Study of the spin dynamics of a honeycomb ruthenate using spin polarized muons

S. Yoon,[*1,*2] S.-H. Do,[*3] K.-Y. Choi,[*3] B. J. Suh,[*2] and I. Watanabe[*1,*2]

Honeycomb ruthenate α-$RuCl_3$ was recently suggested as a candidate to realize the Kitaev-Heisenberg spin model for the following reasons.[1)] Ru^{3+} ions can be in the low spin state because of the competition between the spin orbit coupling and the electronic correlation on the octahedral environment surrounded by Cl^- ions. Also, they form a nearly two-dimensional honeycomb network for the weak coupling by a van der Waals force among honeycomb layers. These environments are expected to serve the bond-dependent anisotropic exchange coupling between Ru^{3+} ions by an orthogonally bridged Cl^- ion in the honeycomb network.

We prepared a single crystal sample of α-$RuCl_3$ with a rhombohedral lattice observed by the X-ray diffraction. In this lattice, the anisotropic exchange can be revealed for the close cubic environment in the two-dimensional honeycomb layer. In addition, we carried out the measurements for DC susceptibility and specific heat. The DC susceptibility result shows a magnetic anomaly around 6 K. The specific heat result also exhibits a sharp peak around 6 K, as well as two broad humps around 10 K and 13 K. These anomalies are lower than previously presented results.[2-4)]

In order to obtain details of the magnetic ordered states, we performed a local probe investigation using spin polarized muons at the RIKEN-RAL Muon Facility because muons are highly sensitive to a small magnetic field. In the muon polarization at zero field, we confirmed results similar to the previous experiment,[5)] two magnetic transitions around 6 K and 13 K. It was also found that both transitions are close to the two dimensional Ising spin state by fitting the phenomenological equation of the magnetic ordered state.

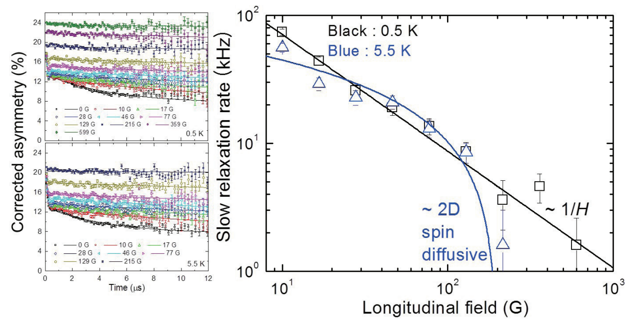

Fig. 1. (Left panel) Muon polarization spectra in several longitudinal fields at 0.5 K (up), and 5.5 K (down), respectively. (Right panel) Longitudinal field dependences of the slow relaxation rates with their fits at 0.5 K and 5.5 K, respectively.

In addition, we obtained information about the electronic spin fluctuations from the muon polarization in the external longitudinal field by fitting with the superposition of two exponential functions. We then extracted the relaxation rate of the slow-relaxing component on the latter time region. As shown in Fig. 1, the slow relaxation rates of the whole spectra are strongly dependent on the external longitudinal field. The spin diffusive model is used to describe the behavior of the electronic spin fluctuation.[6)] It was found that the result of the relaxation rates at 5.5 K is close to the two-dimensional diffusive model rather than the result at 0.5 K which is almost inversely proportional to the longitudinal field.

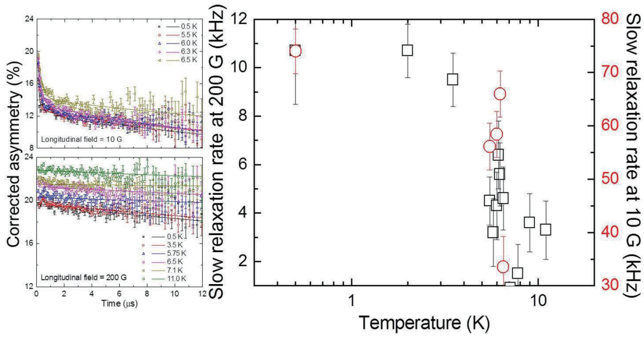

Fig. 2. (Left panel) Several time differential spectra of the muon polarization at some temperatures in the longitudinal fields of 10 G and 200 G, respectively. (Right panel) Temperature dependence of the slow relaxation rates from the muon polarization at longitudinal fields of 10 G and 200 G, respectively.

Moreover, we also extracted the relaxation rate on the latter time region by fitting with the superposition of two exponential functions from the muon polarization at several temperatures in the longitudinal fields of 10 G and 200 G, as shown in Fig. 2. Both relaxation rates on latter times in the longitudinal fields of 10 G and 200 G are dependent on the temperature and exhibit a sharp peak around 6 K. Then, as the temperature cools, both relaxation rates increase, and become almost saturated below 2 K.

References
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*1 RIKEN Nishina Center
*2 Department of Physics, The Catholic University of Korea
*3 Department of Physics, Chung-Ang University