Wroclaw University of Science and Technology

GENERAL PHYSICS
LABORATORY REPORT

Theme of class: DETERMINATION OF PLANCK CONSTANT BASED ON CURRENT-VOLTAGE CHARACTERISTICS OF LEDS

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Contents

1 Introduction

The main goal of this experiment is to conduct a measurement of the resistivity of objects made of metal and semiconductor as a function of temperature and determine the temperature coefficient of resistivity of metals and the energy gap of semiconductor.

1.1 Equipment

The following tools were used during the laboratory:

- The chamber with the given objects and with a heating element and a ventilator
- Ohmmeter

2 Experiment

2.1 Explanation of the experiment

Once the equipment is ready, the experimental procedure can be carried out. The steps for conducting the measurements are as follows:

Measurement at room temperature: Begin by reading the resistivities of the samples at the initial temperature of 27.1. Record the obtained resistivity values.

Incremental Temperature Increase: Increase the temperature by 5 C increments. Allow the system to stabilize at each new temperature setting before proceeding with measurements. At each temperature point, record the resistivities of the samples.

Temperature Range: Continue increasing the temperature until it reaches 100 C, following the 5 C increment pattern. Take note of the actual temperature of the samples, as it may vary slightly from the set value due to system variations.

2.2 Uncertainties

- $$\Delta X = \frac{a}{100\%} \cdot X + n \cdot \Delta_{res}$$
- $$u(t) = \frac{\Delta t}{\sqrt{3}}$$
- $$u(t) = u(T)$$
- $$u(1000/T) = 1000 \cdot \sqrt{\frac{u^2(T)}{T^4}}$$
- $$u(ln(R)) = \frac{u(R)}{R}$$

For the metal objects, we need to plot the resistivity as a function of temperature in Kelvins and use linear regression method to find the coefficients a and b and their uncertainties u(a) and u(b):

$$R_m = f(t) = a \cdot t + b = R_0 \cdot \alpha \cdot t + R_0$$

R_0, α and their uncertainties are calculated as follows:

- $R_0 = b$
- $u(R_0) = u(b)$
- $\alpha = fracaR_0$

- $$u(\alpha) = \sqrt{\frac{u^2(a)}{R_0^2} + \frac{a^2 \cdot u^2(R_0)}{R_0^4}}$$

For the semiconductor, we plot the natural logarithm of the resistivity as a function of 1000 over temperature in Kelvins and apply linear regression method to determine A, B, u(A) and u(B):

$$R_s = A\frac{1000}{T} + B = 10^-3 \cdot \frac{E_g}{2k} \cdot \frac{1000}{T} + ln(R_{s,0})$$

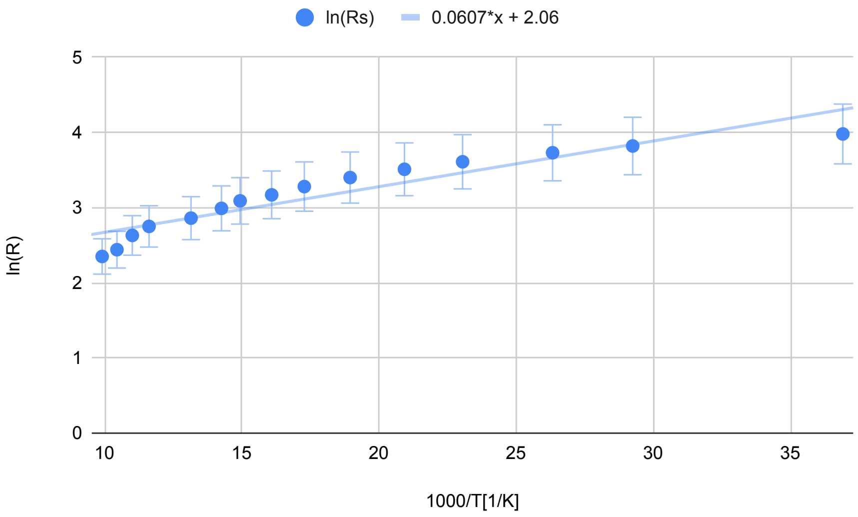
Data

Initial data

$t[°C]$	$R_3[\Omega]$	$R_4[\Omega]$
27.1	53.4	109.9
34.2	45.7	112.6
38	41.8	114.1
43.4	37	116.1
47.8	33.3	117.9
52.8	29.9	119.6
57.9	26.6	121.4
62.2	23.9	123.4
67	21.9	125.2
70.2	19.9	126.4
76.1	17.4	128.4
86.1	15.6	130.2
90.9	13.9	132.4
95.8	11.5	136.2
101	10.5	138.9

