Transport properties in UCoAl under uniaxial pressure

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Abstract

We report the first study of uniaxial pressure ($P_u$) effect on the transport properties in the unique 5\textit{f} electron metamagnet UCoAl. A metamagnetic transition around a critical magnetic field $B_M \sim 0.7$ T applied along the c axis at ambient pressure shifts to higher fields with increasing $P_u$ applied along the a axis. This increase is in contrast to the decrease of $B_M$ under $P_u$ applied along the c axis. The result may be interpreted most likely as an enhancement of 3\textit{d}-5\textit{f} hybridization in the basal plane under $P_u$ along the a axis.

Key words: 5\textit{f}-electron metamagnet; ligand hybridization; uniaxial pressure; UCoAl.

UCoAl, crystallizing into the hexagonal ZrNiAl-type hexagonal structure, is an unique 5\textit{f} electron compound which exhibits a metamagnetic transition (MT) from a paramagnetic ground state around a magnetic field $B_M \simeq 1$ T when the field is applied along the c axis [1–4]. As a possible origin of MT, a field-induced ferromagnetism due to the 5\textit{f} band splitting has been inferred. $B_M$ is reported to increase with the hydrostatic pressure ($P_h$), stabilizing the paramagnetic state [5]. The magnetic behavior in this compound is strongly anisotropic, reflecting the anisotropic 5\textit{f} ligand hybridization in the layered structure. The uniaxial pressure experiment has a merit to provide information on the anisotropy in the hybridization-mediated exchange interaction. In fact, we explored the anisotropic effect under $P_u$ in CeRu$_2$Si$_2$ that exhibits a metamagnetic anomaly [6]. Recently, magnetization measurements were performed in UCoAl under $P_u$ applied along the c axis in which $B_M$ was found to decrease with increasing $P_u$, leading to a ferromagnetism in zero field around 0.56 kbar [7]. However, study the effect of $P_u$ along the a axis on $B_M$ as well as the study of transport properties under $P_u$ are essentially important. In this proceedings, we report the preliminary results of the first study of the effect of $P_u$ on the transport property in UCoAl.

Single crystals of UCoAl were grown by Czochralski pulling method in a tetra-arc furnace with an argon atmosphere. The quality of the single crystal was inferred from the residual resistivity ratio $\geq 16$, which is close to that used in Ref. [4]. Electrical resistivity was measured by the standard dc four-probe method. Uniaxial pressures were generated by using a piston cylinder type CuBe pressure cell, recently designed and constructed [6]. $P_u$ were determined by measuring the superconducting transition temperature of Sn placed near the sample by an induction method.

Figure 1 shows the effect of $P_u$ \parallel a$ axis on the magnetic field ($B$) dependence of the resistivity ($\rho$) in the $B \parallel J \parallel c$ axis geometry. At ambient pressure, $\rho$ increases with magnetic fields and then shows a steplike increase across a characteristic magnetic field $B_M \simeq 0.7$ T, tracing the metamagnetic transition. The increase of $\rho$ across $B_M$ is attributed to the change of density of states at the Fermi level [3,4]. The presence

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of hysteresis between $\rho$ for increasing and decreasing $B$ (as indicated by the up and down short arrows) across $B_M$ indicates the first order type transition. These behaviors at the ambient pressure are in close agreement with those reported in Ref. [4].

With increasing $P_u$ along the $a$ axis, the metamagnetic transition across $B_M$ shifts to higher magnetic fields [see Fig. 2]. This increase is in contrast to the decrease of $B_M$ and hence the appearance of ferromagnetism in the magnetization measurement under $P_u \parallel c$ axis reported in Ref. [7]. The absolute value of $\rho$ increases for all fields both below and above $B_M$ with increasing $P_u$ as indicated by the long upward arrows in Fig. 1. At the present stage, an increase of spin fluctuations and inclusion of microcracks should be taken into account as the possible origins of this increase of $\rho$ with $P_u \parallel a$ axis.

The result may be interpreted qualitatively as follows: The UCoAl crystal structure consists of U-Co and Co-Al basal-plane layers alternating along the $c$ axis. According to Sechovičky et al. [8,7], ferromagnetic (F) type U-U exchange coupling is favored along the $c$ axis assisted by $5f$-$3d$ hybridization within the basal plane in UCoAl. The linear compressibility in UCoAl is anisotropic, i.e., $a$ axis is softer than $c$ axis [7]. Under hydrostatic pressure ($P_h$) an enhancement of $5f$-$3d$ hybridization within the basal plane is expected to lead to an increase of $B_M$, as indeed was observed [5]. Under $P_u \parallel c$ axis, $c$ axis expands and $a$ axis shrinks, which may cause an enhancement of $5f$-$3d$ hybridization in the basal plane that weaken the F-coupling along the $c$ axis, leading to an increase of $B_M$; It should be noted that the magnetostriction across the metamagnetic transition in UCoAl are positive along the $a$ axis and negative along the $c$ axis [9]; The scenario is also consistent in the light of the anisotropic magnetoresistance.

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