Magnetic excitations in $La_{2-x}Ca_xCoO_4$

K. Horigane, T. Uchida, H. Hiraka*, K. Yamada* and J. Akimitsu
Department of Physics and Mathematics, Aoyama-Gakuin University, Sagamihara 229-8558;
**Institute for Materials Research, Tohoku University, Sendai 980-8577*

Layered transition metal oxides have attracted much attention due to their wide variety of magnetic, electrical and structural properties. In some of the doped transition metal compounds, there is a real space ordering due to the charge carriers in a certain carrier concentration, resulting in an orbital ordering (OO) and sometimes a charge ordering (CO). In a recent neutron scattering study, Zaliznyak et al. observed a checkerboard charge order of Co^{2+}/Co^{3+} and Co^{2+} magnetic order in the half-doped cobaltate $La_{1.5}Sr_{0.5}CoO_4$ [1]. From the analysis of the magnetic and charge order scattering, they concluded a checkerboard arrangement of Co^{2+} and non-magnetic Co^{3+} ions in the CoO_2 plane. On the other hand, Y. Moritomo et al. reported the drastic change of effective moment μ_{eff} in $La_{2-x}Sr_xCoO_4$($0.4<x<1.0$), suggesting a spin-state transition of Co^{3+} ions from the high-spin to intermediate spin state[2]. Our purpose of this study is to clarify the exchange interaction between Co spins, spin and charge configurations of CoO_2 plane and to observe the intermediate spin state.

Single crystal of $La_{2-x}Ca_xCoO_4$ ($0.3 \leqq x \leqq 0.8$) was grown by the TSFZ method. The sample volume was about 1.0 cc each and it was mounted in a cryostat with the b-axis vertical, allowing the wave vector transfers in the (h0l) reciprocal lattice plane. The crystal structure remains in the tetragonal phase (space group I4/mmm) even at the lowest temperature. However, to index the superlattice peaks it is convenient to choose a unit cell as twice as the primitive unit cell, corresponding to a space group F4/mmm. The neutron scattering experiments were carried out on the 3-axis spectrometer TOPAN (6G).

In order to clarify the exchange interaction, we have performed the inelastic neutron experiments. Spin wave dispersion at Q=(h, 0, 3) are shown in Fig.1-(a). This spin-wave is seen up to 16meV, in contrast to 50meV in $La_{1.5}Sr_{0.5}NiO_4$. This indicates a much weaker exchange interaction in the cobaltates than that in nickelates. We have obtained the magnetic dispersion curves for the different Ca concentrations and its spin excitations are basically same. These results suggest that magnetic interaction is not changed by Ca substitutions. To solve this strange phenomena, we examined the hole-doping dependence of magnetic correlation in a wide carrier-doping range of $0.3<x<0.8$.

Fig.1-(b) shows Ca dependence of magnetic correlation lengths. From the hole-doping dependence, the in-plane correlation lengths of spin order are found to give a maximum at x=0.5 and spin ordered peaks exist in the entire x range. From the results, unchanged magnon dispersion can be understood as existing the long ranged magnetic order in a wide hole-doping range.

Moreover, we discovered the Ca dependence of two types of magnetic peaks for a different Ca concentration. In the lower doping samples ($x<0.5$), we only observed the l=half-integer (type 1 stacking) patterns, while we observed the l=integer (type 2 stacking) patterns in higher doping samples($x>0.5$). This result is consistent with the Larochelle's result of perovskite manganites[3]. From this point of view, $La_{2-x}Ca_xCoO_4$ can be explained by the two-type of stackings and CE-type spin and charge configuration was clearly observed in this system.

Reference

[1]I. A. Zaliznyak et al., Phys. Rev. Lett. 85

(2000) 4353
[2]Y. Moritomo et al., Phys. Rev. B 55 (1997) 14725
[3]S. Larochelle et al., Phys. Rev. B 71, 024435 (2005)

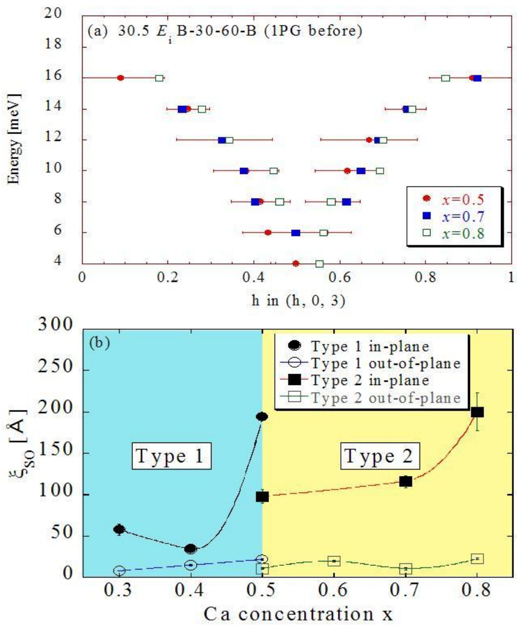

Fig. 1. (a) Ca dependence of magnon dispersion at Q=(h, 0, 3) and (b) Ca dependence of magnetic correlation lengths in La2-xCaxCoO4.