Superstructures in superoxygenated $La_{2-x}Sr_xCuO_{4+y}$

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In recent years it has become increasingly obvious that high temperature superconductors have inhomogeneous charge and spin ordering resulting in stripe formation [1, 2]. For most cases the charge variations appear to be short ranged, associated with a length scale of a few nanometers at most. However, for the special cases of La_2CuO_{4+y} (LCO+O) or oxygen co-doped $La_{2-x}Sr_xCuO_{4+y}$ (LSCO+O), muon and superconducting quantum interference techniques suggest that the electronic inhomogeneity moves beyond such local variations to form fully phase separated regions [3]. With hole concentrations (n_h) between 0.125 and 0.16 per Cu site a magnetic phase consistent with n_h = 1/8 that is not superconducting and an optimally doped superconductor with n_h = 0.16 that is not magnetically ordered is formed, both having transition temperature of 40K. The driving force for this phase separation appears to be interactions between the doped holes themselves rather than any specific O or Sr chemistry [3]. The full implications of this complete phase separation are still to be determined both theoretically and empirically.

An important issue is to establish the role of oxygen and charge ordering on the phase separation. The excess oxygen is known to order in superstructures called staging for LCO+O. The staging is seen as satellites along qz close to the allowed peaks of the $Bmab$ crystal structure.

Here we have used the BW5 beam line and high-energy photons (100 keV) to study the oxygen and charge ordering properties of LCO+O and LSCO+O with x = 0.04. These experiments are similar and complimentary to experiments carried out at BW5 in 2007 on LSCO+O with x=0.065 and x=0.09.

For LCO+O the low temperature splitting of the (020) peak due to twinning of the crystal is clearly resolvable in the longitudinal direction and the domains are approximately equally populated. Staging is detected around several $Bmab$ positions as shown in Figure 1. The central $Bmab$ peak persists to T=300 K whereas the staging satellite peaks decrease gradually up to T=280 K where after they can no longer be detected.

We searched for charge order peaks around $(2, 2, 0)$ and found the best candidates at $(2, 2, 0) \pm (0.67, 0, qz)$ with qz integer. These peaks however persisted to RT as seen in Figure 2.

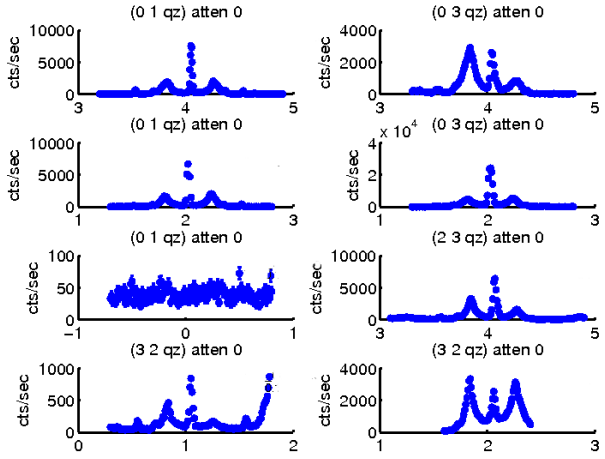

Figure 1: Staging peaks along qz of LCO+O @ 10K. The (010) and (322) peaks are not allowed in the $Bmab$ phase, hence there is no staging around (010). However there seems to be staging around (322) but we suspect that peak at this position is actually the (233) of the twin domain which is indeed allowed in $Bmab$. All scans except (0 1 qz) lined up on central peak.

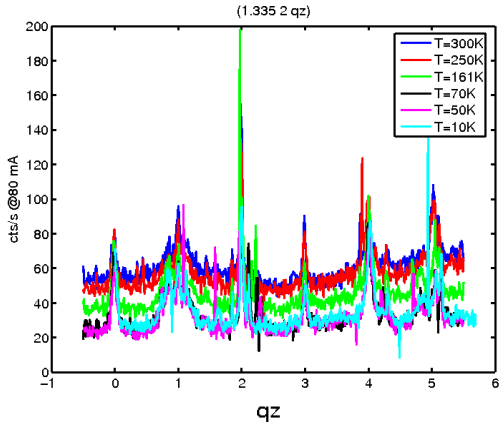

Figure 2: qz-scans through possible charge-order peaks, at the range of temperatures. They are seen to persist almost unchanged to T=300 K except for increasing background.

A piece of LSCO+O x=0.04 crystal was studied at BW5 in 2006 in which the central $Bmab$ peak was not present but this time we studied another piece of LSCO+O x=0.04 crystal which was recently studied by neutron scatetring (NS). The low temperature splitting of the (020) peak due to the twinning of the crystal is resolvable in the longitudinal direction and the low-q set of domains has twice the population of the high-q ones. The staging pattern shown in Figure 3 (left) is similar to the one found by NS. It is interesting and still under discussion why the central peak disappears at T=150 K whereas the supposed superstructure of the central peak disappears at the much higher T=230 K. This is the opposite tendency of what is observed in LCO+O and it is confirmed by NS. We searched for charge order peaks and found the best candidates at $(2, 2, 0) \pm (0.15, 0.15, qz)$ with qz approximately an even integer or zero. These peaks however persisted to RT as seen in Figure 3 (right).
In the near future we plan to perform a more extensive hard x-ray study in search for charge order peaks in LSCO+O with x=0,0.04,0.065 and 0.09 around forbidden Bragg positions.

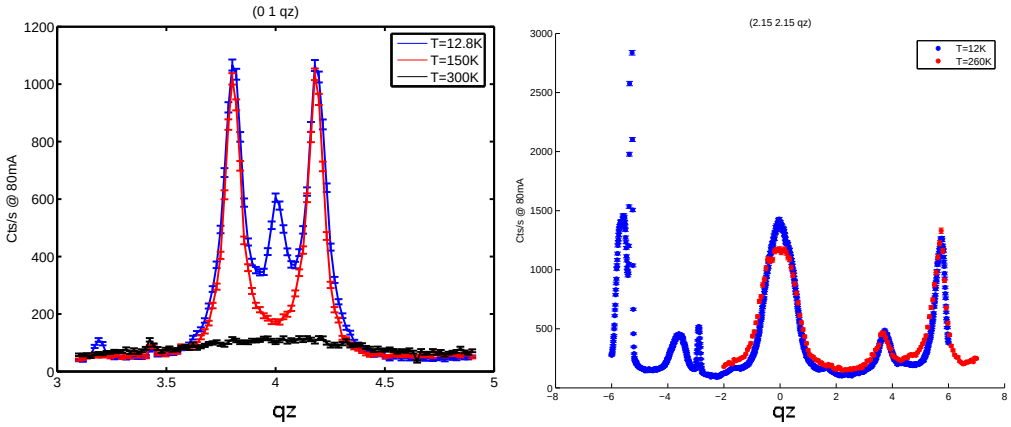

Figure 3: Left: The staging peaks of LSCO+O x=0.04 by qz scans through (014) at selected temperatures. Right:qz-scans through possible charge-order peaks, at T=10 K and T=300 K.

References

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[3] H.E. Mohottala *et al*, Nature Materials 5, 377 (2006)