High Frequency Probes of Superconductivity and Magnetism in Anisotropic Materials

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Introduction

Organic materials reveal many different phenomena depending on the temperature, the applied magnetic field and its direction with the sample crystallographic axes. The \(\lambda\)-(BETS)\(_2\)GaCl\(_4\) and \(\lambda\)-(BETS)\(_2\)FeCl\(_4\) (\(\lambda\)-phase BETS salts) are a good examples of such materials. The \(\lambda\)-(BETS)\(_2\)GaCl\(_4\) and \(\lambda\)-(BETS)\(_2\)FeCl\(_4\) have totally different behavior at the same conditions. Basically, while the superconductivity state is destroyed for the \(\lambda\)-(BETS)\(_2\)GaCl\(_4\) by applying a magnetic field, it is induced for the \(\lambda\)-(BETS)\(_2\)FeCl\(_4\) by applying a magnetic field parallel to c-axis. Because of this behavior \(\lambda\)-(BETS)\(_2\)FeCl\(_4\) is considered as a field induced superconductor (FISC) under these conditions [1, 2]. To study these different behaviors, an improved method has been developed to measure the upper critical fields of quasi-two dimensional (highly anisotropic) superconductors. The method involves an ac tunnel diode oscillator (TDO) circuit that can measure penetration depths and skin depths on very tiny single crystals with great sensitivity [3]. The TDO circuit has been designed to rotate at low temperatures and in high magnetic fields, and good control over the direction of the magnetic field with respect to the crystallographic axes is obtained. The instrumentation that has been developed was first used to search for the Meissner signal in the superconducting state of \(\lambda\)-(BETS)\(_2\)GaCl\(_4\) where careful alignment of the sample’s c-axis with magnetic field is crucial. Future work focusing on searching for the Meissner signal in the field induced superconducting state of \(\lambda\)-(BETS)\(_2\)FeCl\(_4\) where careful alignment of the sample c-axis is needed too.

Experimental

In this experiment, a single crystal of \(\lambda\)-(BETS)\(_2\)GaCl\(_4\) (2×0.07×0.035 mm\(^3\)) was inserted in a testing coil (radius equal to 0.24 mm) with a very stable resonance frequency of 134.440720 MHz. The circuit was fixed on single axis rotating probe and it was rotated in magnetic field up to 9 tesla and low temperature as low as 1.6 K. Then the shift in the resonance frequency is observed.

Results and Discussion

The alignment of the crystallographic axes with the external magnetic field enables us to reconstruct the superconductivity phase diagram of \(\lambda\)-(BETS)\(_2\)GaCl\(_4\) when the field is parallel to the c or b axes, as in Fig. 1. Also, as shown in Fig. 1, the new field-temperature measurements that performed using TDO probe show a good agreement with resistance measurements which done by Tanatar for this material [4].

Conclusions

It can be concluded that, the TDO probe is a very powerful technique to study organic materials because of its ability to probe different orientations of the sample and the applied field. In addition, the TDO will be a very good tool to study the field induced superconductor compound \(\lambda\)-(BETS)\(_2\)FeCl\(_4\).

Acknowledgements

We would like to thanks Catalin Martin and Phil Kuhns, for the valuable discussion and comments. This work was supported by the NSF Grant No: 0602859 and the NHMFL. The NHMFL is supported by contractual agreement between NSF and the state of Florida.

References