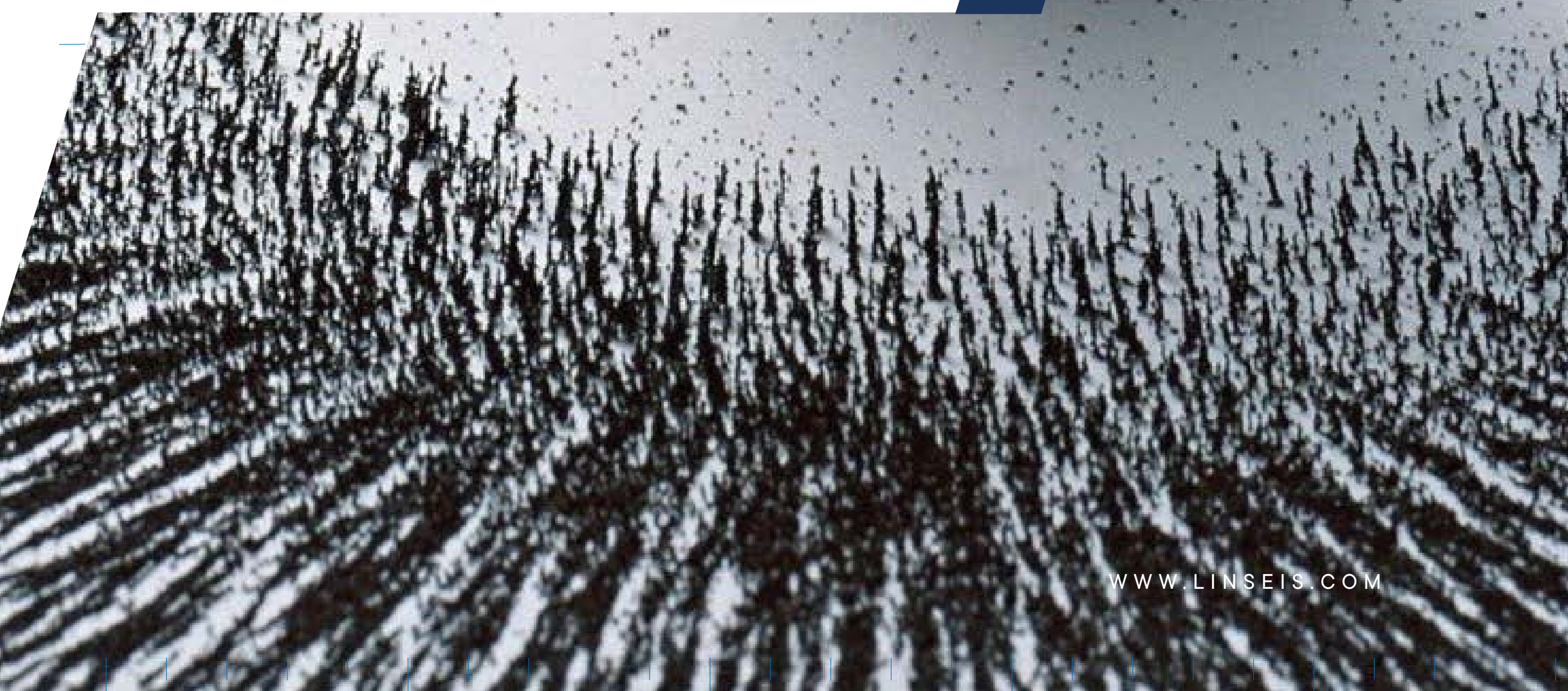
pushing boundaries

HCS 1
HCS 10

Hall-Effect **Characterization System**



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.

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 to constantly develop new technologies to enable continued discovery in Science.

Engineering & Innovation

Hall-Effect **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.

