Competition or coexistence of multiple order parameters in the heavy fermion antiferromagnet $CeRh_{1-x}Ir_xIn_5$

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The heavy-fermion family of $CeMIn_5$, where M represents Ir, Co, or Rh, has attracted much interest on account of the relationship between superconductivity and magnetism. $CeCoIn_5$ and $CeIrIn_5$ are superconductors with SC transition temperatures of $T_c = 2.3$ and 0.4 K, respectively. $CeRhIn_5$ orders in an incommensurate antiferromagnetic phase with the modulation of $q = (1/2, 1/2, 0.297)$ below $T_N = 3.8$ K [1]. Interestingly, a new commensurate antiferromagnetic order with $q = (1/2, 1/2, 1/2)$ was found in a x-range of 0.25-0.6 for $CeRh_{1-x}Ir_xIn_5$, and these two commensurate and incommensurate magnetic orders coexist with superconductivity [2]. A similar coexistence was also reported in $CeRh_{0.6}Co_{0.4}In_5$ [3]. Such an unusual coexistence of three different types of cooperative ordered states is quite unique among unconventional superconductors. However, for consideration of results in the $CeRh_{1-x}Co_xIn_5$ system, it is under debate if there is a coexistence region of the commensurate and incommensurate orders in a phase diagram [3, 4]. To elucidate the mechanism of the unconventional superconductivity in the $CeMIn_5$ systems, therefore, it is important to examine their magnetic properties in more detail.

The key of this work is to reduce the inhomogeneity arising from a distribution of x because our preliminary results of thermodynamic experiments using single crystals of $CeRh_{1-x}Ir_xIn_5$ showed that the inhomogeneity may mislead us to an incorrect understanding of a phase diagram of the system. To avoid this, we intentionally prepared powdered polycrystalline samples of $CeRh_{0.6}Ir_{0.4}In_5$ by melting single crystals of $CeRhIn_5$ and $CeIrIn_5$ with a tetra-arc furnace under a high-purity argon atmosphere. The sample was put in a vanadium can with double-cylinder structure, and cooled down to 0.7 K using a ^{3}He cryostat [5]. Neutron diffraction experiments were performed at ISSP/GPTAS installed in the research reactor JRR-3.

Figure 1 shows a powder pattern of $CeRh_{0.6}Ir_{0.4}In_5$ at $T = 0.75$ and 10 K, obtained at GPTAS with the incident energy $E_i \sim 13.7$ meV. According to a previous report [2], the Néel temperature is about 3.6 and 2.6 K for the incommensurate and commensurate order, respectively. We have found the Bragg reflection at the commensurate reciprocal point $q = (1/2, 1/2, 1/2)$, which are truly of magnetic origin since it disappears above $T_N \sim 2.7$ K. It is noteworthy that the incommensurate magnetic order at reciprocal point $q = (1/2, 1/2, 0.297)$ was not detected within experimental resolutions. This result seems contrary to the previous neutron scattering experiments with single crystals [2], but consistent with our thermodynamic experiments.

To clarify the coexistence of the different types of cooperative ordered states and to reveal the mechanism of the unconventional superconductivity in the $CeMIn_5$ systems, a further experiment is in progress for other compositions of $CeRh_{1-x}Ir_xIn_5$.

References

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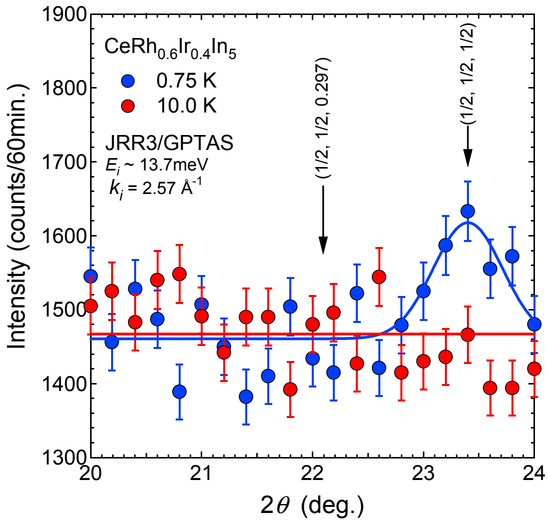

Fig. 1. Powder pattern of $CeRh_{0.6}Ir_{0.4}In_5$ obtained at $T = 0.75$ and 10 K. Arrows show the expected Bragg-peak positions of incommensurate and commensurate antiferromagnetic orders.