Evidence for superconductivity in the boron layers of MgB$_2$

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Abstract

We examine the superconducting anisotropy $\gamma = \sqrt{m_c/m_{ab}}$ of a metallic high-$T_c$ superconductor MgB$_2$ by measuring the magnetic torque of a single crystal. The anisotropy $\gamma$ does not depend sensitively on the applied magnetic field at 10 K. We obtain the anisotropy parameter $\gamma = 4.31 \pm 0.14$. The torque curve shows the sharp hysteresis peak when the field is applied parallel to the boron layers. We consider that this comes from the intrinsic pinning and is direct evidence for the occurrence of superconductivity in the boron layers. This is consistent with what the band calculations predict in the electronic states.

Key words: torque; anisotropy; MgB$_2$; layered superconductor

1. Introduction

Since MgB$_2$ [1] has a high critical temperature (40 K) and is easily processed, it is expected to utilize for various applications. Therefore, many groups involve in studying fundamental properties of MgB$_2$. An anisotropy parameter $\gamma = \sqrt{m_c/m_{ab}}$ of MgB$_2$ is very important, but it varies from 1.2 to 9 in the literature [3]. The discrepancy of $\gamma$ partly comes from the use of the polycrystals. Melting point of magnesium is 650°C, while that of boron is 2550°C. This makes it difficult to grow a single crystal.

Magnetic torque is a useful tool to investigate anisotropy. We have developed an automatic torque magnetometer, and have used to investigate the electronic anisotropy of high-$T_c$ cuprates [4]. According to Kortus et al. [2], MgB$_2$ consists of boron layers which are responsible for superconductivity. If a layered superconductivity comes out in MgB$_2$, an intrinsic pinning would appear in the torque signal. Angst et al. [6] reported that $\gamma$ depends on $H$ and $T$.

In this paper, we report the anisotropy and the intrinsic pinning of single crystalline MgB$_2$.

2. Experiment

Xu et al. succeeded to synthesize a single crystal of MgB$_2$ by using a vapor transport method, of which the details were reported elsewhere [5]. The starting materials (Mg (99.99%) chunk and B (99.9%) chunk) were sealed in a molybdenum crucible. The crucible was heated to 1400°C at a rate of 200°C/h, and kept for two hours. After that, it was cooled to 1000°C at a rate of 100°C/h, and was restored to room temperature. The onset temperature of samples was 38.6K.

Our torque magnetometer can change a magnetic field continuously from $-60$ kG to $+60$ kG in the temperature range from 4 K to 300 K. This instrument controls a sample direction by an optical position sensor, and rotates a torque sensing part by a stepping motor. We can get the torque signal from a current through a feedback coil. A sample temperature was fixed to 10 K while the applied magnetic field was varied from 10 kG to 60 kG. The angular step was 0.5° in torque curves.
From the sample size.

In conclusion, the anisotropy parameter $\gamma$ is constant in fields larger than 20 kG, and the averaged $<\gamma>$ is 4.31±0.14. We consider that a sharp hysteresis in 10 kG is from the intrinsic pinning, and is evidence for a layered superconductivity in the boron layers of MgB$_2$.

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References