

**LINSEIS**

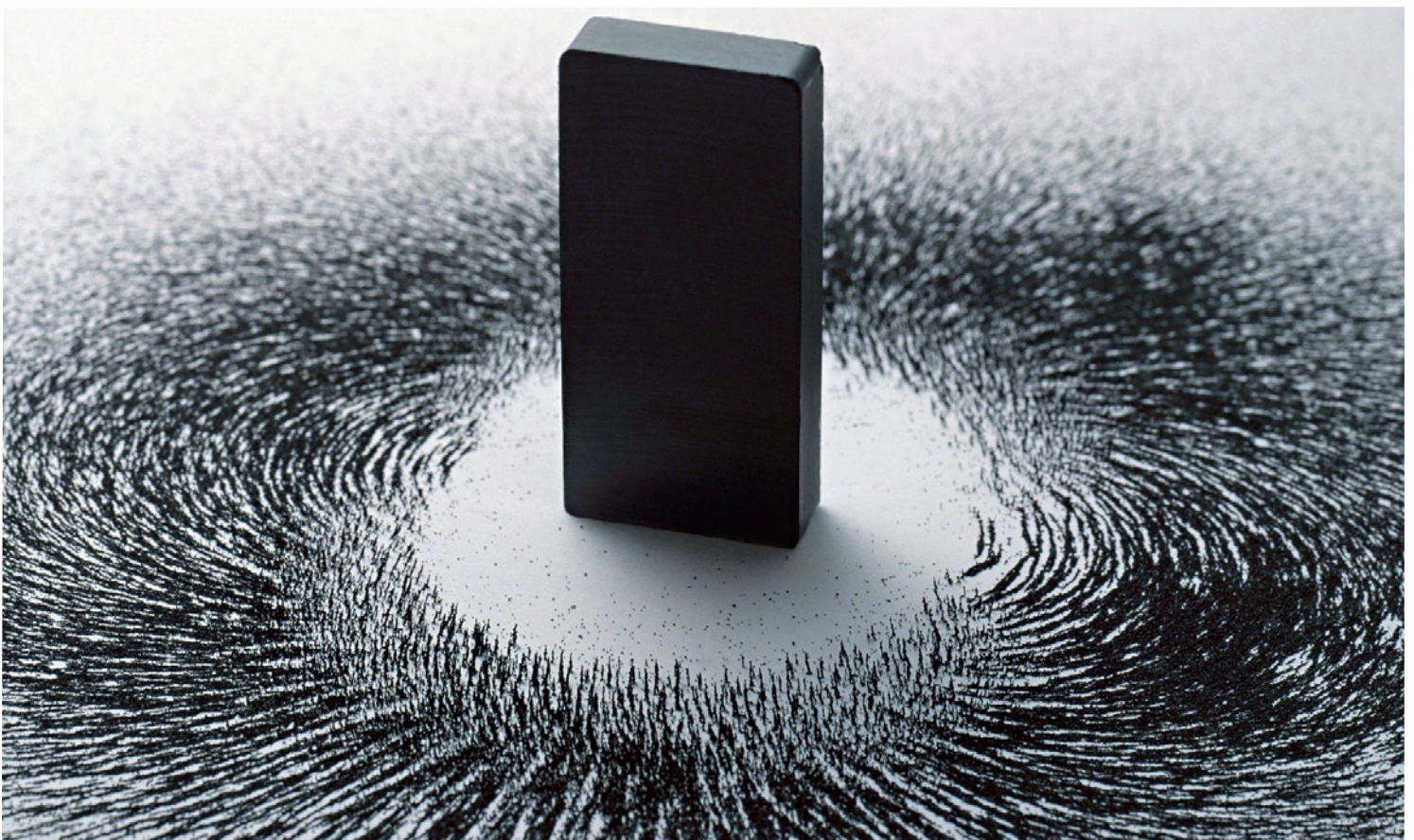
T H E R M A L   A N A L Y S I S

# **HALL-EFFECT Characterization Systems**

HCS 1

HCS 10

HCS 100



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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 worldwide and has been offering highly innovative benchmark products for many years.

