

Competition of different antiferromagnetic correlations in a heavy fermion $Ce(Ru_{1-x}Rh_x)_2(Si_{1-y}Ge_y)_2$

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$CeRu_2Si_2$ is a paramagnetic heavy fermion locating close to an antiferromagnetic (AFM) quantum critical point (QCP). Interestingly, in this compound three AFM correlations with the magnetic wave vector $q_1=(0.31,0,0)$, $q_2=(0.31,0.31,0)$ and $q_3=(0,0,0.35)$ coexist [1], and may compete each other. By substituting Rh for Ru, the q_3 -AFM correlation develops the long-range magnetic order, q_3 -phase, in the Rh-concentration x range of $0.03 < x < 0.35$ [2]. On the other hand, appearance of the q_1 -AFM order, q_1 -phase, was reported by substituting Ge for Si or by substituting La for Ce [3]. It takes a great interest in quantum phase transitions among such a competing antiferromagnetic phases and paramagnetic Fermi liquid (FL). As a first step for studying such quantum phase transitions, we have grown many single crystalline samples of $Ce(Ru_{1-x}Rh_x)_2(Si_{1-y}Ge_y)_2$ and have tried to make up the xy phase diagram.

Figure. 1 shows the xy phase diagram of $Ce(Ru_{1-x}Rh_x)_2(Si_{1-y}Ge_y)_2$ obtained from neutron scattering experiments and magnetization measurements. A 3rd AFM phase where both the q_1 and the q_3 magnetic scattering are observed, q_1+q_3 -phase, has been discovered between the q_1 - and the q_3 -phases. No hysteretic behavior was observed in the q_1+q_3 -phase, and hence, we conclude that the q_1+q_3 -phase is a thermodynamic equilibrium state, may have a double- q structure. And also, we have found that the AFM phase appeared by substituting Ge for Si in $CeRu_2Si_2$ is not a simple q_1 -phase but the q_1+q_3 -phase.

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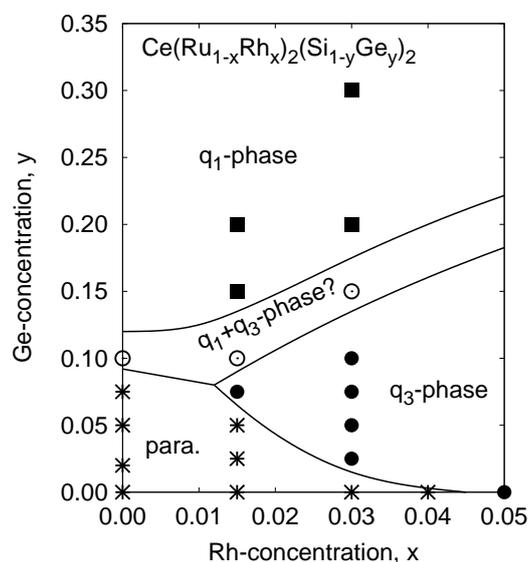


Fig. 1. The xy phase diagram of $Ce(Ru_{1-x}Rh_x)_2(Si_{1-y}Ge_y)_2$ at $T = 1.5K$ obtained from neutron scattering experiments. Asterisk, closed square, closed circle and open circle denote the paramagnetic FL, the q_1 -, the q_3 - and the q_1+q_3 -phases respectively.