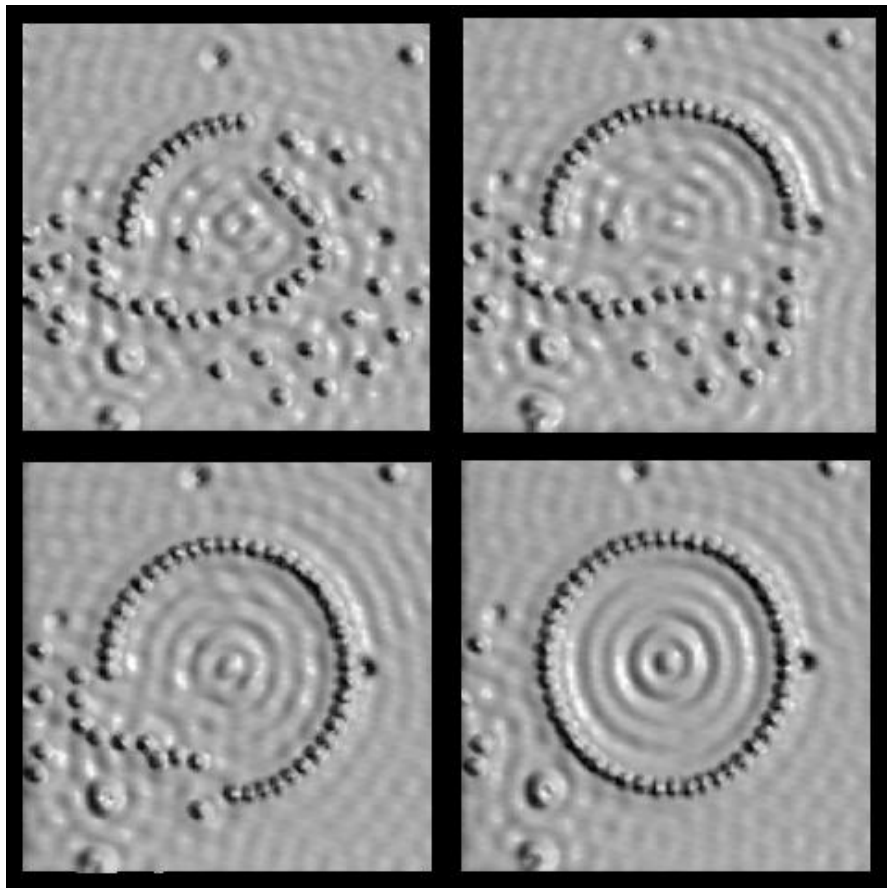
Nanomaterials

Lecture 11: Scanning Probe Lithography

Quantum Corrals



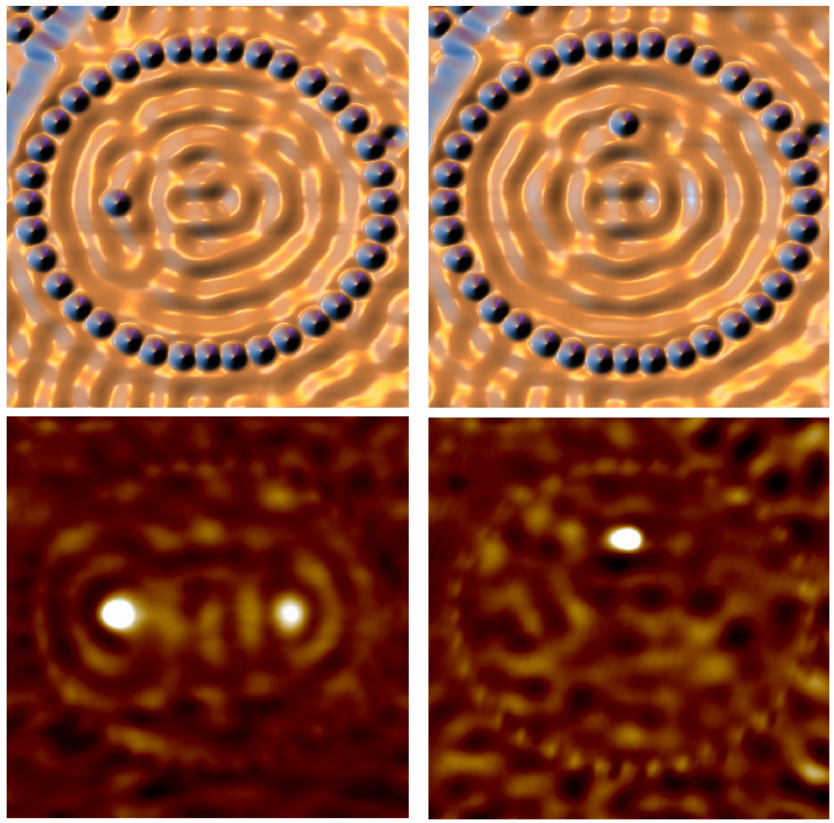
Fe atoms on Cu(111)

