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Quotation 2017-18

Subject: Proposal for Seebeck Co-efficient measurement system and dc resistivity measurement system

Dear Sir,

Refer to your enquiry for Seebeck Co-efficient measurement system dc resistivity measurement system

The **Seebeck coefficient** (also known as **thermopower**,[1] **thermoelectric power**, and **thermoelectric sensitivity**) of a material is a measure of the magnitude of an induced thermoelectric voltage in response to a temperature difference across that material, as induced by the Seebeck effect.[2] The SI unit of the Seebeck coefficient is volts per kelvin (V/K),[2] although it is more often given in microvolts per kelvin (µV/K).

Specifications of the system

Specifications of seebeck measurement system

Chamber

SS chamber with facility to hold vacuum

Facility to hold specimen rectangular type 16mm *4mm*2mm

Four probes as thermocouples are installed along with dynamic heating facility to maintain hot and cold junction.

Sample holder shall have all connections on side plate for connection to current source and DC voltmeter connector for heater and thermocouple sensor each .

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Gas purging facility

One no's control valve is installed operated manually to purge gas if desired in case test needs to be carried out in specified environment.

MFC of user choice can be connected directly to set the flow rate of the test gas

A combination of 129 gases can be selected through MFC

Specification of Seebeck and DC resistance measurement system.

Seebcek measurement range

Resolution 0.1 microvolts per kelvin (µV/K).

Range 1 microvolt pe Kelvin to 20,000 microvolt per kelvin

Facility to set gradiant between hot and cold junction up to 1 degree diffewrence.

Resistance measurement range

1 Milliohm to 100 Giga Ohm

Temperature range

- **RT to 550 degree C in high temp attachment**

- **Accuracy 1 degree**
- **Resolution 0.1 degree**

Various items and attachments Included

Current Source

- Current range 1 nA to 10 m A
- Resolution 1% of the range
- Voltage compliance 100 Volts

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DC Voltmeter

- Range 1 microV to 100 Volt
- Resolution 1% of the range
- Voltage compliance 100 Volts
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Temperature Stage

- SS construction sample holder RT – 500 degree C
- Facility to load bulk rectangular pellet for four probe setup of size 16*4*2 mm
- 4 nos PID controlled heating arrangement using NX4 controller having RS232 interface
- 4 nos 2.5 K watt thyrester power supply embedded in the main control box
- RS232 PCI card to control the temperature controller.

Vacuum pump

Mono block type vacuum pump included to attain vacuum of the order of milli .

Software

- Standard graph and data in tabular form for following
    o I/V Current vs voltage in fixed interval
    o DC resistivity at different temperatures
    o Seebeck microvolt per kelvin vs temperature

- RS232/USB interface hardware.

Software Requirements

- A normal PIV computer to be provided by the user

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Price Details and Terms & Conditions

Seebeck measurement system   Rs14,00,000/-

MFC 0 – 200 CCM   Rs 2,00,000
(Optional incase user wishes to measure in gas environment)

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- From 1st July GST @ 18% will be charged.
- Payment 100% against delivery
- Performa invoice will be provided after material is ready for inspection
- Warranty 1 year from date of installation
- Warranty certificate shall be provided

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Technical information on Seebeck measurement

One way to define the Seebeck coefficient is the voltage built up when a small temperature gradient is applied to a material, and when the material has come to a steady state where the current density is zero everywhere. If the temperature difference ΔT between the two ends of a material is small, then the Seebeck coefficient of a material is defined as:

$$S = -\frac{\Delta V}{\Delta T}$$

where ΔV is the thermoelectric voltage seen at the terminals. (See below for more on the signs of ΔV and ΔT.)

Note that the voltage shift expressed by the Seebeck effect cannot be measured directly, since the measured voltage (by attaching a voltmeter) contains an additional voltage contribution, due to the temperature gradient and Seebeck effect in the measurement leads. The voltmeter voltage is always dependent on *relative* Seebeck coefficients among the various materials involved.

Most generally and technically, the Seebeck coefficient is defined in terms of the portion of electric current driven by temperature gradients, as in the vector differential equation

$$\mathbf{J} = -\sigma\boldsymbol{\nabla}V - \sigma S\boldsymbol{\nabla}T$$

where $\mathbf{J}$ is the current density, σ is the electrical conductivity, $\boldsymbol{\nabla}V$ is the voltage gradient, and $\boldsymbol{\nabla}T$ is the temperature gradient. The zero-current, steady state special case described above has $\mathbf{J}=0$, which implies that the two current density terms have cancelled out and so $\boldsymbol{\nabla}V=-S\boldsymbol{\nabla}T$.

Sign convention[edit]

The sign is made explicit in the following expression:

$$S = -\frac{V_{left} - V_{right}}{T_{left} - T_{right}}$$

Thus, if S is positive, the end with the higher temperature has the lower voltage, and vice-versa. The voltage gradient in the material will point against the temperature gradient.

The Seebeck effect is generally dominated by the contribution from charge carrier diffusion (see below) which tends to push charge carriers towards the cold side of the material until a compensating voltage has built up. As a result, in p-type semiconductors (which have only positive mobile charges, electron holes), S is positive. Likewise, in n-type semiconductors

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(which have only negative mobile charges, electrons), *S* is negative. In most conductors, however, the charge carriers exhibit both hole-like and electron-like behaviour and the sign of *S* usually depends on which of them predominates.

