SUPERCOMET 2 – Modelling superconductivity

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Abstract

Physics education should deliver insight into modern physics. The aim of the EU-project SUPERCOMET 2 is the development of teaching material in order to introduce basic elements and applications of superconductivity in secondary schools. Partners from more than 15 European countries collaborate in SUPERCOMET 2. The cooperation with teachers at various schools is essential for the project since they are involved in all phases like development, adaptation and evaluation of the material.

Models of superconductivity can be built up on a macroscopic and microscopic scale. The first ones include experiments, the second ones can only be visualised by animations. Within SUPERCOMET 2, proposals of both kinds of models have been developed. They are collected on a CD-Rom which is meantime available in 10 different languages.

A main focus of the German-speaking partners lies on the development of hands-on kits for producing and investigating high-temperature superconductors. Suggestions are given for baking superconductors at schools as well as using them in easy-to-perform experiments. Furthermore a new module about applications of superconductivity is in progress.

To facilitate the approaches, a teacher guide has been translated into and adapted to German and Austrian requirements and teacher seminars have been organised.

Superconductivity in school

In the past, a crisis in physics education has become obvious (Wilson & Warmbein, 2001). It is therefore necessary to think about new ways of teaching physics in school. One approach is to include contents of contemporary physics in the curricula [e.g. (Ostermann & Moreira, 2004)]. The discovery of superconductivity is one of the fundamental breakthroughs in the physics of the last century with consequences for everyday technologies (important applications in medicine, communication, energy and transportation) and also exciting possibilities for the future. Therefore it will be highly appropriate to think about and to make proposals how to include phenomena of superconductivity in the curricula. But it is also important to connect the "new" physics to the classical one (Ostermann & Moreira, 2004). Magnetism, electricity and thermodynamic are such links between classical physics and the modern topic superconductivity.

One possibility to imply superconductivity in school is to illustrate experiments with YBaCu superconductors [(Brandl, 1988), (Brüggemann, 1988), (Deger, 1988), (Deger, 1991), (Guarner & Sanchez, 1992), (Oberholz, 1989), (Schneider et al, 1991), (Shukor & Lee, 1998)] or even producing such pellets [(Brandl, 1988), (Deger & Luchner, 1988), (Deger, 1997), (Oberholz, 1989), (Zwittlinger, 2006)]. The critical temperature (T_c) of these superconductors is around 80K, which is high enough to use cheap liquid nitrogen (77K). So it is feasible to demonstrate experiments like levitation, the Meißner-Ochsenfeld-Effect and the vanishing resistance. Thus students can observe the phenomena of superconductivity on a macroscopic level. In order to understand the behaviour of superconductors on a microscopic scale, simulations and animations have proven to be very helpful tools. These two approaches of teaching superconductivity at school are combined in the developed material of the SUPERCOMET 2 project.

The project

The EU-project SUPERCOMET 2 (**SUPERCO**nductivity **M**ultimedia **E**ducational **T**ool) is the follow-up project of the SUPERCOMET project. Within SUPERCOMET, material like self-contained e-modules about electricity, magnetism and superconductivity have been developed. They contain animations, texts, quiz games, a glossary of important terms plus a FAQ section, a search engine as well as some literature references and links to useful online resources. Also an accompanying teacher guide and an in-service teacher training seminar have been developed.

In SUPERCOMET 2, the partners from more than 15 European countries translated and adapted these contents to a large number of languages and national curricula. Furthermore they are in the process of developing material like hands-on kits, additional simulations and a module about applications. Teacher seminars and testing in school to evaluate the material will complete the project.

Contributions of the German-speaking partners

One focus of the German-speaking partners lies in the development of a hands-on kit in order to demonstrate and perform experiments with superconductors in school. At the moment, the hands-on kit includes an instruction for baking superconductors in school and suggestions for easy-to-perform experiments. As mentioned above, it is possible to produce superconducting pellets with students in school. The recipe for baking such superconductors reads like one for a cake: take three different powders in well balanced quantities, mix them thoroughly, crush the mixture in an agate mortar and press tablets (Figs. 1, 2, 3)

Fig. 1. Utilities

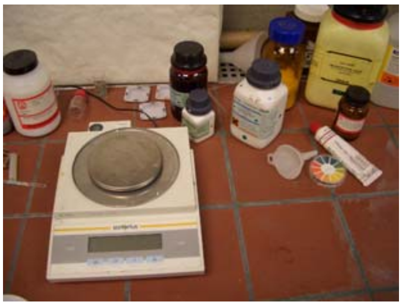


Fig. 2. Mixture

Fig. 3. Press

After the tablets have been baked in a special oven (Figs. 4, 5) at 950°C for more than one day, they have to be cooled within two more days. Afterwards, the tablets have to be crushed, pressed and baked once again.