Don Eigler, IBM Alamden, http://www.almaden.ibm.com/vis/stm/atomo.html

Quantum Mirage (Kondo Resonance)

Topography:

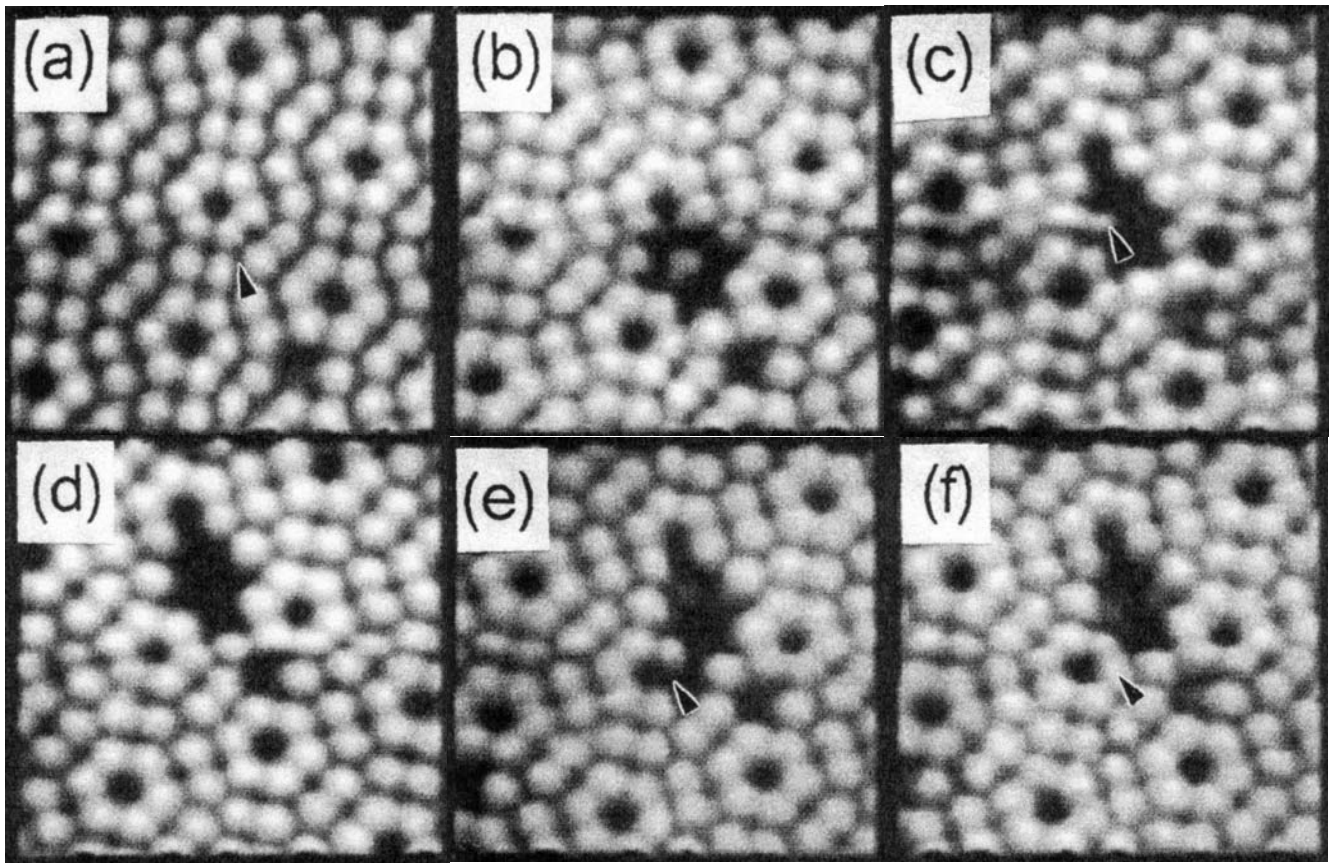
dI/dV:



