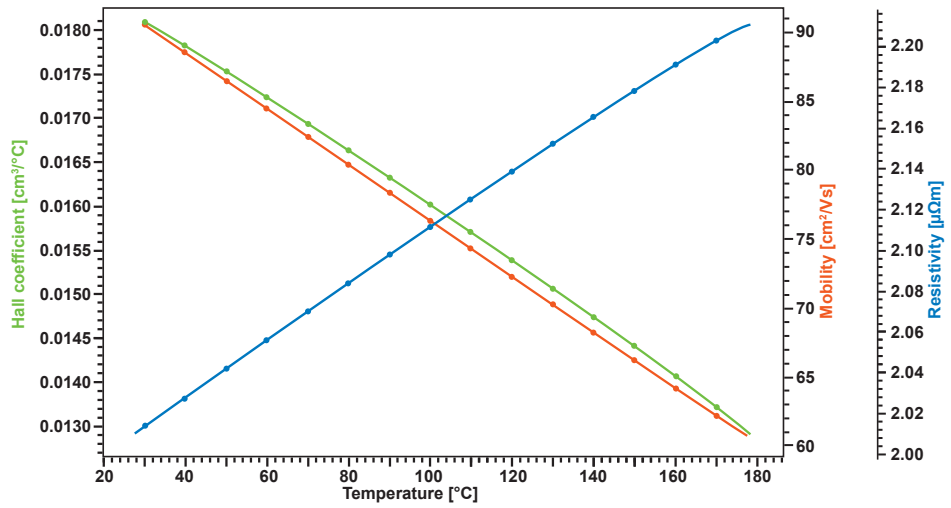
Measurement of the Constantan reference sample



Seebeck Coefficient measurement on a Conctantan reference sample from -140°C up to +180°C. The Seebeck Coefficient is measured using the slope technique (see inset) for each temperature measurement point. The result can be plotted as Relative Seebeck Coefficient against Pt or as Absolute Seebeck Coefficient.

APPLICATIONS

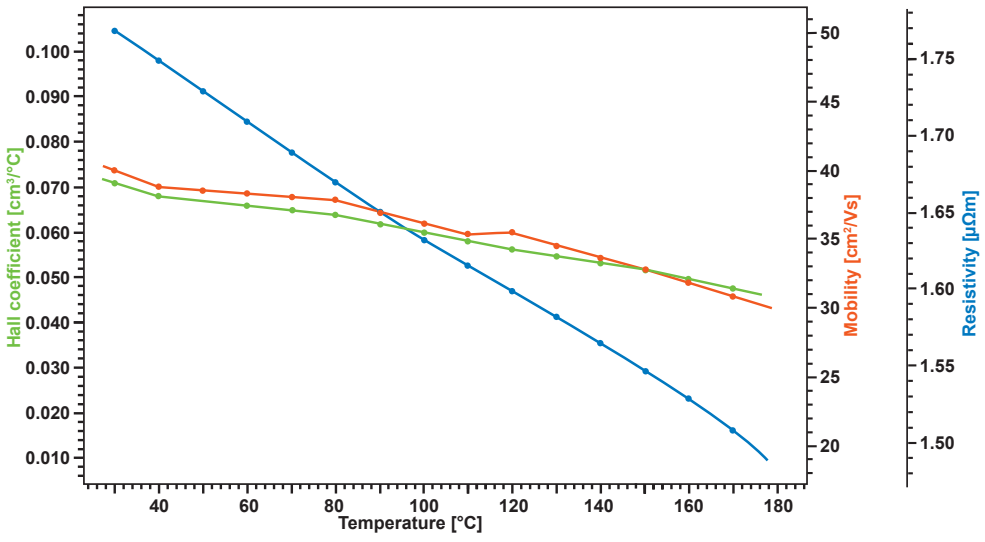
Antimony Thin Film (150 nm Sb)



Antimony (Sb) is a semimetal, which is widely used in the field of thermoelectrics (in form of alloys, e.g. $Bi_{1-x}Sb_x$) and as an emerging application is the field of microelectronics. Nevertheless, the largest applications for metallic antimony are lead antimony plates in lead–acid batteries.

The figure shows a full characterization of a thin film on SiO_2/Si substrate, prepared by sputter deposition, with the Linseis HCS 1 (RT to 200°C option).

