First measurement of magnetic correlations in T*-214 cuprate

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Superconductivity in copper oxides is considered to appear with either hole- or electron-doping into an antiferromagnetic Mott insulator. However, the appearance of superconductivity in a parent compound has been recently reported for R_2CuO_4 (R = Pr, Nd, Sm, Eu) with the Nd_2CuO_4-type structure.[1] An ab-initio calculation supports the fact that the T' structured compound with CuO_4 coplanar coordination has a rather metallic ground state, in contrast to the Mott insulating state of T structured compound with CuO_6 octahedra.[2] These results suggest the dominant role of Cu coordination in determining the physical properties of CuO_2 plane.

There is another 214 system, namely, T*-structured copper oxide which has the intermediate crystal structure between the T and T' structures with CuO_5 pyramid coordination. T*-structured $Nd_{2-x-y}Ce_xSr_yCuO_4$ is known to exhibit superconductivity below $T_c \sim 32$ K after heat treatment under high oxygen pressures.[3] Although the T* compound is suitable for a study of the relation between the Cu coordination and the physical properties, only little is known about the magnetism of the T*-structured compound.

We performed muon spin rotation/relaxation (μSR) measurements to investigate the magnetism of the T* compound. We chose $La_{1-x/2}Eu_{1-x/2}Sr_xCuO_4$ (LESCO) as a target substance because magnetic rare earth ions are absent and thereby μSR data can be simply analyzed as the intrinsic signal from Cu^{2+} spins. The pelletized polycrystals were fired at 1050°C in air. Subsequently, the as-sintered samples were annealed under high oxygen pressure of 400 atm at 500°C for 60 h to obtain superconducting (SC) samples with T_c = 20–30 K. The heat treatment was performed in the Koike Laboratory in Tohoku University. Zero-field μSR measurements were performed on both as-sintered and annealed samples using the spectrometer CHRONUS installed at Port 4, RIKEN-RAL.

Figure 1 shows the zero-field μSR time spectra for the as-sintered LESCO with x = 0.16. A slow Gaussian-type decay can be observed in the time spectra at high temperatures above 30 K. Upon cooling, the muon spin relaxation changes gradually and an exponential-type decay component appears below 10 K, suggesting the development of electronic magnetic correlations. No evidence of oscillatory behavior down to the lowest temperature of 5.0 K indicates the absence of long range magnetic order in this compound. In the as-sintered LESCO, the temperature below which the muon spin relaxation begins to develop, tends to decrease with hole doping from ~30 K (x = 0.14) to ~ 15 K (x = 0.24). This is basically the same trend as the doping evolution of magnetic correlations in $La_{2-x}Sr_xCuO_4$ (LSCO) and $YBa_2Cu_3O_{7-\delta}$. Compared to as-sintered T' compounds in which the long-range magnetic order is formed at low temperatures, spin correlation is rather weak in the T* compound. The in-plane defects possibly cut off the superexchange paths between the neighboring Cu and O ions in the T* compounds, resulting in the degradation of spin correlations, while partially existing apical oxygens do not directly break the superexchange coupling in the T* compound.

The SC samples of LESCO with x = 0.14 and 0.18 do not show any indication of the development of muon spin relaxation down to 2 K. Therefore, it was revealed that the oxygen annealing weakens the magnetic correlations in the T^*-214 copper oxides. Furthermore, the absence of magnetic order in the SC LESCO with x = 0.14 and 0.18 is consistent with the result for LSCO with hole concentrations comparable to those of LESCO. To elucidate the universality of magnetism in the T and T* compounds, further measurements on underdoped LESCO are needed. Further investigation of the precise crystal structures before and after the oxygen annealing is also necessary to understand the physical properties of the T*-structured system and thier relation to local structures.

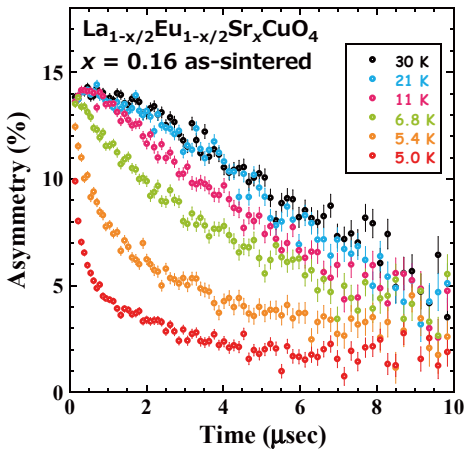

Fig. 1. The μSR time spectra for as-sintered and non-SC $La_{1-x/2}Eu_{1-x/2}Sr_xCuO_4$ with x = 0.16.

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References

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