THE RESTRAINT OF VALENCE TRANSITION IN $YbInCu_4$ BY HIGH PRESSURE*

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We have measured the electrical resistivity of single crystal $YbInCu_4$ under hydrostatic pressure up to 3.76 GPa and at temperature down to 33 mK. At ambient pressure, $YbInCu_4$ undergoes a valence transition at about 40 K. The transition temperature $T_{\rm v}$ decreases linearly with increasing pressure: $dT_{\rm v}/dP = -19.5$ K/GPa below 1 GPa. Above 3 GPa, a hysteresis due to valence transition disappears and the transition could not be confirmed clearly. The resistivity of $YbInCu_4$ at low temperature varies as $\rho(T) = \rho_0 + AT^2$. The resistivity coefficient A and the residual resistivity ρ_0 increase gradually with the increasing pressure. These values increase rapidly just before a transition disappears and take maximum around 3.5 GPa. We observed a 'filamentary'-superconductivity above 0.74 GPa and below $\sim$ 1.2 K.

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1. Introduction

$YbInCu_4$ undergoes a first-order isostructual valence transition at about 40 K, from the magnetic state of Yb^{3+} in the high temperature phase to the non-magnetic state of Yb^{2+} in the low temperature phase at ambient pressure. The condition of Yb^{3+} in the high temperature phase becomes

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stable by the pressure, and valence transition temperature T_{v} shifts to lower temperature. This valence transition disappears under high pressure. It is proposed that the possibility of ferromagnetic transition [1] or superconducting transition [2] will take place. In these Proceedings we report the electrical resistivity measurement of $YbInCu_4$ under the high pressure by using the newly developed 4GPa-class piston cylinder high pressure cell. We especially have concentrated on the behavior of $YbInCu_4$ under high pressure after the valence-transition disappearance at low temperature.

2. Experimental details

Single crystal of $YbInCu_4$ was grown by stoichiometric ratios of the constituent elements with In–Cu flux. [3] The electrical resistivity was measured by a conventional four-wire method in an Oxford ^{3}He–^{4}He dilution refrigerator down to 33 mK with Linear Research LR-700 ac resistance bridge operating excitation current of 0.5 mA. The hydrostatic pressure up to about 4 GPa was generated in a piston cylinder type pressure cell using the double cylinder; inner shell made from NiCrAl alloy and outer jacket from Cu–Be alloy [4], with Daphne oil 7373 pressure medium. The pressure at low temperature was calibrated with the help of the pressure dependence of the superconducting transition of lead.

3. Results

The electrical resistivity of $YbInCu_4$ decreases almost linearly above valence transition temperature T_{v}, and drops abruptly at T_{v}, as shown in Fig. 1. T_{v} decreases linearly at a rate of -19.5 K/ GPa with increasing pressure up to 1 GPa. Above 1 GPa, however, T_{v} decreases more gradually.

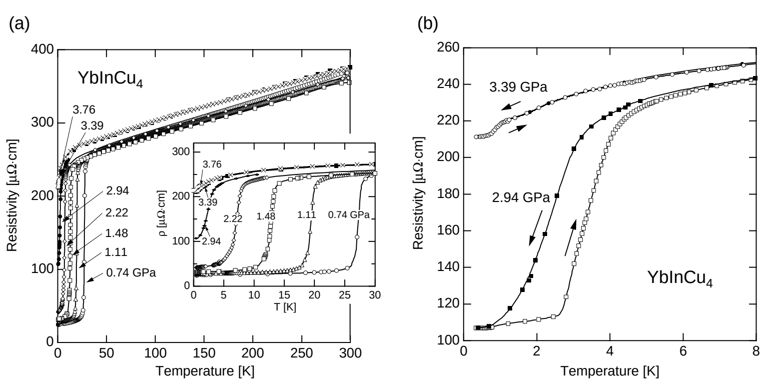

Fig. 1. Temperature dependence of resistivity in $YbInCu_4$ under the selected values of pressure.

These results are in good agreement with the previous works [3,4]. At ambient pressure, the resistivity above T_v increases rapidly due to a huge internal strain of the sample, induced by thermal cycling through the transition [3]. At high pressure, the resistivity does not change so much after the transition has taken place.

