5.3.04-11 Band gap of germanium with Cobra3

What you can learn about …

- → Semiconductor
- → Band theory
- → Forbidden band
- → Intrinsic conduction
- → Extrinsic conduction
- → Impurity depletion
- → Valence band
- → Conduction band

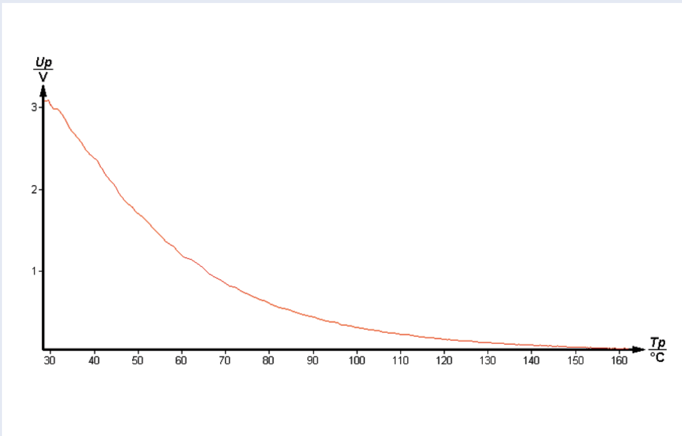
Principle:

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

What you need:

Hall effect module	11801.00	1
Intrinsic conductor, 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
Connecting cable, 4 mm plug, 32 A, black, l = 50 cm	07361.05	2
Cobra3 Basic-Unit, USB	12150.50	1
Power supply 12V/2A	12151.99	1
Software Cobra3 Hall effect	14521.61	1
Data cable 2 x SUB-D, plug/socket, 9 pole	14602.00	1
PC, Windows® XP or higher		

Complete Equipment Set, Manual on CD-ROM included
Band gap of germanium with Cobra3 P2530411



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

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.

Band gap of germanium with Cobra3

LEP 5.3.04 -11

Related topics

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

Principle

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Equipment

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Tripod base -PASS-	02002.55	1
Support rod -PASS-, square, l = 250 mm	02025.55	1
Right angle clamp -PASS-	02040.55	1
Connecting cord, l = 500 mm, black	07361.05	2
Cobra3 Basic-Unit	12150.00	1
Power supply, 12 V	12151.99	1
Cobra3 Software Hall	14521.61	1
RS 232 data cable	14602.00	2
PC, Windows® 95 or higher		

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.

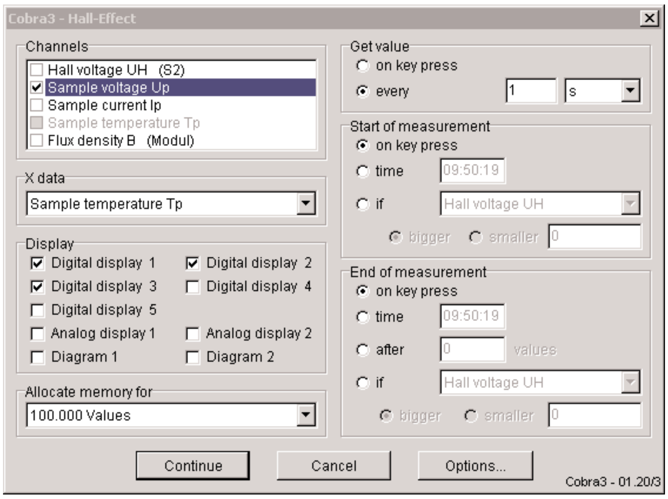
Set-up and procedure

The experimental set-up is shown in Fig.1. The test piece on the board has to be put into the hall-effect-module 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 direct connection with the PC is realized via the RS232 port.
The voltage and the current across the sample and the temperature of the probe are measured with the hall-effect-module and evaluated with the PC.
Therefore, start the programme measure and choose as gauge ”Cobra3 hall effect”.

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

Start a new measurement and set the measuring parameters as described in Fig.2.

Fig. 2: Measuring parameters for the software



The current and temperature can also be easily read on the integrated display of the module. 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.

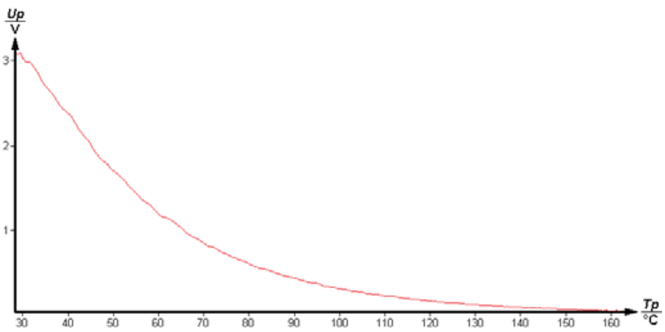
Start the new measurement in the software and activate the heating coil with the "on/off"-knob on the backside of the module.

