Related topics

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

Principle

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

Equipment

Hall effect module,	11801.00	1
Hall effect, undot.-Ge, carrier board	11807.01	1
Power supply 0-12 V DC/6 V, 12 V AC	13505.93	1
Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Right angle clamp -PASS-	02040.55	1
Digital multimeter	07134.00	1
Connecting cord, l = 500 mm, black	07361.05	2
Connecting cord, l = 100 mm, red	07359.01	1
Connecting cord, l = 100 mm, blue	07359.04	1

Tasks

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 shown in Fig.1. The test piece on the board has to be put into the hall-effekt-modul via the guide-groove. The module is directly connected with the 12 V~ output of the power unit over the ac-input on the backside of the module.
The voltage across the sample is measured with a multimeter. Therefore, use the two lower sockets on the front-side of the module. The current and temperature can be easily read on the integrated display of the module. Be sure, that the display works in the temperature mode during the measurement. You can change the mode with the ”Display”-knob. At the beginning, set the current to a value of 5 mA. The current remains nearly constant during the measurement, but the voltage changes according to a change in temperature. Set the display in the temperature mode, now. Start the measurement by activating the heating coil with the ”on/off”-knob on the backside of the module. Determine the change in voltage dependent on the change in temperature for a temperature range of room temperature to a maximum of 170°C.
You will receive a typical curve as shown in Fig.2.

Fig.1: Experimental set-up for the determination of the band gap of germanium

Theory and evaluation

The conductivity σ is defined as following:

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

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)

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 = energy gap, k = Boltzmann's constant, T = absolute temperature).

The logarithm of this equation

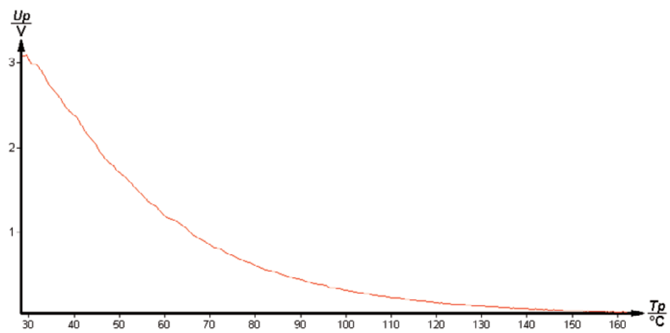
$$\ln \sigma = \ln \sigma_0 - \frac{E_g}{2\,kT}$$

is with $y = \ln \sigma$ and $x = \frac{1}{T}$, a linear equation on the type $y = a + bx$, where

$$b = -\frac{E_g}{2k}$$

is slope of the straight line.

Fig.2: Typical measurement of the probe-voltage as a function of the temperature



With the measured values from Fig. 2, the regression with the expression

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

provides the slope $b = (4.05 \pm 0.06) \cdot 10^3$ K (Fig. 4).

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

$$E_g = b \cdot 2\,k = (0.70 \pm 0.01)\text{ eV. (Literature value 0.67 eV)}$$

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

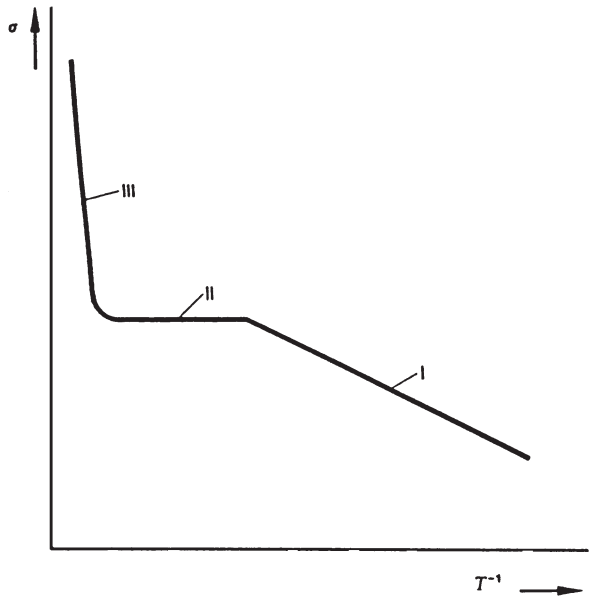


Fig.4: Regression of the conductivity versus the reciprocal of the absolute temperature