μSR studies on antiferromagnet RRu_2Al_{10} (R = Sm, Gd)

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The Kondo semiconductor CeT_2Al_{10} (T = Ru, Os) with an orthorhombic-type structure shows a unique antiferromagnetic (AFM) order at $T_0 \sim 30$ K.[1,2] This compound exhibits numerous unusual electronic properties that can be ascribed to the strong electron correlation between conduction and localized $4f$ electrons, namely, the $c-f$ hybridization effect, by which a renormalized quasi-particle state with heavy effective electron mass is formed in the case of many Ce- or Yb-based intermetallic compounds. However, in the class of materials known as the Kondo semiconductors or insulators, a temperature-dependent energy gap is formed instead. One of the most salient features of this system is magnetic anisotropy in the AFM ordered state. Since the magnetic susceptibility shows a large anisotropy of $\chi_a \gg \chi_c \gg \chi_b$, an AFM ordered moment (m_{AF}) is expected to be parallel to the a-axis in the AFM ordered state. However, $m_{AF} \| c$ is realized, as was revealed by neutron scattering and ^{27}Al NMR/NQR studies.[3–5] The AFM structure is not robust and is easily tuned by magnetic field[4], pressure[6], or chemical doping.[7–9] This indicates that magnetic exchange interactions are not a key parameter for this magnetic ordering, but there could be an unknown parameter related to the strong $c-f$ hybridization effect, which must be related to the extraordinary high transition temperature of $T_0 \sim$30 K.

We previously performed μSR experiments on the above undoped and Rh-doped $CeRu_2Al_{10}$. The results have been published elsewhere.[9] One of the residual problems is the serious inconsistency in the temperature dependence of internal fields (H_{int}) between two muon sites, that is, one component shows a usual mean-field behavior, but the other does not. To address this problem, we planned to perform zero-field μSR on related antiferromagnets with more localized $4f$-electron character, RRu_2Al_{10} (R = Nd, Sm, and Gd). These compounds are worthy of investigation for their AFM ordered state; for instance, in the sample R = Gd, m_{AF} is suggested to be parallel to the [011] direction, although a simple dipole-field calculation suggests that m_{AF} prefers the a-axis direction.[10] In ref. 9, a possible origin of this discrepancy was suggested to be the zig-zag chain structure of Gd sites along the c-axis direction.

Figure 1 shows the zero-field time spectra of $GdRu_2Al_{10}$ at T = 20 K and 15 K; the data were recorded under double-pulse-beam condition. We found that the initial asymmetry is reduced when the temperature is lowered below the AFM transition temperature of T_N = 17 K. This is clear evidence for magnetic ordering. Since H_{int} is expected to be large because of the large magnetic moment of Gd-$4f$ electrons, we should use single-pulse condition with much greater time resolution than that of the double-pulse condition. However, we had to use the double-pulse condition within our beam time because we could not break the extrinsic noise resulting from the kicker operation. Within the present resolution, we could not identify any muon-spin precession behavior, and thus, from the zero field measurement, we could not obtain quantitative information on H_{int}.

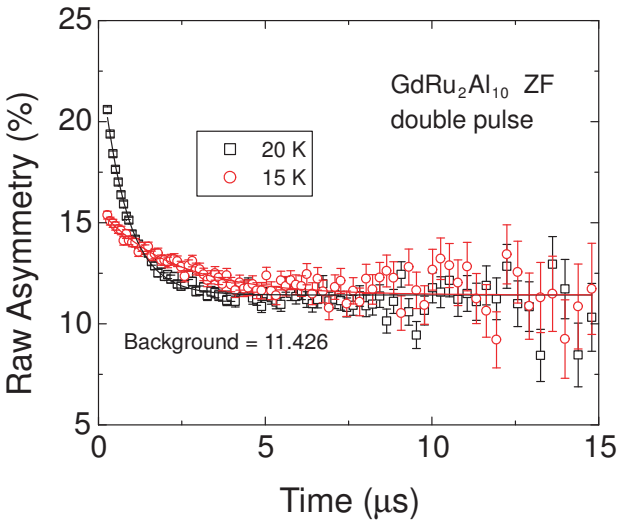

Fig. 1. Zero-field time spectra of $GdRu_2Al_{10}$ at T = 20 and 15 K under double-pulse-beam condition.

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References
1) A. M. Strydom: Physica B **404**, 2981 (2009).
2) T. Nishioka *et al.*: J. Phys. Soc. Jpn. **78**, 123705 (2009).
3) D. D. Khalyavin *et al.*: Phys. Rev. B **82**, 100405(R) (2010).
4) H. Tanida *et al.*: Phys. Rev. B **84**, 233202 (2011).
5) M. Matsumura *et al.*: J. Phys. Soc. Jpn. **78** 123713 (2009).
6) H. Tanida *et al.*: Phys. Rev. B **88**, 045135 (2013).
7) A. Kondo *et al.*: J. Phys. Soc. Jpn. **82**, 054709 (2013).
8) R. Kobayashi *et al.*: J. Phys. Soc. Jpn. **82**, 093702 (2013).
9) H. Guo *et al.*: Phys. Rev. B **88**, 115206 (2013).
10) M. Sera *et al.*: Phys. Rev. B **88**, 100404(R) (2013).