Orbital and charge order in $La_{0.89}Sr_{0.11}MnO_3$

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Introduction

Recently, in several synchrotron x-ray scattering studies it was shown that orbital and charge ordering can be investigated through the use of resonant scattering methods [1]. In the case of the manganites, there is an ongoing debate concerning the mechanism responsible for the observed strong orbital resonances [2, 3]. We used this same technique to study the orbital ordering (OO) and charge ordering (CO) in the doped manganite $La_{0.89}Sr_{0.11}MnO_3$ and to shed some light on this problem.

Methods and Materials

X-ray diffraction experiments were performed on beamline 1-ID-C at the Advanced Photon Source. The energy of the incident beam was tuned to the Mn K-edge. A Si(111) double monochromator gave an incident energy resolution of ~1 eV. The incident beam of 0.5 x 0.5 mm^2 was unfocused and ~ 99% linearly polarized in the horizontal plane (σ). The experiment was performed in vertical scattering geometry. The polarization of the scattered beam was analyzed with a Cu(220) analyzer crystal, which also provided inelastic background suppression. The single crystals used in this study were grown by a floating-zone technique. The (100)-oriented surfaces were cut, ground, and polished with diamond paste. The mosaic spread of samples with x = 0.11 was in the range between 0.05° and 0.09°, depending on orientation.

Results

The (030) Bragg peak is forbidden in the Pbnm space group. But in resonance condition at the Mn-K edge, it is strongly enhanced due to orbital order. Figure 1 shows an energy scan of the (030) Bragg peak at 297 K. It clearly shows a pronounced maximum (1) at 6.553 keV and broader maxima (2) and (3) at higher energies, as well as a small shoulder (4) below the main peak (1). Similar to previous experiments [1], the polarization of the orbital order scattering is completely rotated from σ to π and the intensity exhibits a two-fold symmetry in the azimuthal scan. We could show that these features are the same for maxima (1) and (2). Below 124 K, the intensity of the resonant (030) peak drops by a factor of ~6, concomittantly with the observation of new superlattice peaks at (0,0,0.5) positions and a strong reduction of the orthorhombicity. Above 308 K, the intensity of (030) drops by a factor ~10, again together with a reduction of the orthorhombicity. Qualitatively, the energy, azimuthal, and polarization dependence is the same above and below 124 K.

Discussion

The transition at 124 K has been ascribed by Yamada and associates [4] to a charge order transition on the Mn^{3+}/Mn^{4+} sublattice with a doubling of the periodicity in the (001) direction. In a recent study [5] on $La_{0.875}Sr_{0.125}MnO_3$ it was reported that above this transition there was no resonant scattering at (030) observable, only below. This is in clear contradiction to our results for $x_{Sr} = 0.11$. In [5], a theoretical model based on strong electronic interactions neglecting electron-lattice coupling has been developed. On the other hand, Elfimov and coworkers showed that the hybridization between Mn 4p and neighboring Mn 3d and O 2p orbitals is very sensitive to Jahn-Teller distortions and that this should be the main reason for the resonant Mn K-edge scattering. Very recently, Van den Brink and associates showed that all the features of the resonant scattering that we observed, especially the additional side maxima of the energy scan (Figure 1) and the dependence on the Jahn-Teller distortion, can be explained by band structure effects. The observation of orbital order in the manganites is therefore an indirect one, as is also theoretically inferred by Benfatto and associates [2].

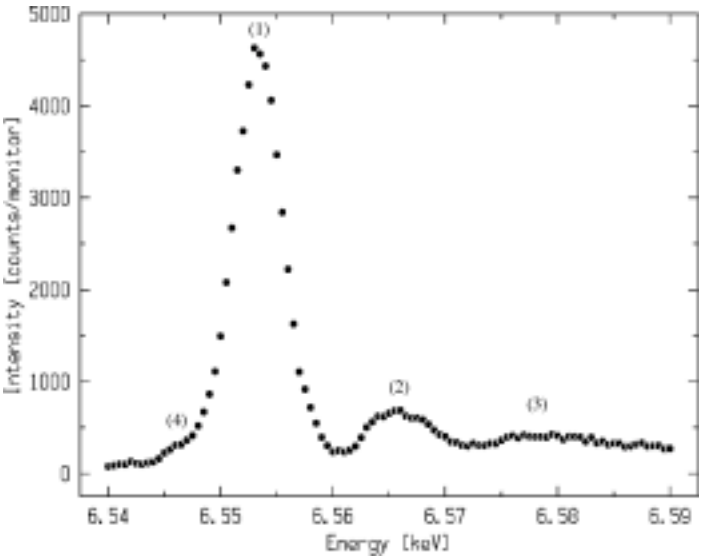

Figure 1: Energy dependence of the (030) forbidden Bragg peak with $\sigma-\pi$ analyzer setting.

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References

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