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Single-Site Effects of Pr and U Ions Doped in RRu_2Si_2 (R = Th, Y and La)

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So far, dilute uranium sysytems $R_{1-x}U_xRu_2Si_2$ (R = Th, Y and La) have been intensively studied[1] to clarify the $5f$ electron state in URu_2Si_2. All these systems show a remarkably strong uniaxial magnetic anisotropy along the tetragonal c-axis. On the other hand, the behavior of physical quantities observed at low temperature varies depending on the host metals. For example, $Th_{1-x}U_xRu_2Si_2$ shows the non-Fermi-liquid (NFL) behavior, whereas $La_{1-x}U_xRu_2Si_2$ does not. Many theoretical approaches to explain the observed anomalous behavior are reported. However, including the crystaline-electric-field (CEF) level scheme, a comprehensive view is not given at the present stage. To understand the low-temperature properties of these dilute uranium systems, we have studied the basic CEF effects on the Pr and U ions doped in the different host metals. The ground J multiplets of the tetravalent U and trivalent Pr ions are the same. Therefore, dilute praseodymium systems $R_{1-x}Pr_xRu_2Si_2$ (R = Th, Y and La) may serve as good reference to study the dilute uranium systems for the investigation on the fundamental CEF scheme. So far, the La-dilution study[2] has been reported, where the $4f$ state of the single Pr ion is explained in terms of the singlet-singlet CEF model: the Kondo screening seems not to occur.

The $4f$ electronic specific heat C_{4f}/T for $R_{1-x}Pr_xRu_2Si_2$ (R = Th and Y; x = 0.05 and 0.1) polycrystals are shown in Fig. 1. The specific heat for RRu_2Si_2 (R = Th and Y) are subtracted as the contribution of the phonon part. The experimental data are well scalled by the doped Pr concentration, and described by the CEF calculation based on the singlet-singlet-singlet ($\Gamma_{t1}^{(1)} - \Gamma_{t2} - \Gamma_{t3}$) level schemes with the energy splitting $\Delta_1 \equiv \Delta_{\Gamma_{t1}^{(1)}-\Gamma_{t2}} = 30$K, $\Delta_2 \equiv \Delta_{\Gamma_{t2}-\Gamma_{t3}} = 70$K (R = Th) and $\Delta_1 = 38$K, $\Delta_2 = 100$K (R = Y), respectively. It seems that $4f$ electrons are also localized in these systems as in the La-dilution sytem, although the Δ_1 values of the present systems are somewhat larger than that reported for the La system ($\Delta_1 = 20$K)[2]. This indicated that the entropy release is shifted to higher temperature in these systems. On the other hand, in the R = Th case the finite C_{4f}/T value of ~ 20 mJ/K^2 Pr mol remains at the lowest temperature, in contrast to the R = Y case. This suggests that in the Th dilution $4f$ electrons may not be completely localized. We discuss the experimental results in detail from the point of view of the competition between the CEF and Kondo effect, in connection with the anomoluos behavior in the dilute uranium systems.

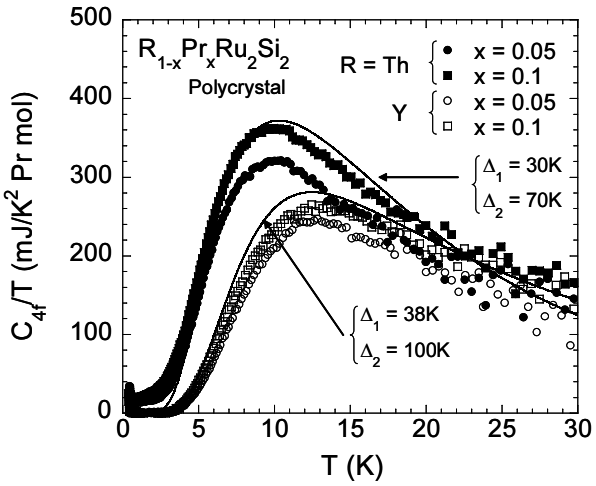

Figure 1: The $4f$ contribution to the specific heat C_{4f}/T for $R_{1-x}Pr_xRu_2Si_2$ (R = Th and Y; x = 0.05 and 0.1). The solid lines are the results of CEF calculations (Δ_1 and Δ_2 are defined in the text).

[1] H. Amitsuka *et al.*: Physica **B281**&**282** (2000) 326.
[2] K. Marumoto, F. Takayama and Y. Miyako: J. Magn. Magn. Mater. **177-181** (1998) 353-354.