Co atoms on Cu(111)

Don Eigler, IBM Alamden, http://www.almaden.ibm.com/vis/stm/atomo.html

Room Temperature Manipulation of Si(111)



C. Julian Chen, *Introduction to Scanning Tunneling Microscopy*

Field Evaporation of Gold

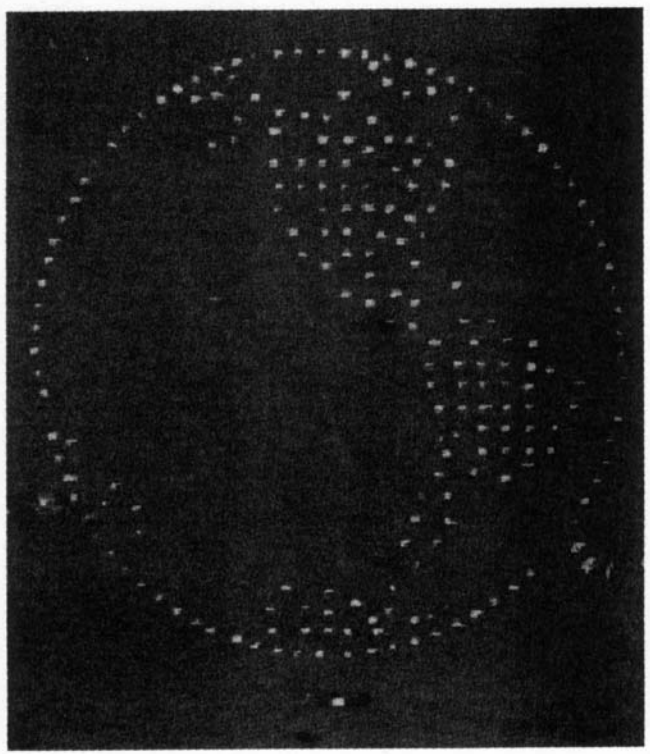
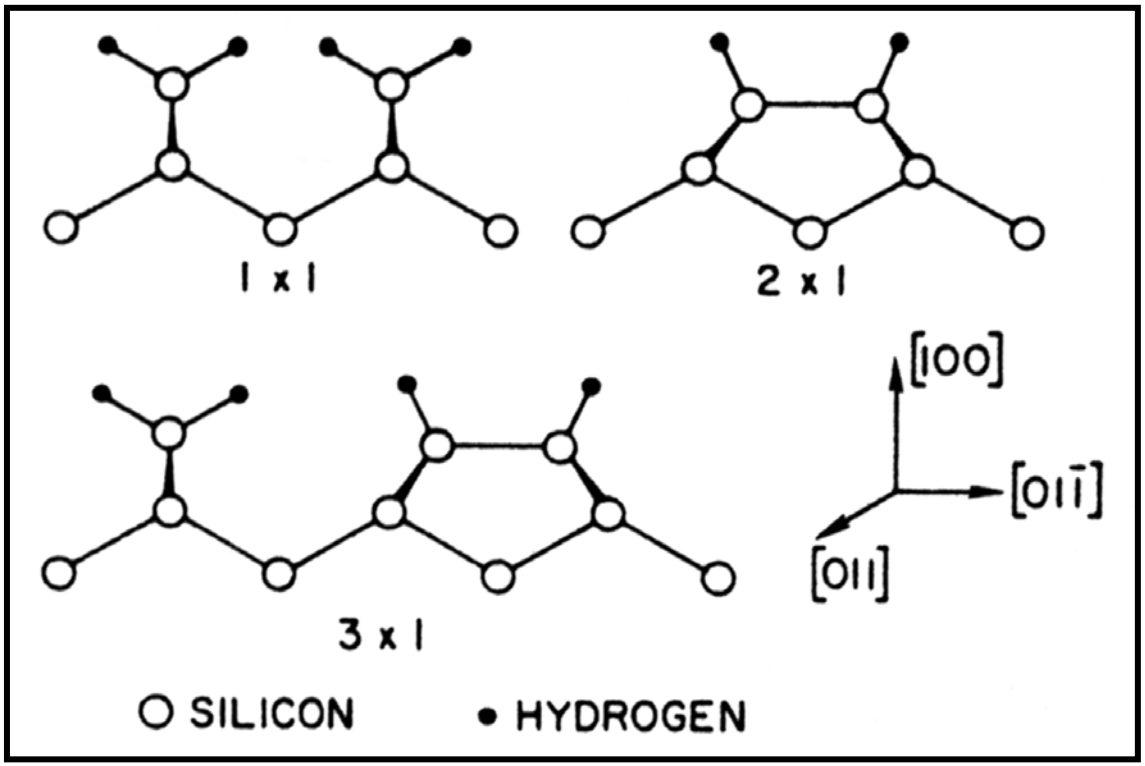
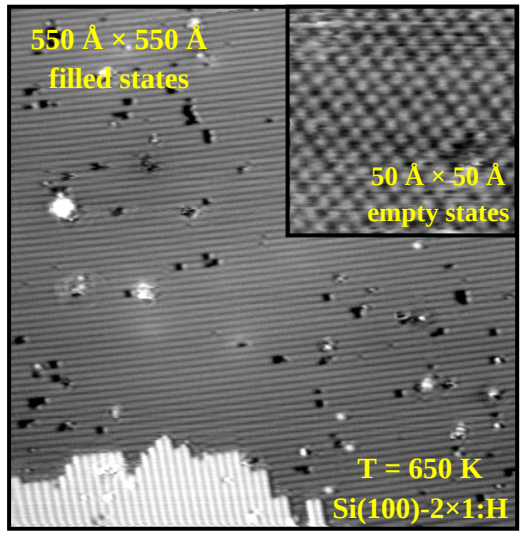


