

Physikpraktikum für Vorgerückte (VP)

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Superconductivity

Abstract

One of the fascinating examples of how the properties of matter change when cooled to very low temperatures is the phenomenon of superconductivity. When certain materials are cooled below a critical temperature, their resistance drops to zero and low magnetic fields are expelled from their interior.

Aim

Students are given several superconducting samples of different type. They carry out the magnetisation measurements, determine the type of each superconductor and study their properties, such as the critical magnetic fields, energy gap, condensation energy, etc.

Magnetisation

Type-I superconductors show a sudden drop of the magnetisation, M, to zero when a critical magnetic field, H_c , is reached.

Type-II superconductors exhibit a linear increase of M (as in type-I) until a lower critical magnetic field is reached, H_{c1} . Then M decreases slowly until it reaches zero at H_{c2} (Fig.1).



Fig.1. Magnetisation curve for type-I (black) and type-II (blue) superconductors.

Pick-up coils

Faraday's law of induction: a changing magnetic flux induces an electromotive force in an electrical circuit.

The studied sample is surrounded by two concentric (pick-up) coils and placed in a changing magnetic field. The total induced voltage is then

$$U_{ind} = \frac{d\Phi}{dt} = -\frac{d}{dt} \int \vec{H} \cdot \vec{n} dA =$$
$$= -\left(\int \frac{d}{dt} (\vec{H} + \vec{M}) \cdot \vec{n} dA - \int \frac{d}{dt} \vec{H} \cdot \vec{n} dA\right)$$

where Φ is the magnetic flux, *t* is time, *A* is the area and *n* is the normal.

In the absence of the sample the pick-up coils must be balanced to have the magnetisation proportional to the integral of the induced voltage over time:

$$\dot{\vec{M}} = \frac{dM}{dt} \propto U_{ind} \qquad M \propto \int U_{ind} dt$$

Measurements

By measuring the integrated induced voltage as a function of magnetic field one gets curves similar to those shown in Fig.1:



Fig.2. Measured magnetisation curves for lead (type-I) and lead-indium allows (type-II).