Field-reinforced superconductivity and spin-triplet state in uranium compounds

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The microscopic coexistence of ferromagnetism and superconductivity is realized in uranium compounds, that is UGe_2, URhGe and UCoGe. One of the highlights in this system is the field-reinforced superconductivity, where the upper critical field, H_{c2} highly exceeds the Pauli limit. Thus, the spin-triplet state with equal spin-pairing is most likely realized. Furthermore, in URhGe and UCoGe, when the field is applied along the hard magnetization axis, H_{c2} is strongly enhanced as field-reinforced superconductivity. This is because the longitudinal ferromagnetic fluctuations increases as a function of field, corresponding to the collapse of the Curie temperature.

Very recently, a new superconductor, UTe_2, which is a paramagnet but is located at the verge of ferromagnetic order, was discovered[3,4]. The superconducting transition temperature is relatively high, ~1.6K with the large and sharp specific heat jump. H_{c2} again highly exceeds the Pauli limit, thus UTe_2 is potentially the spin-triplet superconductor. Interestingly, when the field is applied along b-axis in the orthorhombic structure, a sharp metamagnetic transition occurs with the first order at H_m~35T[5,6]. The energy scale is comparable to the temperature, T_χ^{max}, where the magnetic susceptibility shows the broad maximum. Approaching H_m, the effective mass increases rapidly and shows the maximum at H_m. Surprisingly, superconductivity is reinforced at high fields with the strong increase of T_{sc}, and is suddenly suppressed at H_m~35T[7]. This field-reinforced superconductivity looks similar to the cases of URhGe and UCoGe. However, a clear difference is that H_m does not correspond to the collapse of the Curie temperature, since UTe_2 has the paramagnetic ground state. The metamagnetic transition is most likely related to the drastic change of the electronic structure. In UTe_2, the low carrier numbers with heavy quasi-particles, which is close to the Kondo semiconducting state, is predicted by the band structure calculations. The magnetic field can easily change the electronic states of UTe_2, such as Lifshitz transition. Another interesting point is that UTe_2 may provide a good platform for the topological superconductivity.

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