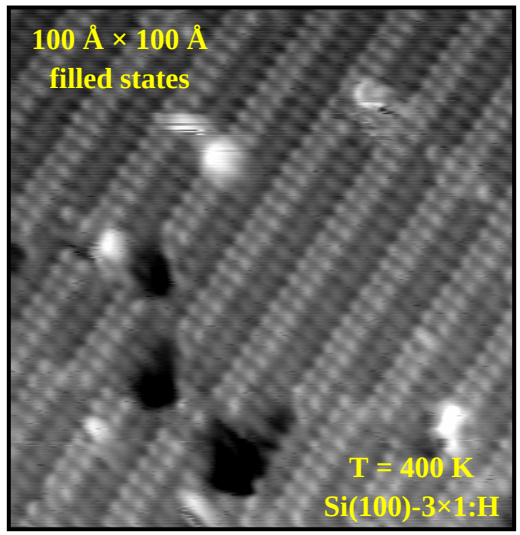
Plate 31. "It's a Small World": A miniature map of the Western Hemisphere. By applying a voltage pulse between a gold tip and a gold surface, a mound of 100–200 Å in diameter and 10–20 Å in height is formed. The location of the mound can be precisely controlled. By programming the positions of the mounds, a gold map is constructed. The diameter of the map is about 1 μm, giving the map a scale of about 10 trillion to 1. For the deposition process, see Mamin, Guenter, and Rugar (1990) for details. Original image courtesy of H. J. Mamin.

