μSR study of cluster-glass state in $Sr_{1-x}La_xRuO_3$

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Strontium ruthenate shows various types of physical properties attributed to the itinerant feature of Ru $4d$ electrons and the strong mixing between Ru $4d$ and O $2p$ electrons.[1,2] $SrRuO_3$ crystallizes into a distorted perovskite structure and is a ferromagnet with a Curie temperature of about 160 K.[3] Photoemission experiments showed that the density of states at Fermi level is dominated by the Ru $4d$ state.[4] Therefore, itinerant Ru $4d$ electrons are considered to be responsible for the magnetic properties. It is also argued that the development of the incoherent component in the density of states reflects the electronic correlation effects. In addition, this system shows "bad metal" behavior in transport at high temperatures: the electrical resistivity continues to increase with increasing temperature, even though the Boltzmann mean free path becomes smaller than the lattice constants, indicating that the itinerant quasi-particle description is no longer available in the high temperature range.[5] These experimental findings suggest that the physical properties are strongly influenced by the correlation of the Ru $4d$ electrons, and the Ru $4d$ states have a duality of itinerant and localized natures.

We have studied the Sr site-substituted system $Sr_{1-x}La_xRuO_3$.[6] Substituting La for Sr suppress the Ferromagnetism.[7] In addition, the Ru-O distance increases with increasing x, suggesting that doping La may enhance the role of the electronic interaction. Recent our studies suggest that for $x \geq 0.3$, disorder plays an important role and this system shows a short range ferromagnetic ordering (cluster formation), and with further decreasing temperature these clusters freeze into a cluster-glass state.

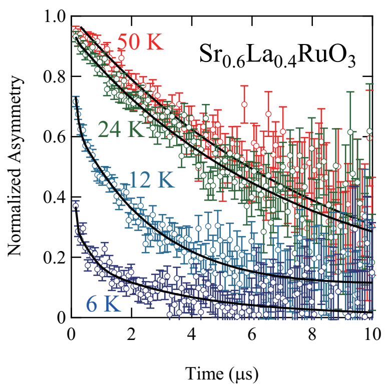

Fig. 1. Zero-field μSR spectra.

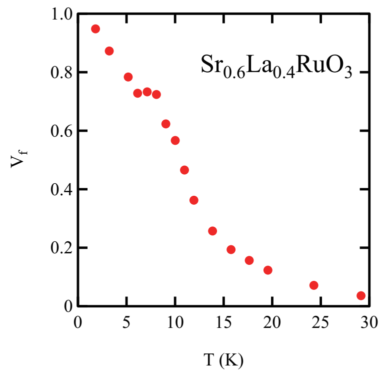

Fig. 2. Temperature dependence of the volume fraction.

In the present study, we performed μSR experiments on polycrystalline sample of $Sr_{1-x}La_xRuO_3$ to further investigate the cluster-glass state of this system. The μSR experiments were carried out at the RIKEN RAL Muon Facility in the UK, where an intense pulsed muon beam is available.

Figure 1 shows the zero-field spectra for $x = 0.4$ measured at various temperatures. Below 30 K, the relaxation rate develops and a loss of initial asymmetry is observed, indicating a development of magnetic clusters. The ZF-spectra are well fitted by the following function, which assumes a presence of two components:

$$P(t) = A_1[\frac{1}{3}e^{-\lambda_1 t} + \frac{2}{3}(1-\Delta_1 t)e^{-\Delta_1 t}] + A_2[\frac{1}{3}e^{-\lambda_2 t} + \frac{2}{3}(1-\Delta_2 t)e^{-\Delta_2 t}],$$

where A_1 and A_2 represent the paramagnetic and ordered volume fractions respectively. The temperature dependence of the volume fraction of the magnetic ordered region is shown in Fig. 2. The volume fraction exhibits a rapid increase at around 10 K, where the magnetic susceptibility shows a peak,[6] and reaches nearly 100% at the lowest temperature. The presence of the magnetic ground state with the volume fraction of 100% inevitably indicates the itinerant nature of the Ru $4d$ electrons in this system.

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