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Single-electron tunneling force spectroscopy of electronic states in nonconducting surfaces[1] EZRA BUSSMANN, NING ZHENG, CLAYTON C. WILLIAMS, University of Utah — Typically, the scanning tunneling microscope (STM) cannot directly perform current-voltage spectroscopy on any electronic state with a lifetime greater than $\sim 10^{-6}$ seconds—the state cannot empty fast enough to supply the necessary $\sim$0.1 pA ($\sim 10^6$ e/s) imaging current. Recently, we reported a scanning probe technique that detects, by electrostatic force, single-electron tunneling events between a probe and states in a nonconducting surface. Here we determine the energy level of such a state by a single-electron tunneling spectroscopy, implemented by tuning the probe Fermi level with respect to the state by a dc voltage. A random telegraph signal (RTS), due to an electron tunneling back-and-forth between the probe and state, is observed when the Fermi level is near the state energy. We present spectroscopic data and extract the energy of a state in a thermal silicon dioxide film. The origin of the RTS is discussed. Additionally, we find evidence for energy relaxation and charge movement in these states. This new nanometer-scale approach provides the means to characterize electronic states in nonconducting surfaces, opening for exploration materials not accessible to the STM.
[1] E. Bussmann, D. J. Kim & C.C. Williams, *Appl. Phys. Lett.* **85**, 2538 (2004)

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