Magnetic ordering and spin dynamics of $Nd_2Ru_2O_7$ studied by μSR

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Pyrochlore ruthenate ($R_2Ru_2O_7$) is one of the systems that have a pyrochlore structure with the general formula $A_2B_2O_6O'$, where A is a trivalent rare-earth ion and B is a tetravalent transition metal ion. This structure is composed of two corner-sharing tetrahedral lattices, which induce the magnetic frustration of spins on each corner of the tetrahedral lattices. Novel physical properties such as the spin-glass,[1] spin-ice,[2] and metal-insulator transition accompanied by a magnetic transition,[3–5] are induced by this magnetically frustrated state. Those exotic properties originate from the competition and/or cooperation among the Coulomb interaction (U), spin-orbit coupling (SOC) effect, and exchange interaction between the rare-earth and transition metal ions.

The temperature dependence of the specific heat of $R_2Ru_2O_7$ shows a λ-type peak accompanied by a small cusp in the temperature dependence of magnetic susceptibility at the magnetic transition temperature, T_N.[6–8] T_N shifts to the higher temperature side from approximately 76 K to 160 K with increase in the ionic radius of R.[6] Ku *et al.* showed that three anomalies occur in $Nd_2Ru_2O_7$ at 146 K, 21 K, and 1.8 K.[8] At present, the origin of those anomalies is unclear. Accordingly, we investigated the magnetic properties of $Nd_2Ru_2O_7$ by the muon spin relaxation (μSR) method and compared the results with our previous results for $Nd_2Ir_2O_7$.[4,5]

The time evolution of the muon-spin polarization (μSR time spectrum) in zero field (ZF) was measured at several temperatures and analyzed by the following two-component relaxation function:

$$A(t) = A_1 \exp(-\lambda_1 t) + A_2 \exp(-\lambda_2 t). \quad (1)$$

The first and second components describe the fast and slow relaxation components, respectively. A_1 and A_2 are the asymmetry parameters while λ_1 and λ_2 are the muon relaxation rates of the two components.

We confirmed from the current study an ordered state of Ru spins below 146 K, showing a decrease in the initial asymmetry parameter accompanied by the appearance of a critical slowing down behavior of the Ru spin fluctuations.[9] Another anomaly of the muon relaxation rate was detected around 30 K as a broad dip in its temperature dependence.[9] This anomaly is unlikely to be due to the appearance of the magnetic ordering of Nd spins because no critical slowing down behavior was observed at lower temperatures in $Nd_2Ir_2O_7$.[4,5]

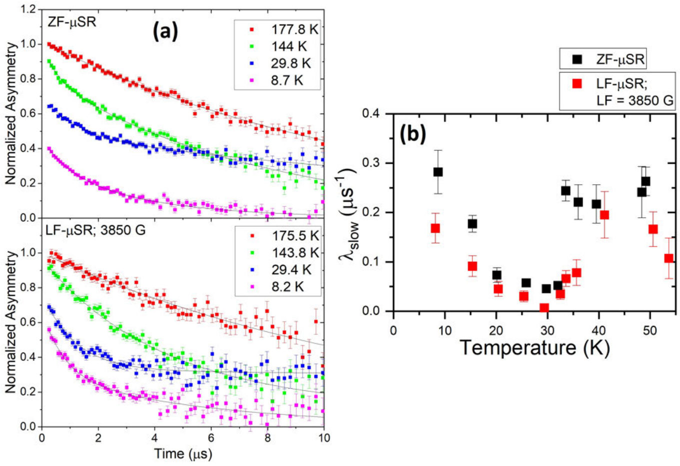

Fig. 1. (a) ZF- and LF-μSR time spectra of $Nd_2Ru_2O_7$ measured at various temperatures. An LF of 3850 G was applied for LF-μSR measurement. (b) Temperature dependences of the slow relaxation rate in both the ZF and LF condition.

In order to clarify the anomaly around 30 K, we measured μSR in the longitudinal-field (LF) condition under an applied field of 3850 G. Both ZF- and LF-μSR time spectra are shown in Fig. 1(a). We confirmed that the relaxation rate still showed the anomaly around 30 K in LF-μSR,[9] but this anomaly was slightly smaller compared to the case of ZF-μSR. To obtain more information about the origin of the anomaly around 30 K, we are now planning to conduct further μSR measurements of the LF scan at several temperatures to investigate the change in spin dynamics.

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