Tunnel-Electron-Induced Oxygen Movement in $YBa_2Cu_3O_{7-\delta}$ Measured with Near-Field Optical Microscopy

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The movement of atoms induced by electron motion, electromigration or electron-induced-motion (EIM), has been studied in many systems. In the case of the classic electron-wind mechanism, the atom motion is in the same direction as the current. We show here that this is not necessarily the case when few-eV electrons are used in an electron-excitation mechanism. In this case, the local electron interaction enhances the diffusion of the atoms. Naively, this localization of an electron interaction in a conductor seems unlikely, but it will occur when the electron can excite a carrier from a localized state on the atom rather than from the extended conduction states. The excitation places the atom in an unstable configuration, a Franck-Condon excitation, and it may move before relaxation if a vacancy is adjacent. Excitation from a localized state entails a threshold energy for the injected electron, which we measure for the case of oxygen motion in Yttrium barium cuprate (YBCO) and will present here. To better understand the mechanism of oxygen movement in YBCO while avoiding complications due to grain boundaries, we use a near-field scanning optical microscope (NSOM). The metal cladding of the NSOM probe provides a scanning tunneling microscope (STM) tip to pull (inject) electrons from (into) an industrial quality sample of YBCO. This induces movement of oxygen. We have shown that reflection-mode near-field scanning optical microscope can be used to image oxygen movement in YBCO. [1,2] Optical NSOM images taken before and after EIM are compared to eliminate the native background oxygen concentration variations and determine the amount of oxygen moved in the lattice and where the movement occurred, Fig. 1. It is interesting that the motion of oxygen described here shares many of the same qualitative features as the motion of vacancies in gold films with injection of few-eV tunnel electrons. [3,4] Both have *energy thresholds*, related to their respective band structures. The EIM is limited to a single grain in both cases, indicating that *few-eV electrons are scattered strongly at grain boundaries* in quite disparate materials. There are differences, however. The topographies of the gold films change as the atoms move, whereas the oxygen atoms in YBCO move in a fixed lattice with no detectable topographic change. The EIM of oxygen in YBCO changes in its superconducting properties, since they depend on the oxygen concentration. [5,6] We thank Brian Moeckly of Conductus for providing the YBCO.

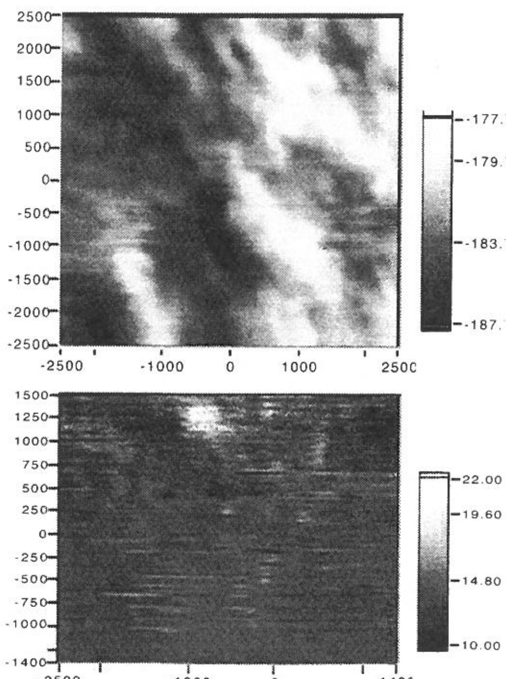

Figure 1: Top: background oxygen variation. Bottom: Drift-corrected difference image showing the change in oxygen concentration after electromigrating at 2 nA, 1 eV for 36 min.

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