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A possibility of gravitational force shielding by bulk $YBa_2Cu_3O_{7-x}$ superconductor

E. Podkletnov and R. Nieminen
Tampere University of Technology, Institute of Materials Science, P.O. Box 589, SF-33101 Tampere, Finland

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Shielding properties of single-phase dense bulk superconducting ceramics of $YBa_2Cu_3O_{7-x}$ against the gravitational force were studied at temperatures below 77 K. A small non-conducting and non-magnetic sample weighing 5.48 g was placed over a levitating superconducting disk and the loss of weight was measured with high precision using an electro-optical balance system. The sample was found to lose from 0.05 to 0.3% of its weight, depending on the rotation speed of the superconducting disk. Partial loss of weight might be the result of a certain state of energy which exists inside the crystal structure of the superconductor at low temperatures. The unusual state of energy might have changed a regular interaction between electromagnetic, nuclear and gravitational forces inside a solid body and is responsible for the gravity shielding effect.

1. Introduction

High-temperature ceramic oxide superconductors as well as conventional ones can be used as effective shields against electromagnetic fields at low temperatures due to the Meissner effect. But physical phenomena inside metal superconductors and ceramic ones might be entirely different, as well as the mechanisms of superconductivity. It is well-known that the current carriers in both types of superconductors have a charge of 2−. But the energy state in the structure of ceramic superconductors seems to be of a different nature, as compared to metallic ones. The internal state of energy of ceramic superconductors can be influenced by several parameters forming a crystal lattice with a defined order.

Various physical properties of ceramic superconductors, such as thermal conductivity, lattice distances, optical reflection etc. show abnormal changes near the transition temperature. No overwhelming theory has yet been proposed to explain the mechanism of superconductivity and the abnormal behaviour of high-T_c oxide ceramic materials at low temperatures.

The aim of this study was initially to investigate the shielding properties of dense y-based bulk superconductors against electromagnetic fields of various frequencies and intensities in a wide range of temperatures. But an unusual behaviour of the ceramic material observed during the first stage of this work initiated a separate set of experiments dealing with the shielding of the gravitational force.

2. Experimental

Superconducting single-phase $YBa_2Cu_3O_{7-x}$ compound was prepared in a form of a disk with a diameter of 145 mm and a thickness of 6 mm. The preparation procedure consisted of mixing the initial oxides followed by calcining the powder at 930°C in air, grinding, pressing the disk at 150 MPa and sintering it in oxygen at 930°C for 12 h with slow cooling down to room temperature.

The disk was placed over a toroidal solenoid and kept at a temperature below 77 K using liquid helium and its vapours. The disk was usually first submerged into liquid helium and kept there for several minutes, then the power was connected to the toroidal solenoid and the disk raised over the surface of the helium. This massive disk maintained its temperature below 60 K for about 2.5 min.

Two coils with rotating magnetic fields, similar to those used in regular electric motors, were placed on both sides of the disk, as shown in fig. 1. The disk levitated above the toroidal magnet and was able to rotate around its central axis at a variable speed. The frequency of the electromagnetic field in all three solenoids was varied from 50 to 10^6 Hz. A sample made of silicon dioxide hanging on a thread was placed over the disk at a distance of about 15 mm from it, and was separated from the He vapours by a thin transparent plastic foil. The weight of the sample was measured with high precision using an electro-optical comparing balance.

The phase and crystal structure of the superconductor were studied by X-ray diffraction analysis (XRD) and under a scanning electron microscope (SEM). The electrical resistivity of the superconductor was measured by the four-probe method using an AC current and gold contacts.

3. Results

As determined by XRD-analysis, the sintered disk was pure single-phase orthorhombic 123-compound

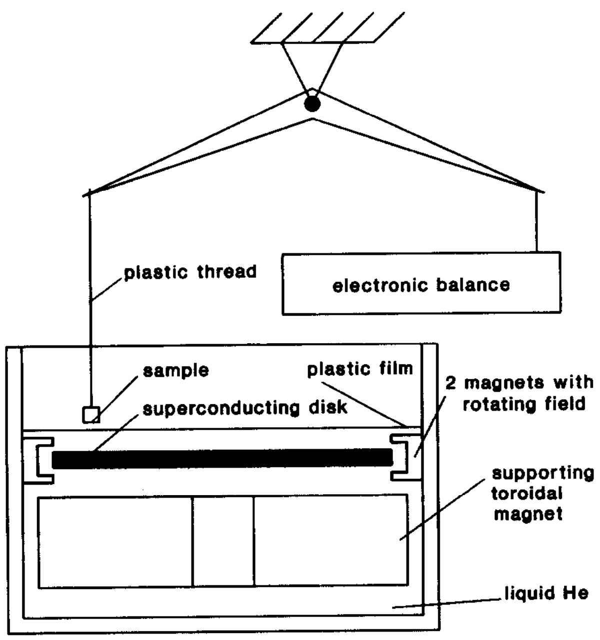

Fig. 1. Schematic diagram of the installation for the measurements of shielding properties of the $YBa_2Cu_3O_{7-x}$ bulk ceramics.

with random orientation and lattice parameters: $a=0.381$ nm, $b=0.385$ nm, $c=1.165$ nm. SEM investigations showed that the material was extremely dense with no open porosity and consisted of small grains with pure grain boundaries free from phase segregation.

The transition temperature T_c measured from the resistive transition was 92 K with a width of 0.7 K.