C. Julian Chen, *Introduction to Scanning Tunneling Microscopy*

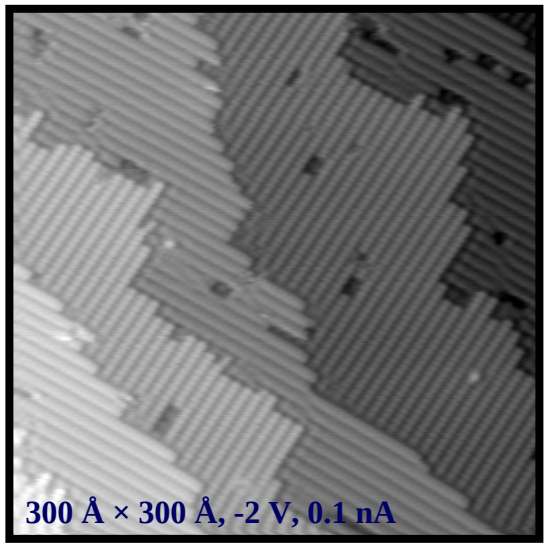
Hydrogen Passivated Si(100)



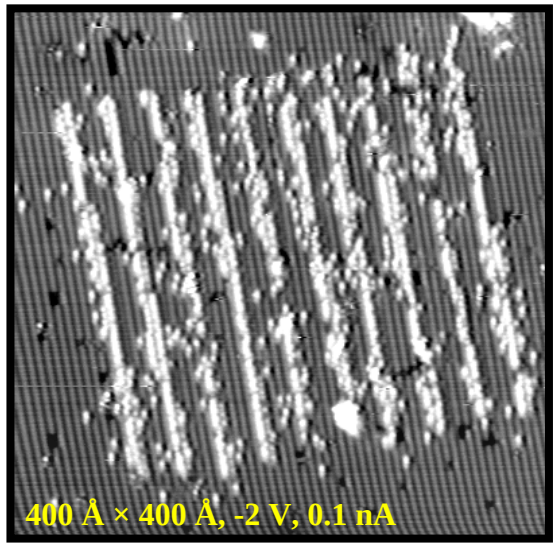




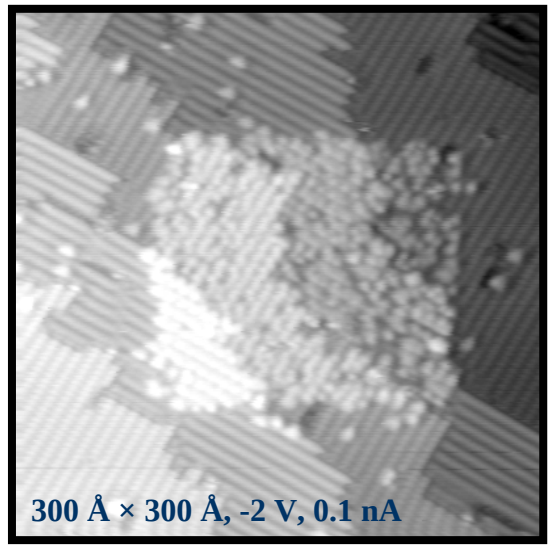
STM Nanolithography on Si(100)-2×1:H



A relatively stable and unreactive surface is produced by hydrogen passivating the Si(100)-2×1 surface in ultra-high vacuum (UHV).



Highly reactive "dangling bonds" are created by using the STM as a highly localized electron beam.

