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Charge and orbital ordering in $Nd_{1-x}Sr_{1+x}MnO_4$

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Introduction

We are studying the order of electron degrees of freedom (charge, spin, and orbital) in strongly correlated electron systems by resonant x-ray scattering (RXS) technique. Our goal is to understand the ordering mechanism in charge-, spin-, and orbital-ordered systems. This year we have studied the charge and orbital ordering in $Nd_{1-x}Sr_{1+x}MnO_4$ (x = 0.67, 0.75). The charge and orbital ordering of $La_{1-x}Sr_{1+x}MnO_4$ has been intensively investigated. However, the ordered states with x > 0.5 have not been studied owing to the chemical phase separation. Recently the sample has been prepared by substituting Nd for La. The important question is whether the charge state (the ordering of Mn^{3+} and Mn^{4+}) of this sample is localized or delocalized one. The orbital state is also interesting concerned with the type of the ordering, that is, Wigner-crystal type or bi-stripe type.

Experimental Results

X-ray diffraction experiments were carried out with Mn K-absorption edge energy. A four-circle diffractometer equipped with a closed cycle He cryostat was used. The plane indices are denoted in the I4/mmm which is a space group at room temperature.

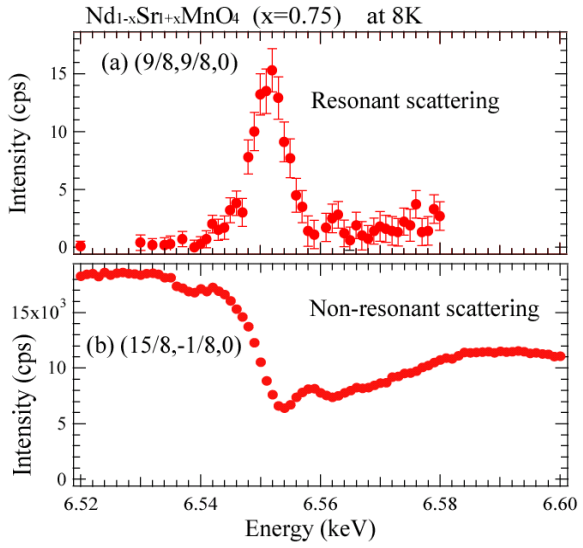
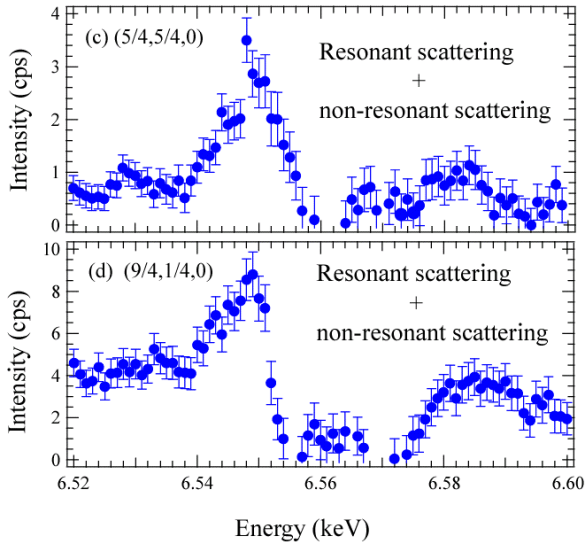


Figure 1. Energy dependence of the superlattice peaks (a) (9/8, 9/8, 0), (b) (15/8, -1/8, 0),

The diffraction peaks were searched in the direction along (h, h, 0) in the sample of x = 0.75. We could observe only the resonant scattering at q=(n±1/8, n±1/8, 0) (Fig.1 (a)) and the resonant and nonresonat scattering at q=(n±1/4, n±1/4, 0) (Fig.1 (c)). The signal from the lattice distortion of oxygen is not observed on this principle axis. We also observe the signal off this axis (Fig.1 (b) and (d)). These peaks come from the lattice distortion of oxygen. It is found from these results that the charge-orbital structure has the unit cell of $4\sqrt{2}a \times \sqrt{2}a \times c$.

The same measurements in the sample of x = 0.67 have been performed. We have observed the resonant and nonresonant scattering at the modulation wave vectors δ = 1/6, 1/3 though the superlattice intensity is much weaker than that of x = 0.75. The unit cell of the charge-orbital structure is $3\sqrt{2}a \times \sqrt{2}a \times c$.

By comparing between the observed peak intensities and the model calculations, we have concluded that the charge is rather delocalized with a sinusoidal modulation and the orbital state has Wigner-crystal type in the low temperature phase of $Nd_{1-x}Sr_{1+x}MnO_4$ (x = 0.67, 0.75).



(c) (5/4, 5/4, 0) and (d) (9/4, 1/4, 0) in $Nd_{1-x}Sr_{1+x}MnO_4$, x = 0.75 at T = 8 K.

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