Research Group for Actinide Materials Science

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5*f* electrons in actinide compounds play essential roles in various phase transitions in actinide compounds. The electronic states can be modified by the chemical or physical environment around these electrons. It is therefore interesting to investigate new materials under various conditions such as pressure, magnetic field or low temperature to find new phenomena. The purification of a known compound also provides new insight particularly for phenomena occurring at low temperatures, where impurity disorder can deeply disturb and hence hide the intrinsic behavior.

Superconductivity and hidden-order in URu_2Si_2 investigated with high-quality sample and high-pressure technique

One of the problems in condensed-matter physics is the superconductivity occurring in strongly correlated electron systems where an unconventional type of pairing interaction is required. A uranium intermetallic compound URu_2Si_2 shows ‘heavy fermion’ superconductivity where the effective mass of conduction electrons is much larger than that of conventional metals. It is known that this superconductivity coexists with a so-called ‘hidden-order’ state where some of the electronic degrees of freedom order. Although extensive studies have been carried out for more than 25 years, the order parameter characterizing the ‘hidden-order’ is not established. We investigated the peculiar properties of the superconductivity and hidden-order phase by analyzing the impurity effects and extracted intrinsic behavior which is only seen in high-quality single crystals, as shown in Fig. 1 [1]. The study is further extended to high-pressure phase where both the ‘hidden-order’ and superconducting transition temperature vary and are finally replaced by an antiferromagnetic order. From this study, an unusual electron scattering in the ‘hidden-order’ state relevant to superconductivity was found [2]. See ‘Research Highlights’ for details.

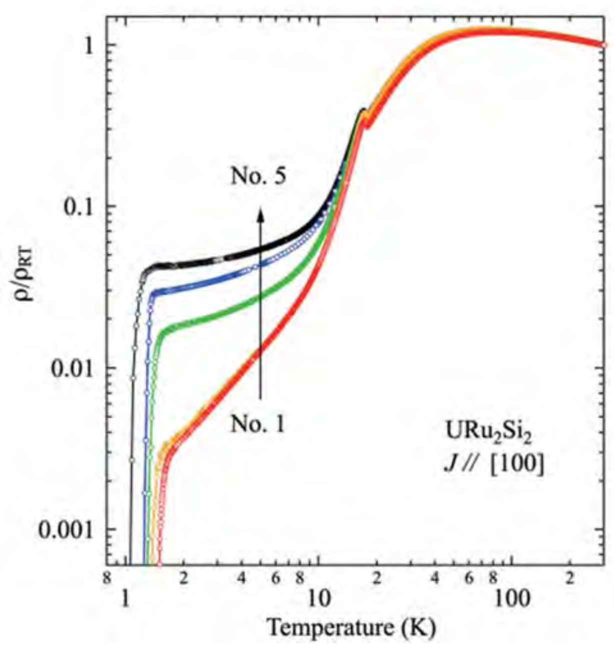

Fig. 1 Temperature dependence of electrical resistivity measured of URu_2Si_2 single crystals with different residual resistivities. The low temperature behavior as well as the superconducting transition temperature strongly depend on the crystal quality.

New neptunium-gallium intermetallic phases

Successive crystal transformations as a function of temperature or pressure are one of the prominent properties observed in actinide elemental metals. In contrast to elemental metals, however, such structural transitions are not likely to occur in compounds because they are composed of more than two kinds of atoms and such structural transitions usually accompany changes in the arrangement of the different atomic species. It is therefore worth investigating the metallic phase diagram at lower temperatures to look for possible occurrences of low-temperature phases. Most previous studies on actinide binary phases have been performed using arc-melted samples where the high-temperature melt typically around 1,500 ˚C is quenched to low temperature. We investigated Np-Ga phases using Gallium flux technique where the crystal growth takes place below 1,000 ˚C. The previous study reports $NpGa_3$ with cubic $AuCu_3$-type structure. We found trigonal phase of $NpGa_3$ instead of cubic phase and a new compound Np_3Ga_{11} [3]. As shown in Fig. 2, the structure of both compounds conserves a local atomic arrangement similar to that in the cubic $AuCu_3$-type structure.

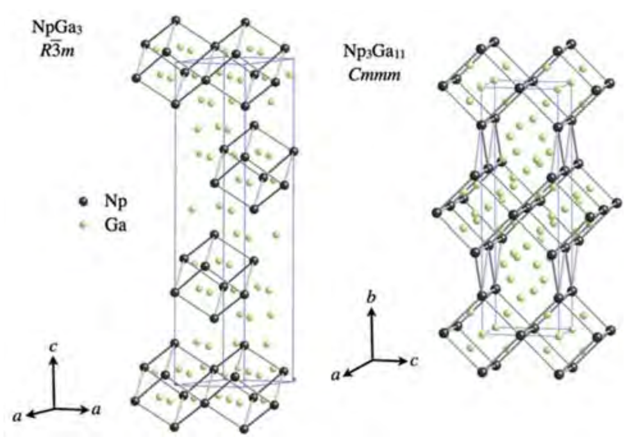

Fig. 2 Crystal structure of trigonal $NpGa_3$ and Np_3Ga_{11}.

References

[1] T. D. Matsuda *et al*., J. Phys. Soc. Jpn. **80**, 114710 (2011).
[2] N. Tateiwa *et al*., Phys. Rev. B **85**, 054516 (2012).
[3] Y. Haga *et al*., J. Phys. Soc. Jpn. **80**, SA109 (2011).