HCS 1

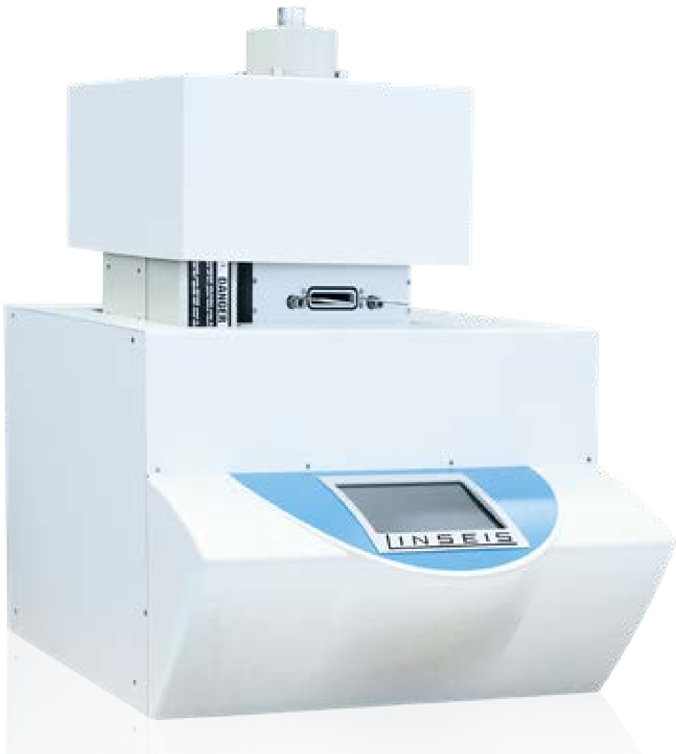
Measurement features

- Charge Carrier Concentration (Sheet [1/cm^2]/ Bulk [1/cm^3])
- Hall-Constant [cm^3/C]
- Hall-Mobility [cm^2/Vs]
- Sheet resistance [Ω]
- Resistivity [Ωcm]
- Conductivity [S/cm]
- Alpha (horizontal/vertical ration of resistance)
- Megneto resistance
- Seebeck Coefficient [µV/K]

- Hall Constant
- Mobility
- High temperature
- Easy handling
- Charge carrier concentration
- Seebeck coefficient addon

The systems can be equipped with different sample holder for various geometries and temperature requirements. An optional low temperature (LN2) attachments is available as well as a high temperature version up to 600°C/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.



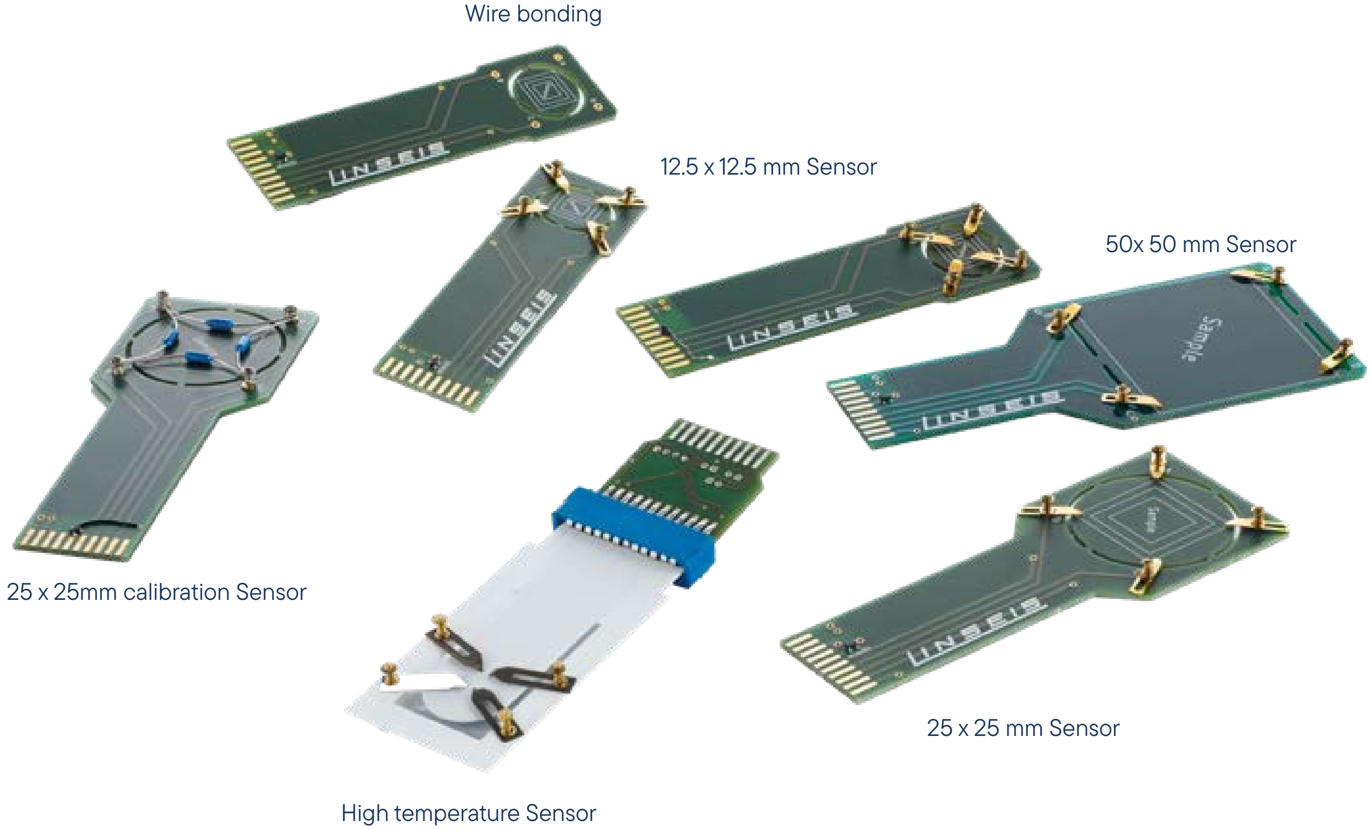
HCS 10

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 600°C / 800°C
- 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

