The effect of hydrostatic pressure 15 GPa on magnetism of UIrGe

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The physics of uranium intermetallics is subject of an uninterrupted interest due to the behavior of the 5*f* electrons on the boundary of localized and itinerant characters. Diverse electronic properties of these compounds originate from crystal symmetry and unique balance between direct interaction of the 5*f* states and their simultaneous hybridization with electron states of *T* and *X*-elements. Then, external variables act as an effective tool affecting the electronic state of the uranium ion and various phenomena like superconductivity (SC), magnetism or heavy fermion behavior can be elicited. Particularly interesting are compounds located close to empirical Hill criterion [1]. Isostructural compounds URhGe and UCoGe crystallizing in TiNiSi-type structure naturally fulfil this condition and fundamental coexistence of ferromagneticm (FM) and superconductivity (SC) was discovered [2, 3].

The UIrGe compound was highlighted by systematic research of the magnetic and structural parameters of the U*T*Ge compounds of *Pnma* space group symmetry [4, 5]. Location of the UIrGe compound is intriguing not only by the proximity of $d_{U\text{-}U}$ to the Hill criterion but also the fact that FM/AFM transition also takes place at the almost identical value of $d_{U\text{-}U}$[6]. It is known that UIrGe orders antiferromagnetically [7] at T_N = 16.5 K. UIrGe clearly represents promising candidate where electron correlation phenomena can be raised when a requisite external variable will be applied. The effect of contraction of the unit cell volume and shrinking of the $d_{U\text{-}U}$ distance by hydrostatic pressure may drive the UIrGe compound to a magnetic instability.

We have performed a series of high-pressure experiments in two types of pressure cells using so far the best available UIrGe single crystals. It allowed us to investigate the *p*-*T* phase diagram up to 15 GPa and examine the potential non-Fermi liquid state (NFL) development at critical pressure. All the measurements were carried out on samples in the form of a bar along the *b*-axis. CuBe/NiCrAl piston-cylinder-type high-pressure cell was utilized to study the T_N response to hydrostatic pressure up to 1.7 GPa. Daphne oil 7373 was used as a pressure-transmitting medium. Advanced experiment up to 15 GPa were performed in a cubic-anvil apparatus. Gasket was made of semi-sintered MgO ceramics with Fluorinert as a transmitting medium inside a Teflon capsule. We measured down to temperature 10 mK using a dilution refrigerator.

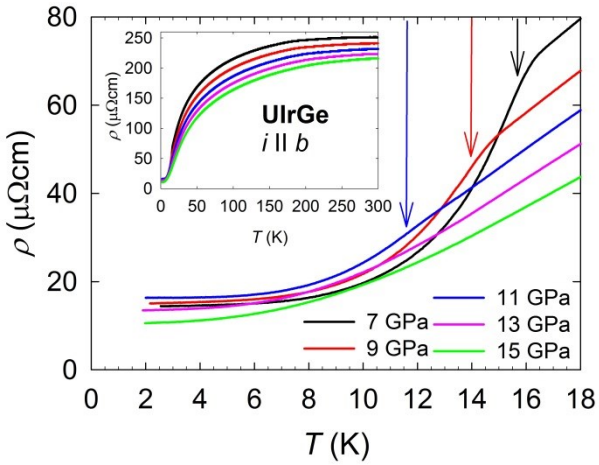

Figure 1. Electrical resistivity isobar curves obtained by measurements in the cubic anvil cell up to 15 GPa. A sample with *RRR* ≈ 28 was used. The inset shows the results of temperature scans up to room temperature[8].