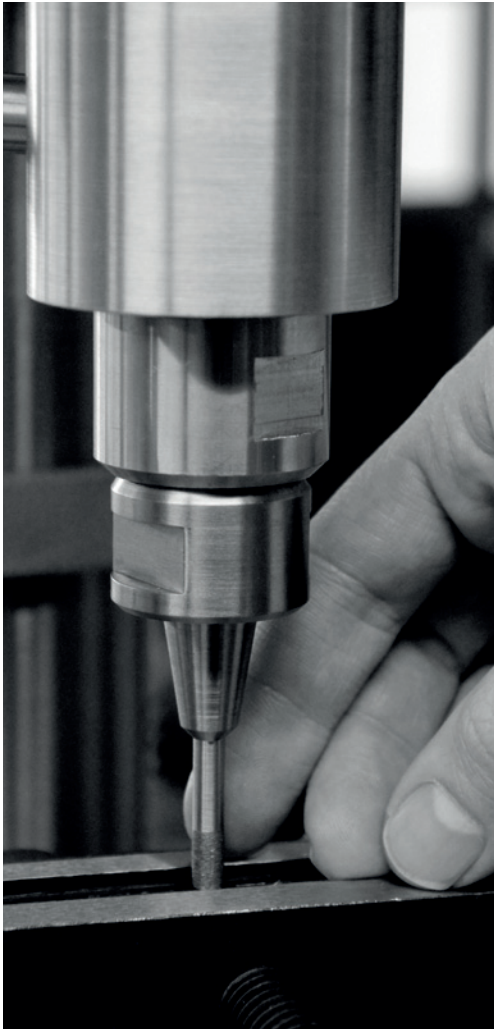
LINSEIS provides technological leadership. We develop and manufacture thermo analytic and thermo physical testing equipment to the highest standards and precision. Due to our innovative drive and precision, we are a leading manufacturer of thermal Analysis equipment.

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.

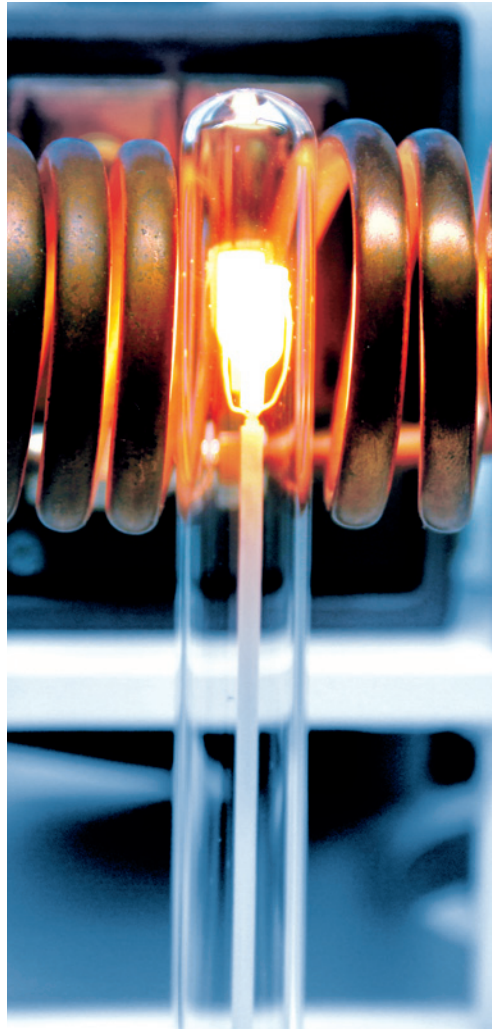


**Claus Linseis**  
Managing Director



## 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

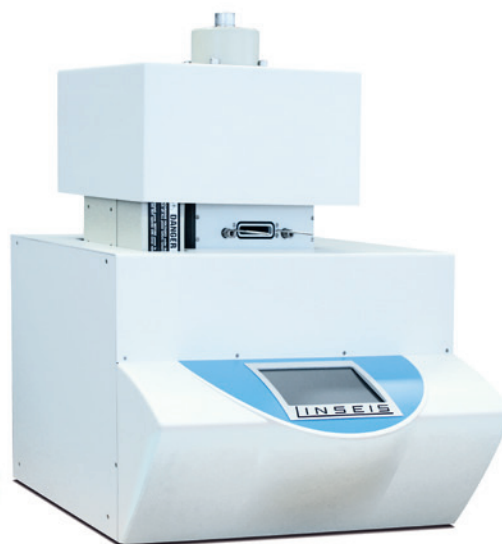
We want to deliver the latest and best technology for our customers. LINSEIS continues to innovate and enhance our existing thermal analyzers. Our goal is constantly develop new technologies to enable continued discovery in Science.



