# $\mu$SR study of the Al-induced magnetic order in $La_{2-x}Sr_xCu_{1-y}Al_yO_4$

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The so-called stripe correlation of spins and holes has been studied intensively in order to clarify its relationship with the appearance of superconductivity in the high-$T_c$ cuprates. Nevertheless, the details of the stripes have not yet been clarified to date. One of the reasons is that the frequencies of the dynamical stripes are faster than the $\mu$SR frequency range in a wide range of the hole-concentration per Cu, $p$, where the superconductivity appears. For this reason, impurity substitution is one of crucial ways to study the stripe correlation, because substituted impurities tend to slow down the spin fluctuations, leading to the formation of the static stripe order. Formerly, we have found from the zero-field (ZF) $\mu$SR that the magnetic impurity $Fe^{3+}$ tends to stabilize a magnetic order in the whole superconducting regime of $La_{2-x}Sr_xCu_{1-y}Fe_yO_4$ (LSCFO).[1,2] Intriguing is that double successive magnetic transitions are observed in the overdoped regime of LSCFO, indicating that the stripe order induced by the Fe substitution persists up to $p \sim 0.30$ and terminates there. As for effects of non-magnetic $Zn^{2+}$ substitution, weakness of the develpment of the Cu-spin correlation by the Zn substitution prevents us from understanding the nature of the Cu-spin correlation especially in the overdoped regime.[3] Recently, we have observed unexpected behavior in non-magnetic $Al^{3+}$-substituted $La_{2-x}Sr_xCu_{1-y}Al_yO_4$ (LSCAO) by the $\mu$SR measurements, namely, a static magnetic state is induced by 3% Al-substitution in the overdoped regime. It is expected that effects of non-magnetic impurities on the Cu-spin correlation will be clarified even in the overdoped regime.

Therefore, in order to investigate the magnetism induced by the Al substitution, we have performed ZF-$\mu$SR experiments for LSCAO with $x = 0.11 - 0.30$ and $y = 0.03$. The polycrystalline samples were prepared by the ordinary solid-state reaction method. ZF-$\mu$SR measurements were carried out using a Variox, a Heliox and a Janis cryostats at temperatures down to 0.3 K at RIKEN-RAL.

Figure 1(a) shows the ZF-$\mu$SR time spectra of LSCAO with $x = 0.30$ and $y = 0.03$. At 5.0 K, the spectral shows the Gaussian-type relaxation due to the randomly-oriented nuclear dipole field, indicating electron spins fluctuate fast beyond the $\mu$SR time window. With decreasing temperature, the muon-spin depolarization becomes fast progressively down to 0.8 K and finally a nearly-static magnetic order is formed at 0.3 K, suggesting a remarkable effect of the Al-substitution on the development of the Cu-spin correlation even in the heavily-doped regime. Figure 1(b) shows the $p$ dependence of the magnetic transition temperature, $T_N$, defined as the midpoint of the change in the initial asymmetry of the magnetic component in an analytical function. It is found that $T_N$ decreases monotoniously with increasing $p$, suggesting that the stripe order is induced also in the overdoped regime. Moreover, $T_N$ disappears at $p \sim 0.30$ as observed in LSCFO[2] and LSCZO.[3] Therefore, it has been concluded that, regardless of the type of impurities, the development of the stripe correlation is observed up to $p \sim 0.30$, suggesting an intimate relationship between the stripe correlation and the appearance of the high-$T_c$ superconductivity. Considering the difference between the results of $Fe^{3+}$, $Zn^{2+}$ and $Al^{3+}$, charge disorder as well as large magnetic moments may play an important role in the stabilization of the stripe correlation.

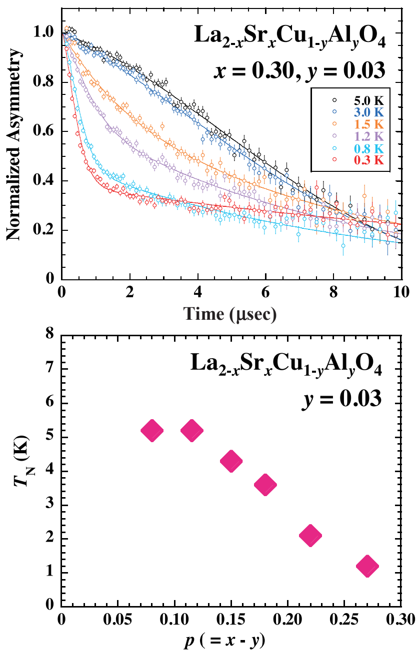


Fig. 1. (a) Zero-field $\mu$SR time spectra of $La_{2-x}Sr_xCu_{1-y}Al_yO_4$ (LSCAO) with $x = 0.30$ and $y = 0.03$. (b) Temperature dependence of the magnetic transition temperature, $T_N$, of LSCAO with $y = 0.03$.

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References

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