Experiment in the piston-cylinder type cell at pressures up to 1.7 GPa revealed a very small shift of the ordering temperature from T_N = 16.6 K at ambient pressure to 16.4 K at 1.7 GPa. The calculated slope of $dT_N/dp \approx$ -0.11 K/GPa is small and linear extrapolation of T_N indicates an anomalously high critical pressure. we extended the hydrostatic pressure range up to 15 GPa using a cubic anvil cell (Fig. 1). The value of T_N is only moderately affected up to 7 GPa. The analysis of T_N up to 11 GPa is straightforward because the anomaly is detectable as a clear peak in the derivative $d\rho/dT$ at T_N = 11.5 K . In contrast, we did not find any evidence of a magnetic transition at 13 and 15 GPa in either the resistivity or its derivative. This suggests a sudden drop in T_N between 11 and 13 GPa (Fig. 2).

The sudden drop in T_N at p_c and the resulting rectangular *p*-*T* phase diagram of UIrGe have the signature of a first-order transition. The reported AFM magnetic structure of UIrGe consists of canted FM chains along the *a* axis that are mutually antiferromagnetically coupled [9]. The FM chains along the *a* axis in UIrGe are identical to the magnetic structure of the FM SC UCoGe and URhGe. Thus, we can deduce that there are two magnetic interactions in UIrGe, antiferromagnetic inter-*J*- and FM intra-*J**-chain interactions competing with each other. The *J** has the same nature as that in FM compounds. The pressure may affect the *J*-*J** balance in

UIrGe and make the FM component more important at p_c. First order transition was also later reported when the AFM phase is vanished by magnetic field aplied along *b* axis [10].

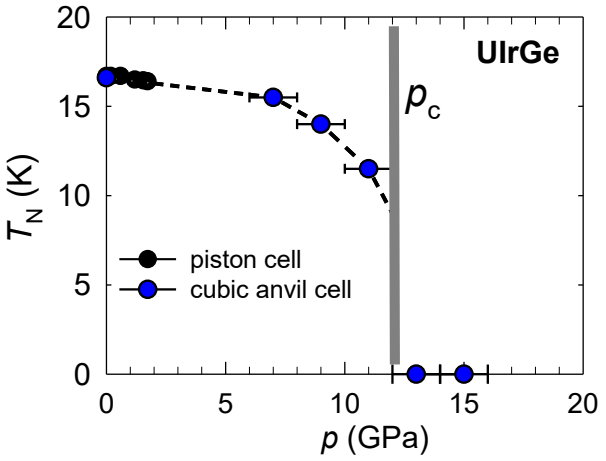

Figure 2. p-T phase diagram of UIrGe compound. The wide gray line tentatively defines the expected critical pressure p_c [8].

The development of electron-electron correlations can be deduced from the increase in the parameter A in AT^2 term of electrical resistivity. The obtained value of $A \approx 0.06$ μΩcm/K^2 at 15 GPa is significantly larger than the value at 11 GPa just below p_c suggesting the moderately enhanced electron effective mass in the paramagnetic state. We attempted to estimate the high-pressure γ of UIrGe taking into account the Kadowaki-Woods empirical ratio [11] of $A/\gamma^2 = 1.0\text{x}10^{-5}$ μΩcm (molK/mJ)^2. We obtained $\gamma_{15\text{GPa}} \approx 80$ mJ/molK^2. This is four times higher than the value at ambient pressure of ~20 mJ/molK^2. The value of $\gamma_{15\text{GPa}} \approx 80$ mJ/molK^2 is similar to the value of γ extrapolated from the paramagnetic limit of the heat capacity data [12]. We also attempted to calculate the ambient pressure A using the reported value of $\gamma \approx 20$ mJ/molK^2. The calculated value of $A \approx 0.004$ μΩcm/K^2 is in very good agreement with the value we obtained at 11 GPa just below the p_c. This corroborates the scenario of instantaneous closing of the large AFM gap at p_c and an increase in the density of 5*f* electronic states at the Fermi level.

We will present extended phase diagram of UIrGe compound in extreme conditions in mK temperatures and 15 GPa and discuss the scenario of the first-order AFM/PM transition in realation to other AFM uranium intermetalics where similar phenomenon was recently also detected.

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