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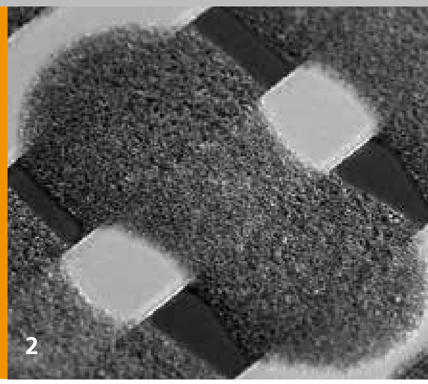

*1 Measurement setup to characterize and optimize the semiconductor material at temperatures of 20 to 800°C.*

*2 Gas sensor microstructure: The properties of the semiconductor used must be precisely adjusted during development.*


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# HALL MEASUREMENT SYSTEM

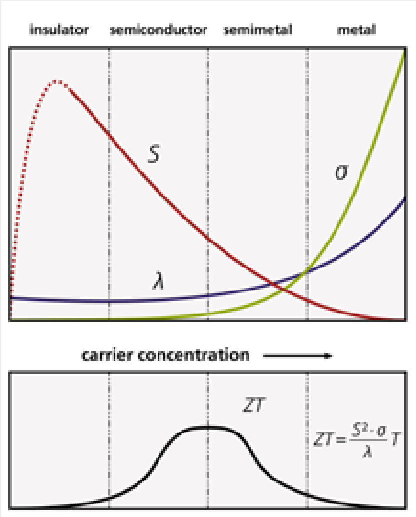
## MATERIAL CHARACTERIZATION AT HIGH TEMPERATURES

Hall measurements allow deep insights into the properties of materials: In addition to the identification of the charge carriers, it is also possible to determine their mobility and concentration. For this reason, the Hall effect measurement has become an important tool in the development of modern materials.

Commercially available devices, also known as Physical Property Measurement Systems (PPMS), measure at temperatures ranging from 4 K to a maximum of about 400 K. With the Hall measurement system IPM-HT-Hall, Fraunhofer IPM has brought Hall measurements into a temperature range of 20°C to 800°C. Thanks to the innovative measurement setup, it is possible to precisely measure the electrical, thermal, or magnetic properties of material samples with various geometries over a wide temperature range and with up to five different magnetic field strengths – quickly, easily, and reliably.

### Characterization of semiconductors and other solids

The properties of modern semiconductors (SCs) are specifically influenced to obtain the desired material properties for the final application. An important method is the process of doping of the material: the number, mobility, and type of charge carriers in the material are thereby precisely adjusted by incorporating specific quantities of impurity atoms. For thermoelectric semiconductor materials, for example, the charge carrier concentration is influenced through doping so that the optimal ratio of the electrical conductivity and Seebeck coefficient is obtained, which then yields material of the highest possible quality. In general, fewer than one doping atom per one million atoms of material is required. This means highly sensitive measuring devices are needed to analyze the charge carrier concentration and doping results. IPM-HT-Hall

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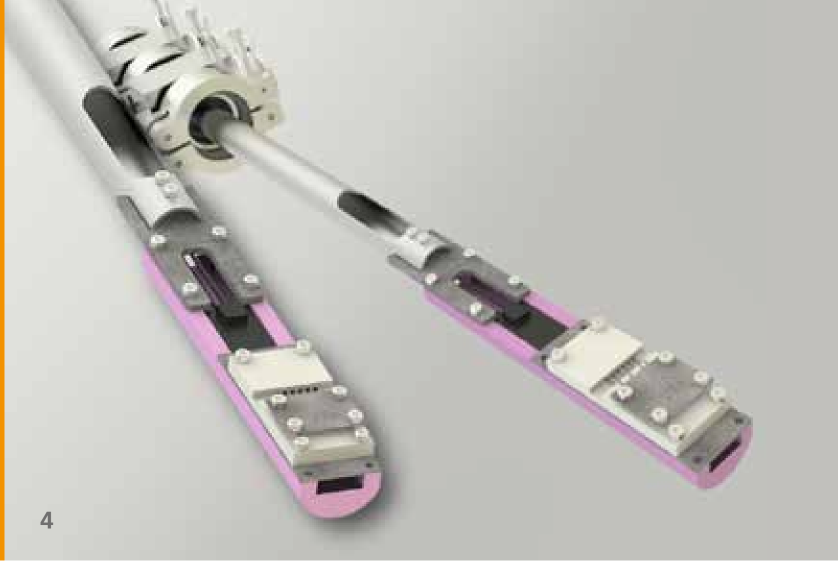

