Incommensurate antiferromagnetic order in the heavily overdoped Bi-2201 cuprates with Fe impurity

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Hole-doped high-T_c cuprate superconductivity arises by hole doping into a parent antiferromagnetic (AF) Mott insulator, suggesting that superconductivity is mediated by AF spin fluctuations in the underdoped and optimally doped regimes. For the overdoped regime where superconductivity weakens and eventually disappears with hole doping, it has been theoretically suggested that a ferromagnetic (FM) phase exists in the nonsuperconducting heavily overdoped regime and competes with superconductivity [1]. In fact, muon-spin-relaxation (μSR) and transport measurements have suggested the occurrence of FM order/fluctuations in nonsuperconducting heavily overdoped cuprates such as Bi-2201 [2]. To further understand the details of the FM fluctuations, we formerly performed μSR in 5% Fe-substituted Bi-2201 cuprates and found that spin fluctuations were significantly enhanced at low temperatures [3]. Since the spin-glass like behavior was also observed at low temperatures from the magnetic susceptibility, these results suggest the occurrence of an FM cluster spin-glass state in which FM spin clusters are formed around Fe and the random orientation of the spins between the clusters results in the formation of a spin-glass state. On the other hand, the formation of AF spin clusters has been proposed in the overdoped regime of Bi-2201 [4]. Therefore, to investigate the AF spin fluctuations in the heavily overdoped Bi-2201, we performed elastic and inelastic neutron-scattering experiments at 6G and C1-1.

Figure 1 shows the difference peak profile between the data at ~12 K and 50 K in the elastic scattering obtained on 6G for the heavily overdoped $Bi_{1.74}Pb_{0.38}Sr_{1.88}Cu_{1-y}Fe_yO_{6+\delta}$ with y = 0.05. Clear incommensurate magnetic peaks are observed in the (1+h, h, 0) scattering plane, indicating the formation of an AF order. The estimated incommensurability was 0.221(4) and is close to the value of ~0.22 obtained in the overdoped $Bi_{1.75}Pb_{0.35}Sr_{1.90}Cu_{1-y}Fe_yO_{6+\delta}$ with y = 0.09 [4]. These suggest that the incommensurability or the modulation period of the AF order is almost independent of the hole concentration. The AF transition temperature T_N, below which the incommensurate magnetic peaks appear, was estimated from the temperature dependence of the peak intensity to be ~35 K.

As the AF order would be induced by Fe impurity, it is concluded that the AF spin fluctuations are robust in the nonsuperconducting heavily overdoped Bi-2201 cuprates.

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[3] Y. Komiyama *et al*., J. Phys. Soc. Jpn. **90**, 084701 (2021).
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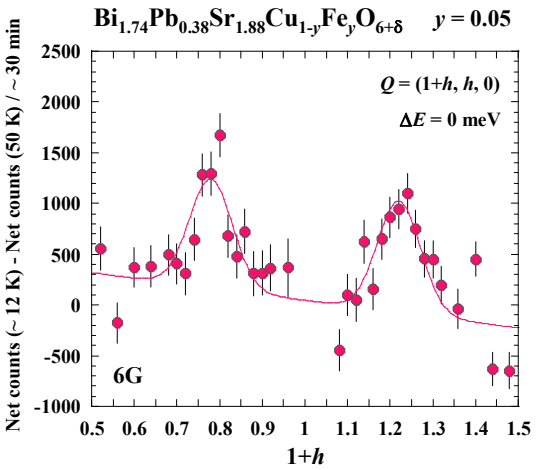

Fig. 1. Difference plot of the elastic neutron scattering spectra obtained on 6G in heavily overdoped $Bi_{1.74}Pb_{0.38}Sr_{1.88}Cu_{1-y}Fe_yO_{6+\delta}$ with y = 0.05.