# LINSEIS HCS-SERIES



HCS 100



HCS 10



HCS 1

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# 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 automated 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<sub>2</sub>) 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/cm<sup>2</sup>]/ Bulk [1/cm<sup>3</sup>])
- Hall-Constant [cm<sup>3</sup>/C]
- Hall-Mobility [cm<sup>2</sup>/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 homogeneity 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 option to apply on board temperature gradients up to 20K

**HALL CONSTANT**

**MOBILITY**

**CHARGE CARRIER CONCENTRATION**

**SEEBECK COEFFICIENT ADDON**

**HIGH TEMPERATURE**

**EASY HANDLING**

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# FEATURES

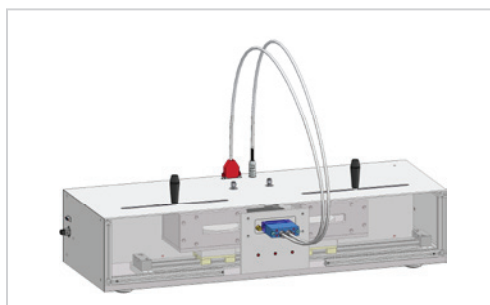
## MEASUREMENT SYSTEM

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 LN<sub>2</sub> up to 800°C.

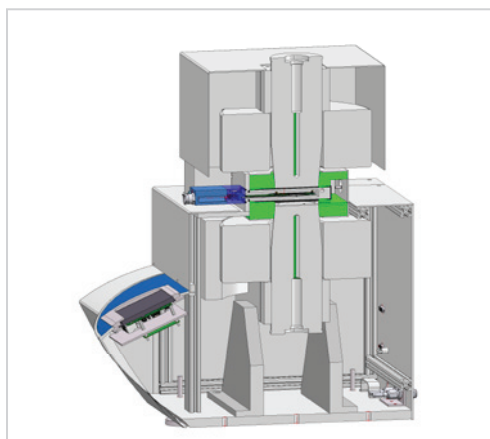
### Permanent Magnet Option (HCS 1)

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



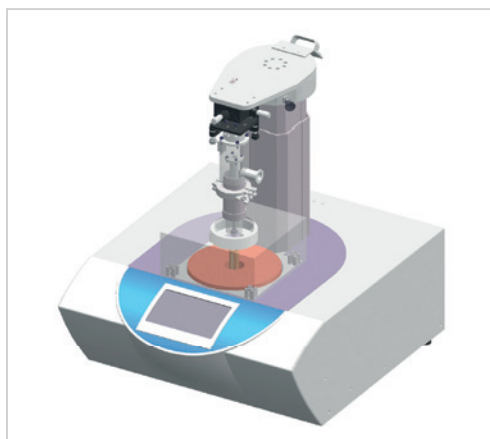
### Electromagnet Option (HCS 10)

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.

