# Neutron Scattering Study of the Charge and the Magnetic Ordering in $La_{2-x}Sr_xNiO_4$

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**Abstract**

We have observed the charge and the magnetic ordering in $La_{2-x}Sr_xNiO_4(0.28 \leq x \leq 0.46)$ by neutron scattering. In the $c$-plane, holes and spins order as a two dimensional system, where holes form stripes and they are inserted into the antiferromagnetic ordering. Along the $c$-axis, the two dimensional ordering stacks. However, the coherence along the $c$-axis is much weaker than that in the $c$-plane. We discuss how two dimensional ordering stacks and why the coherence along the $c$-axis becomes weak.

*Key words:* neutron scattering; nickelate; stripe structure; magnetic ordering

There has been much interest in charge and magnetic ordering of $La_{2-x}Sr_xNiO_4$, a hole-doped two- dimensional antiferromagnet on a square-lattice with a hole concentration $n_H = x$. When $n_H$ is small, holes form stripe structures, which are inserted into the antiferromagnetic ordering. [1] Yoshizawa *et al.* found that the optimized hole concentration for the stripe structure is $\frac{1}{3}$. At this concentration, the phase transition temperature is the highest and the coherent lengths in the $c$-plane is the longest for both charge and magnetic orderings. [2] On the other hand, Lee *et al.* reported that the coherent length along the $c$-axis becomes short at $n_H = \frac{1}{3}$. [3] To explore why the coherence along the $c$-axis becomes poor at $n_H = \frac{1}{3}$, We have carried out neutron diffraction measurements on the $La_{2-x}Sr_xNiO_4(0.28 \leq x \leq 0.46)$ crystal samples.

Single crystals were grown by the floating zone method. Neutron diffraction measurements were carried out with the ISSP triple-axis spectrometer GPTAS installed at the 4G experimental port of JRR-3M in JAERI (Tokai). We used neutrons with $k_I = 3.83$ $\AA^{-1}$ obtained by the (0 0 2) reflection from pyrolytic graphite and employed the collimation of 40'-40'-40'-40' in the triple-axis mode. To remove higher order neutrons, we used a pyrolytic graphite filter.

Figure 1 shows line profiles along $(4 - 2\epsilon\ 0\ l)$ for charge ordering and $(1 + \epsilon\ 0\ l)$ for magnetic ordering, where $\epsilon = x$. Neither the line width of the charge ordering nor that of the magnetic ordering seem to become wider particular at $n_H = \frac{1}{3}$. However, the line profile shows some sample dependence at $n_H = \frac{1}{3}$.

Figure 2 shows the line profiles along $(1 + \epsilon\ 0\ l)$ for two different samples with $n_H = \frac{1}{3}$, the A sample and the B sample. Both samples $\epsilon$ are exactly $\frac{1}{3}$, indicating that the hole concentrations of the both samples agree well. However, the line profiles are significantly different. The B sample does not exhibit even peaks and the line width of the odd peaks of the B sample is much wider than that of the A sample.

Figurer 3 shows the schematic picture of the magnetic ordering at $n_H = \frac{1}{3}$ along the $c$-axis if only the Coulomb repulsion force between stripes in the neighbouring $c$-plane is relevant. This force translates the neighbouring stripe structure with either $\delta$ or $-\delta$ at

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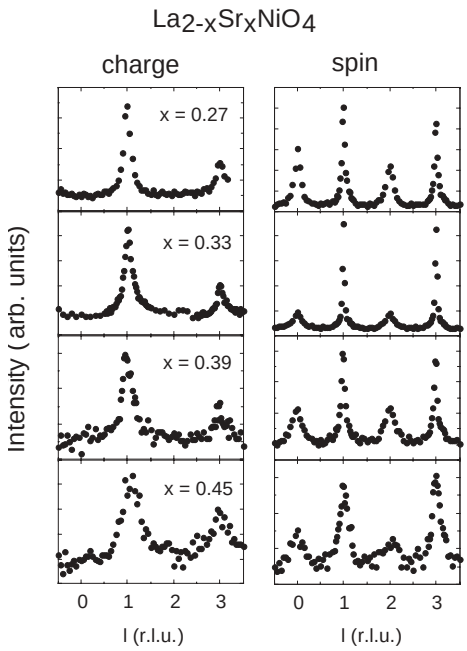


