6-5 Investigation of New Plutonium-Based Superconductor

—Identification of Exotic Superconducting State by Nuclear Magnetic Resonance—

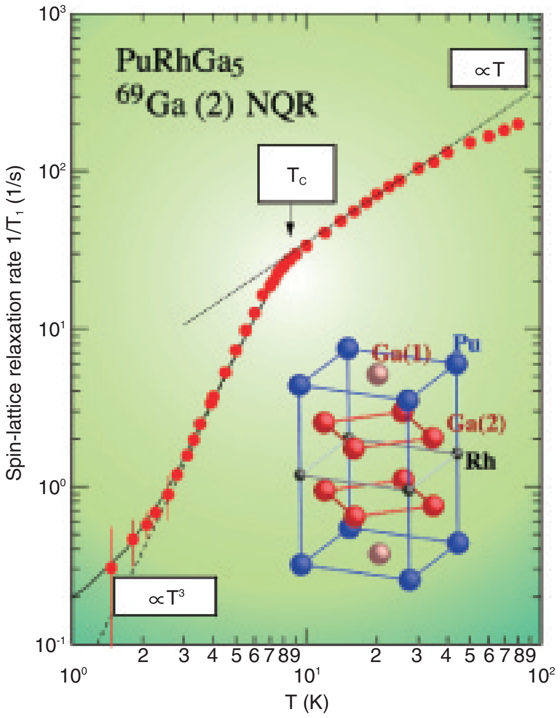

Fig.6-8 T-dependence of spin-lattice relaxation rate ($1/T_1$) in superconducting $PuRhGa_5$
No coherence peak appears just below T_c, and $1/T_1$ is proportional to T^3 below T_c, indicating non-conventional superconductivity. The tetragonal crystal structure is shown in the inset.

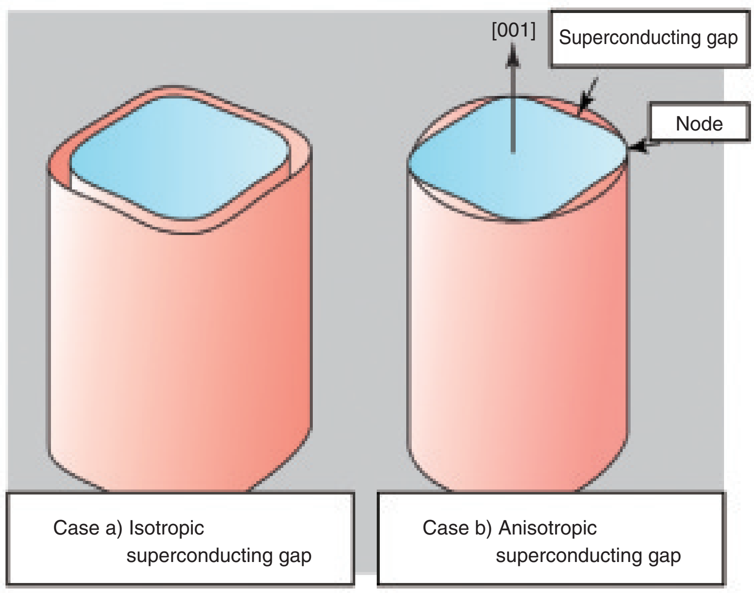

Fig.6-9 Two dimensional Fermi surfaces with d - wave superconducting gap
In the non-conventional superconductor, the superconducting gap has nodes.

In uranium and transuranium compounds, many exotic magnetic and superconducting states due to strong correlation of electrons have been found. We have synthesized a single crystal of a new superconductor $PuRhGa_5$ for the first time and clarified its exotic superconducting state by the nuclear magnetic resonance (NMR) measurements. In order to clarify the superconducting state, the spin-lattice relaxation rate ($1/T_1$) is particularly important. The BCS model theory for ordinary superconductors is well established, since measurements of ($1/T_1$) show the coherence peak just below T_c predicted by the BCS model.

In the present study, the nuclear quadrupole resonance of ^{69}Ga nuclei has been observed at zero field. Because of the zero field measurement, no distribution of superconducting order parameter due to the mixed state occurs. Fig.6-8 shows the T-dependence of $1/T_1$. The important point here is that no coherence peak just below T_c is observed, $1/T_1$ decreasing with decreasing T in the superconducting state. This fact indicates that the superconducting state in this compound is a non-conventional one with an anisotropic superconducting gap. In ordinary superconductors, $1/T_1$ is proportional to exp ($-\Delta/T$) below T_c. In contrast, T-dependence of $1/T_1$ shows a power law behavior: $1/T_1 \propto T^n$ in a non-conventional superconducting state. In $PuRhGa_5$, n is estimated as 3. The value of n reflects the type of anisotropy in the superconducting gap. From measurements of the upper critical field H_{C2}, it was revealed that the Fermi surface has a two dimensional nature. Combined with this fact, the observed T-dependence can be well reproduced by a model of two dimensional Fermi surfaces whose gap disappears at some points (nodes) (Fig.6-9) and a residual density of states due to defects.

As described above, we have identified an exotic superconducting state in a Pu-based new superconductor and now we will be investigating this origin of the non-conventional superconductivity.

Reference

Sakai, H. et al., Anisotropic Superconducting Gap in Transuranium Superconductor PuRhGa5: Ga NQR Study on a Single Crystal, Journal of Physical Society of Japan, vol.74, no.6, 2005, p.1710-1713.