Pressure Dependence of Chiral-Glass Transition in Y-Ba-Cu-O Ceramics

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Abstract

Ceramic high-T_C superconductors may be viewed as a weakly coupled random Josephson network containing the so-called π-junctions, and a chiral-glass transition is predicted to be occured in such d-wave ceramics. In the present work, pressure dependence of the chiral-glass transition have been investigated on $YBa_2Cu_3O_{7-y}$ and $YBa_2Cu_4O_8$ ceramics. With decreasing temperature, a superconducting order occurs at first inside each grain at T_{C1} and furthermore among the grains at T_{C2} ($< T_{C1}$). The T_{C2} increases with increase of pressure, while the sharpness of the transition at T_{C2} does not change. In spite of differences in not only T_{C2}'s but also T_{C1}'s, the increasing rates of T_{C2} by pressure are nearly the same.

Key words: YBCO ceramics; chiral-glass; Josephson network; pressure effects;

1. Introduction

A pairing symmetry of so-called high-T_C superconductors is recently considered to have the d-wave type relating to the anisotropic two-dimensionality, both experimentally and theoretically. The Josephson junction with such the anisotropic nature can show the phase shift π. Ceramic high-T_C superconductors may be viewed as a weakly coupled random Josephson network containing so-called π-junctions. Theoretically there should exist frustrations, if the number of π-junctions in a closed loop consisting from some Josephson junctions was odd. The superconducting current would occur spontaneously in such closed loop, and spontaneous magnetic moment should appear under the chiral glass transition temperature in frustrated Josephson network below the superconducting temperature [1]. The ceramic $YBa_2Cu_4O_8$ sample composed of homogeneous sub-micron size grains [2] shows successive phase transitions under the zero field [3]. With decreasing temperature, a superconducting order occurs at first inside each grain at T_{C1}(=80K) and furthermore among the grains at T_{C2}($< T_{C1}$). The value of T_{C2} is considered to depend on the strength of Josephson coupling between grains. The discrepancy between field-cooled and zero-field-cooled magnetization appears below T_{C2} and negative divergence of nonlinear susceptibility is observed at T_{C2} [3,4]. Furthermore, dynamic properties of the transition are investigated by magnetic measurement and a reasonable scaling fit of the data with chiral-glass critical exponents is found [5]. Such characteristic critical behaviors of the intergrain ordering strongly suggest a chiral-glass ordering. In the present work, the pressure dependence upon the chiral glass transition have been investigated on the $YBa_2Cu_3O_{7-y}$ and $YBa_2Cu_4O_8$ ceramic samples. The external uniform pressure on ceramic samples should control the strength of Josephson junctions between grains. Two kinds of critical temperatures, usual superconducting temperature T_{C1} and chiral glass ordering temperature among grains T_{C2} have been determined from the temperature dependences of linear and nonlinear susceptibility.

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2. Experiment

The ceramic $YBa_2Cu_4O_8$ sample composed of homogeneous sub-micron size grains is synthesized by the citrate pyrolysis method reported in Ref. [2]. Well mixed sub-micron powders of $YBa_2Cu_3O_{7-y}$ prepared by the coprecipitation method were calcined at 800 - 860 ℃ for 24 hours in air. The calcined powder was then pulverized, cold-pressed into a disk shape and sintered at the same temperature for the same hours in air as in the calcination process, and then cooled slowly in order to prevent the oxygen deficiency of samples. The magnetic susceptibility under pressure was measured with SQUID magnetometer (Quantum Design MPMS-5S). The nonlinear susceptibility is derived from the third harmonics in-phase Fourier component for the applied *ac*-field of 0.05 Oe with frequency of 10 Hz. The linear susceptibilities were measured with applying the *ac*-field with the same frequency and the same amplitude under zero external *dc*-field. The pressure was attained with the CuBe clamp cell, and the fluorine oil was used as the pressure transmitter oil. The value of actual pressure for a load was calibrated from the superconducting transition temperature of metallic Pb put in the clamp cell.

3. Results and Discussion

The observed grain size of $YBa_2Cu_3O_{7-y}$ samples by the scaning electron microscope (SEM) grows drastically from 0.2 to 2 μm with increasing synthesis temperature from 800 to 860 ℃. The Meissner signals at T_{C1} are quite small because grain size is the same order with the field penetration length. The cause of increase in T_{C2} with increase of synthesis temperature is considered as the change of strength of Josephson junction between grains accompanying the growth of grain size. The temperature T_{C1} shifts toward higher temperature with increasing pressure for both $YBa_2Cu_3O_{7-y}$ and $YBa_2Cu_4O_8$, as shown in Fig.1(a) and Fig.1(b), respectively. The pressure derivatives of T_{C1}, $\mathrm{d}T_{C1}/\mathrm{d}P = 0.19$ and 0.56 K/kbar for $YBa_2Cu_3O_{7-y}$ and $YBa_2Cu_4O_8$, respectively are in good agreement with the values for bulk samples. The nonlinear susceptibility shows a very sharp peak at T_{C2} and the T_{C2} increases with increasing pressure, while the sharpness of the transition at T_{C2} does not change up to 6 kbar. The results show that the pressure on ceramic samples is applied uniformly in grain level and controls the strength of Josephson junctions between grains. The pressure dependences of T_{C1} and T_{C2} are summarized in Fig.1. Fig.1(a) is the results for the $YBa_2Cu_3O_{7-y}$ ceramic samples with T_{C2} = 70 K and T_{C2} = 33 K at ambient pressure (P = 0), and Fig.1(b) for the $YBa_2Cu_4O_8$ ceramic sample with T_{C2} = 44K at P = 0. In spite of differences between not only $YBa_2Cu_3O_{7-y}$ and $YBa_2Cu_4O_8$ but also those in T_{C2}'s (= 70 K, 33 K and 44 K) at P = 0, the increasing rates of T_{C2} by pressure are nearly the same with each other ($\mathrm{d}T_{C2}/\mathrm{d}P$ = 0.8 K/kbar). The pressure effects on the chiral-glass transition for the further higher pressure region are now in progress.

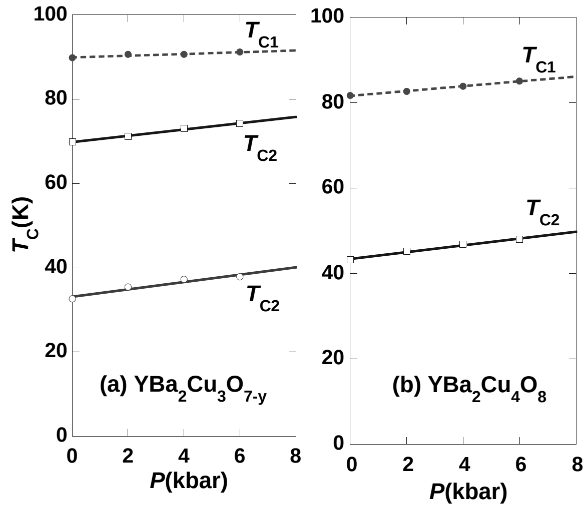

Fig. 1. Pressure dependence of T_{C1} and T_{C2} for (a) $YBa_2Cu_3O_{7-y}$ with T_{C2} = 70 K and T_{C2} = 33 K at P = 0 and (b) $YBa_2Cu_4O_8$ with T_{C2} = 44K at P = 0.

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