# PHYSICS DEPARTMENT COLLOQUIUM

## "Addressing Atomic-scale Electronic States with Single Electrons"

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Atomic scale electronic states are of interest for two distinct reasons. As defects in electronic materials (such as gate oxides), they can limit the performance of devices. They also represent the ultimate quantum dot, potentially useful for information storage and processing. A novel method has been developed for manipulating single electrons to and from electrically isolated electronic states by quantum tunneling. The approach can be thought of as a "single electron" Scanning Tunneling Microscope (STM), requiring no sample conductivity. Single electrons can be induced to tunnel to/from an individual electron states by adjusting the voltage and gap between the scanning probe tip and state. Each tunneling electron is detected by electrostatic force. Since the transfer occurs by tunneling, *electrons can be injected or extracted from individual electronic states with atomic scale precision.* Recent images of HfSiOx and $SiO_2$ films, based upon this method, show a random array of individual "point-like"defect states, some with sub-nanometer size. Additionally, single electron spectroscopy measurements have been performed to determine the energy of individual electron states. In some of these measurements, post-tunneling energy relaxation of the state is observed. These new capabilities provide a new window through which to study and understand atomic scale defects in many electronic materials. They also provide a means to control the occupancy of individual electronic states on an atomic scale.


## THURSDAY, January 18, 2007
## 4:00 PM IN 102 JFB
## REFRESHMENTS AT 3:30 PM IN 219 JFB