Magnetic ordering of $(Eu_{1\text{-}x}Ca_x)_2Ir_2O_7$ studied using muon spin relaxation (μSR)

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Pyrochlore oxides have been studied extensively because they show various physical properties such as superconductivity,[1)] spin-glass-like transition,[2)] possibility of a spin liquid state,[3)] and metal-insulator transition (MIT).[4,5)] Pyrochlore lattices have a network of corner-sharing tetrahedra, which makes these systems geometrically frustrated. Pyrochlore iridate series is one of those frustrated systems. In pyrochlore iridates, $R_2Ir_2O_7$ (R is the $4f$ rare element), the electronic properties vary with the changing value of R. Previous study showed MIT at $T_{\rm MI}$ accompanied by a magnetic transition in Ir^{4+}. The $T_{\rm MI}$ decreases with an increase in the R^{3+} ionic radius and MIT disappears between R = Nd and Pr.[5)] In $Eu_2Ir_2O_7$ ($T_{\rm MI} = 120$ K), Eu^{3+} is a non-magnetic ion ($J = 0$; $4f^6$).[5)] Accordingly, the ordered state of Ir^{4+} magnetic moment can be directly examined. This study aims to investigate the hole-doped effect on the magnetic properties in $(Eu_{1\text{-}x}Ca_x)_2Ir_2O_7$.

Polycrystalline samples were synthesized using the solid-state reaction and characterized by measuring the muon spin relaxation (μSR). The measurement was conducted at the RIKEN-RAL Muon Facility in the United Kingdom using a single pulsed muon beam. The samples were measured in zero-field condition in a temperature range between 1.6 and 200 K.

The results of μSR measurement were plotted in the zero-field μSR (ZF-μSR) time spectra, which can be analyzed and fit using the Lorentzian relaxation function, as shown in Eq. (1).

$$\mathrm{A}(t) = \mathrm{A}_0 \exp(-\lambda t) \tag{1}$$

This function expresses the muon spin relaxation. A_0 is the initial asymmetry at $t = 0$ and λ is the relaxation rate of the muon. Figure 1 shows the ZF-μSR time spectra, where the solid line represents the best-fit results. The corrected asymmetry is obtained by subtracting the background components from its asymmetry. It decreases with a decrease in temperature, thereby indicating the existence of an ordered state. The temperature dependence of normalized asymmetry for various x is shown in Fig. 2. It can be seen for $x = 0.035$ and 0.07, the ordered states appear in the samples with onset temperature around 100 K. However, for $x = 0.13$, there is no ordered state. The result indicates that the magnetic volume fraction decreases with an increase in the concentration of Ca.

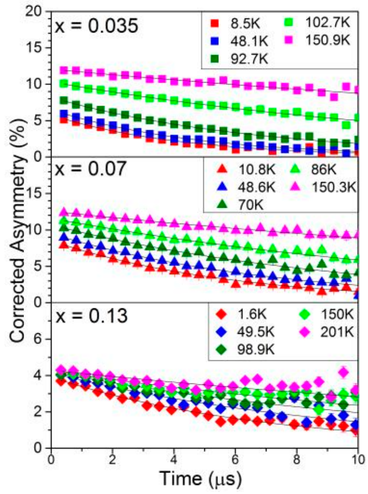

Fig. 1. Zero-field μSR time spectra of $(Eu_{1\text{-}x}Ca_x)_2Ir_2O_7$ measured at several temperatures.

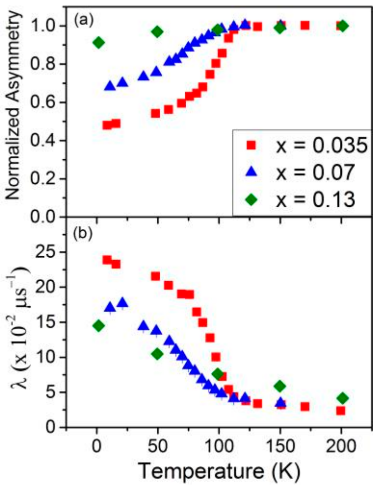

Fig. 2. Temperature dependence of (a) normalized asymmetry and (b) muon relaxation rate obtained from the analysis of ZF-μSR time spectra of $(Eu_{1\text{-}x}Ca_x)_2Ir_2O_7$.

From the result of μSR, it can be concluded that hole doping diminishes the magnetic ordered state of the sample. The effect of hole doping on magnetic ordered states and the physical properties of this system must be investigated by comparing the result of μSR obtained here with those obtained in other macroscopic studies.

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