$YbInCu_4$ exhibits large hysteresis below 3 GPa around T_v. But, above 3 GPa, there is no observed hysteresis at the transition, and then the transition disappears above 3 GPa. At pressures close to the critical pressure P_{cv}, where the valence transition disappeares, both the residual resistivity ρ_0 and the coefficient A in the relation $\rho = \rho_0 + AT^2$ increase drastically, and reach maximal values around 3.5 GPa. The corresponding values are 220 $\mu\Omega$cm and 2.2 $\mu\Omega\text{cm/K}^2$, respectively.

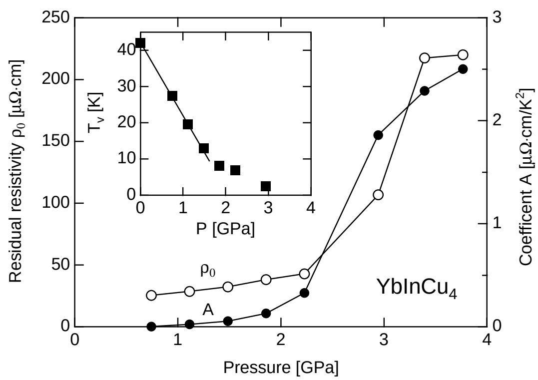

Fig. 2. Pressure dependence of the residual resistivity ρ_0 and of the coefficient A in the relation $\rho = \rho_0 + AT^2$.

We observed a 'filamentary' superconductivity (with a non-zero resistivity) above 0.74 GPa and below $\sim$ 1.4 K, though it could not be detected at ambient pressure, as shown in Fig. 3. The drop of resistivity vanishes in magnetic field above about 360 G. This superconductivity survives up to 4 GPa and the superconducting temperature T_c is almost independent of the pressure. Above P_{cv}, the resistivity follows the linear behavior in T in the range 0.9 K to 2.5 K.

From these experimental results, it is concluded that $YbInCu_4$ above P_{cv} is in the vicinity of the quantum critical point [5]. In contradiction with the case of Ce-based system, the heavy fermion state becomes robust with the pressure increase in the case of Yb-based system. Therefore, the behavior ofthe enhancement of coefficient A and the residual resistivity ρ_0 in $YbInCu_4$ under pressure corresponds to a rapid decrease of those quantities observed in $CeCu_2Ge_2$ with the increasing pressure [6].

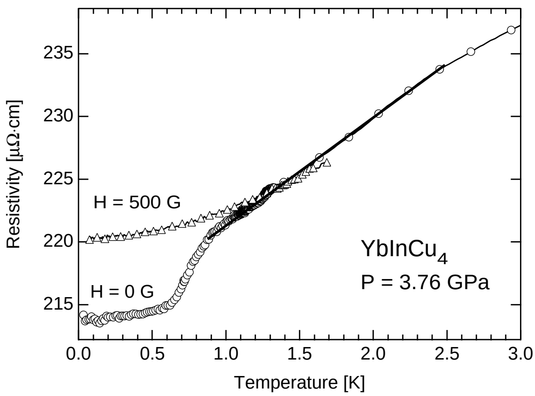

Fig. 3. Low temperature resistivity in $H = 0$ and $H = 500$ G under $P = 3.76$ GPa. Solid line is T-linear line as guide to eyes.

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REFERENCES

[1] I.V. Svechkarev, A.S. Panfilov, S.N. Dolja, H. Nakamura, M. Shiga, *J. Phys.: Condens. Matter* **11**, 4381 (1999) .

[2] K. Miyake, private communication.

[3] J.L. Sarrao, C.D. Immer, C.L. Benton, Z. Fisk, J.M. Lawrence, D. Mandrus, J.D. Thompson, *Phys. Rev.* **B54**, 12207 (1996) .

[4] A. Uchida, M. Kosaka, N. Mori, T. Matsumoto, Y. Uwatoko, J.L. Sarrao, J.D. Thompson, *Physica B* **312–313**, 339 (2002) .

[5] K. Miyake, O. Narikiyo, *J. Phys. Soc. Jpn.* **71**, 867 (2002).

[6] D. Jaccard, H. Wilhelm, K. Alami-Yadri, E. Vargoz, *Physica B* **259–261**, 1 (1999) .