Incommensurate Magnetic Order in the Pressure-Induced Superconductor $CeRhSi_3$

N. Aso, H. Miyano, H. Yoshizawa, N. Kimura[A], T. Komatsubara[A], H. Aoki[A]
NSL-ISSP Univ. of Tokyo, Graduate School Sci. Tohoku Univ.[A]

Coexistence between magnetism and superconductivity is the central issue in condensed matter physics. Recently non-centrosymmetric heavy-fermion superconductor $CePt_3Si$ [1] and UIr [2] were reported. From the fundamental point of view of symmetry, the discovery of these materials are very surprising because there are two basic symmetries which are considered indispensable to form Cooper pair: time reversal symmetry and parity. The former is important for Cooper pairing in any case while the latter is mandatory for pairing in the triplet channel. Thus there is no right picture for the non-centrosymmetric superconductivity at present.

Kimura *et al.* [3] discovered another non-centrosymmetric superconductor $CeRhSi_3$. Its crystal structure is the $BaNiSn_3$-type belonging to space group *I4mm* (No. 107) without an inversion center. [4] $CeRhSi_3$ exhibits the antiferromagnetic (AFM) ordering below T_N = 1.6 K at ambient pressure. By increasing the pressure, T_N shows a maximum around 0.7 GPa, then gradually decreases. Superconductivity appears in a wide pressure range from 1.2 to 2.3 GPa (and more). Very recently, $CeIrSi_3$, with the same crystal structure, was reported to be categorized in the pressure-induced superconductor. [5] It shows AFM ordering below T_N = 5.0 K at ambient pressure, then T_N decreases monotonically with increasing pressure. Superconductivity appears in a wide pressure region from 1.8 to 3.5 GPa. Concerning the magnetic structure, there is only one neutron diffraction work on polycrystalline samples for both materials, [6] which exhibits no magnetic reflections with possible maximum magnetic moment of 0.25 μ_B/Ce. To determine the magnetic structure which is closely connected with the superconductivity in $CeRhSi_3$, therefore, we performed the neutron diffraction measurements using single crystals $CeRhSi_3$.

Single crystals were grown by Czochralsky pulling method in a tetra-arc furnace. Neutron diffraction experiments have been performed on ISSP triple-axis spectrometers GPTAS (4G) and PONTA (5G) installed at the research reactor JRR-3M of Japan Atomic Energy Agency, with the incident energy of $k_i \sim 2.67$ Å^{-1} and the configuration of 2-axis mode. Pyrolytic graphite filters were used for both incident and scattered neutron to reduce the higher-order contamination. The crystals were cooled down to 0.75 K.

We have searched magnetic reflections in the major symmetry axes of three scattering planes of (H0L), (HHL) and (HK0). Only in the (H0L)-zone, the magnetic reflections can be observed. Figure 1 (a) and (b) show typical scan profiles through (H, 0, 1.5). One can clearly recognize the Bragg reflections at incommensurate reciprocal points Q = (0.215, 0, 1.5) and Q = (0.785, 0, 1.5), respectively, at 0.75 and 1.5 K (below T_N), which disappeared at 2.0 K (above T_N). These observation indicate that the above Bragg reflections are of magnetic origin. The magnetic intensity of the former is larger than that of the latter, which roughly indicates that the magnetic moment lies in the $a-b$ plane. This fact is in excellent agreement with an anisotropy of the susceptibility measurement. [7]

Temperature dependence of the peak intensities at Q = (0.215, 0, 1.5) and (0.785, 0, 0.5)are not shown in this report. At Q = (0.215, 0, 1.5), the intensities of $\sim$ 800 counts well below T_N gradually decreases with temperature and suddenly drops to $\sim$ 180 counts of background intensity around T_N $\sim$ 1.6 K. The temperature dependence at Q = (0.785, 0, 0.5) also shows the similar behavior. It should be noted that the obtained Néel temperature of 1.6 K corresponds to the anomaly in both the susceptibility and electrical resistivity measurements using single crystals. [7]

To determine the incommensurate magnetic structure, we have performed radial scans at 17 inequivalent Bragg points. After calculating the integrated intensities of various models, we propose that the longitudinal spin-density wave (LSDW) state is realized below T_N in $CeRhSi_3$. This magnetis structure is in excellent agreement with the dHvA experiments [7], in which dHvA signals in both $CeRhSi_3$ and $LaRhSi_3$ are observed and the different Fermi surfaces lead to that the 4f electrons of $CeRhSi_3$ are itinerant. The samll size of the magnetic moment is 0.16(10) m_B/f.u., which indicates that this material is located in the vicinity of quantum critial point (QCP).

Another interesting feature of the magnetic structure is the propagating along c-axis of up-up-down-down spin arrangement because Q = (0, 0, 1) is not allowed for the $BaNiSn_3$-type crystal structure. This is possibly due to the lack of the inversion center along c-axis and the legand electrons of Rh and/or Si atoms might play an important role in the magnetic structure.

The neutron experiments were supported by ISSP, University of Tokyo (PACS No. 6418). A part of this work was supported by the Grant-in-Aid for the Ministry of Education, Culture, Sports, and Science of Japan.

References

[1] E. Bauer, G. Hilscher, H. Michor, Ch. Paul, E. W. Scheidt, A. Gribanov, Yu. Seropegin, H. Noel, M. Sigrist and P. Rogl, *Phys. Rev. Lett* 92 (2004), p. 027003.

[2] T. Akazawa, H. Hidaka, H. Kotegawa, T. C. Kobayashi, T. Fujiwara, E. Yamamoto, Y. Haga, R. Settai and Y. Onuki, *J. Phys. Soc. Jpn.* 73 (2004), p. 3129.

[3] N. Kimura, K. Ito, K. Saitoh, Y. Umeda, H. Aoki and T. Terashima, *Phys. Rev. Lett.* 95 (2005), p. 247004.

[4] Y. Muro, N. Takeda and M. Ishikawa, *J. Phys. Soc, Jpn.* 67 (1998), p. 3601.

[5] I. Sugitani, Y. Okuda, H. Shishido, T. Yamada, A. Thamizhavel, E. Yamamoto, T. D. Matsuda, Y. Haga, T. Takeuchi, R, Settai and Y. Onuki, *J. Phys. Soc, Jpn.* 75 (2006), p. 043703.

[6] A. Krimmel, M. Reehuis and A. Loidl, *Appl. Phys.* A 74 Suppl. (2002) p. S695.

[7] N. Kimura, Y. Umeda, T. Asai, T. Terashima and H. Aoki *Physica* B 294-295 (2001) p. 280.

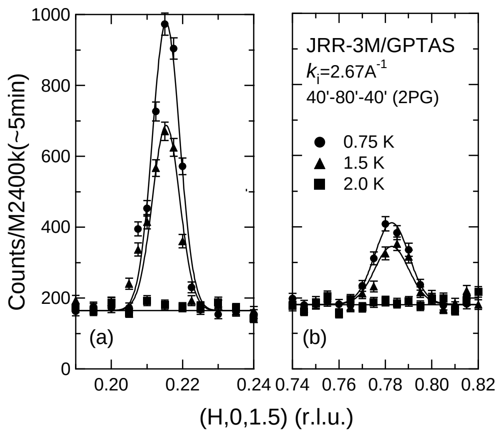

Fig. 1. Peak profiles through (a) Q = (0.215, 0, 1.5) (left) and (b) Q = (0.785, 0, 1.5) (right), which has asymmetric shape due to the sample mosaicity.