Direct Imaging of the Charge Ordered Stripes in $Bi_{1-x}Ca_xMnO_3$ Using Scanning Tunneling Microscopy

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One of the exciting properties of hole-doped manganites is the phenomenon of charge-ordering (CO). This phenomenon is observed for certain amounts of hole doping below the charge-ordering temperature T_{CO}. In the charge ordered state the Mn^{3+} and Mn^{4+} ions arrange themselves in separate sublattices. The associated lattice distortion with this arrangement of ions has been observed using Transmission Electron Microscopy (TEM). A direct image of the CO has not been obtained so far. To obtain such direct images of the CO, we have imaged the surface of the charge-ordered compound $Bi_{1-x}Ca_xMnO_3$ ($x \approx 0.7$) which has a T_{CO} of 307 K using a Scanning Tunneling Microscope (STM). One such image is shown in figure 1. The CO stripes are clearly seen. The distance between the marked stripes is 1.2 nm. This shows that the CO stripes can be observed directly using an STM. The brighter stripes are Mn^{3+} ions since the sample is negatively biased with respect to the tip and we are imaging the filled electronic states of the sample. However, we have to do further experiments to confirm this. We have also obtained bias dependent images of these materials as shown in figure 2 which shows that these stripes have an electronic origin and are not due to the topography. Future experiments will check for these stripes as a function of temperature both above and below T_{CO} and also obtain the temperature and spatial variations of the tunneling spectra on the surface of the sample. We will also determine accurately the bias dependence of the images and figure out how they are related to the magnitude of the CO gap, Δ_{CO}.

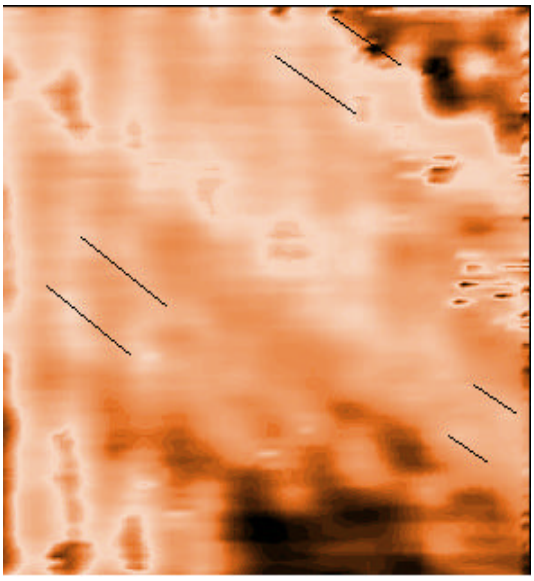

Fig. 1. STM image of $Bi_{1-x}Ca_xMnO_3$ at 297 K. Image size is 9.0 nm × 9.6 nm. Sample bias is −100 mV and the tunneling current is 10 nA. The distance between the marked stripes is 1.2 nm.

Fig. 2. A series of STM images taken on the same 19.8 nm × 19.8 nm area with sample biases −90 mV, -500 mV and −750 mV respectively.