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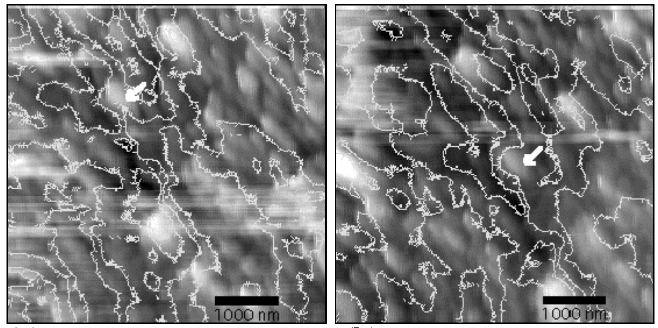
Optical characterization of YBCO using a near-field scanning optical Microscope

S. H. Huerth, H. D. Hallen, North Carolina State Univ.

The near-field scanning optical microscope (NSOM) can be used as a metrology tool or a fabrication tool. Our studies of electromigration (EM) in YBCO (write out correct name) (YBCO) illustrate this point. We use the topographic image from the NSOM to locate the region on the sample to modify, a tunnel current through the NSOM probe tip to induce EM of oxygen ions, and NSOM reflectivity to sense the resultant changes in oxygen content. The results of these studies allow us to determine the mechanism of EM in this system, and the effects of grain boundaries on the process.



(a) (b)

Figure 1. Representative images of YBCO in a 5 micron square region. (a) An overlay of the topography in gray scale with a 150 nm range (white higher, and the corresponding optical (green) image with a 6 nW range (~43 nW average value). The tick marks on the contours point towards lower oxygen content. (d) As (c) but using the after EM and optical images. The images are shifted due to microscope drift. The white arrow shows a major path of oxygen flow during the EM as the contour has shifted across the grain pointed to.

We have studied several aged samples from Conductus to characterize the starting samples and determine the structural relation to oxygen loss. We find that there is a strong relationship between the surface topographic features and the oxygenation as measured by optical reflectance (with far-subwavelength resolution). The NSOM provides simultaneous images as seen in Fig. 1. If oxygen motion in the ab plane is fast, then one would expect that the concentration would be uniform across regions with the same topographic height. It may or may not vary between regions of different topographic height. This is what is seen in the figure. One might expect that the small terraces sticking up out of the sample may loose oxygen. Indeed, the optical signal is often lower when the topography is higher suggesting a lower reflection coefficient in these areas.

Electrons injected from a near-field metal clad probe induce oxygen movement over significant distances in YBCO. Our images show changes in the reflectivity corresponding to a change in the oxygen concentration where the EM occurred. Possible mechanisms for inducing EM include the electron wind force (classical EM), ion drift in the electric field within the sample at these high current densities, or hot electron effects. Our data rules out the former two since the current density does not remain sufficiently large over the affected region, and electric field effects should extend through a grain boundary. No effects in neighboring grains are observed in the data. The results suggest that hot electrons injected into YBCO remain confined to a single grain, at least until they lose sufficient energy such that they are unable to induce oxygen EM. No topographic changes are observed during the EM. Difference images, generated by subtraction of before images from those taken after EM (after shifting to compensate drift), are useful for determining the size of the effect. They also clearly indicate the location of the oxygen movement with respect to the grain boundaries.