# Instability of RKKY-type long-range order in Kondo-lattice compound $Ce(Ru_{0.9}Rh_{0.1})_2(Si_{1-y}Ge_y)_2$ as studied by neutron diffraction

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**Abstract**

Neutron diffraction experiments have been made to study the response of the magnetic order of the heavy-fermion compound $Ce(Ru_{0.9}Rh_{0.1})_2(Si_{1-y}Ge_y)_2$ to hydrostatic pressure and to the chemical-pressure. With changing the Ge concentration, both of the magnitude of the magnetic moment and the value of the wave number show rapid change at around y=0.08. The 3rd harmonic component of the modulation of the y=0.2 compound clealy exhibits localized-electron nature at low temperature.

*Key words:* heavy fermion; $Ce(Ru_{0.9}Rh_{0.1})_2(Si_{1-y}Ge_y)_2$; magnetic instability; neutron diffraction

## 1. Introduction

The long range magnetic order which appeares in heavy electron systems can be categorized into two, depending on the size of the ordered moment, that is, "small (order of $10^{-2}$ $\mu_B$)" or "normal(order of 1 $\mu_B$)" [1,2]. Theoretically, it is implied that, in a system of coexisting localized spins and heavy quasi-particles, instability of the long-range order of the localized spins in the RKKY regime can take place in the first order[3,4].

In the course of searching for an evidence of such a magnetic instability, we have studied the magnetism of the pseudobinary alloy system $Ce(Ru_{0.9}Rh_{0.1})_2(Si_{1-y}Ge_y)_2$ as functions of pressure. The base material $Ce(Ru_{0.9}Rh_{0.1})_2Si_2$ is known as a prototypical heavy fermion compound which have a spin-density wave (SDW) state as the ground state[5]. By substituting Ge for Si of this compound, one can effectively apply, through lattice expansion, negative pressure to the SDW phase. By using also hydrostatic pressure, we examined, by means of neutron diffraction, the magnetic response of this pseudobinary system to negative and positive pressure.

The neutron diffraction experiments were made on the triple-axis spectrometer GPTAS at the JRR-3M reactor of Japan Atomic Energy Research Institute. In order to avoid the extinction effect fine particles of Mo-metal were mixed to the powder specimen[2].

## 2. Results and discussion

The magnetic structures of the compounds with $y$ between 0 and 0.2 are represented by a wave vector (0 0 $q$) in the reciprocal lattice units. The polariza-

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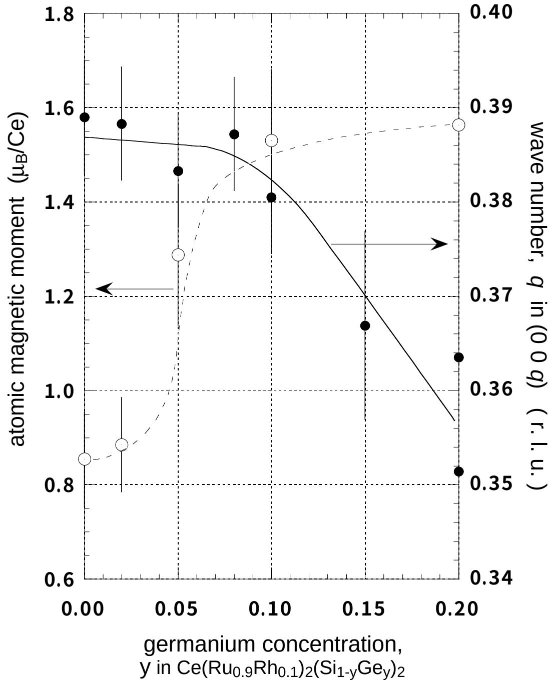


Fig. 1. The atomic magnetic moment and the wave number of the magnetic modulation of the ordered phase, $T$=1.5 K, of the pseudobinary alloy system $Ce(Ru_{0.9}Rh_{0.1})_2(Si_{1-y}Ge_y)_2$. The curves are guides to the eye.