Sensors

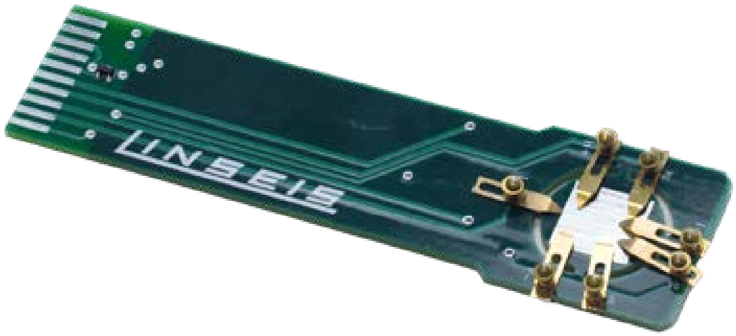
The Linseis HCS systems are modular in design, so that the application areas can be easily expanded with a wide range of options. These include, for example, the Seebeck option, the gated hall bar setup and the illumination option. The plug-and-play system of the sample boards allows the measurement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

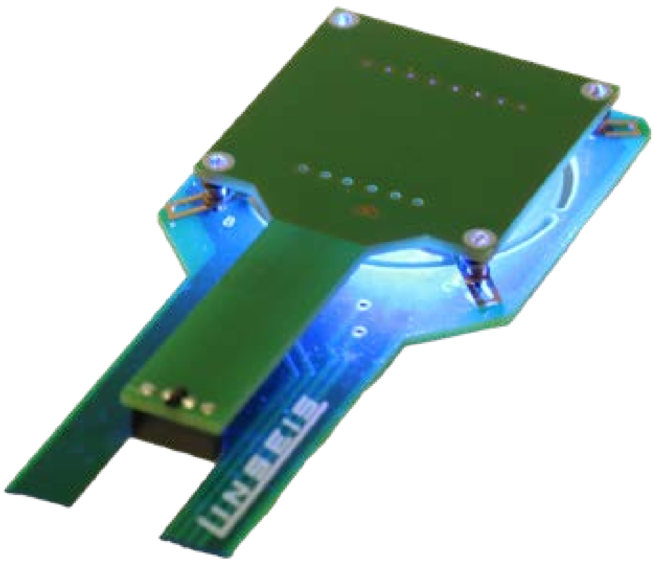


Exchangeable Sensors with an EPROM on it for easy plug and play usage.

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.



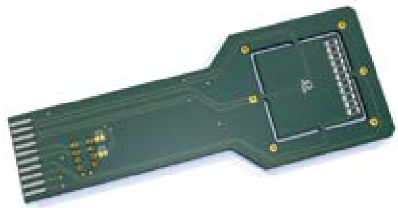


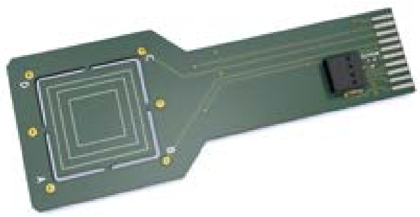
Illumination Option

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.

