Pinning anomalies in organic layered superconductor κ-(BEDT-TTF)$_2$X {X=Cu(NCS)$_2$, Cu[N(CN)$_2$]Br}

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Abstract

Vortices in organic superconductor κ-(BEDT-TTF)$_2$X {X=Cu(NCS)$_2$, Cu[N(CN)$_2$]Br} are interesting for their anisotropic character. To investigate their dynamical behavior, ac complex susceptibility and dc electrical resistance measurements were done in the presence of vortices introduced by dc magnetic fields. In the course of experiments, we found that the dc field dependence of complex susceptibility changes drastically for moderate ac magnetic fields, i.e. the shielding effect of the system ($-\chi'$) has a peak structure and the dissipation term (χ'') shows a dip. In addition to the anomalies in the susceptibility, it turned out that the electrical resistance has a dip structure under the same dc magnetic fields. These anomalies imply that the vortices are less mobile there.

Key words: organic superconductor; vortex dynamics; complex susceptibility; flow resistance;

1. Introduction

Organic superconductors based on BEDT-TTF molecules attract physicists because they have layered structures similar to the cuprate high temperature superconductors and therefore show strongly two dimensional character. Among many organic superconductors, κ-(BEDT-TTF)$_2$X, where X=Cu(NCS)$_2$ or Cu[N(CN)$_2$]Br, shows high critical temperature with T_c = 10.4K and 11.5K, respectively[1][2]. In this paper, we report anomalous features of pinning properties of vortices introduced in these materials.

2. Experiment

We made two types of experiments. In the first experiment, vortices were introduced by a dc magnetic field that is applied in the direction perpendicular to the two dimensional (2D) conducting plane and their response to weak ac magnetic fields in the 2D plane was investigated. We adopted a conventional mutual inductance technique and detected ac complex susceptibility $\chi = \chi' + i\chi''$.

In the second experiment, we applied a weak current in the 2D plane in addition to dc and ac magnetic fields and measured dc electrical resistance due to the flow of depinned vortices.

3. Experimental results and discussions

3.1. *Complex susceptibility measurement for moderate ac magnetic field*

Figure1 shows the dc field dependence of the ac complex susceptibility in κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Br measured at 4.2K. It is noted that there appears peak structures in $-\chi'$ and dip structures in χ'' for moderately strong ac magnetic fields. The qualitative be-

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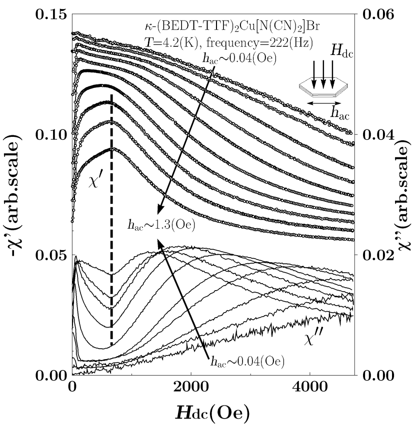

Fig. 1. The dc field dependence of the ac complex susceptibility in κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Br

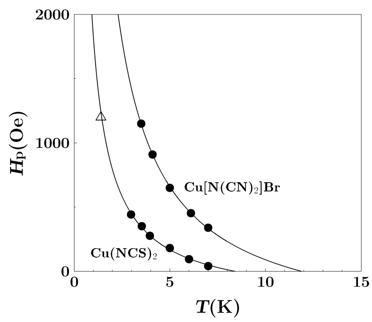

Fig. 2. Temperature dependence of the characteristic dc field H_p where vortices are strongly pinned.

havior of this ac susceptibility in Cu[N(CN)$_2$]Br salt is quite the same as in the Cu(NCS)$_2$ salt which we reported previously[3]. The peak in $-\chi'$ implies that the effective penetration depth of the ac magnetic field is short for this dc magnetic field. On the other hand, the dip structure in χ'' indicates that the mobility of vortices is low in this dc field region. These anomalous structures in the ac complex susceptibility give clear evidence that a strong effective pinning on the dc vortices exist under a certain dc magnetic field.

The temperature dependence of this characteristic magnetic field H_pin in Cu[N(CN)$_2$]Br salt is shown in Fig.2 with that of Cu(NCS)$_2$.

3.2. *Resistance measurement under ac magnetic field*

Next, we demonstrate how the anomalies appear in the electrical resistance measurement. In the experiment, a weak electric current is applied in the 2D plane and the voltage due to the motion of vortices was detected. In addition to a dc magnetic field normal to the 2D plane, an ac magnetic field in the 2D plane was applied. Figure3 shows the dc field dependence of the electrical resistance in κ-(BEDT-TTF)$_2$Cu(NCS)$_2$. In this figure, we recognize a dip structure around $H_\mathrm{dc} \sim$ 200Oe which indicates that the flow of vortex is small in this dc field region. This is just what we concluded from the anomaly in the ac susceptibility. Therefore, we believe that the origin of this anomaly is the same with that of the ac susceptibility anomaly.

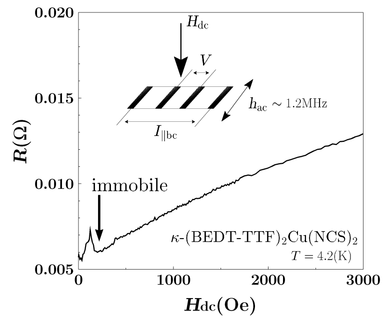

Fig. 3. The dc field dependence of the electrical resistance in Cu(NCS)$_2$ salt.

In the experiment shown in Fig.3, dc magnetic fields were applied normal to the 2D plane. From additional experiments in which dc fields are applied in tilted directions, we found that the position of the resistance anomaly is determined by the dc field component normal to the 2D plane. It indicates that the dip in the resistance appears when the density of pancake vortices which perpendicularly penetrate the 2D plane becomes a certain value.

4. Conclusions

We conclude that the vortices in organic superconductor κ-(BEDT-TTF)$_2$X becomes less mobile under a certain magnetic field. Reflecting the immobility of the vortices, the dc field dependence of the ac complex susceptibility and electrical resistance show anomalous structures.

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