Table 1: Measurement data

Semiconductor



	a	b
	0.061	2.065
u(x)	0.0063	0.125

Table 2: Linear regression

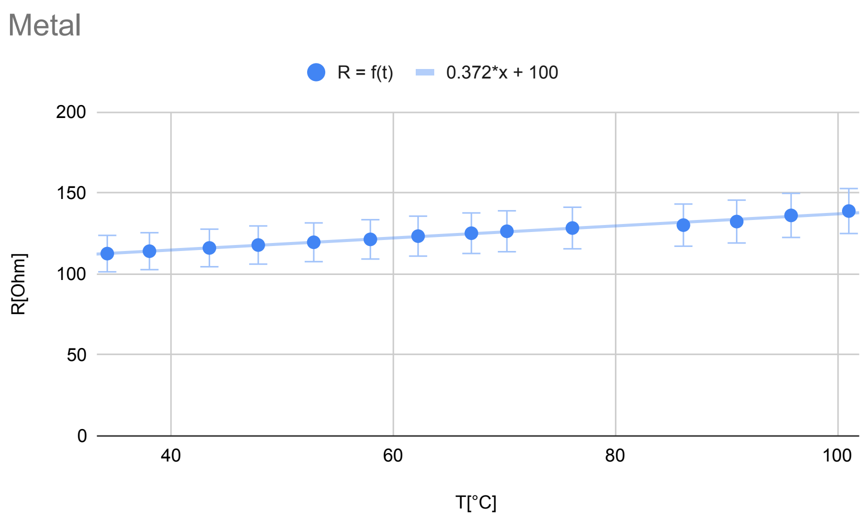
no.	t(C)	1000/T[1/K]	R[Ω]	ln(Rs)
1	27.1	36.9	53.4	3.98
2	34.2	29.24	45.7	3.82
3	38	26.32	41.8	3.73
4	43.4	23.04	37	3.61
5	47.8	20.92	33.3	3.51
6	52.8	18.94	29.9	3.4
7	57.9	17.27	26.6	3.28
8	62.2	16.08	23.9	3.17
9	67	14.93	21.9	3.09
10	70.2	14.25	19.9	2.99
11	76.1	13.14	17.4	2.86
12	86.1	11.61	15.6	2.75
13	90.9	11	13.9	2.63
14	95.8	10.44	11.5	2.44
15	101	9.9	10.5	2.35
$\bar{X}$	63.37	-	26.82	-
ΔX	0.1	-	0.16	-
u(X)	0.058	-	0.093	
$u_c(X)$	-	0.025	-	0.0035

Table 3: Data Analysis

	A[K]	Eg[J]	Eg[eV]
	0.061	1.68E-21	2.065
u(X)	0.0063	-	-
u_c(X)		1.74E-22	0.125

Table 4: Data Analysis

Metal



	a	b
	0.372	99.918
u(x)	0.0089	0.595

Table 5: Linear regression

	T [$°C^{-1}$]	R[Ω]	$a[\frac{\Omega}{°C}]$	b, R0	$\alpha[°C^{-1}]$
1	27.1	109.9	0.372	99.918	0.003700
2	34.2	112.6			
3	38	114.1			
4	43.4	116.1			
5	47.8	117.9			
6	52.8	119.6			
7	57.9	121.4			
8	62.2	123.4			
9	67	125.2			
10	70.2	126.4			
11	76.1	128.4			
12	86.1	130.2			
13	90.9	132.4			
14	95.8	136.2			
15	101	138.9			
$\bar{X}$	63.37	123.51			
ΔX	0.1	0.72	-	-	-
u (X)	0.058	0.42	0.0089	0.595	-
u_c (X)	-	-	-	-	0.000092

Table 6: Data Analysis

2.3 Example Calculations

- $$\Delta X = \frac{0.5}{100\%} \cdot 10.5 + 1 \cdot 0.1 = 0.16\Omega$$

- $$u(t) = \frac{\Delta t}{\sqrt{3}} = \frac{0.1}{\sqrt{3}} = 0.058$$

- $$u(t) = u(T) = 0.058$$

- $$u(1000/T) = 1000 \cdot \sqrt{\frac{u^2(T)}{T^4}} = 1000 \cdot \sqrt{\frac{0.058^2}{63.37^4}} = 0.025$$

- $$u(ln(R)) = \frac{u(R)}{R} = \frac{0.093}{26.82} = 0.035$$

3 Conclusion

In this experiment we learned how to estimate the values for temperature coefficient of resistivity and energy gap by measuring the dependence of resistivity on temperature, using the linear regression method to estimate the function and calculating the needed values using the found coefficients.