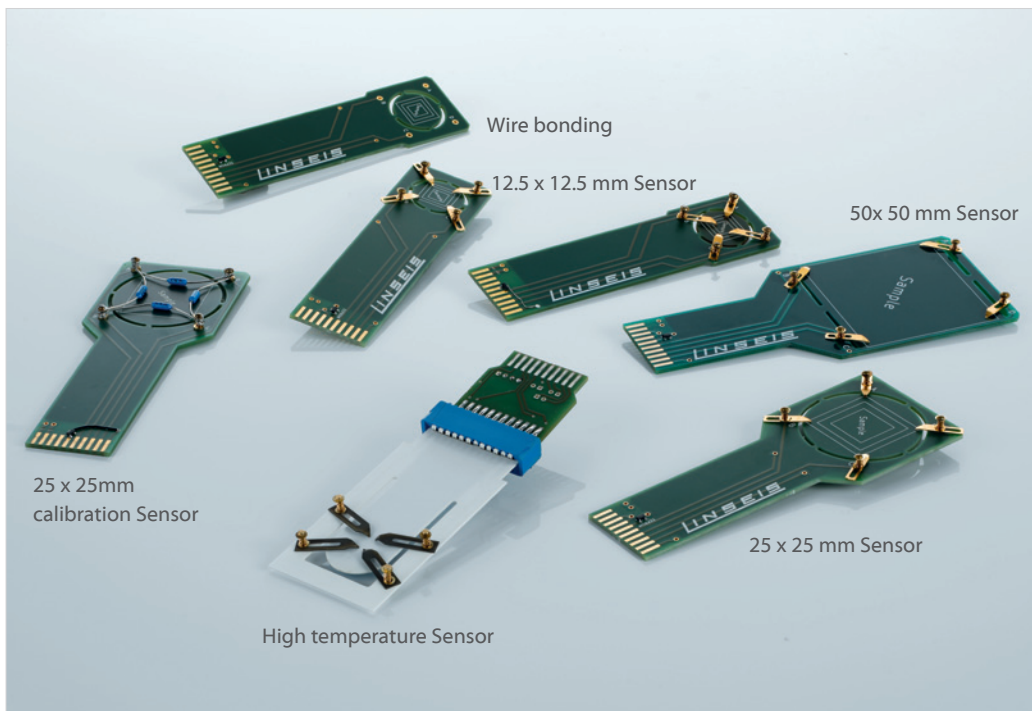


### Halbach option (HCS 100)

The HCS 100 uses a magnet 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 occurring offsets as well as noise can be suppressed in most cases.



# SENSORS



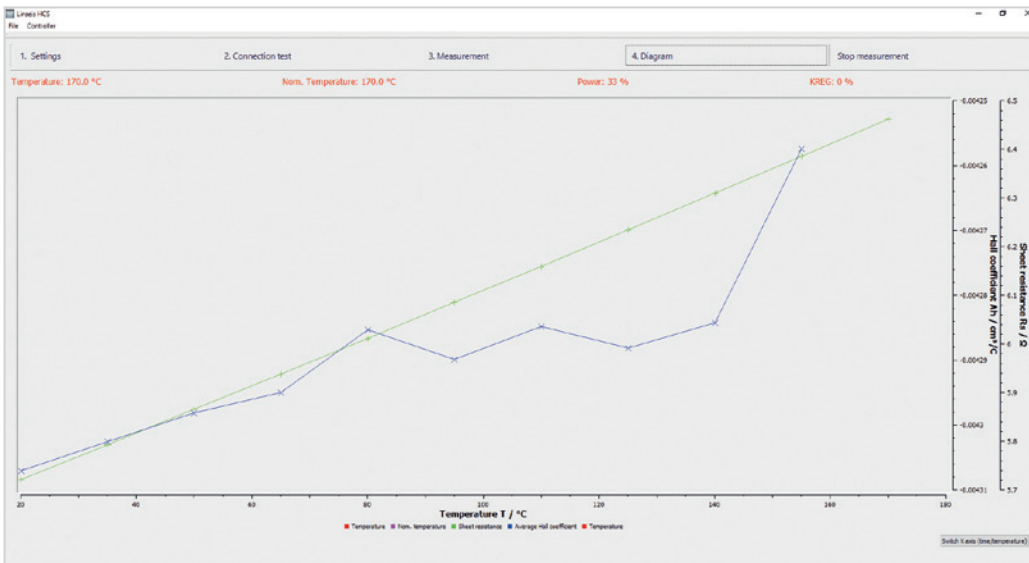
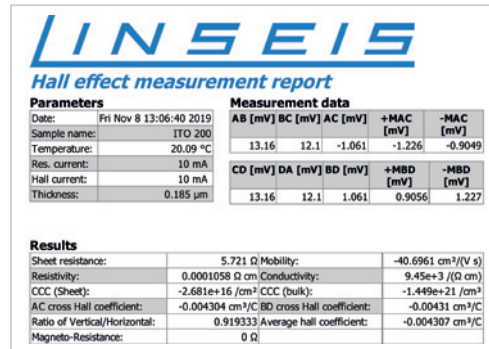
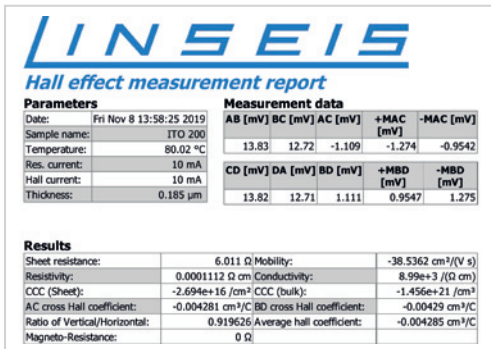
Exchangeable Sensors with an EPROM on it for easy plug and play usage.

