Ni-substitution effects on Cu-spin correlation in $La_{2-x}Sr_xCu_{1-y}Ni_yO_4$ relating to hole trapping and stripe pinning

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In order to investigate Ni-substitution effects on the Cu-spin correlation in a wide hole-concentration range of high-T_c cuprates, we have performed zero-field (ZF) and longitudinal-field (LF) muon-spin-relaxation (μSR) measurements in Ni-substituted $La_{2-x}Sr_xCu_{1-y}Ni_yO_4$ with $x = 0.08$ - 0.30 and $y = 0.05$, 0.10.

At the lowest measured-temperature of 1.8 K, it has been found that μSR time spectra in $x = 0.08$, $y = 0.05$ and $x = 0.13$, $y = 0.10$ are in good agreement with each other. This can be understood in terms of the hole-trapping effect of Ni suggested from neutron-scattering experiments.[1,2] That is, supposed that each Ni^{2+} traps a hole, values of the effective hole-concentration per Cu, $p_{\rm eff}$, in $x = 0.08$, $y = 0.05$ and $x = 0.13$, $y = 0.10$ are both 0.03, leading to the observation of the same spectrum. These results indicate that the hole trapping by Ni is effective for 5-10% Ni-substituted $La_{2-x}Sr_xCu_{1-y}Ni_yO_4$.

On the other hand, a muon-spin precession has been observed in $x = 0.13$, $y = 0.03$ of $p_{\rm eff} = 0.10$ at 1.8 K, while no precession has been observed in the Ni-free sample of $x = 0.10$, $y = 0$, namely, of $p_{\rm eff} = 0.10$ at 1.8 K. This is not understood in terms of the hole-trapping effect of Ni and suggests that a small amount of Ni pin down the dynamical stripe correlations of spins and holes as well as a small amount of Zn.[3-5]

The origin of the hole-trapping effect of Ni in 5-10% Ni-substituted $La_{2-x}Sr_xCu_{1-y}Ni_yO_4$ may be as follows. A large amount of Ni^{2+} ($S = 1$) disturb the Cu-spin ($S = 1/2$) correlation markedly. Therefore, Ni^{2+} may trap a hole so as to change to be effectively Ni^{3+} ($S = 1/2$), in order to maintain the Cu-spin correlation. A large amount of Zn^{2+} ($S = 0$) also destroy the Cu-spin correlation, but it appears that Zn^{2+} traps no hole.[6]

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