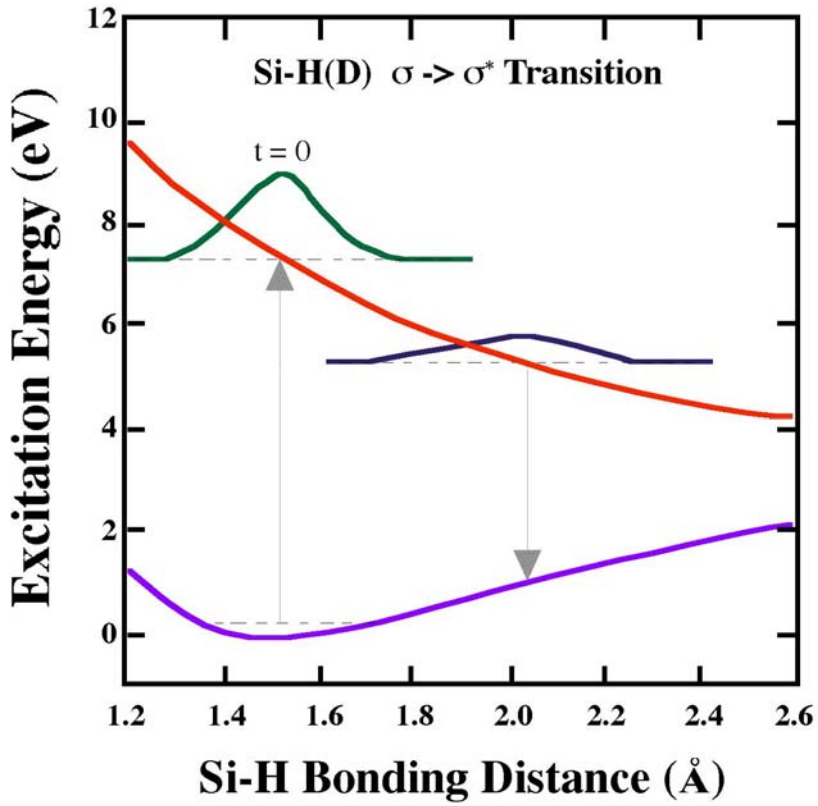


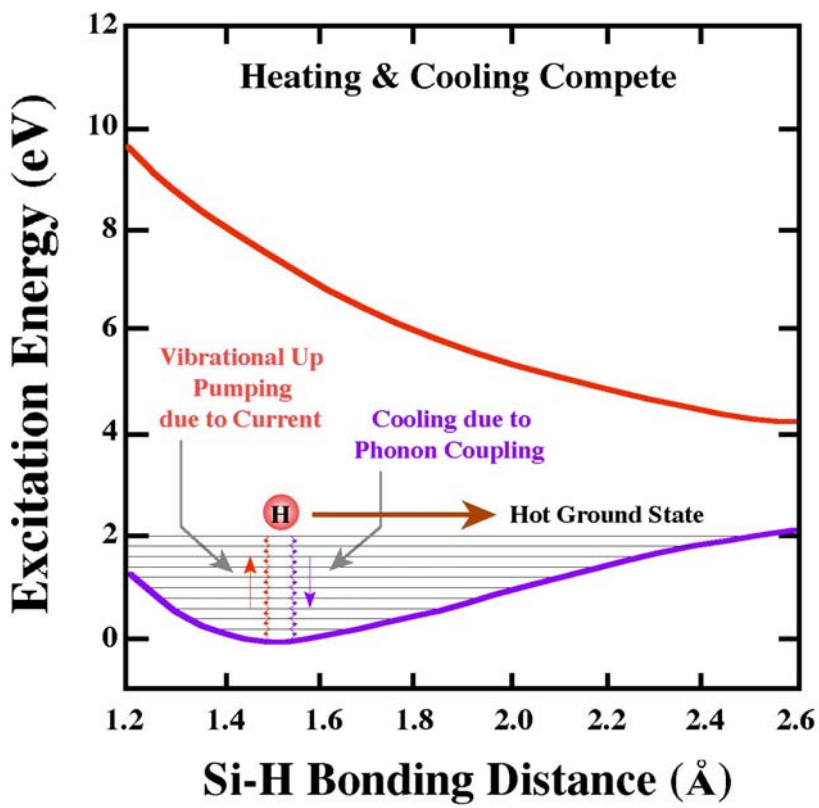
The linewidth and desorption yield are a function of the incident electron energy, the current density, and the total electron dose.