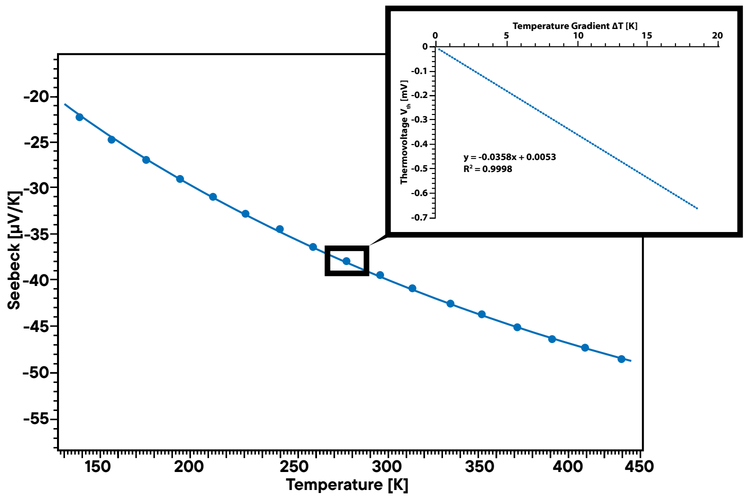
Seebeck Option

	HCS 1	HCS 10
Sample Geometry	length: 6 to 20mm width: 1 to 20mm heigth: thinfilm up to 2mm	length: 6 to 20mm width: 1 to 20mm heigth: thinfilm up to 2mm
Seebeck Coefficient	-2500 µV/K to 2500 µV/K	-2500 µV/K to 2500 µV/K
Measurement	Slope technique: eliminates errors caused by temperature gradient offset or Seebeck voltage offset	Slope technique: eliminates errors caused by temperature gradient offset or Seebeck voltage offset
Gradient heater	temperature gradient up to ~10K	temperature gradient up to ~10K
Thermocouples	Type K	Type K





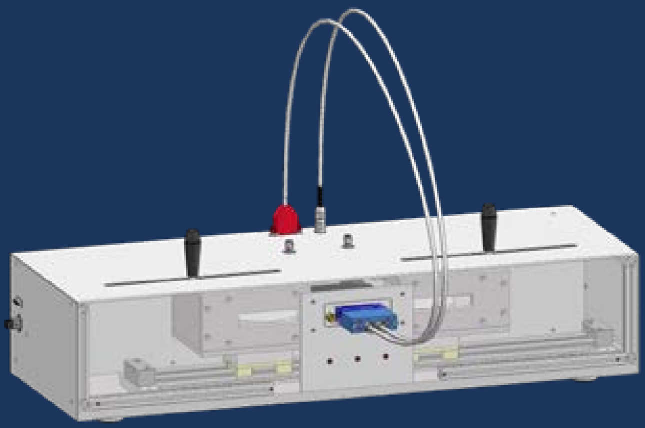
Measurement of the Constantan reference sample



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.

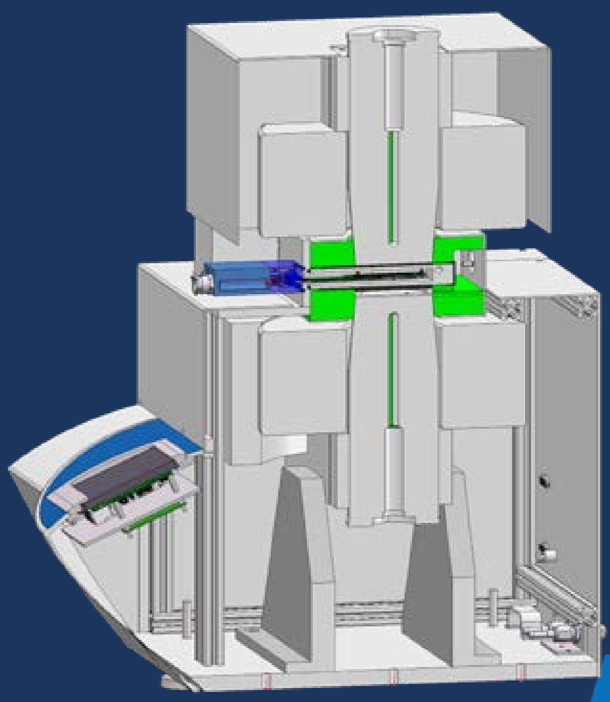
Unique features

Measurement System
A wide variety t sample holders can be plugged into the sample holder socket (for different sample sizes and measurement types). The camber is vacuum-tight and allows measuring the sampler under defined atmospheres.



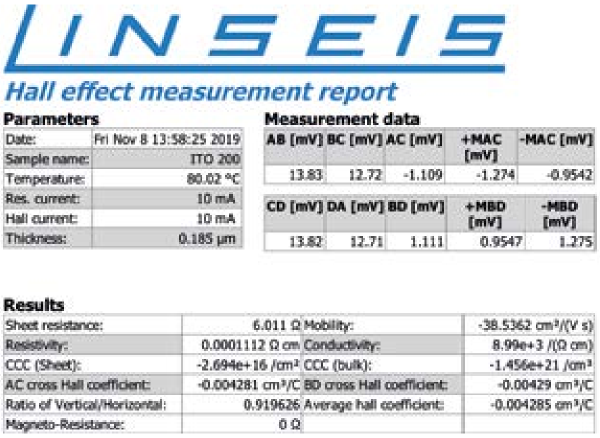
HCS 1
The HCS 1 is equipped with two pairs of neodymium permanent magnets with a diameter of 120mm. This allows for a very homogeneous magnetic field with a high flux density of at least 0.6T. The hall coefficient sample is measured with a DC excitation current. The bipolar current source allows to separation of the hall voltage from DC offsets such as thermovoltages.