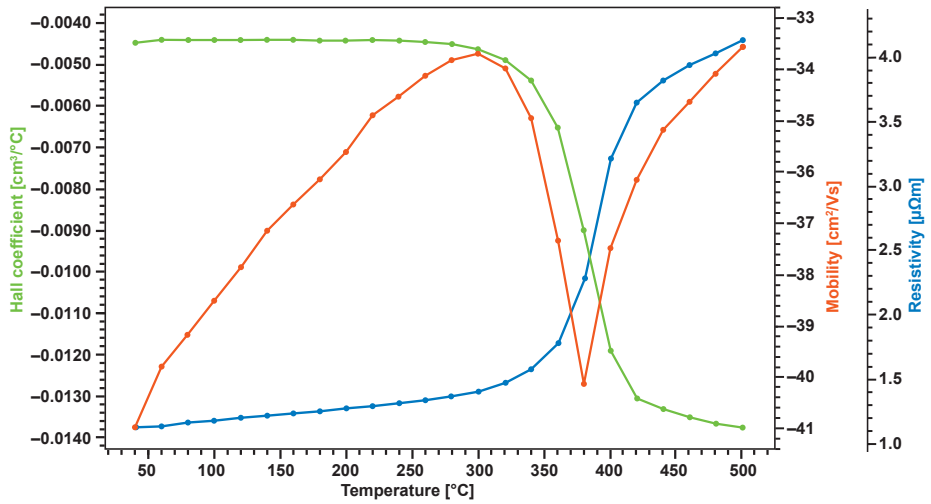
Bismuth-antimony Thin Film (150 nm $Bi_{87}Sb_{13}$)



Bismuth-antimony alloys, ($Bi_{1-x}Sb_x$) are binary alloys of bismuth and antimony in various ratios. Some, in particular $Bi_{0.9}Sb_{0.1}$, were the first experimentally-observed three-dimensional topological insulators, materials that have conducting surface states but have an insulating interior. Various BiSb alloys are also used in low temperature thermoelectric devices.

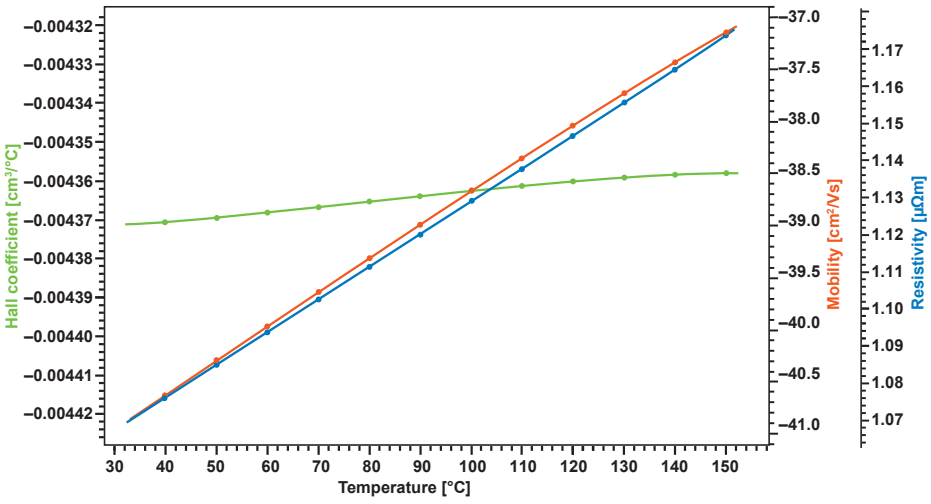
The presented measurement has been conducted on a thermally evaporated $Bi_{87}Sb_{13}$ thin film.

ITO (Indium tin oxide) up to 600°C using HCS 10



Indium tin oxide (ITO) is a ternary composition of indium, tin and oxygen in varying proportions. Depending on the oxygen content, it can either be described as a ceramic or alloy. It is transparent and colorless in thin layers and is one of the most widely used transparent conducting oxides because of its two main properties: its electrical conductivity and optical transparency. As with all transparent conducting films, a compromise must be made between conductivity and transparency, since increasing the thickness and increasing the concentration of charge carriers increases the material's conductivity, but decreases its transparency.

ITO (Indium tin oxide) up to 200°C using HCS 1



The two diagrams show a full characterization of two different ITO thin films (both 185 nm in thickness), prepared by sputter deposition with the Linseis HCS 1 (RT to 200°C option) as well as HCS 10 (High temperature option up to +600°C).

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