μSR study of impurity effects on the Cu-spin correlation and superconductivity in the undoped superconductor T'-$La_{1.8}Eu_{0.2}CuO_4$

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It has long been believed that high-T_c superconductivity appears through hole and electron doping into antiferromagnetic mother compounds Ln_2CuO_4 (Ln: lanthanide elements) with the K_2NiF_4-type (T-type) and Nd_2CuO_4-type (T'-type) structures, respectively. Recently, however, in adequately reduced thin films of T'-$Nd_{2-x}Ce_xCuO_4$, superconductivity was observed in a wide range of x and even in the undoped mother compound of $x = 0$.[1)] In undoped T'-Ln_2CuO_4, it was suggested that the electronic state is explained based on the strong electronic correlation:[2)] carriers are induced at the Fermi level by the collapse of the charge-transfer gap between the upper Hubbard band of Cu3$d_{x^2-y^2}$ and the O2p band.[2)] The electronic state and superconductivity in undoped T'-Ln_2CuO_4 have, therefore, attracted great interest.

For the undoped superconductor T'-$La_{1.8}Eu_{0.2}CuO_4$ (T'-LECO), our recent study of impurity effects on the superconducting critical temperature, T_c, has revealed that T'-LECO shows d-wave superconductitiy mediated by the spin fluctuation and that the electronic state is similar to that in optimally hole-doped and overdoped T-LSCO.[3)] A previous μSR study using a T'-LECO sample ($T_c = 15$ K) showed that a short-range magnetic order appears in the almost whole region of the sample.[4)] Accordingly, in order to investigate the electronic state and superconductivity, the effect of impurities on the development of the Cu-spin correlation in undoped T'-LECO was studied. We performed the zero-field (ZF) and longitudinal-field μSR measurements for another sample of T'-LECO ($T_c = 20$ K) and impurity-substituted samples of T'-$La_{1.8}Eu_{0.2}Cu_{1-y}M_yO_4$ (M = Ni, Zn) at RIKEN-RAL.

Figure 1 shows the ZF spectra of T'-$La_{1.8}Eu_{0.2}Cu_{1-y}$-M_yO_4 (M = Ni, Zn; $y = 0, 0.01$). In all samples, we find that (a) the spectra at 150 K show a slow depolarization of muon spins, (b) the depolarization becomes faster gradually with decreasing temperature, and (c) the spectra show an exponential-like depolarization at 1.5 K, indicating the development of the magnetic order. The volume fraction of the magnetic order at 1.5 K is estimated to be almost the same in all samples. This shows that the magnetic order does not appear around Ni and Zn in the superconducting regions of the impurity-substituted samples. This behavior has been observed in overdoped T-LSCO[5)] and is consistent with the results of impurity effects on T_c.[3)]

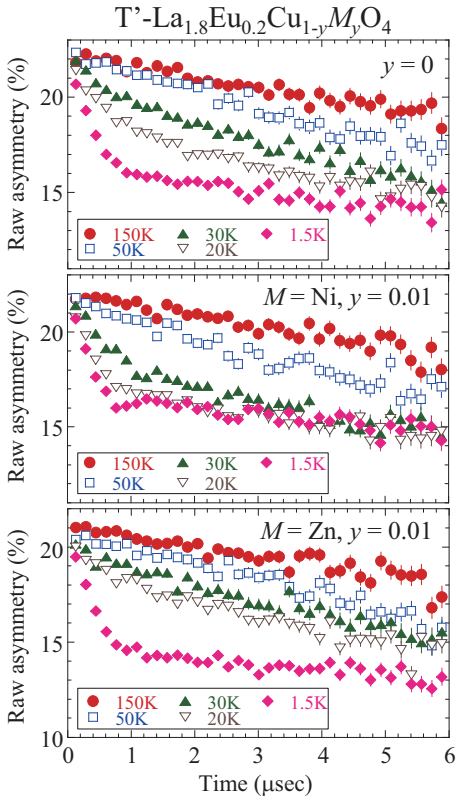

Fig. 1. Zero-field μSR time spectra of T'-$La_{1.8}Eu_{0.2}Cu_{1-y}$-M_yO_4 (M = Ni, Zn; $y = 0, 0.01$).

From the temperature dependence of the depolarization change, moreover, it is found that the magnetic order develops in the Ni- (Zn-) substituted sample below the temperature higher (lower) than that in the non-substituted sample. These impurity effects indicate that the magnetic order is due to the nearest exchange interaction in a localized spin system. The development of the magnetic order is enhanced by Ni with a larger magnetic moment than that of Cu, while the order is suppressed owing to the spin-dilution effect by the substitution of nonmagnetic Zn. These results indicate a strong electronic correlation and suggest the occurrence of phase separation into superconducting and magnetic-ordered regions in T'-LECO. The strong electronic correlation model[2)] in undoped T'-Ln_2CuO_4 is strongly supported.

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