HCS 10
The HCS 10 is equipped with a water-cooled electromagnet. That allows for measurements under a user-adjustable DC magnetic flux density range. The device is also available with an AC power supply for the electromagnet. The alternating magnetic field generates an alternating hall voltage when a DC excitation current is used. The misalignment voltage caused by sample asymmetry and thermovoltages is meaningless for the AC Amplitude measured.
The AC-share of the measured voltage consists only of the hall voltage and a voltage induced into the conductor loops. The AC signal is processed by a lock-in Amplifier with the flux density measured by a sensor to eliminate the 90°-out-of-phase induced voltage.



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.



LINSEIS

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

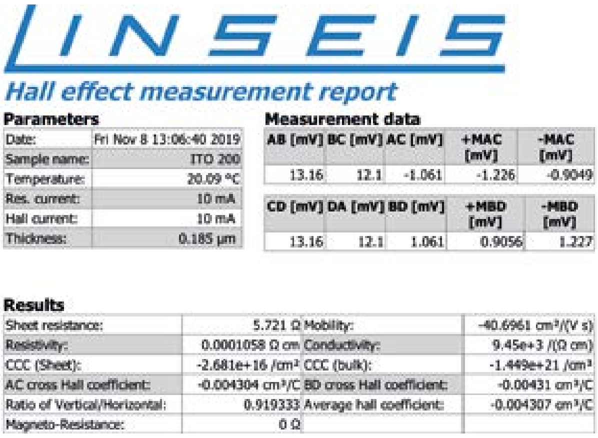
Measurement data

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		

General features

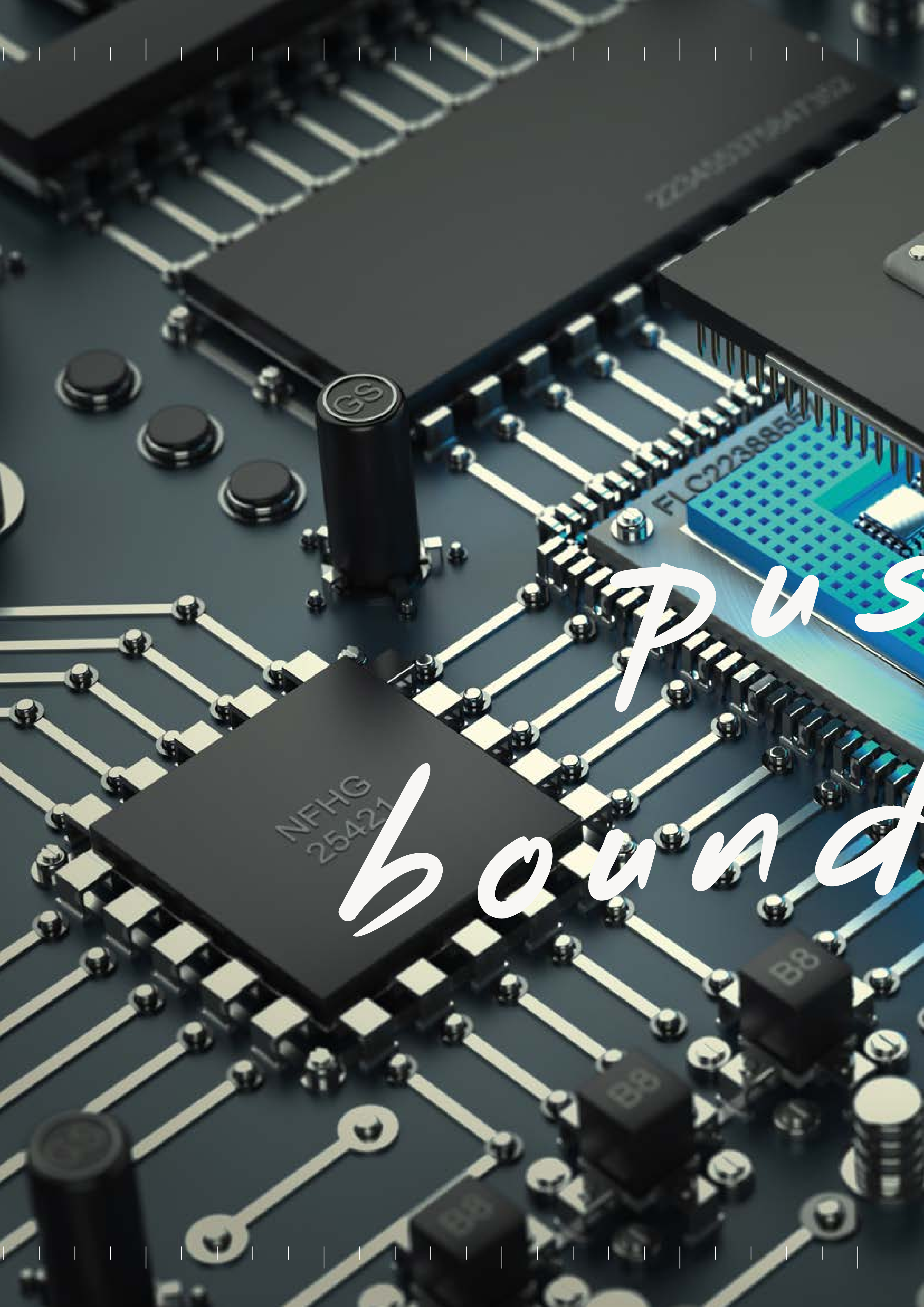
- NIST routine to find optimum measurement settings and get highest accurate results
- Extended connection test
- Possible integration of external electronics
- Optional Database storage
- Optional Lock-in amplifier integration
- Automatic sensor recognition (EEPROM)
- Automatic evaluation
- Fully automatic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