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measures with high sensitivity and detects minimal changes in the charge carrier concentration as well as the influence of the temperature on the doping of the material.

## Measuring at up to 800°C

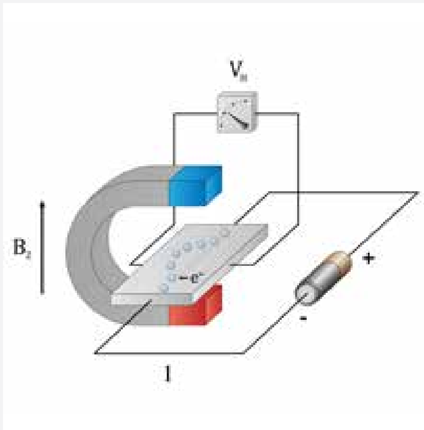
Many SC materials are used at temperatures well above room temperature, for example in solid-state gas sensors or thermoelectric high-temperature modules. To ensure the functionality of the material at the temperatures reached in these applications, it is also necessary to measure the material properties at high temperatures. In addition to the doping process, the ambient temperature also has an influence on the number of charge carriers: In general, the higher the temperature is, the more charge carriers are activated. Solid-state gas sensors operate at temperatures of 200 – 400 °C. The electrical properties of their sensitive coatings change depending on the temperature and gases present. Thanks to its adjustable measuring atmosphere, the IPM-HT-Hall offers the ability to analyze these materials in detail before they are applied to a complex sensor structure. The system measures up to four material parameters simultaneously at temperatures ranging from 20 to 800 °C. In addition to the standard sensor heads for Hall measurements, customers can also integrate their own sensor heads and independently developed measurement electronics into the measurement station.

3 *The electrical conductivity (σ), Seebeck coefficient (S), and thermal conductivity (λ) parameters depend on the charge carrier concentration. In the thermoelectric material, they must be optimized so that a maximum material quality of ZT is achieved. This depends on the temperature.*

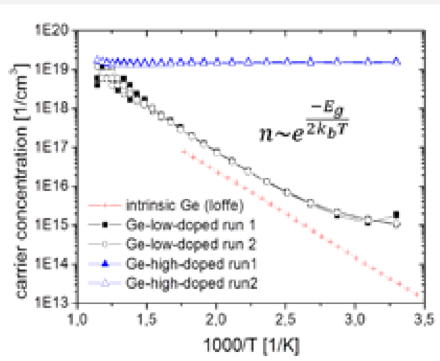
4 *Ceramic sensor head for measurements at temperatures of 800°C or higher.*

### Hall-Effekt

*In 1879, Edwin Herbert Hall discovered the effect named after him. He observed that the current in a conductor can be influenced by applying a magnetic field. The voltage created as a result allows you to gain deep insights into the conductive material being analyzed. This effect can be measured via the voltage, which is measured perpendicular to both the current and the magnetic field on the conductor.*




### High temperature measurement




*The measurement curve shows temperature-dependent measurements of the charge carrier concentration in three different Germanium samples. Pure Germanium, which is also referred to as intrinsic Germanium, shows the linear increase in charge carriers as the temperature increases. The charge carriers are activated thermally by the temperature increase. Lightly doped material has more charge carriers at room temperature than the pure material. At higher temperatures, however, it shows the same linear increase in charge carriers because more and more charge carriers are thermally activated in this case as well. Very highly doped material shows the highest charge carrier concentration at constant temperatures near 600°C.*

*< Charge carrier concentration using Germanium samples as an example.*