Pulsed gyromagnetic phenomena in high-temperature superconductors

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(Submitted 25 April 1988)
Pis'ma Zh. Eksp. Teor. Fiz. **47**, No. 11, 598–599 (10 June 1988)

The rotation of a superconducting cylinder upon application of a longitudinal magnetic field is measured. The direction of this rotation was found to be different for a type-II superconductor and a high-temperature superconductor.

If a superconducting cylinder is suspended on a thin elastic thread (Fig. 1) into a solenoid which generates a longitudinal (parallel to the axis of the cylinder) magnetic field, the electrons in this cylinder will begin to rotate after the field is applied. Because of the conservation of the angular momentum, this rotation will cause the suspended system to rotate in the opposite direction, a rotation which can be detected.

We have conducted an experimental study of such a phenomenon using a high-temperature superconducting ceramic sample $HoBa_2Cu_3O_{7-\delta}$ and a thermodynamically reversible type-II superconductor, a $Ta_{70}Nb_{30}$ single-crystal sample similar to the one used in Refs. 1 and 2.

The samples had the following parameters: $\phi = 2.4$ mm and $l = 4$ mm for $Ta_{70}Nb_{30}$ and $\phi = 5$ mm and $l = 7$ mm for $HoBa_2Cu_3O_{7-\delta}$. Sample 1 was mounted on a straight glass rod 2, to which a light disk 3, made of a material equivalent of Plexiglas, was attached at the upper end. The moment of intertia of this disk was $J = 0.80$ g·cm^2. Rod 2 was suspended on a thin elastic string 4 made from a phosphor bronze ($\phi = 40$ μm, $l = 150$ mm, torsion modulus $f = 1.60$ dyn·cm). The angle of

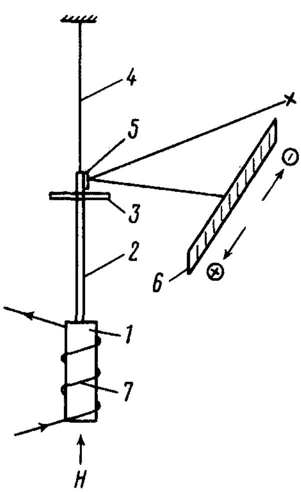

FIG. 1. Experimental setup. 1—Sample; 2—rod sample holder; 3—disk; 4—suspension; 5—mirror; 6—scale; 7—coil.

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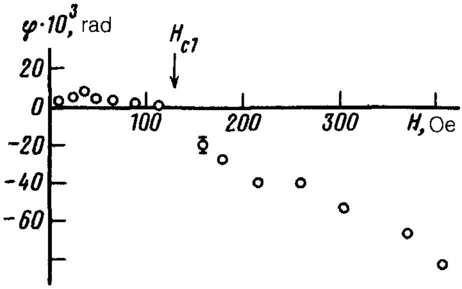

FIG. 2. Angle of rotation φ of the suspended system versus the strength of the magnetic field H for TaNb.

rotation of the suspended system was recorded by means of a laser light spot reflected from a mirror 5, which was observed through a transparent scale 6 (displacement on the scale to the left and to the right of zero is denoted by + and −). The entire low-temperature part of the system, filled with liquid nitrogen or liquid helium, was inserted into a coil 7 which produced a magnetic field up to 500 Oe directed along the axis of the sample. This device was light enough to detect very accurately the rotation of the suspended system initiated as a result of the onset of motion of the charges upon application of a longitudinal magnetic field of a given direction (vertically upward or vertically downward).

The angle of rotation versus the strength of the external field H is plotted in Fig. 2 for a TaNb type-II superconductor. This plot was obtained for an upward-directed field at a temperature $T = 4.2$ K ($T < T_c$). In fields $H < H_{c1}$ ($H_{c1} = 127$ Oe at $T = 4.2$ K)[2] the barely perceptible rotation of the system is difficult to detect with our hardware. In fields $H > H_{c1}$, however, the clearly detectable rotation has a negative sign, indicating that the system is rotating opposite to the motion of the Cooper electron pairs in the Abrikosov vortices.[3]

Of special interest are the results of experimental study of high-temperature superconductors. Figure 3 is a plot of the results of experiments with a $HoBa_2Cu_3O_{7-\delta}$ cylinder, carried out under the same experimental conditions. This plot shows that the effect has the opposite sign in this case. The open circles represent the data obtained at

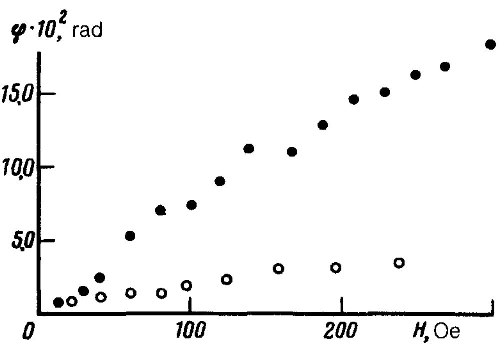

FIG. 3. φ versus H for $HoBa_2Cu_3O_{7-\delta}$.

$T = 80$ K and the filled circles denote the data obtained at $T = 4.2$ K. In another experiment we used a mechanical method[2] to measure H_{c1} of this sample; at $T = 80$ K we found H_{c1} to be 10 Oe.

For comparison we give a similar result obtained by Karasik *et al.*[4] They found H_{c1} for $YBa_2Cu_3O_{7-\delta}$ to be 32 Oe at $T = 85$ K. We can assume, therefore, that our sample is in a mixed state. At $T = 4.2$ K the effect is more pronounced.

The opposite sign of the effect in high-temperature superconductors (with respect to TaNb) may be linked with the sign of the charge carriers[5,6] or with the particular features of the kinetics of vortex formation in high-temperature superconductors.

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Translated by S. J. Amoretty