Dynamic phase diagram of vortices in high-T_c superconductors determined by experimental studies

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Abstract

Dynamic phase of driven vortices of high-T_c cuprate, $Bi_2Sr_2CaCu_2O_y$, was investigated by noise measurement and ac-dc interference measurement. We obtained the magnetic field (H) - temperature (T) - driving force (F) diagram of the dynamic phase. The obtained phase diagram was rather different from that of conventional superconductors and the theoretically expected diagram. We consider that the differences are characteristic of in high-T_c cuprates.

Key words: driven vortices; high-T_c cuprate; dynamic phase diagram; noise measurement

1. Introduction

Since the discovery of high-temperature superconductivity in cuprates, the physics of the vortex matter has attracted greater attention than before the high-T_c era. In particular, the physics of current-driven vortices has attracted much recent attention[1]. This subject concerns the physics of a driven system under random pinning, and much work has been focused on the nature of the moving state and also on the dynamic phase diagram, namely the phase diagram in the $H-T-F$ (H is the applied magnetic field, T is temperature, and F is the driving force) space. The physics of driven vortices has many common aspects to the dynamics of charge- and spin-density waves (CDWs and SDWs) in quasi-one dimensional materials, to those of Wigner crystals in correlated materials, and also to solid friction.

The equilibrium phase diagram of high-T_c superconductors is very different from that in conventional superconductors. This adds another complexity and interest to the study of dynamics of vortices in high-T_c superconductors.

We have performed a coupled study of the resistivity, the local density noise (LDN) and the conduction noise (CN) generated by the motion of driven vortices, together with the so-called ac-dc interference effects in $Bi_2Sr_2CaCu_2O_y$, and obtained a dynamic phase diagram. We found that it was very different from those in conventional superconductors, and those expected by numerical simulations.

2. Experiments

LDN of vortices was measured by a micro-Hall probe array. On the other hand, velocity fluctuation was studied by measuring the CN generated between the voltage contacts. Details on experiments, including those for the ac-dc interference experiments were described elsewhere[2–5].

3. Results and Discussion

Figure 1 shows an example of the resistivity, the local density noise, the conduction noise, and the interference effect, as a function of magnetic field at 80 K.

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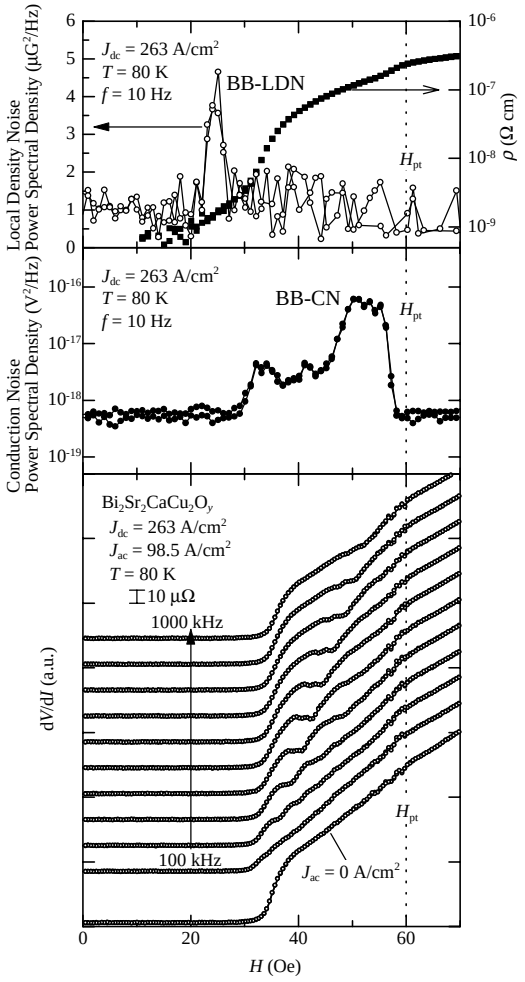

Fig. 1. Resistivity, local density noise, conduction noise and the ac-dc interference effect of $Bi_2Sr_2CaCu_2O_y$ as a function of magnetic field at 80 K (Driving current density is 263 A/cm^2).

Before the resistivity onset, first, the LDN appeared, and the CN followed at this temperature. A detailed study of the LDN[2,4] already clarified that the large LDN corresponded to the plastic motion of the driven vortices. On the other hand, the CN was found to be the manifestation of the enhancement of the coherence of driven vortices because of the two reasons. First, the washboard noise sometimes showed up in the CN spectra, suggesting highly ordered motion[3]. Second, in most cases, the ac-dc interference effect was observed when the large broadband CN was observed in the absence of the large-amplitude alternating driving force[5].

By repeating the same experiment at various driving current and temperatures, the dynamic phase diagram was obtained as in Fig. 2. This is rather different from that obtained in conventional superconductor, $NbSe_2$[6], and is also rather different from what

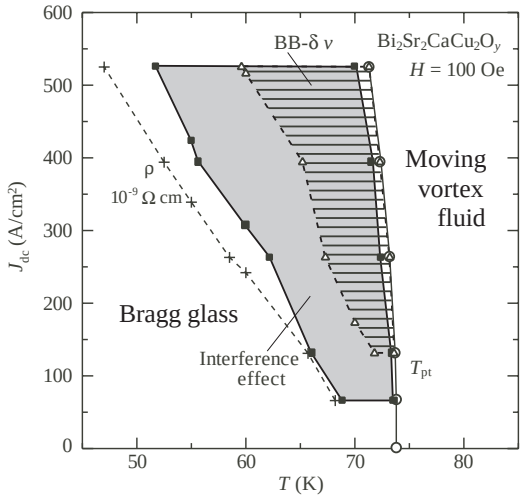

Fig. 2. Temperature *vs.* driving current density cut of the dynamic phase diagram of vortices in $Bi_2Sr_2CaCu_2O_y$.

was obtained by a numerical simulation[7]. We consider that the effect of the magnetic field dependence of the pinning force, which was not considered in the simulation, is important. This might explain the rather characteristic behavior of the dynamic phase diagram of $Bi_2Sr_2CaCu_2O_y$.

4. Conclusion

Dynamic phase of driven vortices of high-T_c cuprate, $Bi_2Sr_2CaCu_2O_y$, was investigated by noise measurement and ac-dc interference measurement. We obtained the magnetic field (H) - temperature (T) - driving force (F) diagram of the dynamic phase. The obtained phase diagram was rather different from that of conventional superconductors and the theoretically expected diagram. We consider that the differences are characteristic of in high-T_c cuprates.

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