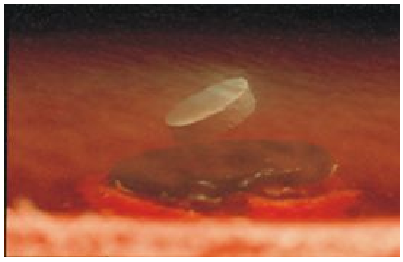
Fig. 4. Oven

Fig. 5. Regulation

After the baking process the superconductors can be tested.
Exciting and easy-to-perform experiments to show the phenomena of superconductivity are the following:
If the sample is very small, it is better to use a toric magnet and let the cooled sample float above (Fig. 6). The sample will heat above T_c within some seconds and then stop floating. A big self-made sample is laid in liquid nitrogen. If a strong magnet floats above the sample, the sample passes the test of superconductivity (Fig. 7).

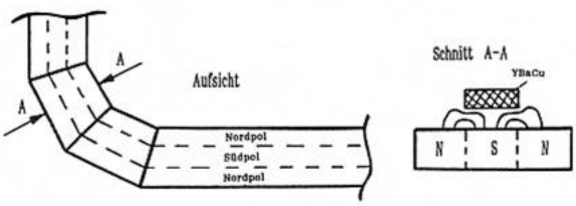
Fig. 6. A small sample floats on a magnet

Fig. 7. A magnet floats on a big sample



For the Meißner-Ochsenfeld-Effect the magnet is laid on the sample at room temperature. According to classic laws, no floating should happen as the magnetic field does not change any more. But after cooling the sample the magnet will float. This shows that superconductivity is more than perfect diamagnetism.
Furthermore one can build a magnetic track in different types (like a half pipe, a half pipe with a bump or a rectangular track) and let a cooled sample float above it (Fig. 8): One cuts stripes from magnetic rubber and forms a racing track. The YBaCu-sample that was cooled below T_c floats above some magnetic lines. The starting point of the track is a little higher than the rest of the track. The well-cooled sample will float some seconds before the temperature rises above T_c.

Figure 8: Magnetic track

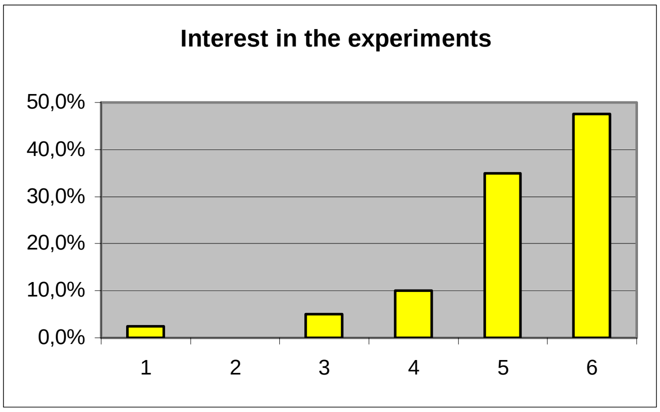


Another focus of our contributions lies on planning and preparing a new module about applications of superconductivity. This can offer insights into modern technological applications of physics and link theoretical knowledge to concrete use in industry, research and every day life. Explanations and illustrations for applications are categorized in six fields: Electric current with a minimum of energy wasting (transmission of electrical power, motors), generating huge magnet fields (e.g. Large Hadron Collider at CERN), magnetic levitation (e. g. maglev), producing magnetic fields for NMR (medical applications), measuring weak magnetic fields with SQUIDS (e.g. measuring the magnetic field produced by the currents due to neural activity in human brain) and accurate measurements of quantum voltage steps based on Josephson junctions.

Furthermore teacher seminars have been organized and first implementations in school have been started. In this connection the presented material was evaluated focusing on the subject, the learning environment and the experiments. Some results of the students´ feedback concerning the experiments and the learning environment should be shown as examples:

The interest in the experiments was clearly positive: the mean was 5.2, almost half of the students noted the highest value of 6 (Fig. 9).

Fig. 9. Interest in the experiments



The interest in the learning program lays with regard to the average below the mean (3.5), as well as clearly below the interest in the experiments (Fig. 10). For interested students the program was better suited than for less interested. The differences between schools were minor; therefore, the shown results are rather related to the material than to the mode of application.)

Figure 10: Interest in the learning program