μSR study of ferromagnetic fluctuations in heavily overdoped Bi-2201 cuprates

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High-temperature superconductivity in cuprates is known to emerge by hole doping into the antiferromagnetic (AF) Mott insulators. Superconducting (SC) transition temperature T_c indicates the maximum in the optimally doped regime and the superconductivity disappears with heavy overdoping. Theoretical studies in this decade[1,2] have suggested that the decrease in T_c with hole doping in the overdoped (OD) regime is related to the development of ferromagnetic (FM) fluctuations. In fact, it has been reported from zero-field (ZF) μSR, ab-plane electrical resistivity ρ_{ab} and magnetization measurements that the FM fluctuations are observed in non-SC heavily overdoped (HOD) $La_{2-x}Sr_xCuO_4$.[3] However, because the FM fluctuations have been observed only in $La_{2-x}Sr_xCuO_4$ thus far, the universality of the FM fluctuations in cuprates is still unclear.

To investigate the universality of the FM fluctuations, we performed ρ_{ab}, magnetization, and μSR measurements on Bi-2201 cuprates.[4] It was found that the temperature dependence of ρ_{ab} is proportional to $T^{4/3}$ in the OD and HOD regimes in a wide temperature range between 2-310 K. This dependence is a characteristic of metals with two-dimensional FM fluctuations according to the self-consistent renormalization (SCR) theory.[5] The magnetization curves in the HOD regime show a tendency to be saturated in high magnetic fields below 20 K. This is a precursor phenomenon to the formation of a possible FM order. Transverse-field (TF) μSR measurements on HOD Bi-2201 also show that muon spin relaxation rate λ increases with decreasing temperature below 100 K and that the enhancement of λ is more pronounced in 9.5 T than in 3 T. These results suggest that the spin correlation is enhanced by the application of a magnetic field, which is consistent with the existence of FM fluctuations. To further investigate the temperature and doping dependences of the FM fluctuations in Bi-2201, we performed ZF-μSR measurements on non-SC HOD (T_c < 2 K) and SC OD (T_c = 13 K) $Bi_{1.76}Pb_{0.35}Sr_{1.89}CuO_{6+\delta}$ single crystals (Bi-2201[A]) using a MiniCryo and a ^{3}He cryostat at RIKEN-RAL. The hole concentration per Cu of p was estimated from the thermoelectric power at 290 K.

Figure 1 shows the temperature dependence of λ in the single crystals of non-SC HOD (p = 0.274) and SC OD (p = 0.236) Bi-2201[A]. The results of HOD $Bi_{1.71}Pb_{0.32}Sr_{1.97}CuO_{6+\delta}$ (Bi-2201[B]) with p = 0.264 at J-PARC, Japan, are also shown. In the HOD Bi-2201[A] and HOD Bi-2201[B], the enhancement of λ is observed below 200 K, suggesting development of the spin correlation. For the OD Bi-2201[A], we find that λ shows a small increase with decreasing temperature. These results suggest that the spin correlation develops with hole doping in the HOD and OD regime, which is consistent with the existence of FM fluctuations in the HOD regime. In light of the resistivity results, the enhancement of λ below 200 K is due to the development of the two-dimensional FM correlation.

From the temperature and doping dependences of λ, we conclude that the FM fluctuations exist in HOD and OD Bi-2201, and that the FM fluctuations are enhanced with hole doping. The existence of FM fluctuations is, therefore, a universal feature in HOD cuprates.

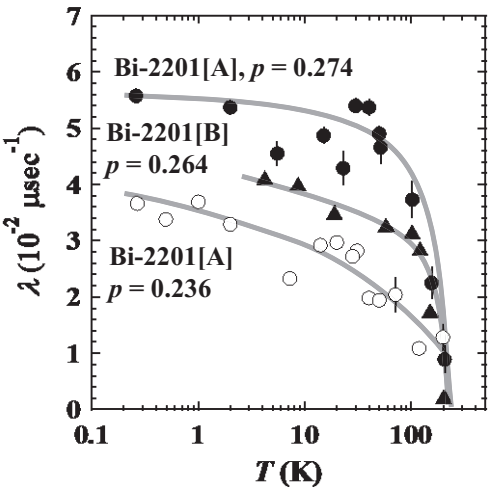

Fig. 1. Temperature dependence of λ in HOD and OD Bi-2201[A] and HOD Bi-2201[B].

References

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