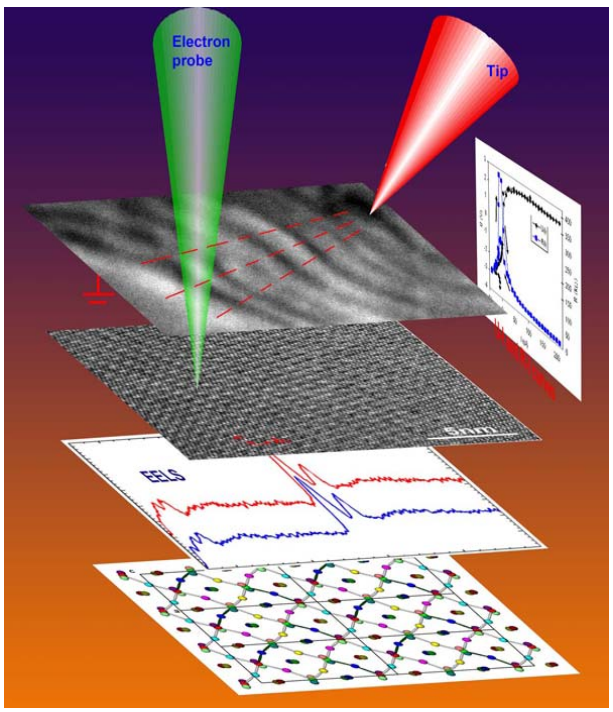
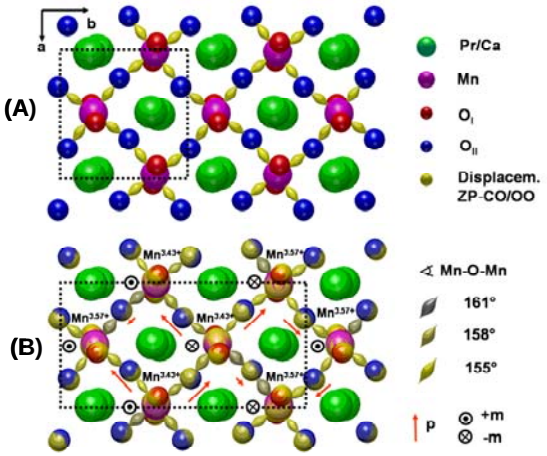
Key mechanism behind the Colossal Magneto-Resistance effect in the Manganites

The manganites are known to exhibit colossal magneto-resistance effects. Using state-of-the-art electron microscopy techniques we were able to reveal the key mechanism, polaron melting and ordering, that underlies the intriguing physical behavior of these materials. Polaron excitations in a crystalline material are dynamic lattice vibrations that accompanying a moving charge carrier as it travels through the crystal lattice. In manganites, this lattice distortion can strongly affect the electrical and magnetic properties of the material, yet the interaction is poorly understood. By imaging and spectrally analyzing manganite crystals on the atomic scale while simultaneously applying a local electric current, it was possible to directly observe colossal-resistance effects reflecting a solid-liquid transition in the polaron-ordered state of the manganite. Combined with the spectroscopy data that helped reveal bonding-electron excitations, this lead to a detailed structural model of the polaron-ordered and -disordered states. The models reveal atomic positions, displacements, polarizations, and magnetic-spin directions responsible for the physical properties and behavior of the material, which has the possibility of strongly impacting the development of correlated-electron devices.





Structural models showing disordered (A) and polaron ordered (B) states during application of electric stimulus. The models reveal details of the atomic position, lattice displacement, electron polarization (p), and magnetic spin direction (m) responsible for the physical properties of the material.

Experimental method: imaging probe (green) and resistance measurement probe (red). The first layered image shows propagation of the polaron waves. The second layer shows individual atoms of the electron ordered state. The third layer displays electron spectra revealing bonding-electron excitation. The bottom layer is the resulting structural model. The vertical graph shows the electrical resistance (I-V curve) of the crystal when current is applied.

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1. Proc. Nat'l. Acad. Sci., 104, 13597–13602 (2007).
2. Phy. Rev. B, 76, 174210 (2007).