# 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 storage
- Optional Lock-in amplifier integration
- Automatic sensor recognition (EEPROM)
- Automatic evaluation
- Fully automatic cooling regulation
- HCS 10 online access to fit data



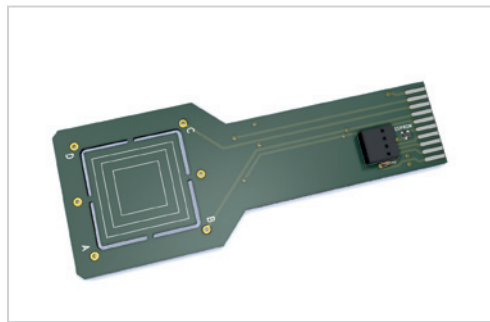
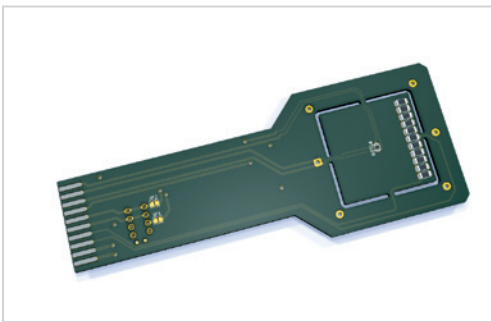


# SPECIFICATIONS

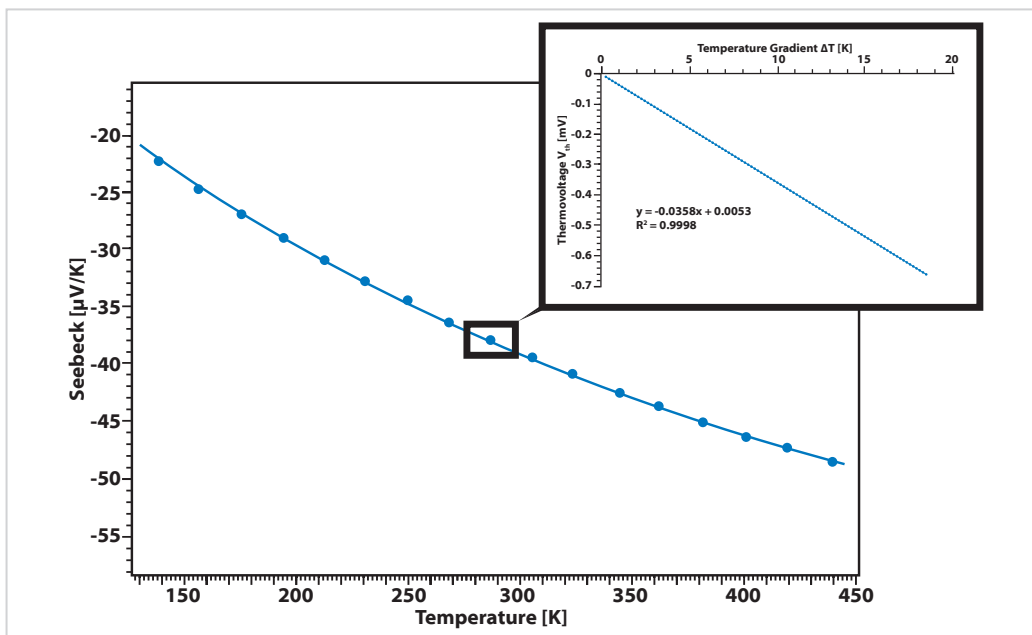
	HCS 1	HCS 10	HCS 100
<b>Temperature range</b>	From LN <sub>2</sub> up to 800°C in different configurations	From LN <sub>2</sub> up to 800°C in different configurations	RT up to 500°C
<b>Magnet</b>	Permanent magnets up to 0.70 T DC field Pole diameter 120 mm Two magnet setup for bipolar measurement.	Electromagnet up to +/-1 T variable DC field Pole diameter 76 mm Power supply 75A / 40V. Current reversal switch for bipolar measurement.	Magnet up to 0.5 T (AC or DC field) Multisegment Halbach configuration Inner diameter: 40mm Height: 98mm
<b>Current source</b>	<b>DC</b> 1nA up to 125mA (8 decades / Compliance +/- 12V) <b>AC</b> 16 µA up to 20 mA and output impedance: >100 GigaOhm from 1 mHz to 100 kHz		
<b>Voltage measurement</b>	<b>DC</b> low noise / low drift 1µV up to 2500mV 4 decades amplification Digital resolution: 300pV <b>AC</b> 20 nV up to 1V Features: GΩ range input impedance, variable integration times and amplification		
<b>Sensors / Sample geometry</b>	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 x 25 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
<b>Resistivity Range</b>	10 <sup>-4</sup> up to 10 <sup>7</sup> (Ωcm)	10 <sup>-4</sup> up to 10 <sup>7</sup> (Ωcm)	10 <sup>-5</sup> up to 10 <sup>7</sup> (Ωcm)
<b>Carrier concentration</b>	10 <sup>7</sup> up to 10 <sup>21</sup> cm <sup>-3</sup>	10 <sup>7</sup> up to 10 <sup>21</sup> cm <sup>-3</sup>	10 <sup>7</sup> up to 10 <sup>22</sup> cm <sup>-3</sup>
<b>Mobility range</b>	10 <sup>2</sup> up to 10 <sup>7</sup> (cm <sup>2</sup> /Volt sec)	10 <sup>2</sup> up to 10 <sup>7</sup> (cm <sup>2</sup> /Volt sec)	10 <sup>3</sup> up to 10 <sup>7</sup> (cm <sup>2</sup> /Volt sec)
<b>Atmospheres</b>	Vacuum, inert, oxidizing, reducing	Vacuum, inert, oxidizing, reducing	Vacuum, inert, oxidizing, reducing
<b>Temperature precision</b>	0.05°C	0.05°C	0.05°C

