Related topics

Semiconductor, band theory, forbidden band, intrinsic conduction, extrinsic conduction, impurity depletion, valence band, conduction band.

Principle and task

The conductivity of a germanium testpiece is measured as a function of temperature. The energy gap is determined from the measured values.

Equipment

Intrinsic conduct. of ge, car.b.	11807.00	1
Connection box	06030.23	1
Distributor	06024.00	1
PEK carbon resistor 1 W 5% 180 Ohm	39104.11	1
Digital multimeter	07134.00	2
Meter, 10/30 mV, 200 deg. C	07019.00	1
Power supply, universal	13500.93	1
Tripod base -PASS-	02002.55	1
Connecting cord, 750 mm, red	07361.01	5
Connecting cord, 750 mm, yellow	07361.02	2
Connecting cord, 750 mm, blue	07361.04	3

Problems

1. The current and voltage are to be measured across a germanium test-piece as a function of temperature.

2. From the measurements, the conductivity σ is to be calculated and plotted against the reciprocal of the temperature T. A linear plot is obtained, from whose slope the energy gap of germanium can be determined.

Set-up and procedure

The experimental set-up is as in Fig. 1 and 2. The test piece is connected via a series resistor to the direct voltage output of the power unit. The current should not exceed 30 mA. The voltage across the test piece is measured with a multimeter.

The conductivity δ is defined as following:

$$\delta = \frac{1}{\rho} = \frac{l \cdot I}{A \cdot U} \left[\frac{1}{\Omega m} \right]$$

with ρ = specific recistivity, l = length of test specimen, A = cross section, I = current, U = voltage.
(Dimensions of Ge-plate $20 \times 10 \times 1$ mm^3)

On the back of the board is the heating coil, supplied by the alternating voltage output of the power unit. It is recommended that the test piece be warmed up slowly for the measurements, applying firstly 2 V, then 4 V and finally 6 V.

The maximum permissible temperature of 175°C must **not** be exceeded. It is also possible to warm up to the maximum temperature first of all, and then take measurements during the cooling-down period.

The test-piece temperature is determined using the Cu/CuNi thermocouple and the mV-meter.