Relationship to other thermoelectric coefficients[edit]

Main article: Thomson relations

According to the second Thomson relation (which holds for all non-magnetic materials in the absence of an externally applied magnetic field), the Seebeck coefficient is related to the Peltier coefficient Π by the exact relation

$$S = \frac{\Pi}{T},$$

where T is the thermodynamic temperature.

According to the first Thomson relation and under the same assumptions about magnetism, the Seebeck coefficient is related to the Thomson coefficient $\mathcal{K}$ by

$$S = \int \frac{\mathcal{K}}{T}\,dT.$$

The constant of integration is such that $S = 0$ at absolute zero, as required by Nernst's theorem.

Measurement[edit]

Relative Seebeck coefficient[edit]

See also: Thermocouple

In practice the absolute Seebeck coefficient is difficult to measure directly, since the voltage output of a thermoelectric circuit, as measured by a voltmeter, only depends on *differences* of Seebeck coefficients. This is because electrodes attached to a voltmeter must be placed onto the material in order to measure the thermoelectric voltage. The temperature gradient then also typically induces a thermoelectric voltage across one leg of the measurement electrodes. Therefore the measured Seebeck coefficient is a contribution from the Seebeck coefficient of the material of interest and the material of the measurement electrodes. This arrangement of two materials is usually called a thermocouple.

The measured Seebeck coefficient is then a contribution from both and can be written as:

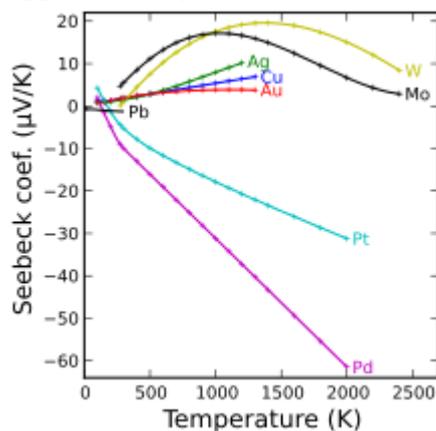$$S_{AB} = S_B - S_A = \frac{\Delta V_B}{\Delta T} - \frac{\Delta V_A}{\Delta T}$$

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Absolute Seebeck coefficient[edit]
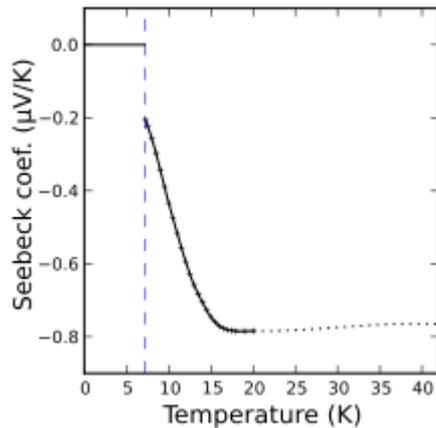
Absolute Seebeck coefficient of lead at low temperature, according to Christian, Jan, Pearson, Templeton (1958). Below the critical temperature of lead (indicated by the dashed line, approximately 7 K) the lead is superconducting.

Absolute Seebeck coefficients of various metals up to high temperatures, mainly from Cusack & Kendall (1958). The data for lead (Pb) is from Christian, Jan, Pearson, Templeton (1958).

Although only relative Seebeck coefficients are important for externally measured voltages, the absolute Seebeck coefficient can be important for other effects where voltage is measured indirectly. Determination of the absolute Seebeck coefficient therefore requires more complicated techniques and is more difficult, however such measurements have been performed on standard materials. These measurements only had to be performed once for all time, and for all materials; for any other material, the absolute Seebeck coefficient can be obtained by performing a relative Seebeck coefficient measurement against a standard material.

A measurement of the Thomson coefficient μ, which expresses the strength of the Thomson effect, can be used to yield the absolute Seebeck coefficient through the relation:

$$S(T) = \int_0^T \frac{\mu(T')}{T'} dT'$$, provided that μ is measured down to absolute zero. The reason this works is that $S(T)$ is expected to decrease to zero as the temperature is brought to zero—a consequence of Nernst's theorem. Such a measurement based on the integration of μ/T was published in 1932,[3] though it relied on the interpolation of the Thomson coefficient in certain regions of temperature.

Superconductors have zero Seebeck coefficient, as mentioned below. By making one of the wires in a thermocouple superconducting, it is possible to get a direct measurement of the absolute Seebeck coefficient of the other wire, since it alone determines the measured voltage from the entire thermocouple. A publication in 1958 used this technique to measure the absolute Seebeck coefficient of lead between 7.2 K and 18 K, thereby filling in an important gap in the previous 1932 experiment mentioned above.[4]

The combination of the superconductor-thermocouple technique up to 18 K, with the Thomson-coefficient-integration technique above 18 K, allowed determination of the absolute Seebeck coefficient of lead up to room temperature. By proxy, these measurements led to the determination of absolute Seebeck coefficients for *all materials*, even up to higher temperatures, by a combination of Thomson coefficient integrations and thermocouple circuits.[5]

The difficulty of these measurements, and the rarity of reproducing experiments, lends some degree of uncertainty to the absolute thermoelectric scale thus obtained. In particular, the 1932 measurements may have incorrectly measured the Thomson coefficient over the range 20 K to 50 K. Since nearly all subsequent publications relied on those measurements, this would mean that all of the commonly used values of absolute Seebeck coefficient (including those shown in the figures) are too low by about 0.3 µV/K, for all temperatures above 50 K.[6]