Now, the change in voltage dependent on the change in temperature for a temperature range of room temperature to a maximum of 170°C will be measured and displayed with the PC.

The Hall-effect-module has a controlled heating coil that stops at a temperature of 170°C. When this temperature is reached and the heating period has ended, stop the measurement.

You will receive a typical curve as shown in Fig.3.

Fig.3: Typical measurement of the probe-voltage as a function of the temperature



Theory and evaluation

The conductivity σ is defined as following:

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

with ρ = specific recistivity, l = length of test specimen, A = cross section, I = current, U = voltage.

(Dimensions of Ge-plate 20×10×1 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 = 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 $x = \frac{1}{T}$, a linear equation on the type $y = a + bx$, where

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

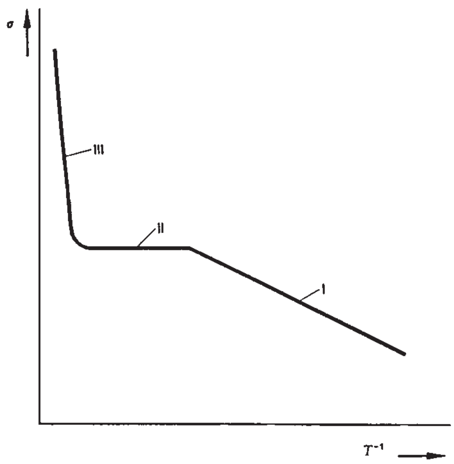
is slope of the straight line.

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).

Fig.4: Conductivity of a semi-conductor as a function of the reciprocal of the temperature



Therefore, you have to modify the measured values.
Choose the item "channel modification" in the menu "analysis".
Set the parameters as shown in Fig. 5. You will receive a new graph.

Fig. 5: Parameters for the first channel modification

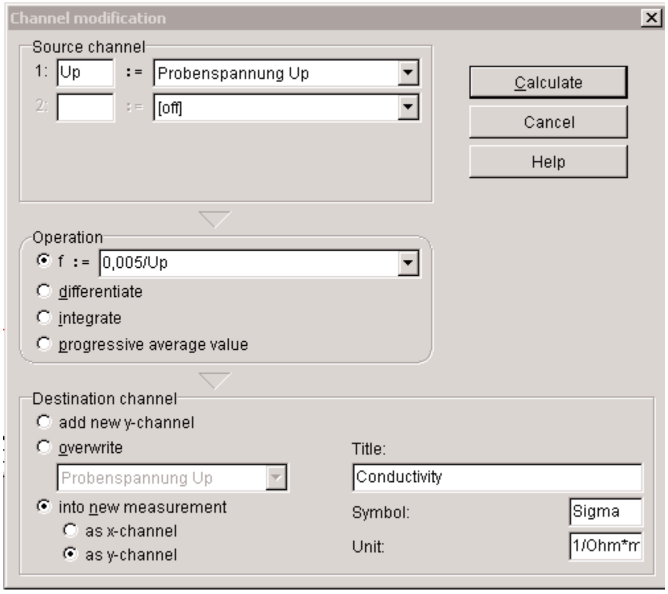
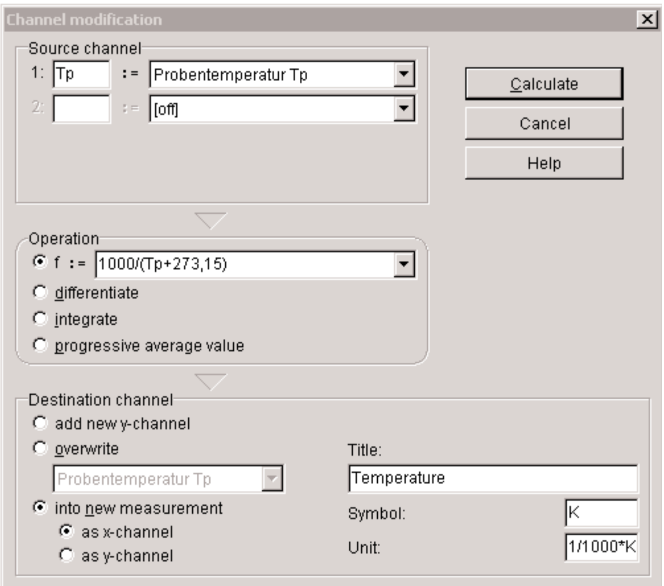


Fig. 6: Parameters for the second channel modification



Repeat the procedure with the new parameters described in Fig. 6 and you will get the graph from Fig. 7.

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

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

Fig. 7: Regression of the conductivity versus the reciprocal of the absolute temperature