## Seebeck Option

	HCS 1	HCS 10
<b>Sample Geometry</b>	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
<b>Seebeck Coefficient</b>	from 1 $\mu\text{V}/\text{K}$ up to 2500 $\mu\text{V}/\text{K}$	from 1 $\mu\text{V}/\text{K}$ up to 2500 $\mu\text{V}/\text{K}$
<b>Measurement</b>	Slope technique with 10 Readings/Sec	Slope technique with 10 Readings/Sec
<b>Gradient heater</b>	from 0.1 K up to 20 K	from 0.1 K up to 20 K
<b>Thermocouples</b>	Type K	Type K



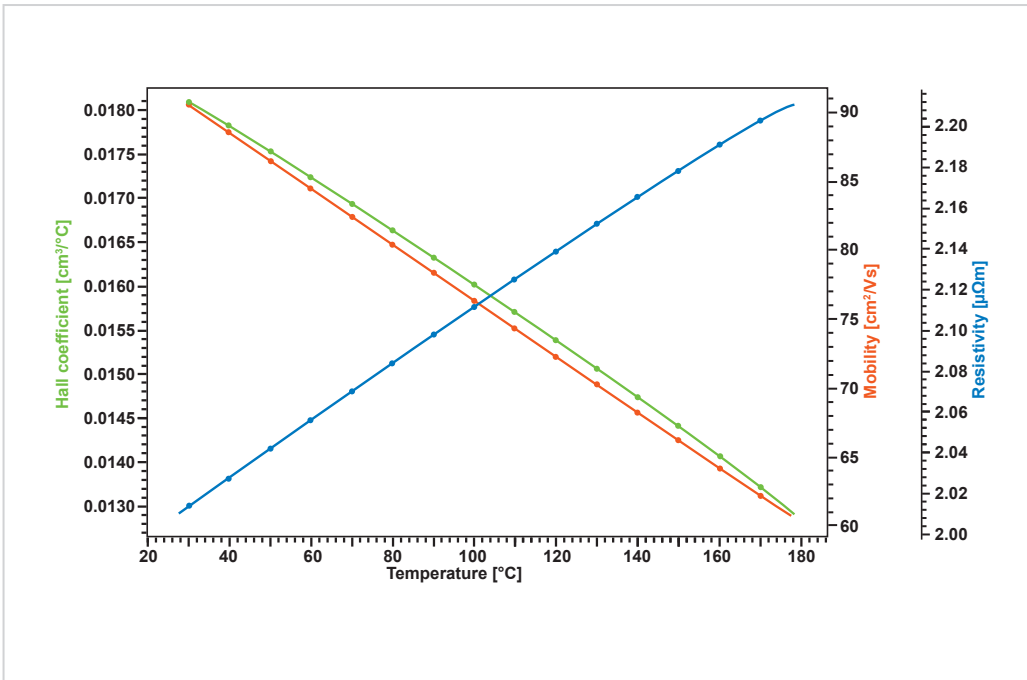
## Measurement of the Constantan reference sample



