Disappearing of the Ir-ordered state in the Pyrochlore iridates $(Nd,Ca)_2Ir_2O_7$ studied by μSR

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Pyrochore iridates, $R_2Ir_2O_7$ (R-227, R = Y and rare-earth element), are an ideal platform to study the interplay between electron correlation (U) and spin-orbit coupling (SOC) in which the electron correlation (U) can be systematically tuned by changing the ionic radius of R-ion (r).[1] Among pyrochlore systems, these compounds have the widest structure stability[2] and experimentally have revealed systematic metal-insulator transition (MIT) and systematic variation of properties with R.[3] The MIT temperature, T_{MI}, decreases monotonically as the ionic radius of R^{3+} increases, and its boundary lies between R = Nd and Pr.[3] Accordingly the study on a change in the magnetically ordered state in $Nd_2Ir_2O_7$ and its doped-systems is important to discuss an intrinsic critical behavior of the electronic state in $R_2Ir_2O_7$.

In this study, we report the effect of Ca substitution on the magnetic ordered state of Ir^{4+} spins in $Nd_2Ir_2O_7$ investigated by muon-spin relaxation. $Nd_2Ir_2O_7$ shows metallic behavior at high temperature and undergoes MIT at temperatures around 33 K,[3] and the magnetic order in this material also seem to occur simultaneously at T_{MI} without any lattice distortion.[4] In our previous μSR results on $Nd_2Ir_2O_7$,[5] we observed the coherent magnetically ordered state of Ir^{4+} spins just below T_{MI} and confirmed that Nd^{3+} moments mainly grew below 15 K as observed in the neutron diffraction.[6]

As observed in the electrical resistivity and the DC magnetization measurements, in which the T_{MI} and magnetic transition (T_M) decrease by increasing Ca doping, we expected the Ca substitution to dramatically suppress the magnetic order of Ir^{4+} spins in $(Nd_{1-x}Ca_x)_2Ir_2O_7$. Figure 1 shows the zero-field (ZF) time spectrum of $(Nd_{1-x}Ca_x)_2Ir_2O_7$ at a temperature of 1.5 K. The spontaneous muon spin precession is still observed in the sample with 3 % of Ca-doped, and it becomes less well-defined at a higher Ca substitution. A heavily damped muon-spin precession with fast damping rate is the characteristic in the time spectrum at a high Ca concentration. A phenomenological function of

$$A_{(t)} = A_1 e^{-\lambda_1 t} + A_2 e^{-\lambda_2 t} + A_3 cos(\gamma_\mu H_{int} + \varphi) e^{-\lambda_3 t} \quad (1)$$

is used to fit the time spectra. λ_1 and λ_2 are the slow and fast relaxation rates, respectively, while λ_3 is the damping rate of muon-spin precession. H_{int} and φ are the internal field at the muon site and the initial phase of muon precession, respectively.

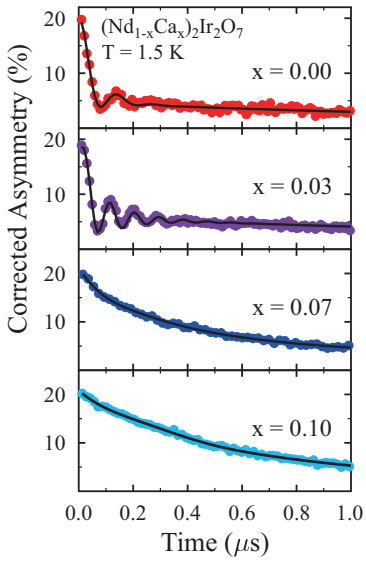

Fig. 1. Zero-field time spectrum of $(Nd_{1-x}Ca_x)_2Ir_2O_7$ in the early time region at a temperature of 1.5 K. The solid lines are fits to Eq. 1.

A spontaneous muon spin precession was observed in the sample with 3 % of Ca concentration at a temperature below 12.5 K, which is lower than the T_{MI} of this sample. At higher Ca concentrations, x = 0.07 and 0.10, no static ordering was observed at temperature below 1.5 K. Although the T_{MI} of these samples is estimated to be approximately 10 K and 5 K, respectively. This indicates that the carrier doping would strongly suppress the magnetic ordering rather than the changes in the electrical transport properties.

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