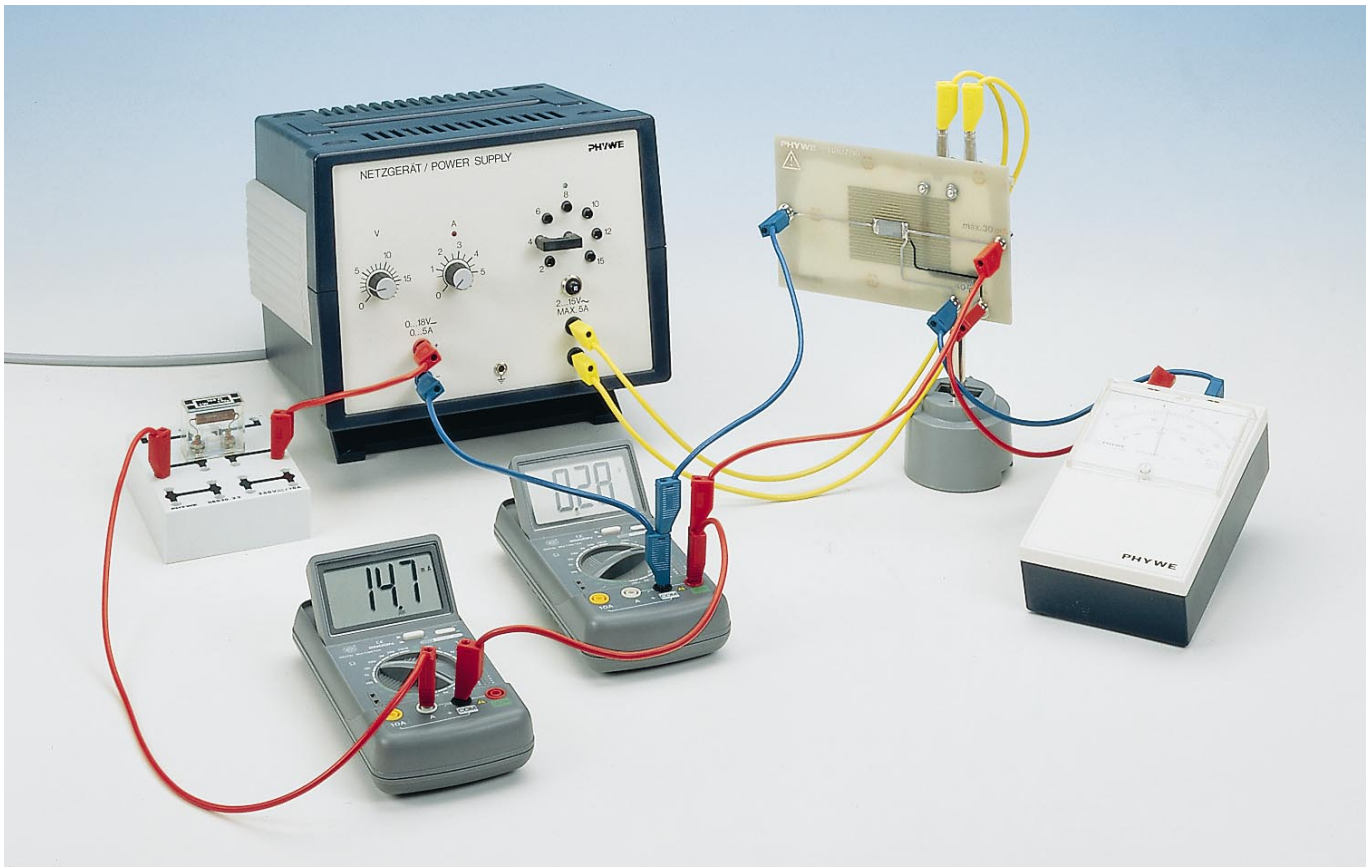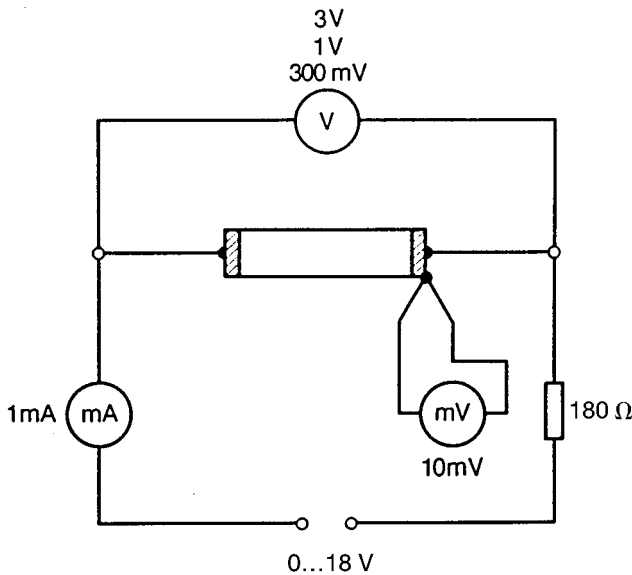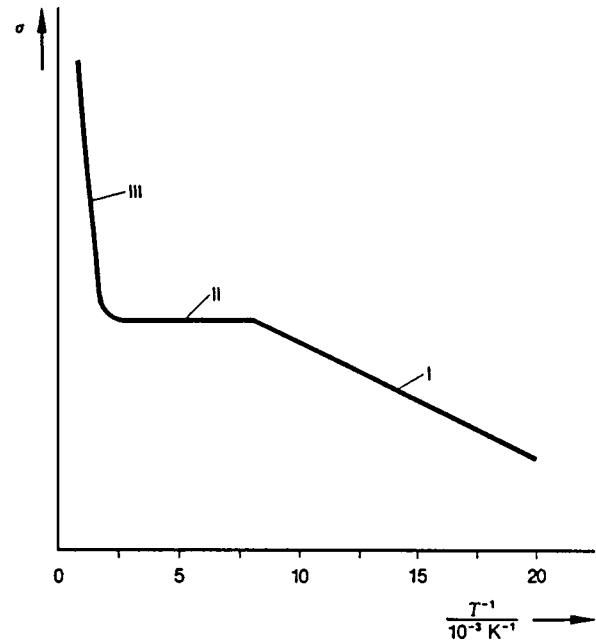Fig. 1: Experimental set-up for energy-gap determination.

