Summary 01: Band Gap of Germanium with Cobra3

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1 Objective

In this experiment, we seek to find the energy gap of the Germanium strip. This is done by finding its conductivity, σ and plotting its regression against the reciprocal of the temperature, T. The following experiments were carried out at constant current of (5 ± 1)mA: firstly, by recording the voltage through the Germanium strip (using Cobra3 Software Hall) while it is being heated (using Hall effect, undot.-Ge, carrier board) to (130.0 ± 0.1)°C and once more when it is cooling down back to a temperature of (28.0 ± 0.1)°C. Doing so will allow us to verify the inverse relationship between conductivity, σ and temperature, T.

2 Introduction

The equation used to find the energy gap is:

$$ln(\sigma) = ln(\sigma_0) - \frac{E_g}{2kT} \tag{1}$$

which is of the form $y = mx + c$, where the gradient of the straight line is $m = -\frac{E_g}{2k}$.

Meanwhile, σ is obtained through the following equation:

$$\frac{1}{\sigma} = \frac{l}{A} \cdot \frac{1}{V_p} \tag{2}$$

where l and A are the length and area of the Germanium strip used while V_p is the sample voltage obtained. For a 20 by 10 by 1 mm^3 strip, this equation simplifies to

$$\frac{1}{\sigma} = \frac{10}{V_p} \tag{3}$$

In Eqn(1), E_g is the energy gap of the Germanium strip and k is the Boltzmann's constant of $8.625 \cdot 10^{-5}$eV.

Also, we have decided to use Varshni's equation as another way to confirm our results.

$$E_g(T) = E_g(0) + \frac{\alpha T^2}{T + \beta} \tag{4}$$

In the above, $E_g(0)$, α, and β are all material constants, which for Germanium is 0.744eV, $4.77 \cdot 10^{-4}$evK^{-1} and 235K respectively. At room temperature of 25.0°, a value of 0.664eV is to be expected.

