Spin dynamics of $Nd_2Pt_2O_7$ at 0.3 K observed by longitudinal-field μSR measurements

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Pyrochlore oxides, $A_2B_2O_7$ (A = trivalent rare-earth ion and B = tetravalent transition metal ion), are constructed from the interpenetrating corner-sharing tetrahedra units of A and B sites.[1] The spins at the vertices of the tetrahedra units are magnetically frustrated and lead to various novel physical properties, such as spin-glass, spin-ice, and spin-liquid states.[1] In Nd-based pyrochlores, $Nd_2B_2O_7$, an Ising-type magnetic interaction occurs among the Nd spins with an easy local axis in the $\langle 111 \rangle$ direction; therefore, the spins point either in to or out from the center of the tetrahedra units.[2–4]

In $Nd_2B_2O_7$ with a nonmagnetic B ion, such as Zr, Hf, and Sn, an Nd spin static ordered state is accompanied by spin fluctuations.[2–4] This phenomenon can be explained by a spin fragmentation model based on the spin-wave theory.[5,6] Compared to $Nd_2B_2O_7$ (B = Zr, Hf, Sn) pyrochlores that have either full or empty d orbitals, $Nd_2Pt_2O_7$ has a nonmagnetic Pt^{4+} ion with a $5d^6$ orbital in a low-spin state, with a configuration of ${t_{2g}}^6$ ${e_g}^0$. The empty e_g orbital can affect the exchange interaction among the Nd spins and change the spin dynamics of $Nd_2Pt_2O_7$.

Previous muon spin relaxation (μSR) measurements on $Nd_2Pt_2O_7$ conducted at the Paul Scherrer Institute showed that the initial asymmetry at $t = 0$ neither oscillated not decreased in the time spectra.[7] It was inferred that the spin fluctuations smeared out the signal from the static ordered state, suggesting the occurrence of spin fragmentation. We observed an ordered state indicated by a sharp peak at approximately 1.5 K in the temperature dependence of the muon-spin relaxation rate, λ.[7] Persistent spin fluctuations were expected to occur from the observation of the remaining λ down to 0.3 K.[7] Accordingly, we conducted measurements by using a pulsed muon beam suitable for observing long-time relaxation and investigating the spin dynamics of Nd.

Polycrystalline $Nd_2Ru_2O_7$ was prepared by mixing the oxides precursors at 4 GPa and 1200°C, following the conditions obtained in a previous study,[8] using a high-pressure apparatus at the Department of Earth Sciences, National Cheng Kung University, Taiwan.[9] μSR experiments were carried out on ARGUS spectrometer at the ISIS, Rutherford Appleton Laboratory, UK. We measured the μSR time spectra in the longitudinal-field (LF) condition at 0.3 K.

The LF-μSR time spectra are shown in Fig. 1(a). At

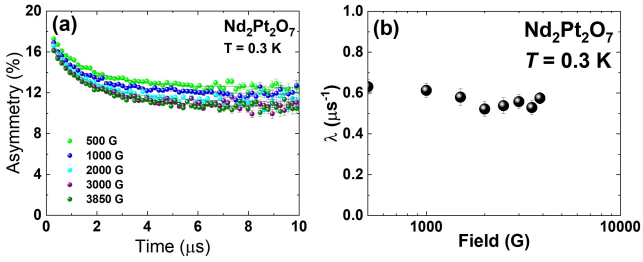

Fig. 1. (a) LF-μSR time spectra of $Nd_2Pt_2O_7$ at 0.3 K. (b) Field dependence of muon-spin relaxation rate at 0.3 K.

3850 G, the time spectrum shows a relaxation, indicating the persistent spin fluctuation at 0.3 K. The baseline shifting in the time spectra is attributed to the background signal when applying an external magnetic field because it also occurs in the paramagnetic state.

The time spectra were analyzed using two exponential functions:

$$A(t) = A_G \exp(-(\sigma t)^2/2) + A_E \exp(-\lambda t) \quad (1)$$

The first and second components of Eq. (1) are Gaussian-type and exponential-type components, respectively. This analysis function has been used to analyze the time spectra in the zero-field condition, where the Gaussian-type component occurs at early time spectra. For consistency, we kept the analysis functions to treat the time spectra. The Gaussian-type component was related to the static ordered state of Nd spins, whereas the exponential one corresponded to the spin dynamics of Nd. Fig. 1(b) shows that no significant change in λ occurs by applying an external field up to 3850 G. This suggests that the muon spin is depolarized by a strong spin fluctuation that occurs even at 0.3 K. Accordingly, from the previous and current μSR measurements, we suggest that the Nd spins are fragmented into two parts: a static ordered state and fluctuating spins.

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