NMR study of itinerant heavy electron system $Ce(Ru_{1-x}Rh_x)_2Si_2$

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Abstract

Spin-lattice relaxation times (T_1) of ^{29}Si in $Ce(Ru_{1-x}Rh_x)_2Si_2$ (x=0, 0.03 and 0.05) were measured in the temperature range between 0.35 K and 60 K. Temperature dependences of T_1 do not obey the Korringa relation, and are well described by the effect of spin fluctuations based on the SCR theory. The best fitted parameters to the observed T_1 are close to the values obtained by the specific heat and the susceptibility measurements. ^{29}Si NMR and ^{101}Ru NQR observed below $T_N \sim 2$ K for x=0.05 have shown the characteristic line shapes associated with the occurrence of longitudinal incommensurate SDW.

Keywords: $Ce(Ru_{1-x}Rh_x)_2Si_2$; SDW; NMR; SCR theory

$CeRu_2Si_2$ with $ThCr_2Si_2$-structure is well known to be a typical non-magnetic heavy electron system. The substitution of Ru by Rh is of great interest, because the hybridization between *4f* and conduction electrons is continuously tuned without destroying the periodicity of Ce sites. Three magnetic instability (quantum critical) points corresponding to Rh concentrations x=0.03, 0.4 and 0.5 in $Ce(Ru_{1-x}Rh_x)_2Si_2$, have recently reported, which are near the phases between SDW-Fermi liquid (FL), SDW-non-Fermi liquid (NFL) and NFL-conventional antiferromagnetic ordered states, respectively. These mixed compounds are thus quite suitable for studying the physical concept for the ground states of both FL and NFL states. Here we report the ^{29}Si NMR and ^{101}Ru NQR results in the paramagnetic states at x=0 and x=0.03 and in the SDW state formed at x=0.05 with the discussion based on the SCR theory.

Fig.s 1(a) and (b) show ^{29}Si NMR spectra for x=0.05, whose *c*-axes are parallel and perpendicular to the magnetic field, obtained above and below T_N of 2 K, respectively. Fig 1(c) is ^{101}Ru NQR spectra, which arise from $\pm 1/2 \leftrightarrow \pm 3/2$ transitions, taken at around 10.6 MHz. As seen in these figures, the linewidths for three kinds of spectra have markedly broaden below T_N by the appearance of the transferred hyperfine field H_{hf}. The deduced H_{hf} from the difference of the line width between two spectra of Fig.1(a) is estimated as about 500 Oe, which is in agreement with the value obtained by the hyperfine coupling constant $A_{\parallel} \simeq 4.3$ kOe/μ_B at Si [1] and the maximum magnetic moment $\sim 0.1\ \mu_B$ of Ce in the SDW state.

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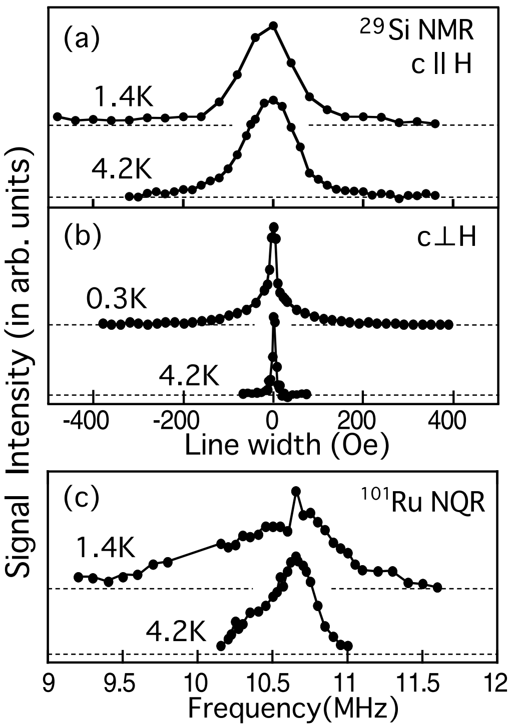

Fig. 1. (a) and (b) are powder patterns for ^{29}Si NMR spectrum of x=0.05 taken at around 1.2 T. (c) is ^{101}Ru NQR spectrum taken at around 10.6 MHz.

The characteristic line shape of ^{29}Si NMR, which is similar to the previous data for x=0.15 [2], is also clearly observed in H perpendicular to the c-axis. Thus it was confirmed that the SDW is not transverse but *longitudinal*. Crystallographically, the H_{hf}'s from *4f* (*5f*) moments are canceled at the Cr-site in $\mathrm{ThCr_2Si_2}$-structure, as no change of NQR line widths of Ru [3] and Pd [4] was measured in conventional antiferromagnets of $\mathrm{URu_2Si_2}$ and $\mathrm{CePd_2Si_2}$ through T_{N}, respectively. Accordingly, an extra linewidth of NQR observed below T_{N} suggests that the SDW for the present case is not commensurate but *incommensurate*.

The relaxation rates of $1/T_1$ were measured at the peak in each spectrum for x=0, 0.03 and 0.05. According to the SCR theory [5], the relaxation rate $1/T_1$ is expressed by

$$\frac{1}{T_1} = \frac{3\hbar\gamma_{\mathrm{N}}^2 t A_{\mathrm{hf}}^2}{8T_{\mathrm{A}}\sqrt{y}},$$

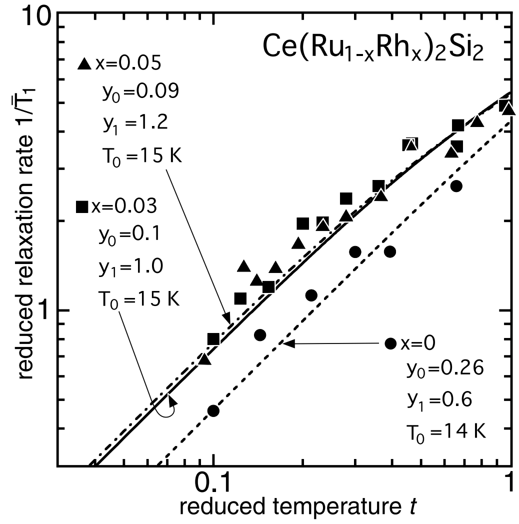

Fig. 2. A plot of reduced relaxation rate $(1/\bar{T}_1)$ *vs.* reduced temperature (t). The closed circles, squares and triangles are the measured reduced ones for x=0, 0.03 and 0.05. The dotted, solid and dot dash lines are the calculated ones.

where the reduced temperature t is defined as T/T_0, and T_0 is the energy width of the spin fluctuation spectrum. Other symbols and parameters are described in the original paper [5]. Shown in Fig. 2 is the reduced relaxation rate $(1/\bar{T}_1 = 3\pi t/(4\sqrt{y}))$ for each sample against t. As seen in Fig. 2, the SCR theory explains well the measured ones by using three parameters, y_0, y_1, T_0, which are 0.26, 0.6, 14 K for x=0, and 0.1, 1.0, 15 K for x=0.03 and 0.09, 1.2, 15 K for x=0.05, respectively. These values are in agreement with those obtained by the specific heat measurement [6].

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