Impurity effects on magnetism of T*-type $La_{1-x/2}Eu_{1-x/2}Sr_xCuO_4$

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Since superconductivity in the cation-free T'-type R_2CuO_4 (R: rear-earth ion) was reported, the physical properties of cuprates have been studied in connection with the local structure around the CuO_2 plane and Cu coordination.[1,2] However, owing to the difficulty in detecting the variation in oxygen states through reduction annealing, the role of annealing in the mechanism of superconductivity and the genuine ground state of T'-type cuprate remain controversial. To achieve progress in these issues, we newly synthesized T*-type $La_{1-x/2}Eu_{1-x/2}Sr_xCuO_4$ (LESCO), which has a CuO_5 pyramid coordination. For the T*-type cuprate, it is considered that the oxygen defect in the as-sintered (AS) non-superconducting (SC) sample is repaired by oxidation annealing.[3] Therefore, LESCO gives a unique opportunity to study the effect of local/global crystal structure on the physical properties.

Our previous muon spin rotation/relaxation (μSR) measurements on LESCO clarified the existence of the disordered magnetic state in the AS sample and the absence of static magnetism in the oxidation-annealed (OA) SC sample, respectively.[4] These results demonstrate a drastic change in the magnetic state due to annealing. To gain further insight into the ground state of the T*-type cuprate through the study of the magnetism, we investigated the impurity substitution effect for both AS and OA samples by μSR measurements.

For the experiments, we prepared a pelletized sample of Zn- or Fe-substituted LESCO. The mixed powders were fired at 1050°C in air with intermediate groundings, following which a part of poly-crystals was annealed under a high oxygen pressure of 400 atm at 500°C for 60 h. Zero-field μSR measurements were performed using a spectrometer installed at Port 2, RIKEN at Rutherford Appleton Laboratory in the UK.

Figures 1(a) and (b) show representative zero-field μSR time spectra. In both AS and OA samples of $La_{0.855}Eu_{0.855}Sr_{0.29}Cu_{0.95}Fe_{0.05}O_4$, Gaussian-type depolarization changes into exponential-type depolarizing upon cooling, and a fast depolarizing component appears at low temperatures, suggesting the development of electronic magnetic correlations. The onset temperature for the appearance of the fast depolarizing component (T_m) was evaluated to be ~22 K for the AS sample, which is higher than T_m of ~7 K for the AS pristine sample with the same hole concentration. Therefore, the static (quasi-static) magnetism in the AS sample is enhanced by the impurity substitution. From a systematic measurement, we found an increase in T_m with increasing Fe concentration. Similarly, in the OA sample, the fast component develops below ~12 K and the

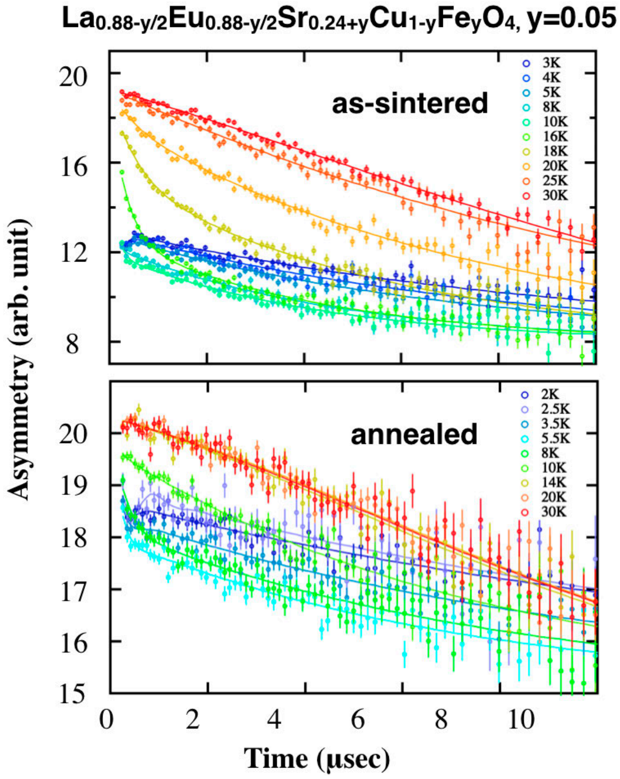

Fig. 1. The μSR time spectra for (a) as-sintered and (b) oxidation annealed $La_{0.855}Eu_{0.855}Sr_{0.29}Cu_{0.95}Fe_{0.05}O_4$.

volume fraction exceeds ~60% at ~3 K, indicating that bulk static (quasi-static) magnetism is induced in the OA sample by Fe substitution.

As for the Zn substitution effect, similar results as in AS Fe-substituted samples we observed, although the enhancement of T_m by Zn substitution is weak (T_m for the 5% Zn-substituted AS $x = 0.24$ sample is ~9 K). However, no evidence of magnetic order was observed in the Zn substituted OA sample down to 2 K, which is quantitatively the same as the result for the pristine OA sample. Thus, the stability of magnetism induced by magnetic and non-magnetic impurity is different; that is, the magnetic impurity more effectively stabilizes/induces the static magnetism in the T*-type cuprate. These results are consistent with the impurity effects reported for the optimally-doped and over-doped $La_{2-x}Sr_xCuO_4$, suggesting the universal nature of spin correlations in hole-doped systems. As the next step, a study of magnetic and SC properties in the under-doped region, where a strong effect of electron correlation can be expected, is important.

References

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