Anomaly of ac susceptibility in low temperature for over-doped $Bi_2Sr_2CaCu_2O_{8+y}$

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Abstract

We studied magnetizations of over-doped $Bi_2Sr_2CaCu_2O_{8+y}$ single crystals. The thermoremanent magnetization shows an anomalous random oscillation in low frequency modulation field below 20K. The result indicates a random motion of the vortices, which suggest there exists a new magnetic phase in the vortex solid phase.

Key words: Vortex matter, Bi2212, Magnetization

1. Introduction

Among the oxide superconductors, Bi-based superconductors have been identified as the materials most suitable for practical use and have been the subject of much application-related research. A similar amount of study has been directed at investigating the basic characteristics of these oxide superconductors. Many studies for the state of magnetic flux in these materials have revealed that they are extremely susceptible to the effects of thermal fluctuations, due to their particular properties, such as high anisotropy and short coherence length, caused by the long blocking layers which are typical of Bi-superconductors. In particular, in a magnetic phase diagram parallel to the *c*-axis, a vortex liquid phase in which individual magnetic fluxes circulate independently appears in regions of high temperature and high magnetic field [1].

In this phase, the magnetic fluxes are not the standard cylindrical shape, but rather have a structure comprising a disc-shaped vortex of super-fluid electrons, known as a two-dimensional vortex structure. This magnetic structure is called "vortex matter" and gives rise to various complex phenomena which are unimaginable in conventional superconductors, such as melting of the magnetic fluxes and the occurrence of a glass state caused by displacement of the atoms in the crystals[2]. "Vortex matter" has an Abrikosov lattice structure at low temperature, but at high temperature, the lattice melts and a vortex liquid phase appears.

In the region below the melting temperature, it is supposed that the magnetic flux in a *clean* single crystal forms a triangular Abrikosov lattice and is in a relatively stable state. Therefore, this temperature region has not received much attention to date. Research activity in this field has focused on the characteristic behaviors of individual magnetic fluxes in the temperature region around the melting temperature.

Our motivation of this study is to investigate the low temperature phase below the melting temperature. By ac magnetization measurement, it is possible to observe the dynamic behavior of the magnetic flux. We have carried out precise magnetization measurement using high quality single crystals.

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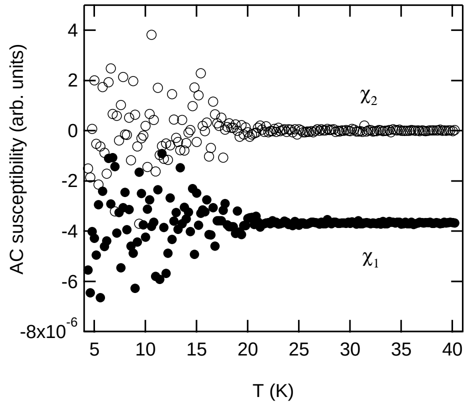

Fig. 1. Temperature dependence of ac susceptibility at H_{ac}=10^{-6}T and f=10 Hz after FC at 10^{-1}T.

2. Experimental

$Bi_2Sr_2CaCu_2O_{8+y}$ single crystals were grown with the floating zone method [3]. To investigate the crystallinity of the samples, X-ray diffraction analysis was performed using the double-crystal diffractometry. In this study, we used a over-doped samples, which was shaped into platelet form by cleaving. The ac and dc magnetizations were measured by a SQUID magnetometer. The magnetic field was applied parallel to the c-axis. The samples were carefully treated to prevent an interfusion when the samples were changed. To fix the samples at an appropriate position in the magnetometer, a thin plastic straw and Teflon tape were used. These materials have diamagnetizations of 10^{-6}emu in dc measurement and 10^{-8}emu in ac measurement in our experimental conditions, respectively. The background signals due to the polymers are negligible in our discussions.

3. Results and Discussion

Figure 1 shows the temperature dependence of the real and imaginary part of the ac magnetic susceptibility. These results were measured in the following manner. Firstly, after cooling from room temperature to 5K in a field of 10^{-1} T, the magnetic field was reduced to zero, and measurements were taken with increasing temperatures. To prevent heating of the samples, we carefully tuned the ac magnetic field, which was set to 10^{-6}T and 10 Hz. As is immediately visible in the diagram, random oscillations were measured at low temperature and converged at 20K. The oscillations below 20K appear to be completely random oscillations having the same amplitude above and below the eventual convergence value. In addition, this behavior is common to both the real and the imaginary part.

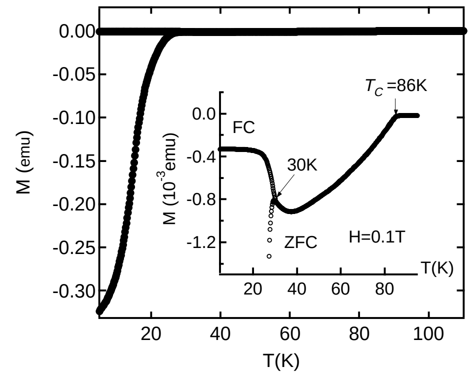

Fig. 2. Temperature dependence of the ZFC and FC magnetizations at 10^{-1}T in $Bi_2Sr_2CaCu_2O_{8+y}$.

For the definition of the irreversibility line, the temperature dependence of the dc magnetic susceptibility was measured. Figure 2 shows the zero field cooling (ZFC) and field cooling (FC) magnetization at 0.1T. The ZFC and FC magnetizations are completely the same values above 30K, which corresponds to the irreversibility temperature. Diamagnetization disappears at 86K, which corresponds to the superconducting temperature(T_C). From the dc magnetization study it is evident that the temperature at which the random oscillations occurs in ac susceptibility differs from the irreversibility temperature. This leads us to the conclusion that the anomalous behavior in ac susceptibility occurs in the temperature region below the irreversibility line. The drastic change in ac susceptibility shows an existence of unstable vortex state in low temperature[4], and also might indicate the existence of a new phase in the temperature range below the irreversibility temperature. The results for the time decay measurements of magnetizations could be suggestive for the explanation about the unstable vortex state in low temperature[5]. The anomalous oscillations were observed only in the metastable state. To proceed to the understanding for the anomalous behavior, a systematic investigation should be necessary.

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