Fig. 2

3V
1V
300 mV

(V)

1mA (mA)

(mV)
10mV

180 Ω

0...18 V

Fig.3 : Conductivity of a semi-conductor as a function of the reciprocal of the temperature.

σ

III

II

I

| 0 | 5 | 10 | 15 | 20 |

$\dfrac{T^{-1}}{10^{-3}\,K^{-1}}$ ⟶

Theory and evaluation

The conductivity of semiconductors is characteristically a function of temperature. Three ranges can be distinguished: at low temperatures we have **extrinsic conduction** (range I), i.e. as the temperature rises charge carriers are activated from the impurities. At moderate temperatures (range II we talk of **impurity depletion,** since a further temperatue rise no longer produces activition of impurities. At high temperatures (range III) it is **intrinsic conduction** which finally predominates (see Fig. 3). In this instance charge carriers are additionally transferred by thermal excitation from the valence band to the conduction band. The temperature dependence is in this case essentially described by an exponential function.

$$\sigma \;=\; \sigma_0 \cdot \exp - \frac{E_g}{2\,kT}$$

(E_g = engergy gap, k = Boltzmann's constant, T = absolute temperature).

The logarithm of this equation

$$\ln \sigma \;=\; \ln \sigma_0 - \frac{E_g}{2\,kT}$$

is with $y = \ln \sigma$ and $x = \dfrac{1}{T}$, a linear

equation on the type $y = a + bx,$ where $b = -\dfrac{E_g}{2k}$ is slope of the straight line.

With the measured values from Fig. 4, the regression with the expression

$$\ln \sigma \;=\; \ln \sigma_0 + \frac{E_g}{2\,k} \cdot \frac{1}{T}$$

provides the slope $b = 3.76 \pm 0.08 \cdot 10^3$ K.

With the Boltzmann's constant $k = 8.625 \cdot 10^{-5}$ eV, we finally obtain

$$E_g \;=\; b \cdot 2k = (0.65 \pm 0.01)\ \text{eV. (Literatur value 0.67 eV)}$$

$\dfrac{\sigma}{10^{-3}\Omega^{-1}\,mm^{-1}}$

1000			
100			
10			
1			
2,1	2,5	3,0	3,5

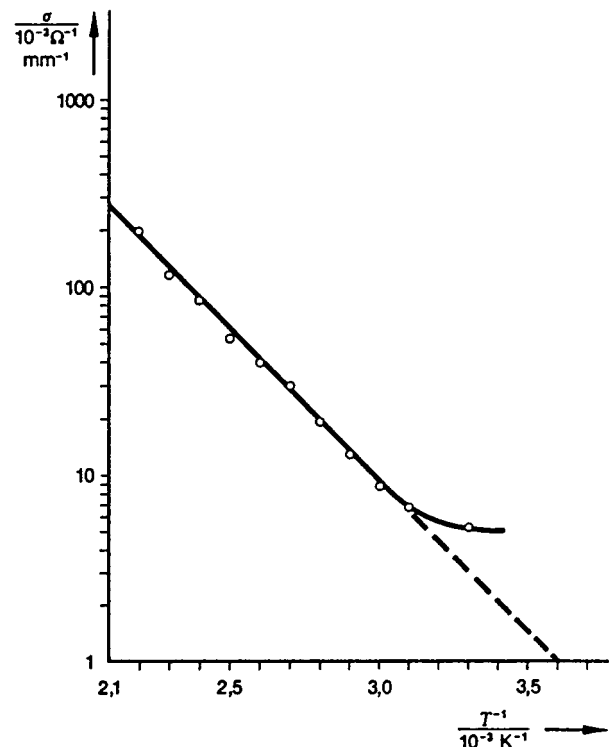$\dfrac{T^{-1}}{10^{-3}\,K^{-1}}$ ⟶

Fig.4 : Logarithm of the conductivity of a germanium test-piece versus the reciprocal of the absolute temperature.