- **Selective chemistry can be accomplished on patterned areas.**

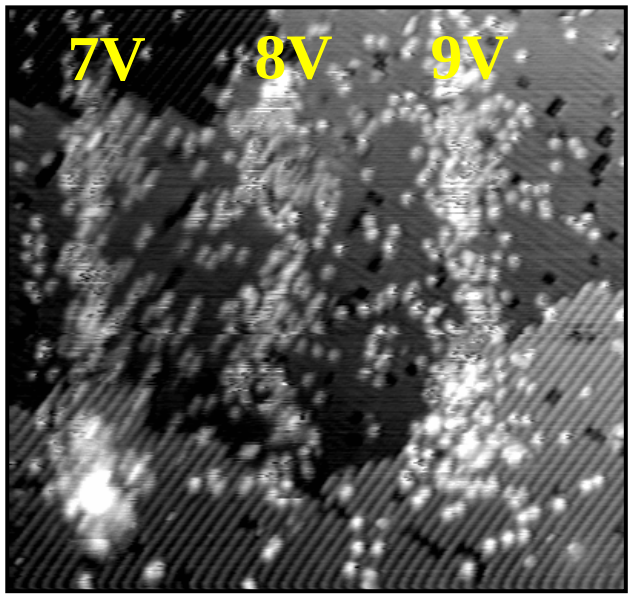
J. W. Lyding, *et al.*, *Appl. Phys. Lett.*, **64**, 2010 (1994).