Technical Specifications

	HCS 1	HCS 10
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)
Magnet	Permanent magnets up to 0.70 T DC field Pole diameter 120 mm Two magnet setup for bipolar measurement.	Electromagnet with 76mm of pole ciameter. AC power supply for measurements up to 0.1Hz at up to +-40A
Current source	**DC** 1nA up to 125mA (8 decades / Compliance +/- 12V)	
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
Sensors / Sample geometry	Seebeck Sensor, Illumination Sensor, Gated hall bar 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 3mm	
Resistivity Range	10^{-4} up to 10^{7} (Ωcm)	10^{-4} up to 10^{7} (Ωcm)
Carrier concentration	10^{7} up to $10^{21}cm^{-3}$	10^{7} up to $10^{21}cm^{-3}$
Mobility range	0.1 ~ 10^{7} cm^{2} V^{-1} s^{-1}	10^{-3} ~ $10^{7}cm^{2}V^{-1}s^{-1}$
Atmospheres	Vacuum, inert, oxidizing, reducing	Vaccum, inert, oxidizing, reducing
Temperature resolution	0.001°C	0.001°C

Options

Seebeck	**Illumination**	**Gated hall bar**
Temperature range: -150°C respectively RT to 200°C (heater temperature)	Temperature range: -150°C respectively RT to 200°C	Temperature range: -150°C respectively RT to 200°C
Functionality: It measures the sample´s Seebeck coefficient	Availablle wave lengths: 630nm: 0 to ~80klx 520nm: 0 to ~200klx 470nm: 0 to ~13klx	Gate voltage: 0V to 30V (manual change of polarity possible)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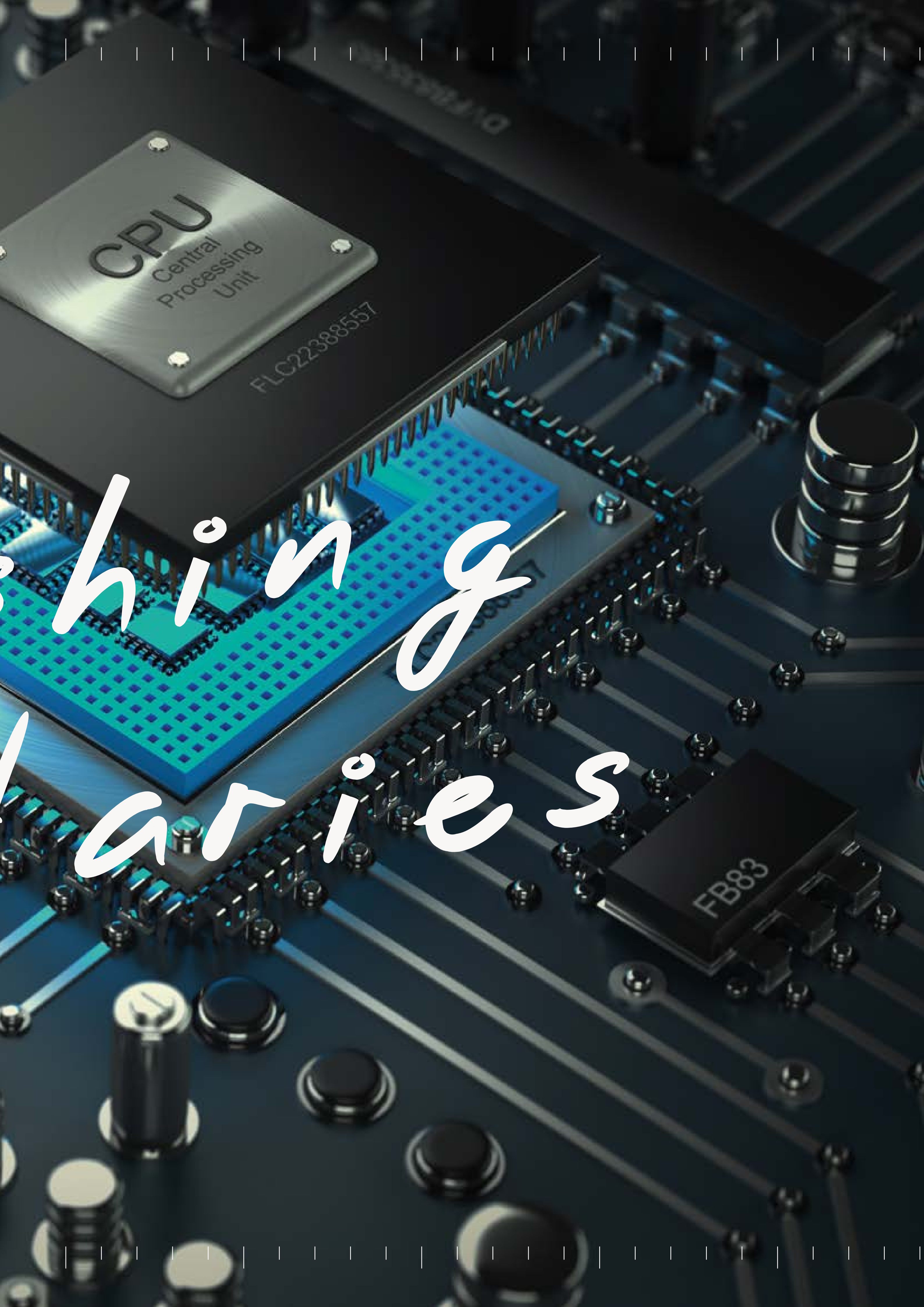
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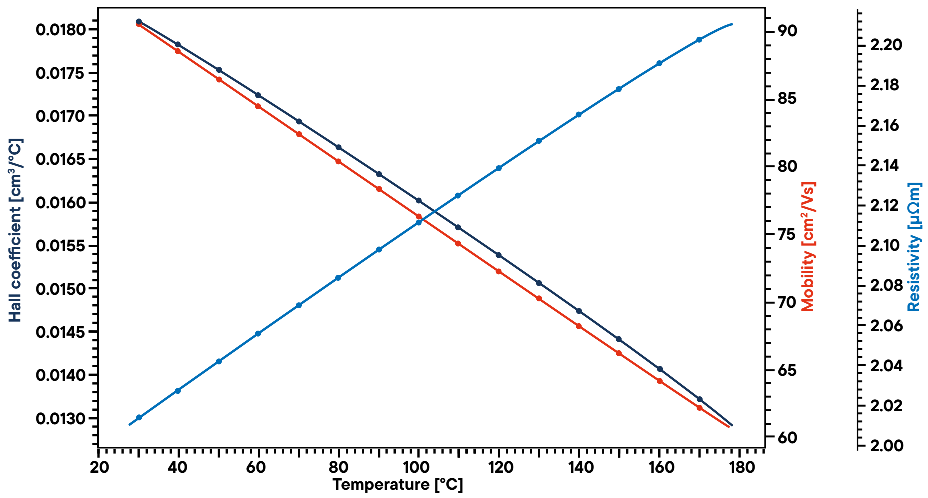
HCS Overview

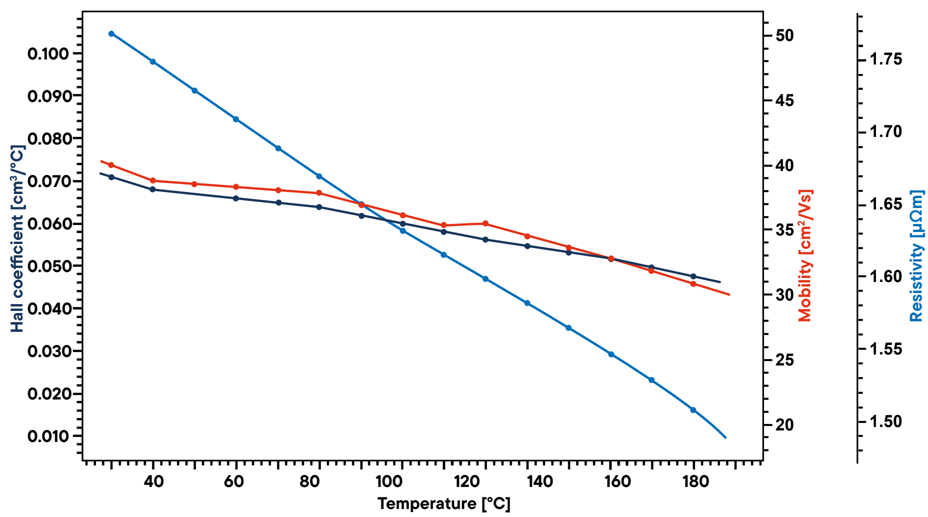
Applications HCS

Antimony Thin Film (150 nm Sb)



