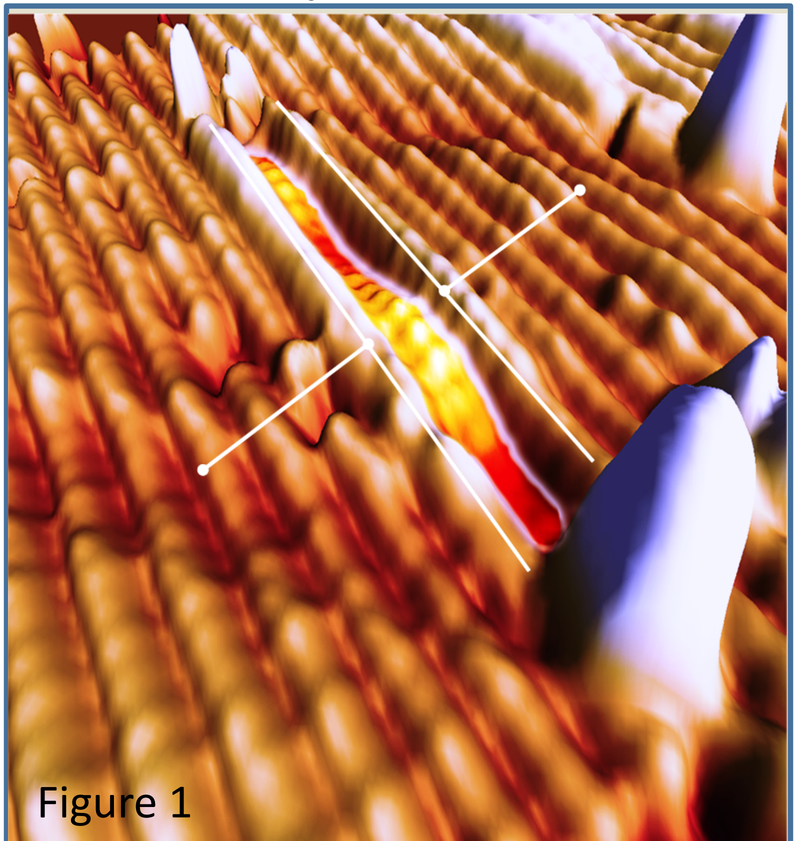
Coulomb blockade behavior in quasi-zero-dimensional quantum well

Vincent Meunier, M. H. Pan, F. Moreau, K. T. Park, and E. W. Plummer

We demonstrated that self-assembled nanostructures (SANs) can be used to fabricate the worlds smallest capacitor, setting up the stage for investigating unusual electron behavior and exploring unique opportunities for energy applications. The SANs consist of pairs of 10 to 20-nm long lines separated by 1.2 nm and act as a quantum well on the surface TiO_2(110). Inside the quantum well, a long wavelength oscillatory feature of the local density of states is observed at room temperature by scanning tunneling microscopy and attributed to the formation of electronic standing wave for the lowest energy quantum state using first principles calculations. This observation is the first attempt ever made to experimentally image the transition from a strongly correlated regime in a zero-dimensional system to a quasi-independent particle or band-like behavior in an extended one-dimensional system. TiO_2 is an important energy material as it is one of the main support used in industrial catalytic reactions. The unusual electronic behavior demonstrated here opens up new possibilities for highly efficient chemical reactivity with unprecedented applications in energy conversion and harvesting.



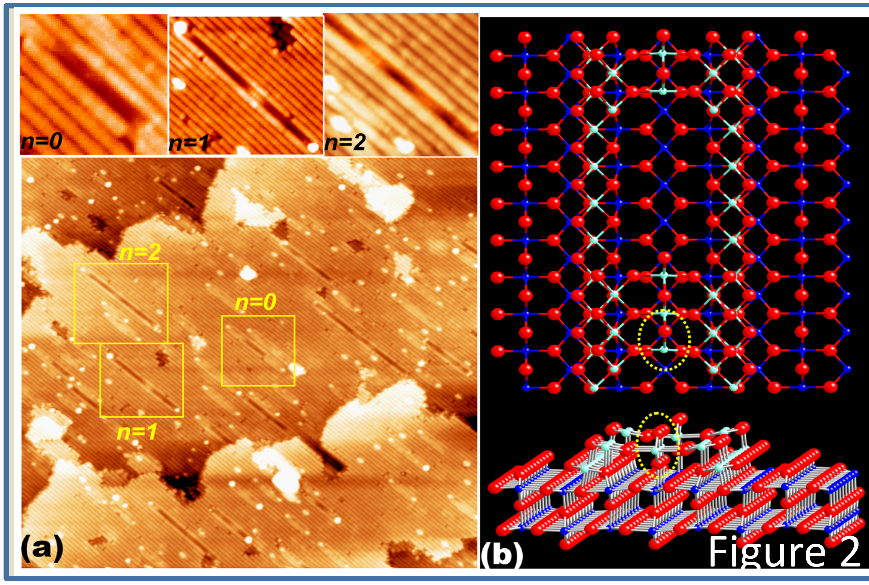


Fig. 1. (A) Three-dimensional STM image of a 10 nm long “nanoclip” nanostructure on TiO_2(110) substrate. A 3.8 nm period oscillation is observed between the two ends of the linear Nanoclip.
Fig. 2. (A) STM image for a large area scan (85 × 85 nm^2, 0.5 nA) exhibiting a number of double-line-defects (nanoclips), which show the observable charge oscillation inside. (B) Ball-and-stick structural model of a typical “nanoclip” viewed from the top and the side (Ti: light blue (nanoclip), dark blue(surface); O: red).

This research published in PNAS 107, 14968(2010), was conducted at the Center for Nanophase Materials Sciences, which is sponsored at Oak Ridge National Laboratory by the Scientific User Facilities Division, U.S. Department of Energy. E.W.P. was supported by DOE #DESC0002136.