Effect of pressure on the ferromagnetism of UCu_2P_2

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An emergent electronic state of which the magnetic ordering temperature T_{mag} tuned to the absolute zero temperature is called as a quantum critical point (QCP), where the magnetic fluctuations become dominant. Around QCP, such as the heavy fermion state, unconventional superconductivity, and non-Fermi liquid nature are often observed. It is widely recognized that the electronic states can be tuned by applying pressure. For example, when pressure P is applied to some Ce-based antiferromagnets, the Néel temperature T_N decreases, and finally reaches to zero at the critical pressure P_c: $T_N \rightarrow 0$ for $P \rightarrow P_c$.

Recently, QCP in uranium compounds with ferromagnetic fluctuations attracts much attention, where the exotic electronic properties such as coexistence of ferromagnetism and superconducting states are observed [1]. As in the cases of pressure-induced superconductors UGe_2 and UIr, it is quite intriguing to study pressure dependence of ferromagnetism (FM) in uranium compounds. Besides tuning the onset of 5*f* magnetism to $T = 0$, an opposite task, to reach as high Curie temperatures as possible, is also interesting. It can bring the 5*f* band magnetism, yielding sizeable orbital moments and giant magnetic anisotropy, to the ambient temperatures. In order to clarify what can be a route to high ordering temperatures in U systems, we are carrying on pressure studies on uranium ferromagnets.

Among ferromagnets with 5*f* moment, UCu_2P_2 indicates the highest Curie temperature of $T_C = 216$ K [2]. UCu_2P_2 crystalizes with the $CaAl_2Si_2$-type hexagonal structure, where the nearest interatomic distance between U is $d_{U\text{-}U} = 0.394$nm. $d_{U\text{-}U}$ is larger than Hill limit (~ 0.35 nm). It is reported that T_C in UCu_2P_2 increases with pressure with 10 K/GPa up to 1 GPa [3], where the pressure coefficients is quite large among U compounds. We have investigated the stability of the FM ordering under higher pressures.

Single crystals of UCu_2P_2 was synthesized by means of a chemical vapor transport method using Iodine as a transport agent. Electrical resistivity under high pressure up to 4 GPa was measured by conventional four probe method using a Bridgman type anvil cell with Daphne oil (DN7373) as a pressure medium and magnetization under high pressure was measured using a diamond anvil cell (DAC) designed for a commercial squid magnetometer MPMS (Quantum Design Inc.) up to 6 GPa with glycelyn as a pressure medium.

Figure 1 shows the obtained *P*-*T* phase diagram of UCu_2P_2. T_C increases with increasing pressure up to 4 GPa at a rate of 10 K/GPa, and tends to saturate for further increasing pressure. The maximum T_C value is recorded at about 267 K around 6 GPa, which breaks the former record of the highest T_C value in the 5*f* moment system. It is suggested that UCu_2P_2 belongs to compounds with intermediate delocalization, where moments are stable and pressure promotes inter-site exchange interactions.

Close to the verge of localization, the purely 5*f*-band picture cannot explain experimental findings in this compound. In particular, a large pressure increase of T_C (or T_N) was observed, which can be understood by a two-band model. So that, pressure first increases inter-site exchange interaction and only then destabilizes the magnetic moments. The temperature dependences of ac-susceptibility, resistivity, and magnetization data reveal a robust pressure increase of T_C. The T_C value of around 270 K give a hint that room temperature ferromagnetism in purely 5*f* ferromagnet may be achieved.

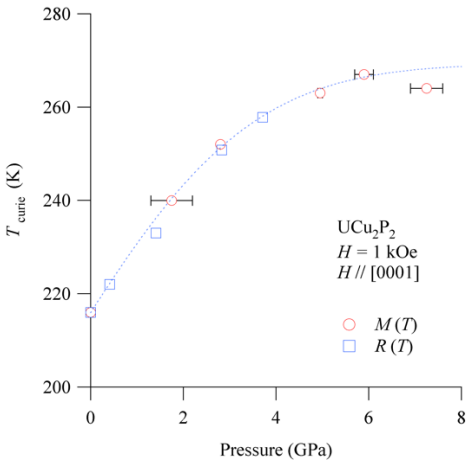

Figure 1. Pressure-temperature phase diagram of an 5*f*-moment ferromagnet UCu_2P_2 determined from $M(T)$ and $R(T)$ measurement under pressure. The inset shows a picture of a DAC for MPMS.

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