Anomalous electrical resistivity associated with unconventional superconductivity in URu_2Si_2

N. Tateiwa[1)], Y. Haga[1)], T. D. Matsuda[1)], Y. Onuki[2)], and Z. Fisk[1, 3)]
1) R.G. for Actinide Materials, ASRC, JAEA
2) Osaka University 3) University of California

Unconventional superconductivity (SC) in the uranium compound URu_2Si_2 below T_{sc} = 1.4 K has attracted much attention due to its novel superconducting properties [1]. The SC has a strong relation with the electronic state of an unknown ordered phase whose transition temperature is T_0 = 17.5 K at ambient pressure. The nature of the ordered phase known as "hidden order" (HO) has not been resolved for more than 25 years. The low temperature physical properties of URu_2Si_2 are very sensitive to the sample quality. We have grown a high quality single crystal of URu_2Si_2 to eliminate impurity effects [2]. In this study, we have investigated the electrical transport under high pressures [3].

Figure 1 shows the pressure-temperature phase diagram in URu_2Si_2 [3]. The ground state is changed from the HO to the antiferromagnetic (AF) state at a first order phase transition pressure P_x. The bulk superconducting state exists only below P_x. We have measured the electrical resistivity ρ under high pressure. The electronic property of the ordered state is reflected through the scattering process of electron. For example, the usual electron-electron scattering gives the T^2-term in the resistivity. We focus on the pressure effects on T_{sc} and the electrical transport. We analyse the temperature dependence of ρ using the expression $\rho = \rho_0 + \alpha_1 T + \alpha_2 T^2$, assuming that the resistivity ρ consists of a T-linear resistivity from the unusual scattering process of electron and the usual T^2-term.

We find a linearity between α_1/α_2 and T_{sc} as shown in Fig. 2. The pressure dependence of the coefficient of α_2 is very weak. The value of T_{sc} depends primarily on the coefficient α_1. This suggests that the anomalous electron scattering derives the unconventional SC in the hidden order phase. This finding provides a key for further studies on the hidden and SC states in URu_2Si_2 [3].

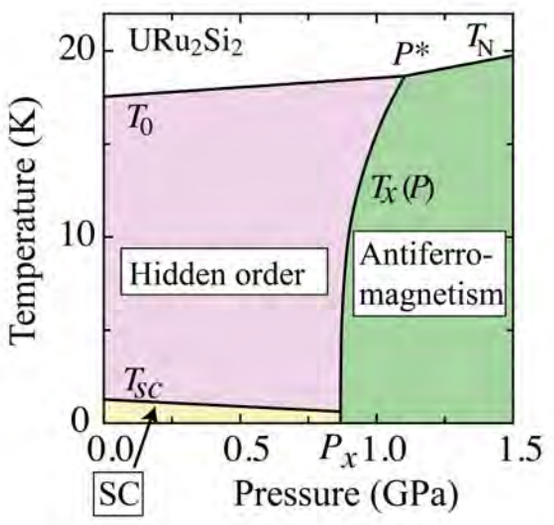

Fig. 1 Temperature pressure phase diagram in URu_2Si_2. "SC" indicates the superconducting phase.

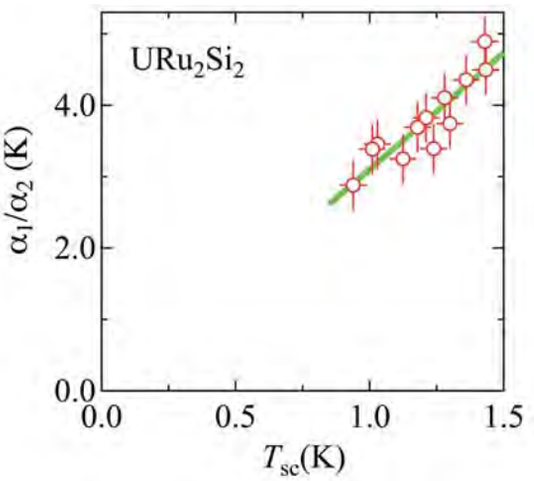

Fig. 2 Relation between α_1/α_2 for the resistivity ρ and superconducting transition temperatures T_{sc}, where the α_1 and α_2 are obtained by the fitting to $\rho_0+\alpha_1 T+\alpha_2 T^2$.

Similar correlation between the T-linear resistivity and T_{sc} has been found in the organic superconductors, the iron pnictide superconductors and the high-T_c cuprate superconductors [4]. This correlation may be a universality in the unconventional superconductors. In these systems, the T-linear resistivity appearing around a magnetic phase boundary has been interpreted as manifestation of quantum criticality.

So far, many theoretical models have been proposed for the HO phase. Generally, the peculiarity of the HO phase originating from the multipolar degree of freedom in the 5f electrons has been stressed but no clear experimental evidence was found. Unidentified mysterious phases have been reported near the SC phase such as "pseudo-gap phase" in the cuprate superconductors. We note recent studies on the mysterious phases from the view point of electronic nematicity [5]. Interestingly, the symmetry breaking of the electronic state has been revealed also in the HO phase by the collaboration work between our research group and Kyoto University [6]. The result as well as the present finding suggests that the HO phase in URu_2Si_2 shares the universality inherent to the strongly correlated electron superconductors near quantum criticality. Our studies provide a different point of view for theories of the HO phase. Future studies on the phase will contribute to the understanding of all strongly correlated electron systems.

References

[1] T. T. M. Palstra *et al.*, Phys. Rev. Lett. **55**, 2727 (1985).
[2] T. D. Matsuda *et al.*, J. Phys. Soc. Jpn. **80**, 114710 (2011).
[3] N. Tateiwa *et al.*, Phys. Rev. B **85**, 054516 (2012).
[4] L. Taillefer, Annu. Rev. Condensed Matter Phys. **1**, 51 (2010).
[5] J-H. Chu *et al.*, Science **329**, 824 (2010).
[6] R. Okazaki *et al.*, Science **331**, 439 (2011).