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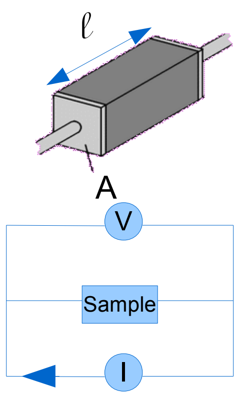
Electrical Conductivity

Abstract

Electrical resistivity represents the ability of a material to oppose the current flow. Evaluating the resistivity is therefore a key element of transport physics.
This quantity is temperature dependent: for a metal, the lower the temperature, the less the electrons feel opposition while going through the material (because the vibrations of the lattice become less and less relevant). In this experiment, the resistivity of Lead (Pb) is measured as a function of temperature (from room temperature to 4,2 K=-269°C!).

How to measure the resistivity of a material?



The resistivity is given by:

$$\rho = R\frac{A}{l}$$

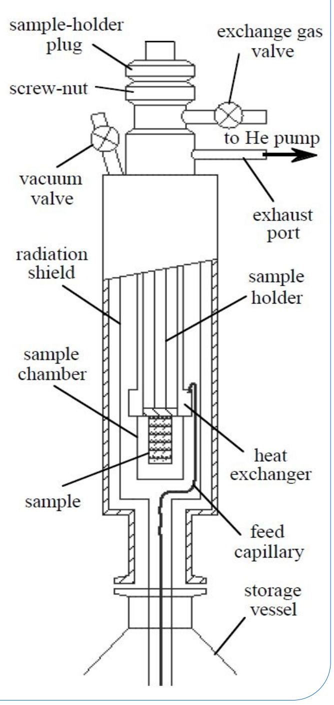
with R the resistance, A the cross-sectional area and ℓ the length.

$$\rho = \frac{V_{measured}}{I_{applied}} \cdot \frac{A}{l}$$

where $I_{applied}$ is the applied current and $V_{measured}$ is the measured voltage.

How to reach low temperatures?

The sample is loaded in the sample chamber in a cryostat. The ^{4}He feed capillary, terminating the cryostat, is then inserted in a liquid Helium dewar.
The temperature of liquid Helium is 4.2 K and therefore the sample can be cooled down to this temperature using the system pictured on the right.
A temperature controller allow us to reach intermediate temperatures.
This way, the dependence of the resistivity on temperature can be investigated.

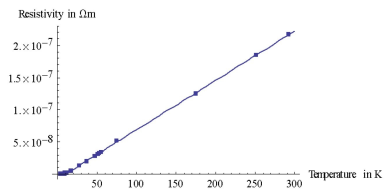


Experimental Setup

Result and interpretation

High temperatures:

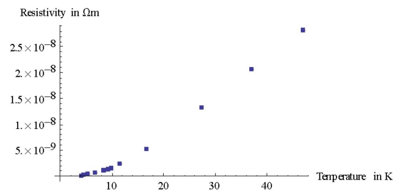
a linear behaviour is observed
→ thermal excitations (phonons).



Low temperatures:

The resistivity drops to zero...

For a „normal“ metal, the resistivity is expected to reach a finite value at low temperature.



The current flows without any opposition!
→ the sample becomes ***superconducting.***
Other materials exhibit this property and could be investigated the same way
→ See Superconductivity experiment!

Conclusion

With this experiment, the resistivity of Lead is investigated as a function of temperature. First a linear dependence is observed, pointing out the major role of thermal excitations in the way the material is able to transport the current. But at lower temperatures (<10K), the material exhibits a different behaviour: where it would be expected to reach a finite value of resistivity (as for „normal“ metal), the resistivity of Lead goes to zero! This means that the material is able to transport the current without any loss: the sample becomes „superconducting“.
Such a property would be extremely valuable to deliver energy for domestic use, if it could be observed at higher temperatures.

References

[1] Andrina Nicola, VP report, 01/04/2011

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