3 Experimental Results

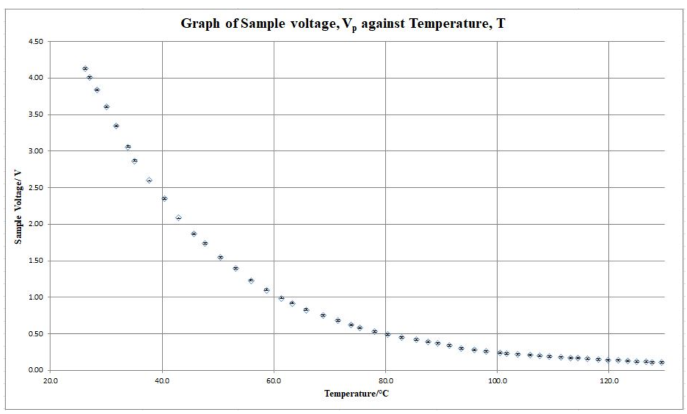

Figure 1: Graph of Sample Voltage against Temperature

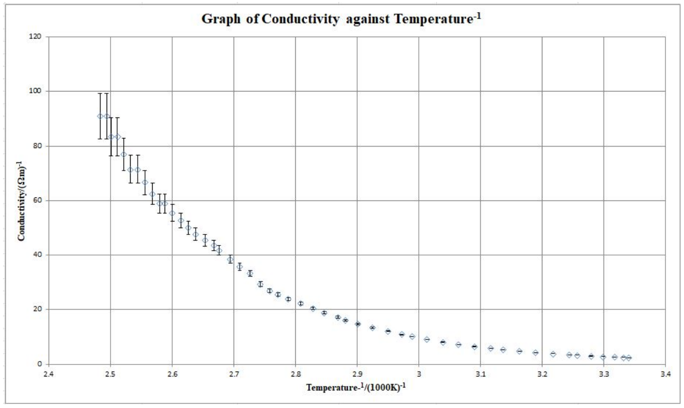

Figure 2: Graph of conductivity against Temperature^{-1}

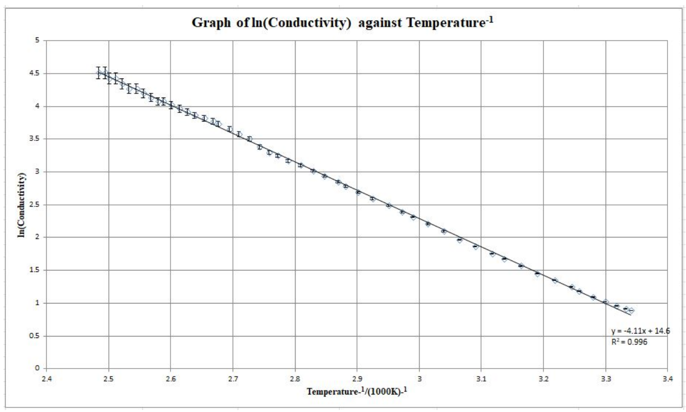

Figure 3: Graph of ln(conductivity) against Temperature^{-1}

Throughout the experiments, we attempted to keep the temperature of the Germanium strip below $(130.0 \pm 0.1)°C$ as this might cause damages to the carrier board. Yet, this was not easy, even with the option to automatically turn off the heater at a certain temperature, as the temperature of the strip continues to increase still despite the fore-mentioned happening. Therefore, repeated measurements might actually cause the experimental results obtained to be worse over time. However, this effect is minimal for 5 repeated measurements. We could of course limit the experiments to a lower temperature, but doing so will cause a larger discrepancy in our results. Furthermore, at higher temperatures, the uncertainty for conductivity is much larger than when the reading is taken during lower temperature. This is due to the resolution uncertainty for the sample voltage, ± 0.01V, having a larger influence. A solution to this is to decrease the upper limit of the temperature range to minimize the resolution uncertainty and get more precise experimental values.

Graph of Sample Voltage, V_p, against Temperature, T	Gradient, m	Uncertainty of m, U_m	Y-intercept, c	Uncertainty of c, U_c	Coefficicent of Determination, R^2	E_g	Percentage Discrepancy
Heating Curve 1	-3.960724207	0.005686882	14.07747403	0.018876541	0.992734044	6.83E-01	1.973869505
Heating Curve 2	-3.985488842	0.006034981	14.18341376	0.019960896	0.991295309	6.87E-01	2.611466446
Heating Curve 3	-4.111705779	0.007581295	14.59205004	0.024617583	0.995740223	7.09E-01	5.861081621
Heating Curve 4	-4.085707507	0.007751126	14.51725939	0.025125968	0.993155105	7.05E-01	5.191723127
Heating Curve 5	-4.097028984	0.007334635	14.54918453	0.02387976	0.995191921	7.07E-01	5.483208906
Cooling Curve 1	-3.969543934	0.001738386	14.16874975	0.005788108	0.906349565	6.85E-01	2.200944578

Figure 4: Table of statistics obtained from applying Weighted Linear Least Square Method to the data collected.

One way the experiment can be improved further is by varying the dimensions of Germanium strip used. This will allow us to study and verify the l and A variable in Eqn(1).

4 Conclusions

The main goal of these experiments were to determine the energy gap of a Germanium strip of defined dimensions. From our experiments, we were able to obtain a mean experimental value of (0.698 ± 0.031)eV for the band gap of the Germanium strip used. With a theoretical value of 0.67eV, our percentage discrepancy is only 4.22%. This is further supported by the low percentage discrepancy in FIg(4). Our experimental results are also in line with the expected results if we were to use Varshni's empirical expression, giving us a percentage discrepancy of 5.16%. Since both of these are less than 10%, we can say that our experimental values agree with that of the theoretical one.

We suspect that the reason for our experimental value to be lesser than that of the expected result is due to impurities in the Germanium strip or wear and tear because of repeated usage, which will cause a decrease in the strip's conductivity.

Our experimental results also have a high R^2 value of around 0.99, as seen in Fig(4). This signify that our data points highly match the linear trend predicted in Eqn(1).