ZF-\(\mu\)SR measurement to investigate thermal hysteresis of MgTi\(_{2}\)O\(_4\) at low temperature

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We investigated spinel titanate (MgTi\(_{2}\)O\(_4\)) which has a 3d\(^3\) electron (\(S = 1/2\)) within the Ti\(^{3+}\) ion and forms a pyrochlore lattice,\(^1\) to explore the magnetic ground state of this strongly correlated system. The lattice of MgTi\(_{2}\)O\(_4\) has a cubic structure at room temperature and shows a transition to a tetragonal structure at \(T_d \simeq 260\) K.\(^2\) This structural phase transition is accompanied by a metal-insulator transition and changes in magnetic properties.\(^2\) Isobe et al. proposed a spin-singlet insulator as the ground state, which did not form any magnetic ordering.\(^2\)

Previously, we found that there was no long-range ordered state in MgTi\(_{2}\)O\(_4\) down to 6 K through zero-field muon spin resonance (ZF-\(\mu\)SR) measurements. Our preliminary study on MgTi\(_{2}\)O\(_4\) showed that thermal hysteresis occurs in the temperature dependence of heat capacity below 3.5 K down to 2.5 K. To investigate the origin of the thermal hysteresis and magnetic properties at a much lower temperature, we extend the ZF-\(\mu\)SR measurement down to 2 K using VARIOX at the RIKEN-RAL Muon Facility in the United Kingdom. ZF-\(\mu\)SR measurements were performed below 30 K with descending temperature (cooling procedure) and ascending temperature (warming procedure) to observe the thermal hysteresis. The time spectra, shown in Fig. 1(a), can be fitted using Eq. (1).

\[
A(t) = A_{\text{GKT}}(1/3 + 2/3(1 - \Delta^2 t^2) \exp(-\Delta^2 t^2/2)) + A_L \exp(-\lambda t),
\]

where \(A_{\text{GKT}}\) and \(A_L\) are the initial asymmetry from Gaussian and Lorentzian components at \(t = 0\), respectively.

The absolute value of the temperature dependence of muon spin relaxation, \(\lambda(T)\), was in good agreement with the previous result\(^3\) and is shown in Fig. 1(b). This result demonstrated that the muon spin relaxation rate does not change significantly indicating the absence of the ordered state down to 2 K. Furthermore, there is no difference in the muon spin relaxation rate measured in the cooling and warming procedures. This indicates that the thermal hysteresis observed in the heat-capacity measurement is beyond the muon-spin time window; therefore, we could not detect such behavior down to 2 K.

Fig. 1. (a) ZF-\(\mu\)SR time spectra of MgTi\(_{2}\)O\(_4\): the solid line is the fitting resulted obtained using Eq. (1). (b) Temperature dependence of the muon spin relaxation rate.

References

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