STUDY OF PRESSURE EFFECT ON THE INTERNAL FIELD OF THE FIELD-INDUCED ORGANIC SUPERCONDUCTOR λ-$(BETS)_2FeCl_4$

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Introduction

Study of BETS compounds containing Fe^{3+} magnetic ions has been of particular interest because the large magnetic moments of Fe^{3+} ions would induce the π-electron spins on donor molecules to develop a π-*d* coupled antiferromagnetic spin structure. Electrical resistivity and magnetic susceptibility measurements reveal that the π conduction electrons from BETS molecules and the localized magnetic moments of the anions coexist down to very low temperature. Measurement of the Shubnikov–de Haas (SdH) oscillations in λ-$(BETS)_2FeCl_4$ at ambient pressure revealed oscillations with two distinct frequencies of 609 and 737 T. The splitting of the SdH oscillations is attributed to the spin-dependent FS separation due to the internal magnetic field, which is 32 T according to the spin-splitting factor of the Lifshitz-Kosevich formula. We have measured the SdH oscillations at a pressure of 6 kbar. Changes of the Fermi surface topology and the internal field with pressure are explored.

Experimental

Annealed gold wires were attached to the sample surfaces so that the current may flow along the least conducting b^* axis. Pressure was generated with a ultra-miniature BeCu pressure clamp cell. A 1:1 mixture of the Daphne 7373 oil and kerosene was used as a pressure medium. The pressure at low temperature was determined from the change of the superconducting T_c of high-purity lead (Pb). The experiments were performed in a 33 T resistive magnet at the NHMFL.

Results and Discussion

Fig. 1(a) shows the oscillatory amplitude of the MR as a function of 1/H at several temperatures. The FFT spectra of the SdH oscillations between 18 and 33 T are displayed in Fig. 1(b). The splitting of both the α and β oscillations are observed. α_1, α_2, β_1, and β_2 have values of 803, 957, 3973, and 4255 T, respectively. The average effective masses are $(2.9\pm0.3)m_0$ for the α and $(5.5\pm0.3)m_0$ for the β orbit. For the closed-orbit oscillations, the effective mass falls from $4.1m_0$ to $2.9m_0$ with pressure. As for the MB orbit, the effective mass of $5.5m_0$ is lighter than that in other BETS compounds containing magnetic ions. Hydrostatic pressure will bring the BETS molecules closer together and hence broaden the energy band. So the decrease in effective mass with pressure is strongly related to the suppression of interaction between π electrons which depends critically on the bandwidth. As stated earlier, the internal field H_{int} can be directly calculated from the difference of frequencies, $2\Delta F$. Applying the expression for H_{int} to the α and β orbits, ΔF_α=77 T and ΔF_β=141 T, and give the estimated values for $H_{int,\alpha}$=53 T and $H_{int,\beta}$=51 T, assuming the *g* factor of 2.

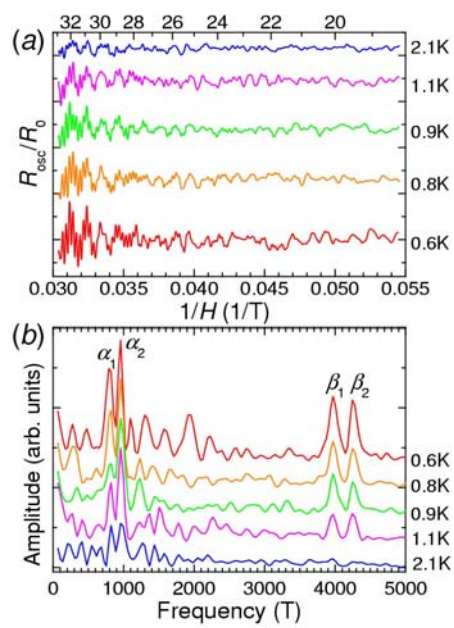

Fig. 1 (a) Oscillatory part of the magnetoresistance at 6 kbar. (b) FFT spectra of the SdH oscillations.

Conclusions

In λ-$(BETS)_2FeCl_4$ under pressure, new SdH oscillations with frequencies faster than those at ambient pressure, are detected and attributed to the magnetic breakdown orbit. The increase of the SdH frequencies indicates an increase in the size of the closed Fermi surface under pressure. The effective mass becomes smaller under pressure most likely due to the broadening of the bandwidth. The estimated internal field increases from 32 to 52 T under a pressure of 6 kbar.

References

[1] Jo, Y. J., *et al.*, Phys. Rev. B, 73, 214532 (2006).