Magnetic Torque Measurements of the Organic Superconductor $(TMTSF)_2ClO_4$ with a Piezoelectric Cantilever

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Introduction

Since the discovery of the Bechgaard salts a quarter century ago, its fascinating physical properties opened a new horizon of the low-dimensional condensed matter physics. But there are still many interesting properties only partially understood or not understood at all. The high magnetic field state of the title compound, following the integer quantum Hall effects, is one of such examples. Originally argued as a reentrant metallic state, identical with the high temperature state, there are now a number of evidences that this state is richer in physics. One of the recent examples is the oscillating Hall resistance of large amplitude above 27 T.[1] Because a simple theory for metals failed to explain the phenomenon, a possibility of novel quantum state was suggested. As a preparative step to investigate the magnetic properties of this high field state, we used the commercial self-sensing piezoelectric cantilever to measure the magnetic torque signal from the sample in a superconducting magnet. We found the cantilever very useful and sensitive tool for the study of small samples like the title compound.

Experimental

Application of the commercial piezoelectric cantilever to study small nonmagnetic samples are often challenged by several reasons.[2,3] In order to test its sensitivity and usefulness, the cantilever method was verified in a 18 T superconducting magnet (NHMFL). The sensitivity of the cantilever is substantially improved by the monolithic design of the symmetric cantilevers and by taking the difference between the two cantilevers with and without a sample. Uncertainly of absolute magnetization and of the sample orientation could be overcome by analyzing the angular and field dependence. The sample platform containing the temperature sensor and the cantilever with a sample is rotated at constant temperature and field. Usual cos θ and sin 2θ dependence and H^2 dependence can be used to extract the contribution of nontrivial ground states.

Results and Discussion

Fig. 1 shows the field dependence of the torque signal at various temperatures after removing the H^2 dependent background. Because the H^2 dependent background magnetic torque is expected for the simple metal, the torque in the graph can be considered being from the field-induced spin-density-waves. In fact, a well develop sawtooth-like torque is observed at the lowest temperature with rapidly changing torque signal at each transition fields between subphases. The step height is particularly large at the so-called negative Hall steps. In addition, well defined oscillations develop above around 12 T. However, these oscillations are from the same origin as the rapid resistance oscillations at the moderate field range. Oscillations of the Hall effect signal with giant amplitude and with the sign reversal [1] can be studied with the same apparatus if a stronger magnetic field is applied.

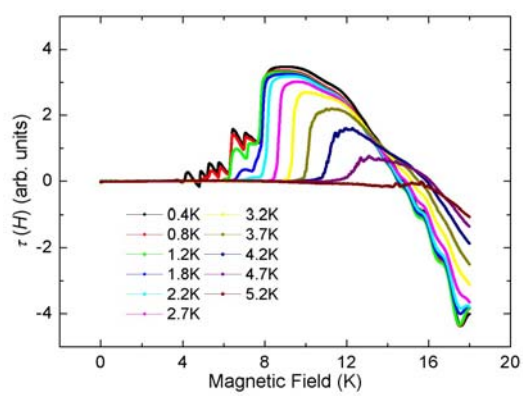

Fig. 1. Magnetic torque signal of micro-cantilever with a $(TMTSF)_2ClO_4$ single crystal glued on its end.

Conclusions

We found that the piezoelectric cantilever could be used to study magnetic properties of small nonmagnetic samples. The method will be used to study the high field state of the title compound.

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References

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