Hole concentration dependence of spin fluctuations enhanced by Fe impurity in overdoped/heavily overdoped Bi-2201 cuprates

Y. Komiyama,[*1,*2] K. Miwa,[*2] H. Kuwahara,[*2] H. Kuroe,[*2] A. Koda,[*3] J. G. Nakamura,[*3] T. Kawamata,[*4] D. P. Sari,[*1,*5] I. Watanabe,[*1] and T. Adachi[*2]

In the field of high-T_c cuprate superconductivity, the relationship between antiferromagnetic (AF) spin fluctuations and superconductivity has been extensively studied. It has been suggested that low-energy AF fluctuations disappear concomitant with the suppression of superconductivity in the overdoped regime.[1)] On the other hand, resonant inelastic X-ray scattering has revealed robust AF fluctuations in the non-superconducting heavily overdoped (HOD) regime.[2)] This suggests that the weakening of AF fluctuations in the overdoped regime is not the only cause of the suppression of superconductivity.

It has been proposed that ferromagnetic (FM) fluctuations exist and are related to the suppression of superconductivity in the HOD regime of high-T_c cuprates.[3,4)] Our previous studies of overdoped and HOD Bi-2201 cuprates revealed that FM fluctuations exist and are enhanced by Fe substitution.[5,6)] Moreover, neutron-scattering experiments revealed that incommensurate AF order is formed in Fe-substituted Bi-2201 in the HOD regime.[7)] Therefore, to clarify how spin fluctuations change from the overdoped to HOD regime with hole doping, we performed muon-spin relaxation (μSR) measurements using single crystals of Bi-2201 with 9% Fe substitution.

Figure 1 shows μSR time spectra of 9% Fe-substituted Bi-2201 at $T \sim 2$ K between the overdoped ($p = 0.24$) and HOD ($p = 0.29$) regimes. Given that all the spectra show muon-spin presession, it is inferred that a long-range magnetic order is formed at low temperatures by the Fe substitution. The frequency of muon-spin precession is found to increase with hole doping, suggesting an increase in the internal magnetic field at the muon site. Moreover, it is found that the magnetic transition temperature, which is determined from the middle temperature of depression of the normalized initial asymmetry in Fig. 2, decreases with hole doping. Given that AF fluctuations are weakened by hole doping,[1)] it is possible a decrease in T_N corresponds to a weakening of AF fluctuations.

On the other hand, an increase in the internal magnetic field might reflect an enhancement of FM fluctuations, because FM fluctuations are strengthened with hole doping from the overdoped to HOD regime.[5)] These results suggest that the suppression of superconductivity in the HOD regime is due to FM fluctuations.

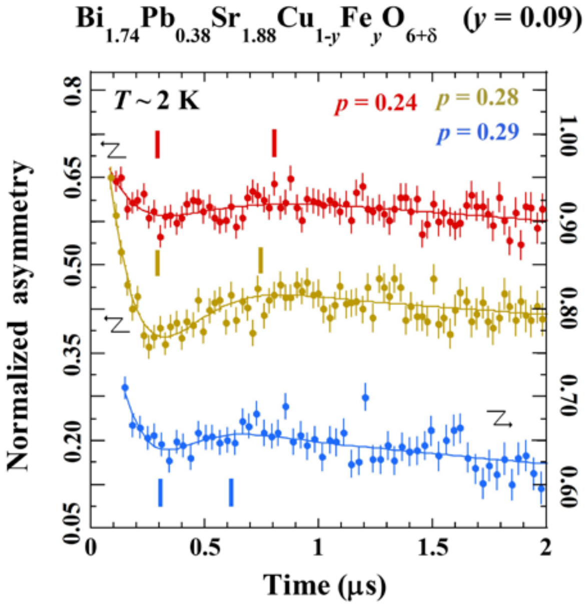

Fig. 1. μSR spectra of $Bi_{1.74}Pb_{0.38}Sr_{1.88}Cu_{1-y}Fe_yO_{6+\delta}$ ($y = 0.09$). Distance between vertical lines corresponds to a half period of muon-spin precession.

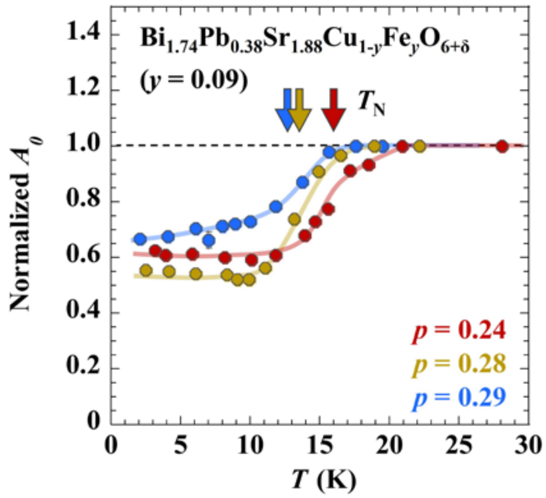

Fig. 2. Temperature dependence of the normalized initial asymmetry of $Bi_{1.74}Pb_{0.38}Sr_{1.88}Cu_{1-y}Fe_yO_{6+\delta}$ ($y = 0.09$). Arrows denote the magnetic transition temperature.

*1 RIKEN Nishina Center
*2 Department of Science and Applied Science, Sophia University
*3 Institute of Materials Structure Science, High Energy Accelerator Research Organization (KEK-IMSS)
*4 Department of Natural Sciences, Tokyo Denki University
*5 College of Engineering, Shibaura Institute of Technology

DOI:10.34448/RIKEN.APR.58-041

References

1) S. Wakimoto *et al.*, Phys. Rev. Lett. **92**, 217004 (2004).
2) M. P. M. Dean *et al.*, Nat. Mat. **12**, 1019 (2013).
3) A. Kopp *et al.*, Proc. Natl. Acad. Sci. U.S.A. **104**, 6123 (2007).
4) J. E. Sonier *et al.*, Proc. Natl. Acad. Sci. U.S.A. **107**, 17131 (2010).
5) K. Kurashima *et al.*, Phys. Rev. Lett. **121**, 057002 (2018).
6) Y. Komiyama *et al.*, J. Phys. Soc. Jpn. **90**, 084701 (2021).
7) Y. Komiyama *et al.*, in preparation.