SIMULTANEOUS EMR AND RESISTANCE MEASUREMENTS OF FIELD-INDUCED SUPERCONDUCTORS $\lambda$-(BETS)$_2$Fe$_{0.4}$Ga$_{0.6}$Cl$_4$

T. Tokumoto, E. Jobiliong, J.S. Brooks (FSU, Physics/NHMFL); S.A. Zvyagin, J. Krzystek, D. Smirnov (NHMFL); H. Tanaka (AIST, Japan); A. Kobayashi (The University of Tokyo, Chemistry, Japan); H. Kobayashi (IMS, Japan)

Recently, the field induced superconducting phase in $\lambda$-(BETS)$_2$FeCl$_4$ was found as a first observation in organic superconductors [1]. Here the center of the FISC ground state is at 33 T below 5 K [2]. In general, the application of a substantial magnetic field destroys the superconducting phase for two reasons. One is the orbital effect and the other is the Zeeman effect. The $\lambda$-(BETS)$_2$FeCl$_4$ crystal has 2-D conducting layers. So the orbital effect is suppressed due to the geometry of the sample when the magnetic field is applied parallel to the layers. Hence the cancellation of the Zeeman effect should be the key to the embodiment of FISC phase. The most possible mechanism is explained by the Jaccarino-Peter effect; the internal magnetic field created by the Fe$^{3+}$ ($S=5/2$) moments through the exchange interaction is compensated by the applied external magnetic field, therefore the Zeeman effect which destroys the superconductivity would be completely absent under this condition [3]. Nevertheless, there are still questions that the Jaccarino-Peter effect is the mechanism of this FISC phase. Hence more precise investigations of the electronic states in these compounds to probe the local magnetic field, such as electron magnetic resonance (EMR) measurements are desirable. To bring the center of the FISC phase down to lower fields, we used $\lambda$-(BETS)$_2$Fe$_{0.4}$Ga$_{0.6}$Cl$_4$ since the FISC phase of organic alloys $\lambda$-(BETS)$_2$Fe$_x$Ga$_{1-x}$Cl$_4$ shifts to lower field as $x$ decreases [4]. To correlate the transport behavior with the EMR signal, we attached four wires on the sample in the BWO sample holder to measure the resistance of the sample while conducting the EMR measurements.

In our preliminary study, EMR on the $\lambda$-(BETS)$_2$Fe$_{0.4}$Ga$_{0.6}$Cl$_4$ was carried out in the 25 T resistive magnet, using backward wave oscillator (BWO) sources, in the range 200 to 700 G Hz. The sample was placed in the Voigt configuration in which the dc magnetic field is perpendicular to the propagation of the light. The direction of the magnetic field is B // c*. A metallic foil was placed around the sample to reduce the background radiation. The resistance of the sample was measured simultaneously. The results of a simultaneous EMR and resistance measurement is shown in Fig.1. Temperature dependence of the EMR peaks, which showed a splitting into two, are shown in Fig.2. In the range of the FISC state, the g-value exhibited a non-monotonic dependence on T. Although the field dependence of the low field antiferromagnetic insulating state was apparent in the transport data shown in Fig. 3, there was no direct evidence for the FISC state in the resistance at higher fields, possibly due to uncertainties in the sample alignment for B//c. In Fig.3, the hysteretic phase diagram of the antiferromagnetic state for $x = 0.4$ is shown. Insets are from a previous study for $x = 0.19$ and 0.45 [4]. Shaded zones in the insets are the predicted FISC phase by J-P effect. Another factor that may compromise the FISC state is the heating from the BWO source, which was noticeable in the highly resistive AF phase.

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References