Seebeck Coefficient measurement on a Constantan reference sample from  $-140^\circ\text{C}$  up to  $+180^\circ\text{C}$ . 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

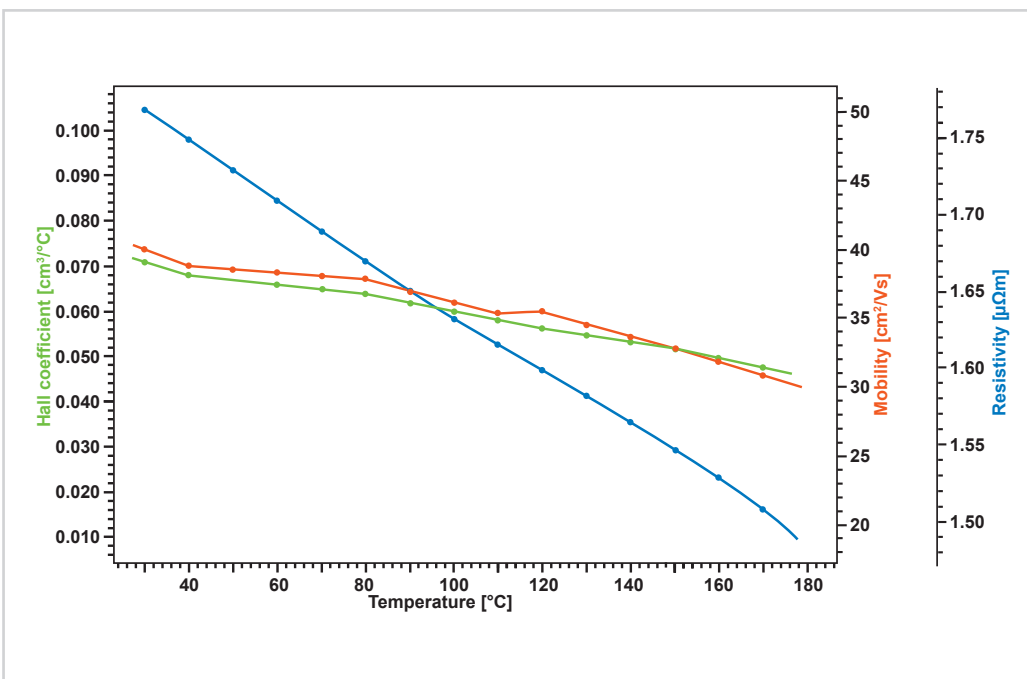
## Antimony Thin Film (150 nm Sb)



Antimony (Sb) is a semi-metal, which is widely used in the field of thermoelectrics (in form of alloys, e.g. Bi<sub>1-x</sub>Sb<sub>x</sub>) 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<sub>2</sub>/Si substrate, prepared by sputter deposition, with the Linseis HCS 1 (RT to 200°C option).

