Link between high field reentrant superconductivity and multiple superconductivity under pressure in UTe_2

We conducted AC calorimetry measurements under high magnetic fields and pressure on the spin-triplet superconductor UTe_2. With increasing pressure, the field-reentrant superconducting phase observed at ambient pressure for the field along the b-axis shifts to a lower field and higher temperature region, revealing double superconducting transitions at high pressure. These results indicate that the high-field reentrant superconducting phase is identical to the high-temperature superconducting phase under pressure.

Recent discovery of superconductivity in UTe_2 attract much attention, because of its unusual superconducting properties. UTe_2 is a heavy fermion paramagnet with the Sommerfeld coefficient γ ~ 120 mJ K^{-2} mol^{-1}. It crystallizes in the orthorhombic structure with the space group *Immm*. Although it is a body-centered structure, the inversion center is not located at the atomic site, meaning that the local inversion symmetry is broken. Superconductivity occurs at T_c=1.6-2.1K. It had been suggested that UTe_2 is an end member of ferromagnetic superconductors, UCoGe, URhGe, and UGe_2. The ferromagnetic fluctuations are, however, not experimentally established, while the antiferromagnetic fluctuations with an incommensurate wave-vector is detected by the inelastic neutron scattering experiments.

The huge superconducting upper critical field H_{c2} and the multiple superconducting phases are a strong support for the spin-triplet state of superconductivity in UTe_2. When the field is applied along the b-axis, which is a hard-magnetization axis, the H_{c2} curve shows the field-reentrant behavior above 15T, and it continues up to 35T, at which the first order metamagnetic transition occurs. The superconducting phase is abruptly suppressed above 35T.

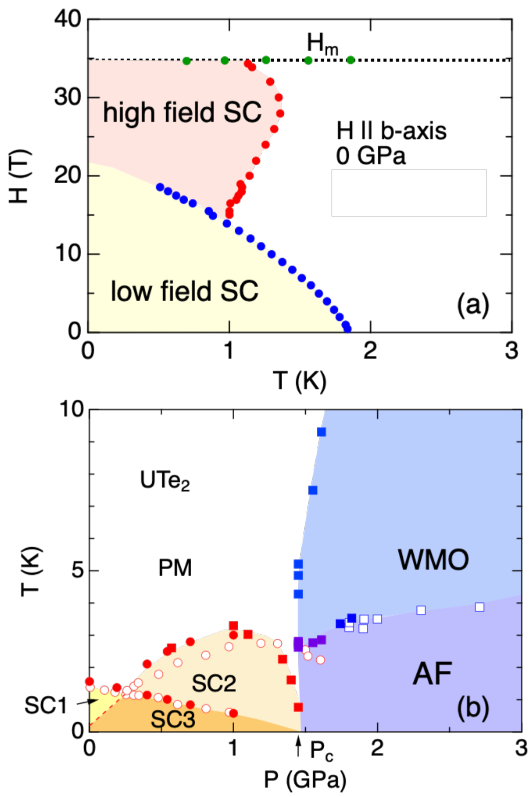

Fig. 1 (a) H-T phase diagram for the fied along b-axis at ambient pressure in UTe_2. (b) T-P phase diagram at zero field.

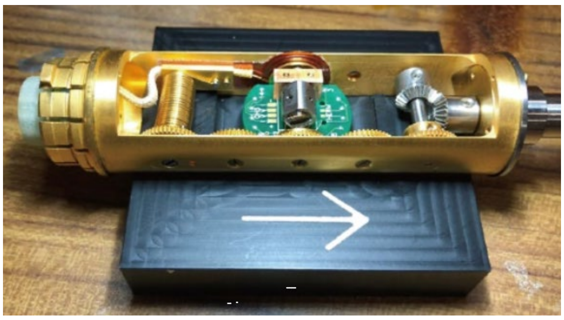

Fig. 2 Photograph of a miniature pressure cell placed on the horizontal rotator for PPMS

As shown in Fig.1(a), our recent specific heat measurements [1] reveals that there is a phase boundary between the field-reentrant superconductivity and low-field superconductivity, indicating multiple superconducting phases as thermodynamic evidence.

On the other hand, the multiple superconductivity is initially found under pressure through our AC calorimetry measurements [2,3]. As shown in Fig.1(b), with increasing pressure, Tc splits at relatively low pressure, ~0.2GPa. The low temperature Tc continuously decreases, while the high temperature Tc increases, reaching a broad maximum, T_c~3K at around 1GPa, and then decreases. At the critical pressure, P_c~1.5GPa, superconducting phases are abruptly suppressed, and the antiferromagnetic state is realized.

It is important to study this rich phase diagram through a thermodynamic method with fine tuning pressure, field direction using high quality single crystals. In this study, we performed the AC calorimetry measurements for the field along the b-axis under pressure.

Our first target is to develop a miniature pressure cell, which can be rotated at high fields and at low temperatures. Figure 2 shows a photograph of our miniature pressure cell, which is placed on the horizontal axis rotator for PPMS. The first attempt to generate pressure was successful. As a 2nd step, we are now testing the pressure cell with a UTe_2 sample for AC calorimetry measurements.

We also performed the AC calorimetry measurements under pressure using a conventional piston cylinder cell for the field along the b-axis. Figure 3(a) shows the temperature dependence of the AC calorimetry under pressure at 0.15Ga at different fields for H || b-axis. A sharp specific heat jump due to superconductivity is observed at zero field. At high fields above 8T, in addition to the sharp specific heat jumps, broad transitions appears at higher temperatures, indicating the high field superconducting phase under magnetic fields.

Further increasing the pressure, high field superconducting phase shifts to lower field region, and finally double superconducting transitions are observed at zero field.

Our results suggest that high field superconducting phase at ambient pressure is identical to the high temperature superconducting phase under pressure. The evolution of the multiple superconducting phases at high fields and at pressure was demonstrated.

This work was done in collaboration with T. Vasina, D. Aoki.

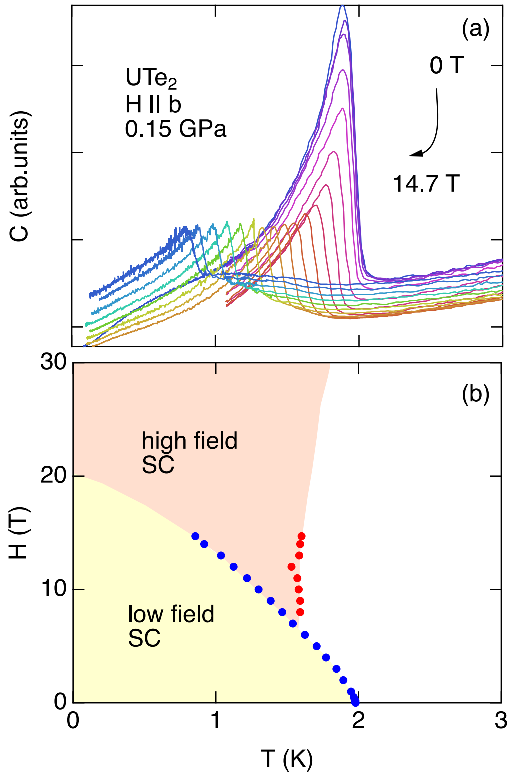

Fig. 3 (a) Temperature dependence of AC calorimetry at different fields for H || b-axis under pressure at 0.15GPa. (b) H-T phase diagram at 0.15 GPa for H || b-axis.

References

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