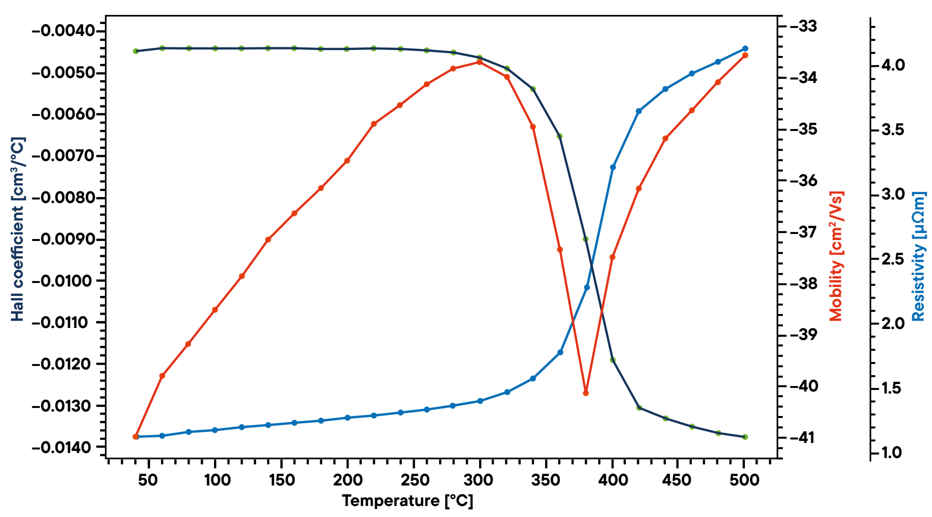
Antimony (Sb) is a semimetal, which is widely used in the field of thermoelectrics (in form of alloys, e.g. Bi1−xSbx) and as an emerging application is the field of microelectronics. Neverthe-less, the largest applications for metallic antimony are lead antimony plates in leadacid batteries. The figure shows a full characterization of a thin film on SiO2/Si substrate, prepared by sputter deposition, with the Linseis HCS 1 (RT to 200°C option).

Bismuth-antimony Thin Film (150 nm Bi87Sb13)



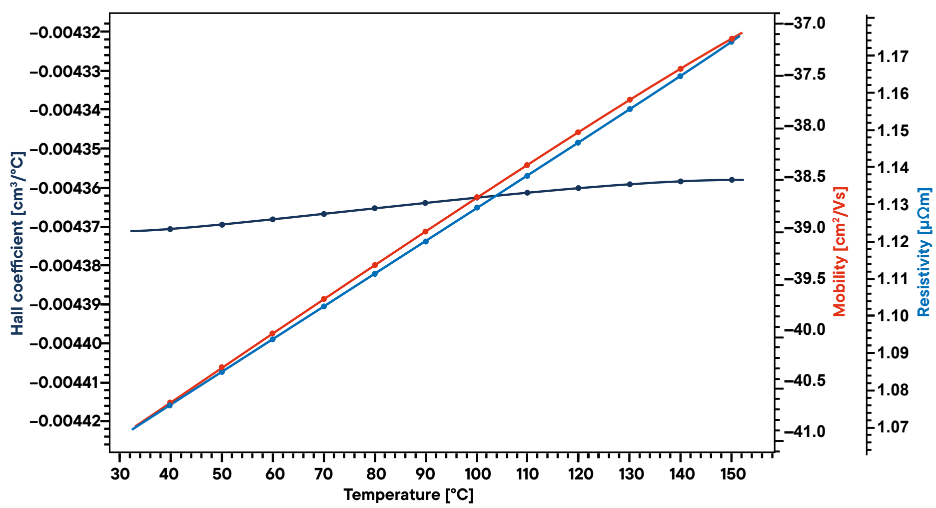
Bismuth-antimony alloys, (Bi1−xSbx) are binary alloys of bismuth and antimony in vari-ous ratios. Some, in particular Bi0.9Sb0.1, were the first experi-mentallyobserved three-dimen-sional topological insulators, materials that have conducting surface states but have an insulating interior. Various BiSb alloys are also used in low temperature thermoelectric de-vices. The presented measure-ment has been conducted on a thermally evaporated Bi87Sb13 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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LINSEIS

pushing boundaries

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