Incommesurate magnetic order in Al-substituted La2-xSrxCu1-yAlyO4 revealed by neutron scattering

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Magnetic correlations are widely recognized as a key for the mechanism of high-T_c copper-oxide superconductors. Despite long intensive studies, however, it has not been reached to consensus regarding characters of the magnetic correlation in the superconducting phase. One of main reasons for the controversial situation is weak nature of magnetic signals stemmed from the small magnetic moment of $S = 1/2$ and the low dimensionality of the magnetic correlation. It is well known that a small amount of impurity substitutions tends to enhance magnetic responses in copper oxide superconductors. It might be a crucial way to study responses of the electronic state to a perturbation induced by impurity substitutions. Recently muon spin relaxation measurements for $La_{2-x}Sr_xCu_{1-y}Al_yO_4$ (LSCAO) have found that a nonmagnetic impurity, Al^{3+}, substituted for the Cu^{2+} site induces a magnetic order in a wide doping range.[1]

To study the Al-induced magnetic order, thus, we have conducted elastic neutron scattering measurements using the cold-neutron triple-axis spectrometers, SIKA, at ANSTO. A cylindrical single crystal of $x = 0.21$ and $y = 0.03$ of LSCAO grown by the floating-solvent method is used for the measurement.

Figure (a) shows the elastic scattering scan along h direction through $(1/2, 1/2, 0)$ for $x = 0.21$, $y = 0.03$ of LSCAO taken at 1.5 K. The CuO_2 plane is chosen as the scattering plane. Magnetic reflection appears at $Q = (1/2 \pm \delta, 1/2, 0)$ where $\delta \sim 0.135$, indicating the formation of an incommensurate magnetic structure. Since there is no magnetic signal in impurity-free ($y = 0$) $La_{1.82}Sr_{0.18}CuO_4$ (LSCO),[2] the incommensurate magnetism is induced by the Al substitution. The value of δ is close to those of LSCO and $La_{2-x}Sr_xCu_{1-y}Fe_yO_4$ (LSCFO) with $x = 0.18$, $y = 0.01$.[3,4] Figure (b) shows the temperature dependence of the intensity at Q = (0.365, 0.5, 0) and (0.330, 0.5, 0). It is shown that the incommensurate magnetic reflection develops below $\sim$ 20 K, which is much higher than the magnetic ordering temperature of 3.5 K estimated by the μSR.[1] This indicates a crossover-like magnetic transition, as reported in impurity-substituted cuprates as discussed for underdoped LSCFO.[5] From these results, it is inferred that the Al substitution induces the magnetic order in a similar way to the Fe substitution. To discuss origins of the magnetic correlation, e.g. in terms of localize spin correlations or itinerant spin correlation as discussed in LSCFO, further measurements in higher hole-doping range is necessary.

References [1] K. M. Suzuki et al., unpublished. [2] C. H. Lee et al., J. Soc. Phys. Jpn. 68, 1170 (2000). [3] K. Yamada et al., Phys. Rev. B 57, 6165 (1998). [4] M. Fujita et al., unpublished. [5] K. M. Suzuki et al., Phys. Rev. B 86, 014522 (2012).

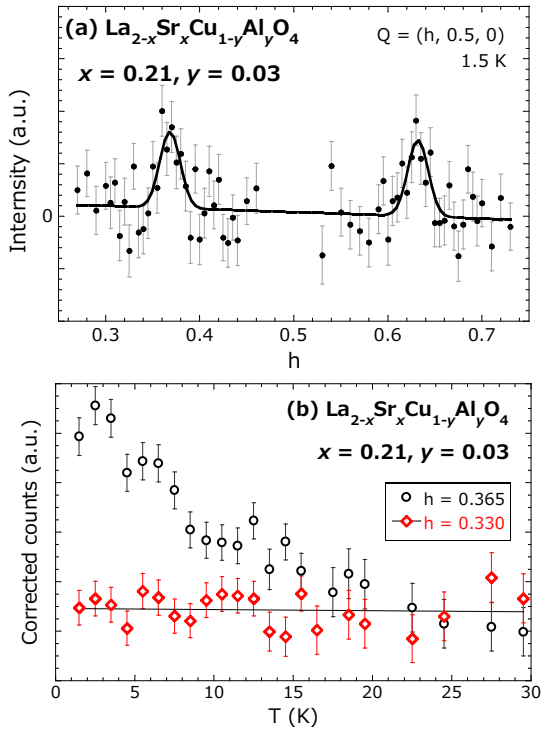

Fig. 1. Elastic scattering scan along h direction in (h, 1/2, 0) for $x = 0.21$, $y = 0.03$ of LSCAO taken at 1.5 K, plotted after subtracting data of 50 K. (b) Temperature dependences of the intentsity at Q = (0.365, 0.5, 0) and (0.330, 0.5, 0).