μSR study of the Cu-spin correlation in heavily electron-doped high-T_c T'-cuprates

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In the history of research on high-T_c superconductivity, numerous efforts have been made to the establishment of the phase diagram of both hole-doped and electron-doped cuprates. However, Matsumoto et al. reported that superconductivity appears even in the parent compound of $x = 0$ and in a wide range of x in $Nd_{2-x}Ce_xCuO_4$ with the so-called T' structure through the appropriate reduction of excess oxygen from the as-grown films, resulting in a completely different phase diagram from that formerly suggested.[1] The superconductivity in the parent compounds of T'-cuprates has also been confirmed for polycrystalline powdered samples of $La_{1.8}Eu_{0.2}CuO_4$.[2] These suggest that the superconductivity in electron-doped T'-cuprates cannot be understood in terms of the doping of carriers into Mott insulators as in the case of hole-doped cuprates.

Recently, through improved reduction annealing, we have succeeded in obtaining high-quality superconducting (SC) single crystals of underdoped T'-$Pr_{1.3-x}La_{0.7}Ce_xCuO_{4+\delta}$ with $x = 0.05 - 0.10$ whose ground states were believed to be antiferromagnetic (AF).[3] Transport measurements have revealed that the strongly localized state of carriers accompanied by the pseudogap due to AF fluctuations in the as-grown crystal changes to a Kondo state without the pseudogap in the SC crystal through reduction annealing. Moreover, our recent μSR measurements of SC crystals of $x = 0.10$ have revealed fast depolarization of muon spins and recovery of asymmetry in a long time region at low temperatures, suggesting the coexistence of superconductivity accompanied by a short-range magnetic order.[4] These results as well as the superconductivity in the parent compounds can be understood in terms of our proposed band picture based on the strong electron correlation.[3,4]

One of the next issues is investigating how superconductivity disappears through Ce doping. Our previous μSR measurements of the SC polycrystal of T'-$Pr_{1-x}LaCe_xCuO_{4+\delta}$ (PLCCO) with $x = 0.14$ revealed slowing down of the Cu-spin fluctuations at low temperatures, but no short-range magnetic order was observed.[5] Therefore, we performed μSR measurements using PLCCO single crystals in the heavily overdoped regime of $x = 0.17$ and 0.20 to obtain detailed information on the Cu-spin correlation. ZF and longitudinal-field μSR measurements were carried out using a MiniCryo and a fly-past-type ^{3}He cryostat at temperatures down to 0.3 K at RIKEN-RAL.

Figure 1 shows ZF μSR spectra of heavily overdoped PLCCO with $x = 0.20$ where superconductivity disappears. At high temperatures around 200 K, the depolarization of muon spins is slow, indicating that the development of the Cu-spin correlation is weak. It is found that, with decreasing temperature, the depolarization of muon spins becomes fast due to the growing effect of Pr^{3+} moments. At low temperatures, it is found that the recovery of the asymmetry in a long time region corresponding to the development of the Cu-spin correlation[5] is negligibly small. This suggests that the Cu-spin correlation is barely developed in the non-SC heavily overdoped regime of PLCCO. Combined with the results in the underdoped[4] and optimally doped[5] regimes, it is concluded that the Cu-spin correlation is crucial for the appearance of superconductivity in T'-cuprates.

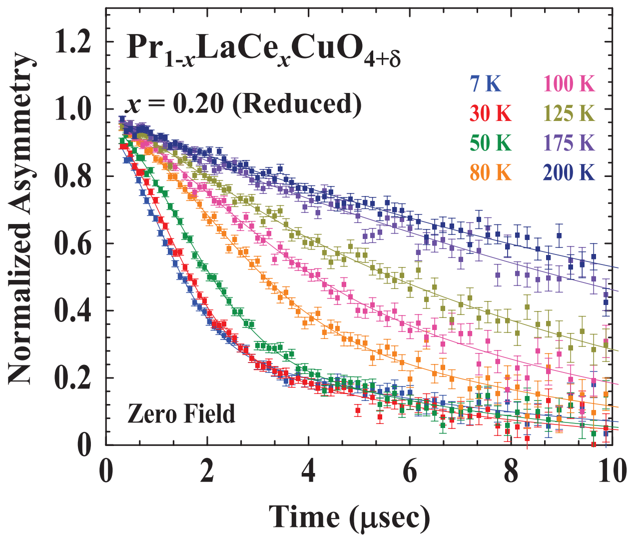

Fig. 1. Zero-field μSR time spectra of the non-superconducting heavily overdoped single crystal of T'-$Pr_{1-x}LaCe_xCuO_{4+\delta}$ with $x = 0.20$.

References
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