Electrical conductivity of metals (Item No.: P2350205)

Curricular Relevance

Area of Expertise: Applied Sciences Engineering
Education Level: University
Topic: Materials Science
Subtopic: Thermal and Electrical Properties
Experiment: Electrical conductivity of metals

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Easy	1 Hour	1 Hour	2 Students

Additional Requirements:

Experiment Variations:

- P2350200 "Thermal and electrical conductivity of metals" to show the relation between thermal and electrical conductivity following the Wiedemann-Franz law
- P2350201 "Thermal conductivity of metals"

Keywords:

Electrical conductivity, Resistivity, Four-point method

Overview

Short description

Principle

The electrical conductivity of copper and aluminium is determined. For a given thermal conductivity of the materials, the Wiedmann-Franz law is tested.

Fig. 1: Set-up

Equipment

Position No.	Material	Order No.	Quantity
1	PHYWE multitap transformer DC: 2/4/6/8/10/12 V, 5 A / AC: 2/4/6/8/10/12/14 V, 5 A	13533-93	1
2	PHYWE Universal measuring amplifier	13626-93	1
3	Heat conductivity rod, Cu	04518-11	1
4	Heat conductivity rod, Al	04518-12	1
5	Rheostat, 10 Ohm , 5.7A	06110-02	1
6	Digital multimeter 2005	07129-00	2
7	Connecting cord, 32 A, 500 mm, red	07361-01	3
8	Connecting cord, 32 A, 500 mm, blue	07361-04	4
9	Connecting cord, 32 A, 1000 mm, red	07363-01	1

Tasks

Determine the electrical conductivity of copper and aluminium by recording a current-voltage characteristic line.

Confirm the Wiedemann-Franz law.

Set-up and procedure

Measurement of the electrical conductivity.

- Set-up the experiment as shown in Fig. 1 and perform the experiment according to the circuit diagram in Fig. 2 (set-up in accordance with a 4-conductor measuring method).

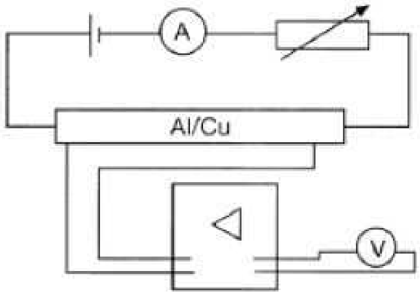

Fig. 2: Circuit diagram.

- Set the voltage on the variable transformer to 6 V.
- The amplifier must be calibrated to 0 in a voltage-free state to avoid a collapse of the output voltage.
- Select the amplifier settings as follows:
  Input: Low Drift
  Amplification: 10^4
  Time Constant: 0
- Set the rheostat to its maximum value and slowly decrease the value during the experiment.
- Read and note the values for current and voltage.
- The resistance, and thus the electrical conductivity, can be determined from the measured values.

Theory and evaluation

The electrical conductivity σ is determined by the resistance R of the rod and its geometric dimensions ($l = 0.315\,\mathrm{m}$, $A = 4.91 \cdot 10^{-4}\,\mathrm{m}^2$):

$$\sigma = \frac{l}{A \cdot R} \tag{1}$$

At room temperature, the conduction electrons in metal have a much greater mean free path than the phonons. For this reason heat conduction in metal is primarily due to the electrons. The resulting correlation between the thermal conductivity λ and the electrical conductivity σ is established by the Wiedemann-Franz law:

$$\frac{\lambda}{\sigma} = LT \tag{2}$$

The Lorenz number L, which can be experimentally determined using Equation (2), is established by the theory of electron vapour (for temperatures above the Debye temperature) to be:

$$L = \frac{\pi^2}{3} \cdot \left(\frac{k^2}{e^2}\right) = 2.4 \cdot 10^{-8}\,\frac{\mathrm{W\Omega}}{\mathrm{K}^2} \tag{3}$$

with
k = Universal gas constant = $1.38 \cdot 10^{-23}\,\mathrm{J/K}$
e = Elementary unit charge = $1.602 \cdot 10^{-19}\,\mathrm{AS}$

From equation (2), the following values result for $T = 300\,\mathrm{K}$ and the given thermal conductivities λ:

	$R/10^{-6}\,\Omega$	$\sigma/10^{7}\,(\Omega\mathrm{m})^{-1}$	$L/10^{-8}\,\mathrm{W\Omega\,K^{-2}}$
Al	19.6	3.27	2.24
Cu	12.04	5.33	2.40

with the literature values
$\lambda_{\mathrm{Al}} = 220\,\mathrm{W/(K\,m)}$
$\lambda_{\mathrm{Cu}} = 384\,\mathrm{W/(K\,m)}$

The Debye temperatures of copper and aluminium are 335 K and 419 K, respectively. Below the Debye temperature the ratio of the conductivity is smaller than given by Equation (2).

Robert-Bosch-Breite 10
D - 37079 Göttingen
Tel: +49 551 604 - 0
Fax: +49 551 604 - 107
info@phywe.de
www.phywe.com