ELECTRICAL CONDUCTORS

UE3020200

EXPERIMENT PROCEDURE

- **Measure voltage drop *U* as a function of distance *d* between contact points at a constant current *I*.**
- **Measure voltage drop *U* as a function of current *I* for a fixed distance *d* between contact points.**
- **Determine the electrical conductivity of copper and aluminium and make a comparison with values quoted in literature.**

OBJECTIVE

Determine the electrical conductivity of copper and aluminium.

SUMMARY

Electrical conductivity of a material is highly dependent on the nature of the material. It is defined as the constant of proportionality between the current density and the electric field in the material under investigation. In this experiment, four-terminal sensing is used to measure current and voltage in metal bars of known cross section and length.

REQUIRED APPARATUS

Quantity	Description	Number
1	Heat Conducting Rod Al	1017331
1	Heat Conducting Rod Cu	1017330
1	DC Power Supply, 1 – 32 V, 0 – 20 A (115 V, 50/60 Hz)	1012858 or
	DC Power Supply, 1 – 32 V, 0 – 20 A (230 V, 50/60 Hz)	1012857
1	Microvoltmeter (230 V, 50/60 Hz)	1001016 or
	Microvoltmeter (115 V, 50/60 Hz)	1001015
1	Digital Multimeter E	1006809
1	Set of 15 Experiment Leads, 75 cm 2.5 mm²	1002841

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BASIC PRINCIPLES

Electrical conductivity of a material is highly dependent on the nature of the material. It is defined as the constant of proportionality between the current density and the electric field in the respective material. In metals it is determined by the number density and mobility of electrons in the conduction band and is also dependent on temperature.

For a long metal conductor of cross-sectional area *A* and length *d*, a relationship between current *I* through the conductor and the voltage *U* which drops over a distance *d* along it can be deduced from the following formula:

(1) $$j = \sigma \cdot E$$

j: current density, *E*: electric field

That relationship is as follows:

(2) $$I = j \cdot A = A \cdot \sigma \cdot \frac{U}{d}$$

In the experiment, this relationship is used to determine the conductivity of metal bars using four-terminal sensing. This involves feeding in a current *I* through two wires and measuring the drop in voltage *U* between two contact locations separated by a distance *d*. Since the area of the cross section *A* is known, it is possible to calculate the conductivity σ.

The experiment uses the same metal bars investigated in the experiment on heat conduction, UE2020100. Two measurement probes are used to measure the voltage drop between the contact points, which can also be used to measure temperature along the bars.

NOTE

By comparing the measurements with the heat conductivity values obtained in experiment UE2020100 it is possible to verify the Wiedemann-Franz law. This states that thermal conductivity is proportional to electrical conductivity in metals and the factor is a universal value temperature-dependent coefficient.

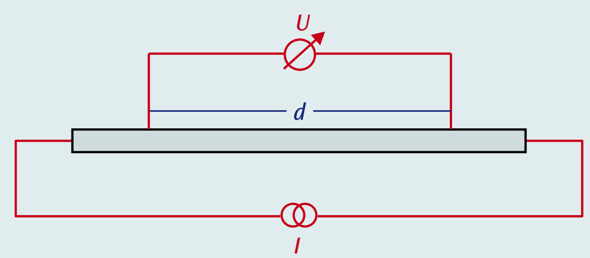

Fig. 3: Schematic of four-terminal sensing measurement

EVALUATION

The values measured for constant current *I* are plotted in a graph of *U* against *d*. Contact voltages between the measurement probes and the metal bar may become apparent by causing the straight lines to be shifted away from the origin. According to equation (2), the following is true

$$\alpha = \frac{I}{A \cdot \sigma} .$$

Since *I* and *A* are known, it is possible to calculate the conductivity:

$$\sigma = \frac{I}{A \cdot \alpha}$$

The gradient of the *U*-*I* graph is

$$\beta = \frac{d}{A \cdot \sigma} .$$

This implies that

$$\sigma = \frac{d}{A \cdot \beta}$$

Comparing the results with values quoted in literature for pure copper and aluminium, it can be seen that that these metal bars are not made of pure metal but are actually copper or aluminium alloys.

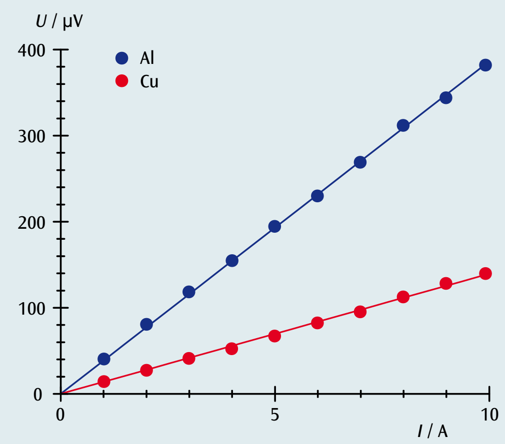

Fig. 1: Plot of *U* against *d* for copper and aluminium

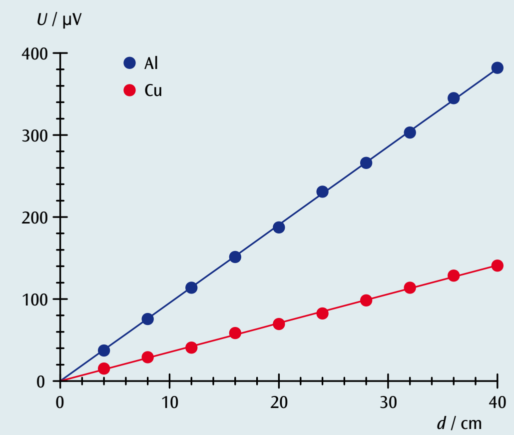

Fig. 2: Plot of *U* against *I* for copper and aluminium