Fig. 1. The hole concentration dependence of line profiles along $(4 - 2\epsilon\ 0\ l)$ for charge ordering and $(1 + \epsilon\ 0\ l)$ for magnetic ordering.

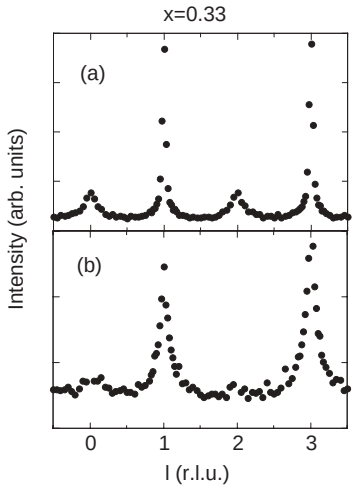


Fig. 2. The sample dependence of line profiles for magnetic ordering at $n_{\rm H} = \frac{1}{3}$; (a) the A sample and (b) the B sample.

$n_{\rm H} = \frac{1}{3}$, where $\delta$ denotes the spacing between the neighbouring Ni site along the $a$-axis. Consequently, the long range order cannot be established. A next-nearest "ferro" charge interaction, $J_{\rm NN}$, is necessary for establishing the long-range order.

Figure 4 shows the calculated line profiles of the $\frac{1}{3}$ sample for strong and weak $J_{\rm NN}$. If $J_{\rm NN}$ is weak, the coherent length along the $c$-axis becomes short and depresses the even peak intensity. The line profile of the B sample is similar to that with $J_{\rm NN} = 0$. Thus,

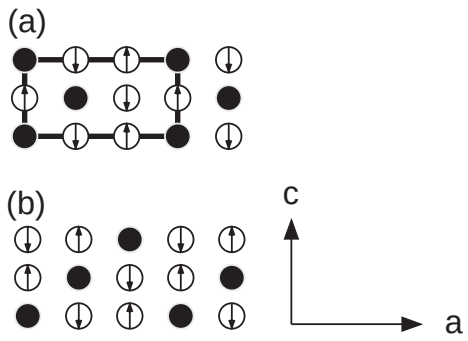


Fig. 3. The schematic picture of two possible positions for the second- nearest stripe structure of the $\frac{1}{3}$ sample. A closed circle denote a hole stripe.

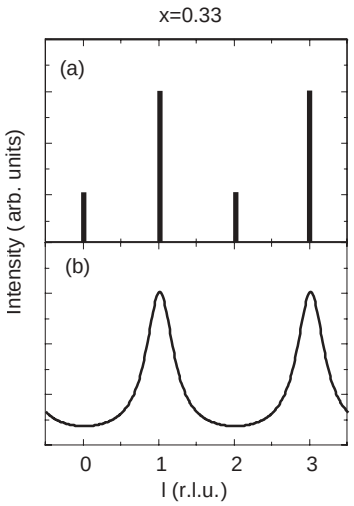


Fig. 4. Calculated magnetic profiles for the $\frac{1}{3}$ sample; (a)the Bragg refflections corresponding to the (a) structure in Fig. 3 built by $J_{\rm NN} >> 0$, and (b) the diffuse signal due to the equivalent mixture of the (a) structure and the (b) structure in Fig. 3 built by $J_{\rm NN} = 0$.

we believe that $J_{\rm NN}$ of the $\frac{1}{3}$ sample is so weak that some subtle perturbed forces (e.g. crystal defects) can disturb the magnetic ordering.

## References


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