Material Physics and PC-Based Instrumentation I
Electrical Transport

Goal

The first goal of this exploration topic is to measure how the electrical resistance (or conductivity) of different materials varies as function of temperature. It is up to you to choose the materials you wish to study. Suggested classes of materials are "pure" elemental metals (e.g., copper), metallic alloys (e.g., brass), semiconductors (e.g. silicon), granular composites (e.g., carbon resistor), superconductors (e.g., yttrium barium copper oxide and niobium). You are not restricted to those materials mentioned as examples. You may wish to concentrate on just one class of materials. The measurements of resistance are to be made by a pc-controlled data acquisition system you will construct. The second goal is to gain some theoretical understanding of the physical mechanisms of the observed temperature dependences. Research and reading of books and publications will be required.

Experiment

An electrical circuitry needs to be constructed for measuring resistance. The magnitude of resistance to be measured is important in choosing a measurement method. It helps to know the approximate range of resistance to be measured. The two basic methods are so-called "two terminal" and "four terminal" measurements.

A thermometer in good thermal contact with the sample material is needed. A measurement system for thermometry is of coursed needed.

A pc-based data acquisition system is needed to measure the resistance as a function of temperature. In practice, the acquisition system measures resistance and temperature as functions of time and the data is displayed as function of time. Instruments which can be communicated and controlled via GPIB, RS-232 or USB must be used. Programs need to be developed for data acquisition. You may use either Labview (icon-based language) or Basic and C (code-based) programs.

A system for varying the sample temperature is needed. The desired temperature range depends on the temperature range of interest for a particular material. At this time, you will be restricted to the temperature range between room temperature (~ 290 K) and the liquid nitrogen temperature (77 K). How to mount the sample and thermometer onto the cryogenic apparatus must be carefully considered.

Useful information and examples of how to set up the experiment as well as background reading on superconductivity may be found in:
http://www.futurescience.com/sc.html and
http://www.futurescience.com/manual/sc500.html
Let me know of other useful links you find.

Analysis

Study textbooks, references, publications and links on the temperature dependence of electrical resistance of the material(s) under study. If there are other existing measurements by others, compare them with your measurements. Try to understand theoretical basis for the observed temperature dependence. Do you think you

made a discovery of new phenomenon? Consider carefully both systematic and random errors in your measurement. Distinguish between accuracy and precision of your measurements.

Final Presentation (Power Point)

In addition to interim reports/presentations, a final oral presentation (15 ~ 20 minutes) to an audience(TBA) will be requested. The presentation should include the following sections:

1. motivation and introduction
2. description of experimental apparatus
3, results and analysis
4. conclusion