tion of the moment was along the crystal c-axis for all the compounds. Fig.1 shows the magnitudes of the atomic magnetic moment and the wave number of $Ce(Ru_{0.9}Rh_{0.1})_2(Si_{1-y}Ge_y)_2$ as functions of Ge concentration, $y$. In the figrure, one can see that, with increasing Ge concentration, the magnetic moment grows up to reach saturation at around $y = 0.08$, while the wave number starts decreasing there. The transition temperatures, $T_N$'s of these compounds show quite similar behavior to that of the magnetic moment. This result is indicating that the regime of the magnetic order of the compounds with $y$ greater than 0.08 is different from the one with $y$ around 0. One should remind that in the complete localized electron regime the size of the moment should not depend on the lattice spacing.

In Fig.2 shown is the result of the measurement of the 3rd higher harmonic component of the magnetic modulation in the $y$=0.2 compound, which has the $T_N$ of 6.5 K. In the figure the amplitude of the 3rd harmonic component, $A(3q)$ is plotted as a function of the 3rd power of the amplitude of the fundamental modulation, $A(1q)^3$. These two quantities are known, from the free-energy based theoretical analysis of the SDW phase transition[6], to be proportional to each other for a canonical SDW, that is, for a magnetic order with purely longitudinal polarization. Such a relation is, in fact, observed in the compound $Ce(Ru_{0.85}Rh_{0.15})_2Si_2$ to hold down to 0.45 K[5]. In contrast, one can see in the figure that the 3rd higher component of the present system starts deviating from the linear relation at around 2.6 K and shows rapid growing at the lowest temperature. This rapid growing of the 3rd harmonic component indicates that the wave form of the modulation is squaring up and hence that the magnetic moment contains a considerable amount of localized component.

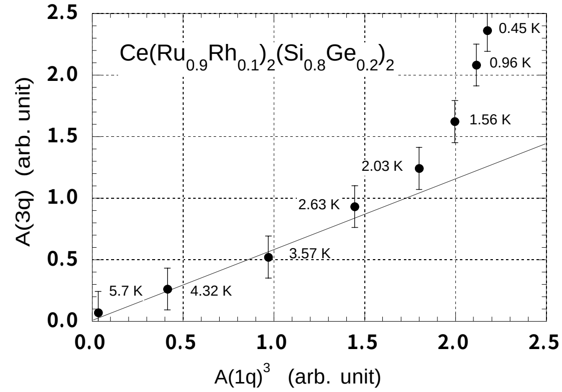


Fig. 2. Plot of the amplitude of the third higher harmonic component versus the third power of the amplitude of the fundamental modulation of the ordered phase of the $Ce(Ru_{0.9}Rh_{0.1})_2(Si_{0.8}Ge0.2)_2$ compound. The linear line is guide to the eye.

On the basis of these experimental results we consider that we have succeeded to observe, in the present pseudobinary alloy system, a rapid shift of the magnetic order from the heavy pseudo-particle regime to the RKKY-regime.

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## References


[1] S. Kawarazaki, K. Watanabe, M. Miyamura and Y. Uwatoko, J. Phys. Soc. Jpn. **69** (2000) Suppl. A. 53.

[2] S. Kawarazaki, M. Sato, Y. Miyako, N. Chigusa, K. Watanabe, N. Metoki, Y. Koike and M. Nishi, Phys. Rev. B**61** (2000) 4167.

[3] K. Miyake and Y. Kuramoto, Physica B**171** (1991) 20.

[4] S. M. M. Evans, J. Phys.: Cond. Matter **3** (1991) 8441.

[5] S. Kawarazaki, M. Sato, H. Kadowaki, Y. Yamamoto and Y. Miyako, J. Phys. Soc. Jpn. **66** (1997) 2473.

[6] A. Kotani, J. Phys. Soc. Jpn.**44** (1978) 1455.