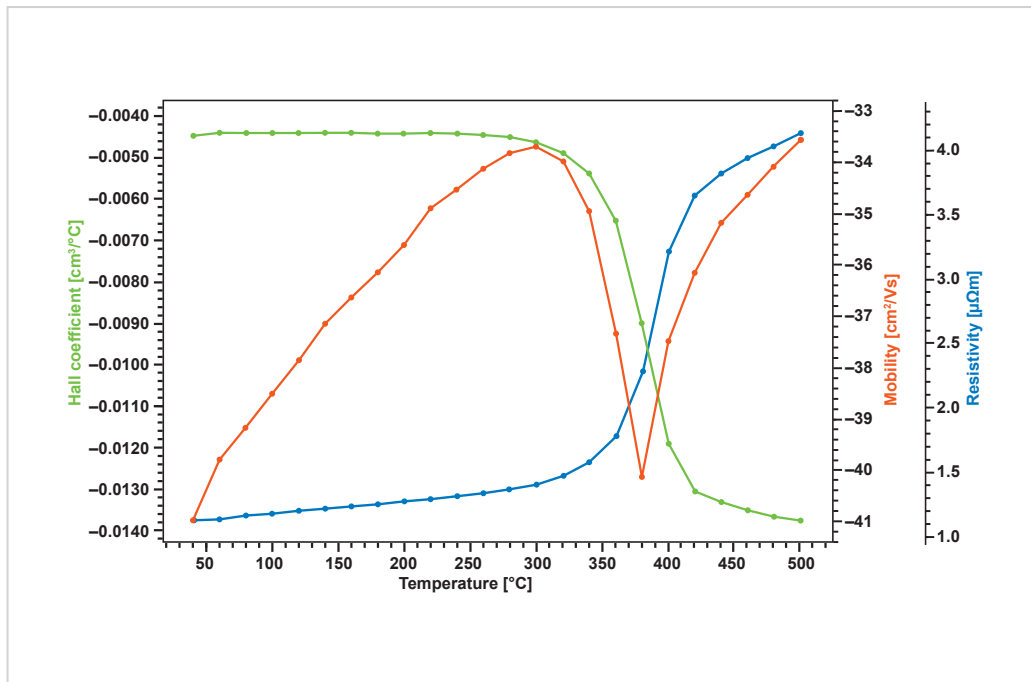
## Bismuth-antimony Thin Film (150 nm Bi<sub>87</sub>Sb<sub>13</sub>)



Bismuth-antimony alloys, (Bi<sub>1-x</sub>Sb<sub>x</sub>) are binary alloys of bismuth and antimony in various ratios. Some, in particular Bi<sub>0.9</sub>Sb<sub>0.1</sub>, 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.

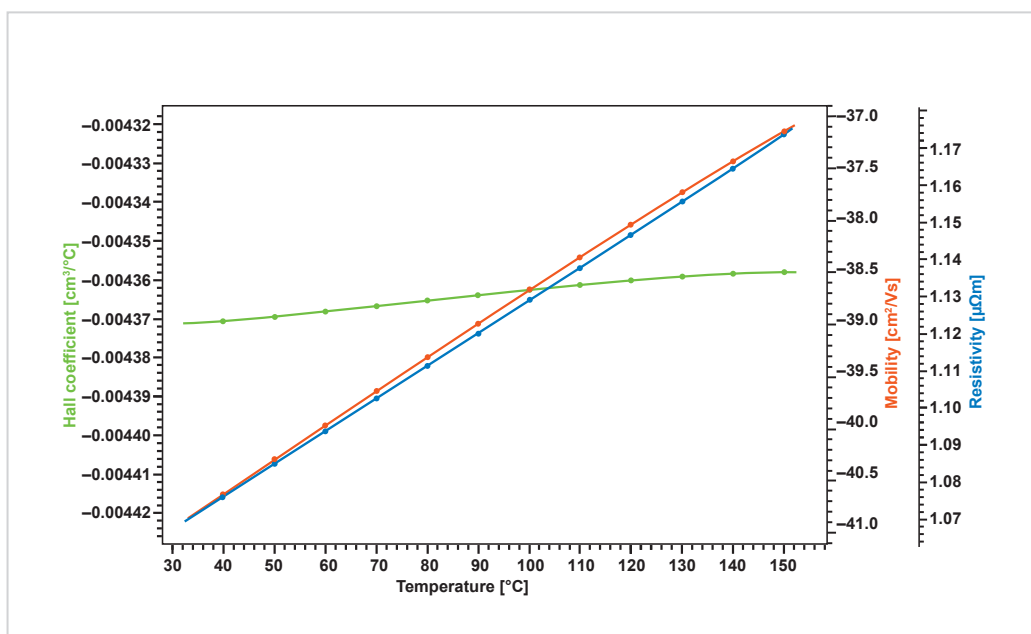
The presented measurement has been conducted on a thermally evaporated Bi<sub>87</sub>Sb<sub>13</sub> thin film.

## 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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