Dynamical Scaling Analysis of Susceptibility in Ceramic YBCO Superconductors

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Abstract

Dynamical properties of the ceramic $YBa_2Cu_3O_{7-\delta}$ have been investigated by magnetic measurements. We measured *ac*-susceptibilities at various frequency under zero external field and carried out dynamic scaling analysis near inter-grain transition temperature. The results exhibit scaling behavior for the critical exponents $z\nu$=8 and β=0.5. These values are fairly close to the ones for the chiral-glass estimated by Monte Carlo simulations.

Key words: YBCO; ceramics; chiral-glass; *ac*-susceptibility

1. Introduction

Ceramic high-T_c superconductors may be considered as random Josephson-coupled networks containing so-called -junctions. There has been increasing interest in the ordering phenomena of these systems from both experimental and theoretical sides. Recent experiments in the ceramic $YBa_2Cu_4O_8$ [1] and $YBa_2Cu_3O_{7-\delta}$ [2] which are composed of sub-micron size grains have shown two successive superconducting transitions under zero field. With decreasing temperature, a transition occurs at first inside each grain at T_{c1} and successively another transition occurs among the grains at T_{c2} where the negative divergence of nonlinear susceptibility is found [1]. This critical phenomenon suggests the onset of a new type glass phase predicted by Kawamura and Li [3]. They proposed that a new zero-field phase, which is called a chiral-glass phase, might be realized in certain ceramic or granular high-T_c superconductors. In the chiral-glass state, local loop-supercurrents spontaneously generated even in zero field are fixed in time in a spatially random manner. Furthermore, they studied the dynamical critical properties of the chiral-glass transition by means of Monte Carlo simulations. Recently, Deguchi *et al* [4] performed the dynamic scaling analysis of the susceptibility of the ceramic $YBa_2Cu_4O_8$ near T_{c2} and found the reasonable scaling fit of the data. In the present work, we study the dynamic properties of the ceramic $YBa_2Cu_3O_{7-\delta}$. The results are discussed with the results of the Monte Carlo simulations and of the ceramic $YBa_2Cu_4O_8$.

2. Experiment

Well mixed sub-micron powders 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 under the same condition as calcination, and after cooled down slowly in order to prevent the deficiency of oxygen in the samples. The *dc*-magnetization and the *ac*-susceptibility of the sample were measured with a SQUID magnetometer (Quantum Design MPMS-5S) with an ultra-low-field option.

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3. Results and discussion

First, we have measured the temperature dependence of zero-field-cooled and field-cooled magnetization at H=1G and also measured the ac-susceptibility under zero external field. The discrepancy between the field-cooled and zero-field-cooled magnetization appears and a negative divergence of nonlinear susceptibility is observed at T_{c2}=56.0K, which is similar to the previous results of the ceramic $YBa_2Cu_4O_8$ [1]. The linear susceptibilities, in-phase susceptibility and out-of-phase one , are measured in the frequency range of 1Hz to 1kHz with an ac-field amplitude of 0.01G under zero external field. The in-phase susceptibility changes abruptly around T_{c2} and the out-of-phase has a maximum below T_{c2}. The ac-susceptibility has a significant frequency dependence as shown in Fig.1. The temperatures at the maximum in and at the onset of the inter-grain diamagnetism in shift toward lower temperature with decreasing frequency. However, both the shape of the peak and the magnitude of hardly depend on the frequency. The result exhibits strong dissipation even in low-frequency region and is similar to the result of the ceramic $YBa_2Cu_4O_8$ [4]. Kawamura and Li studied dynamic properties of the inter-grain ordering of Josephson-junction arrays with d-wave and the s-wave models using Monte Carlo simulations [3]. The frequency dependence of the susceptibility observed in the d-wave model is qualitatively consistent with our results. If the transition at T_{c2} is the chiral-glass one, should satisfy the dynamic scaling relation of the form,

$$\chi"(\omega, T) \approx \omega^{\beta/z\nu} \bar{\chi}"(\omega, t) \qquad (1)$$

,where z, ν and β are chiral-glass exponents and t = | T-T_{c2} |/T_{c2}. Figure 2 shows this scaling relation for the data near T_{c2}. The scaling gives $z\nu$=8 and β=0.5. These values fairly close to the theoretical estimates, $z\nu$=8.2 and β=0.5, and to the values for the ceramic $YBa_2Cu_4O_8$. The dynamical properties of the ac-susceptibility can be well accounted for by the chiral-glass model.

4. Summary

We investigated the inter-grain ordering at T_{c2} of the ceramic $YBa_2Cu_3O_{7-\delta}$ by the ac-susceptibility measurements at zero external field. The frequency dependence and the scaling analysis are consistent with the results for the ceramic $YBa_2Cu_4O_8$ and for the d-wave model of a Josephson-junction array. In conclusion, it is suggested that the inter-grain ordering is the chiral-glass one.

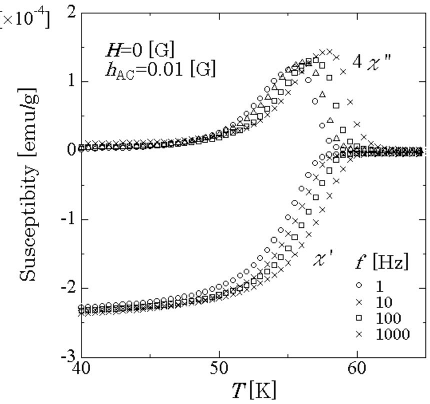

Fig. 1. Temperature dependence of ac-susceptibilities with different measuring frequencies.

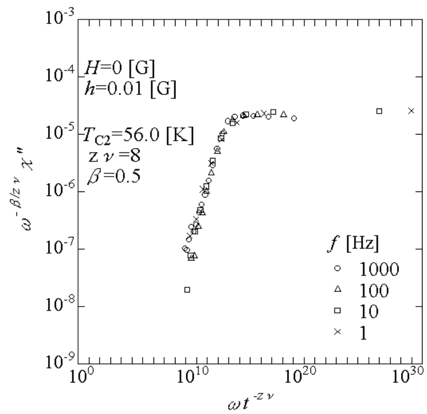

Fig. 2. The scaling plot on the data.

Acknowledgements

The authors are thankful to Professor M.Matsuura of Fukui Institute of Technology, Associate Professor M.Hagiwara of Kyoto Institute of Technology and Professor H.Kawamura of Osaka University for valuable discussions.

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