Material Physics and PC-Based Instrumentation II
Thermal Transport

Goal

The first goal of this exploration topic is to measure how the heat capacity and the thermal conductance of different materials vary as function of temperature. The range of temperature available is between 77 and 300 K. It is up to you to choose the material you wish to study. The measurements 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

As the experiment on the heat capacity of gadolinium shows, thermal properties of materials are much more difficult to measure than electrical resistance. The amount of added heat to the sample material and the associated temperature increase are the only two quantities that need to be measured to evaluate the heat capacity. To measure the thermal conductivity, the amount of power added to one end of sample material and the associated temperature difference between the two ends need to be measured. It all seems simple, in principle. In practice, extreme care is needed in the measurements since heat can flow through many parallel paths and establishment of thermal equilibrium between the sample and the thermometer is a complicated physical process. In designing your experiment, it is crucial to consider these two difficulties.

A pc-based data acquisition system is needed to measure temperatures. In practice, the acquisition system measures temperatures as functions of time as heat is added to the material sample. 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.

Strongly suggested plan: redo the experiment on the heat capacity of gadolinium between 4 and 20 °C using your pc-based instrumentation. Deeper understanding of this experiment will help in improving the present apparatus and in designing a new heat capacity and thermal conductivity apparatus.

Analysis

Study textbooks, references, publications and links on the temperature dependence of thermal properties 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. Have you
discovered a new effect? 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