# Magnetic ordering and spin dynamics driven by *p*-orbital in $RbO_2$

F. Astuti,[*1,*3] D. P. Sari[*2,*3] I. Watanabe,[*1,*3] M. Miyajima,[*4] and T. Kambe[*4]

Magnetism in the $\pi$-electron system has attracted attention for the possibility of the new kinds of the magnetic informative materials. Alkali-metal superoxides $AO_2$ ($A$= Na, K, Rb, Cs) present an interesting example of magnetic materials on the basis of $p$-elements. These systems have a dumbbell-type bonding state of O atoms forming the valence state of $O_2^-$ and resulting in one unpaired $\pi$-electron on the $O_2^-$ dumbbell. They further show the changing of crystal structure introducing the splitting of the $p$-orbital degeneracy, similar to the Jahn-Taller effect. Beside the crystallographic phase transition due to molecular ordering of the disordered $O_2^-$, the magnetic order in alkali metal superoxide is interesting to study. In the case of superoxides, the number of unpaired electrons is only one on the $O_2^-$ dumbbell, and magnetic superexchange interaction is expected between those unpaired spins through the $A$ metal. Accordingly, a different magnetically ordered state from that observed in the solid oxygen molecule[1)] is expected in superoxides, but detailed information on magnetic properties is still missing. The magnetic ordering of $KO_2$, $RbO_2$, and $CsO_2$ have been observed at temperatures of 7 K, 15 K, and 9.6 K, respectively, using specific heat measurement.[2)] The Tomonaga Luttinger Liquid (TLL) model suggests that a field-induced magnetic order should appear in the $CsO_2$ that is related to the TLL state.[3)]

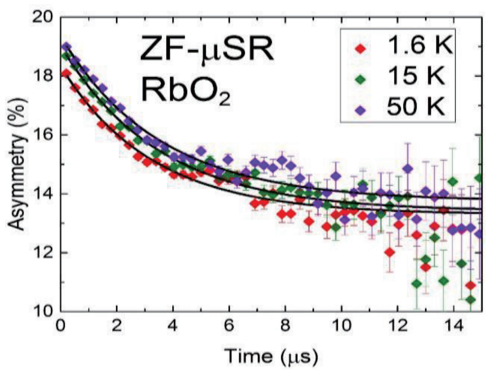


Fig. 1. ZF-µSR time spectra for $CsO_2$ for the first microsecond from 10 K down to base temperature.

Therefore, a detailed investigation on the magnetic properties near or in the zero-field (ZF) condition is strongly required to describe the magnetically ordered state that appears in the $CsO_2$ and other alkali metal superoxides.

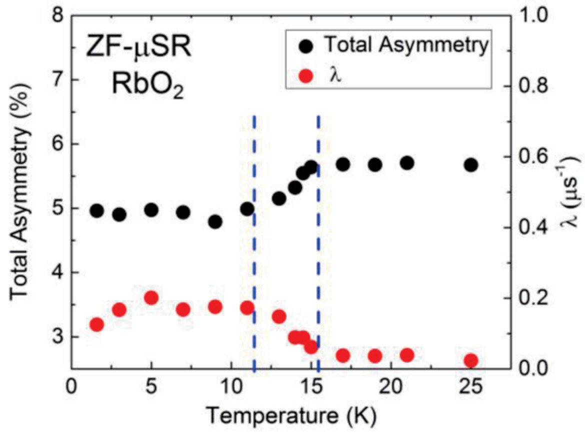


Fig. 2. Temperature dependence of the initial asymmetry and relaxation rate (λ) of the ZF-µSR time spectra measured at the RIKEN-RAL Muon Facility. The anomaly in the µSR measurement is observed in between 10 and 15 K around the suggested $T_N$.

We carried out µSR measurements in $CsO_2$ at the PSI Switzerland using the continuous muon beam. Clear spontaneous muon-spin precession behavior indicates the appearance of a long-range magnetic ordered state. This is evidence of the coherent static magnetically ordered state of $\pi$-electrons in oxygen molecules. Another alkali-metal superoxide, $RbO_2$, which has a crystal structure similar to that of $CsO_2$ ($CaC_2$-like), was tested at the RIKEN-RAL. In this system, only a type of anomaly in the magnetic susceptibility of $RbO_2$ is reported at $T_N$ ~ 15 K, as indicated.[4)] Unfortunately, we could not observe clear muon-spin precession as shown in Fig.1, although the decrease in the initial asymmetry around the suggested $T_N$ was observed, as displayed in Fig. 2. The decrease in the initial asymmetry and increase in the relaxation rate (λ) possibly means the magnetically ordered state appears, causing a depolarization behavior that is faster than the time limitation of the pulsed muon facility. This ordered state might accommodate the fast muon-spin precession as well as the case of $CsO_2$. Therefore, it is necessary to test $RbO_2$ at PSI using the continuous muon beam in order to detect clear evidence of the appearance of magnetically ordered states.

References

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*1 Department of Physics, Hokkaido University
*2 Department of Physics, Osaka University
*3 RIKEN Nishina Center
*4 Department of Physics, Okayama University