Spin excitations in stripe-ordered La$_{2-x}$Sr$_x$NiO$_4$ ($x = 0.275$ and 1/3)

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We report neutron scattering measurements of the spectrum of magnetic excitations in the stripe-ordered phase of La$_{2-x}$Sr$_x$NiO$_4$ ($x = 0.275$ and 1/3). The propagating spin excitations follow a similar dispersion relation for the two compositions, but the line widths are broader for $x = 0.275$ than for $x = 1/3$.

It is now well established that charge carriers doped into antiferromagnets tend to segregate into parallel domain walls separating regions with antiferromagnetic (AF) order of the host spins. This so-called stripe ordering is observed in members of the cuprate family of superconductors [1], making it an exciting field for basic research.

The stripe modulation of spin and charge has been characterized extensively in the layered La$_{2-x}$Sr$_x$NiO$_{1+y}$ system [2,3,4], where $n_h = x + 2y$ is the level of hole doping. Interest is now turning to stripe dynamics. Recently, we reported two separate neutron inelastic scattering studies of the magnetic excitations in the stripe phase of La$_{2-x}$Sr$_x$NiO$_4$ with $x \approx 1/3$ [5,6]. In both cases we observed propagating spin-wave modes throughout the Brillouin zone, with a maximum energy of 80–85 meV.

The case of $x = 1/3$ is special in that the periodicities of the charge and magnetic superlattices are the same and are commensurate with the host lattice. This leads to a very stable stripe order, with a relatively high ordering temperature of 200 K and an in-plane correlation length of several hundred Å [4]. Here we compare the magnetic excitation spectrum in crystals with $x = 0.275$ and $x = 1/3$. These crystals have similar stripe correlation lengths, but at $x = 0.275$ the spin and charge periodicities are not the same and are not commensurate with the host lattice.

Neutron inelastic scattering measurements were made on the MAPS chopper spectrometer at the ISIS Facility. The single-crystal samples were mounted in a closed-cycle refrigerator and aligned with the $c$ axis parallel to the incident beam direction. Scattered neutrons were recorded in large banks of position-sensitive detectors. We analyzed the spectra by making a series of constant-energy slices and projecting the intensity on to the $(h, k, 0)$ reciprocal lattice plane. The $c$ component of the scattering vector is unimportant as there are no measurable spin correlations along the $c$ axis in the range of energies probed.

The diagonal stripe pattern in La$_{2-x}$Sr$_x$NiO$_4$ is twinned, with stripes either parallel to the $[1, -1, 0]$ or $[1, 1, 0]$ directions of the tetragonal lattice (cell parameter $a = 3.8$ Å). These are described by magnetic ordering wave vectors $(1/2, 1/2, l) \pm (\delta, \delta, 0)$ and $(1/2, 1/2, l) \pm (\delta, -\delta, 0)$, respectively, where $\delta \simeq n_h/2$. In our samples we observed an equal population of the twin domains.

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Figure 1. Constant-energy scans at $E = 40\text{ meV}$ through the magnetic zone centres in stripe-ordered La$_{2-x}$Sr$_x$NiO$_4$ ($x = 0.275$ and $1/3$). The scans run parallel to the stripe direction. The lines are fits to Gaussian peak profiles.

Figure 2. Spin wave dispersion perpendicular to the stripe direction in La$_{2-x}$Sr$_x$NiO$_4$. The points at zero energy are from the magnetic order Bragg peaks.

$x = 0.275$ phase possess a significant intrinsic width which increases with energy, whereas those of $x = 1/3$ do not. Remember that both compositions exhibit very long range stripe order.

It is possible that the robustness of the $x = 1/3$ stripes is due to a strong pinning of the commensurate stripes to the lattice. On the other hand, a clear anomaly has been found near 15–20 meV in the spin excitation spectrum of $x = 1/3$ [5]. This may be due to some kind of resonant spin-charge coupling, and investigation of this energy range in the $x = 0.275$ sample will be of interest.

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