The superconducting ceramic disk revealed a weak but clearly detectable shielding effect against the gravitational force at the temperatures from 20 to 70 K. The sample with the initial weight of 5.47834 g was found to loose about 0.05% of its weight when placed over the levitating disk without any rotation. When the rotation speed of the disk increased, the weight of the sample became unstable and gave fluctuations from -2.5 to $+5.4$% of the initial value.

At certain speeds of rotation and at certain frequencies of electromagnetic field in the rotation magnets the weight of the sample stabilized and decreased by 0.3%. The readings in the stable regions were recorded several times with good reproducibility.

The levitating superconducting disk was found to rise by up to 7 mm when its rotation moment increased. Test measurements without the superconducting shielding disk, but with all operating solenoids connected to the power supply, had no effect on the weight of the sample.

Every precaution was taken to prevent the influence of static electricity and air flow on the sample or the supporting thread. Also, the electro-optical balance was shielded from the possible influence of electromagnetic fields.

4. Discussion

There exist several types of levitation which can be explained by different physical phenomena. Free flotation of the objects can be caused by aerodynamic, acoustic, and optical forces, and can also be generated by electrostatic or magnetic fields or by radio-frequency radiation, as analyzed in detail in ref. [2],

In the present work, a typical superconducting levitation due to the Meissner effect is used to lift a superconducting disk by an alternating electromagnetic field. The rotating magnetic field at the position of the hanging sample generates an AC field which is partly shielded by the sample. Therefore, part of the AC magnetic field is expelled from the sample. Since the AC field decreases with increasing height, the expulsion results in a levitation force. Magnetic levitation counteracts the gravitational force and decreases the weight of the sample. This explanation can be given for the case when the superconducting disk is rotated by the magnetic field. But it becomes rather difficult to explain the loss of weight when the field is switched off and the disk is still rotating, and the weight of the sample remains decreased till the rotation speed of the disk decreases.

Another possible explanation of the observed phenomenon could be the levitation of the sample in the radio-frequency (RF) field generated by the solenoids on both sides of the superconducting disk. The RF rotating field penetrates a specimen to a certain skin depth and induces small currents in the surface of the sample. The RF field is then partly screened from the interior and the sample is expelled from the RF field. This interpretation also seems quite reasonable because the maximum loss of weight of the sample was observed only at high frequencies of the magnetic field up to 10^6 Hz. Still, the explanation is not adequate for the conditions of the experiment when 50 Hz electric current was used and also when the rotation solenoids were off and the superconducting disk was immobile.

Partial acoustic levitation, usually caused by a high-intensity ultrasonic field with a frequency of 20 to 40 kHz, seems hardly probable in the present case, as no special transducers generating standing waves were applied and the intensity of ultrasonic radiation from the solenoids was relatively low.

The interaction of an external magnetic field with a bulk ceramic superconductor is defined by several parameters, and the main ones are: the temperature, the coherence length, the flux pinning, the frequency and the force of the field, and the penetration depth. All these factors are interrelated in a complex way. It is known that the coherence length for Y–Ba–Cu–O at 77 K in a zero field is much smaller than the penetration length [1], but these parameters depend on the temperature [3–5] and can change considerably under certain conditions.

The lifting force in a superconductor levitating over a permanent magnet was studied by several authors [6–8], but the interaction of the ceramic superconductor with the alternating field was not studied in detail.

Intergrain boundaries were always regarded only as obstacles for the current, and it is known that the magnetic field penetrates inside a superconductor mainly along the grain boundaries. According to our experience, this penetrating field interacts with the superconducting grain boundaries in such a way that its further propagation inside the material is still possible along the grain boundaries but the intensity of the field is greatly reduced.

When the wavelengths of the external magnetic fields having various directions become comparable to the coherence length and to the interplane distances, they interact with the whole atomic structure inside the superconductor. The rotation of the superconducting body moves the grains and grain boundaries in the field, causing various disturbances of the magnetic fields because of the hysteresis effect These disturbances can also be influenced by the great number of Josephson junctions which exist inside the bulk superconducting disk and are responsible for the corresponding effects.

These disturbances change the standard interaction of magnetic, nuclear and gravitational fields inside a solid body, and the superconductor might obtain its own new gravitational momentum which yields a small gravitation shielding effect. It is well known that any physical body rotating around its vertical axis loses a part of its weight. Under certain conditions, the rotation of magnetic fields around the body might have a similar effect. In the present work the superconducting disk has its own rotation momentum and current carriers with the charge of minus two, and is moving in a high-frequency magnetic field. It might be possible that such a system modifies the magnetic field in such a way that it counteracts the gravitational force.

5. Conclusion

A bulk sintered ceramic disk of $YBa_2Cu_3O_{7-x}$ reveals a small shielding effect against the gravitational force at temperatures below 60 K. This effect increases when the disk is rotated around its central axis and depends on several parameters. The shielding effect depends on the temperature of the Y–Ba–Cu–O superconducting disk and the maximum effect was observed at temperatures below 40 K.

The shielding force depends on the rotational speed of the disk and has a tendency to increase with the speed of rotation. Fluctuations of the weight noticed in the experiment might be due to inhomogeneity and uneven density of the superconducting disk.

The shielding force depends on the frequency of the electromagnetic field, both in the supporting and rotation magnet systems, and shows a resonance behaviour at frequencies over 10^5 Hz.

The gravity shielding effect might be the result of a certain state of energy which exists inside the crystal structure of the superconductor at low temperatures. This unusual state of energy might change the regular interaction between electromagnetic, nuclear and gravitational force fields inside a superconductor, and is responsible for the observed phenomenon.

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