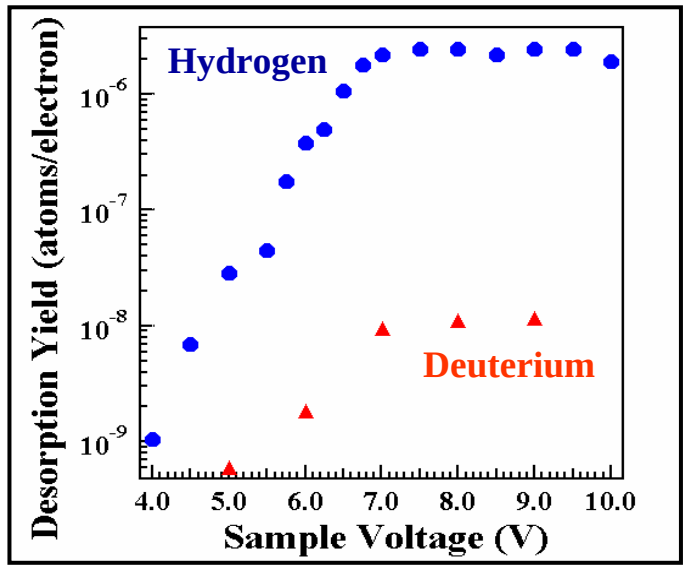
Hydrogen Desorption Mechanisms





Electron Stimulated Desorption Isotope Effect

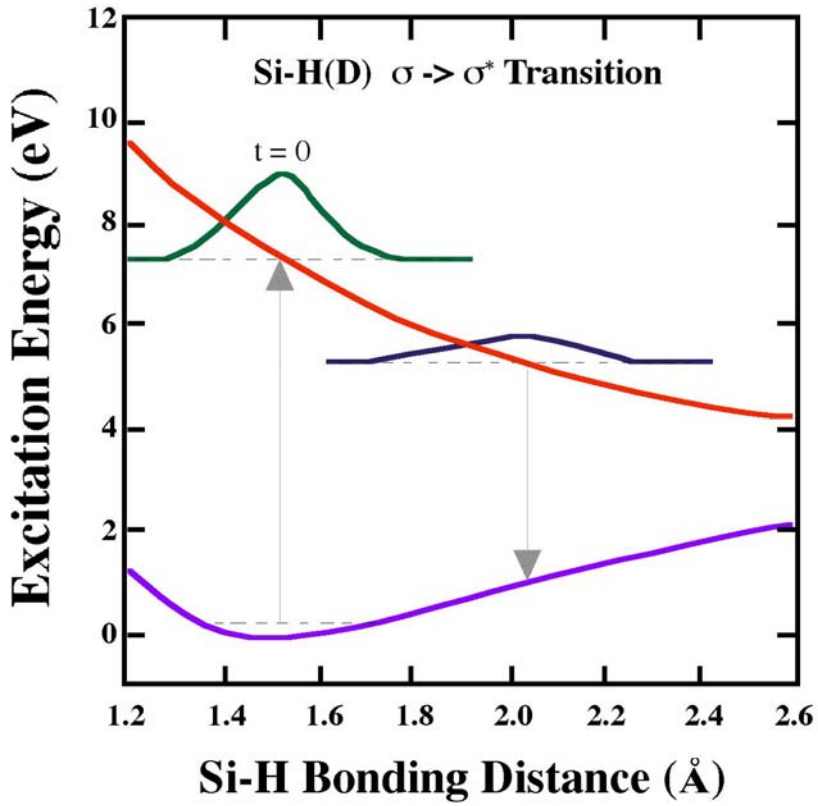


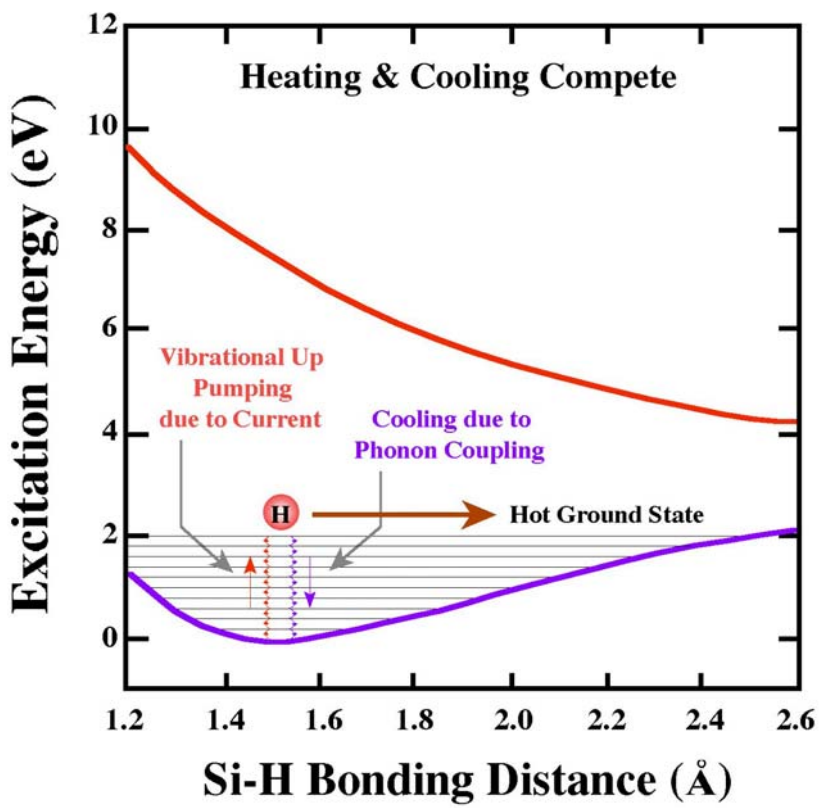


- **Deuterium has a much lower ESD yield than hydrogen.**
- **Desorption conditions exist where all of the hydrogen and none of the deuterium is removed from the surface.**
- **Deuterating CMOS devices leads to longer device lifetimes.**

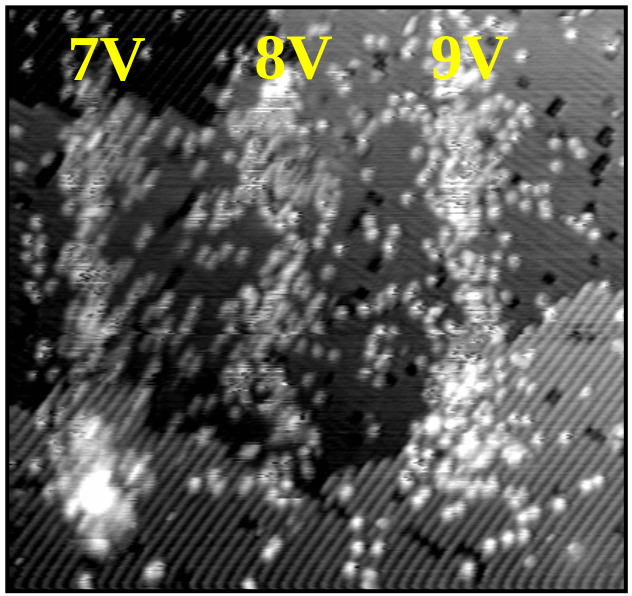
Ph. Avouris, *et al.*, *Chem. Phys. Lett.*, **257**, 148 (1996).

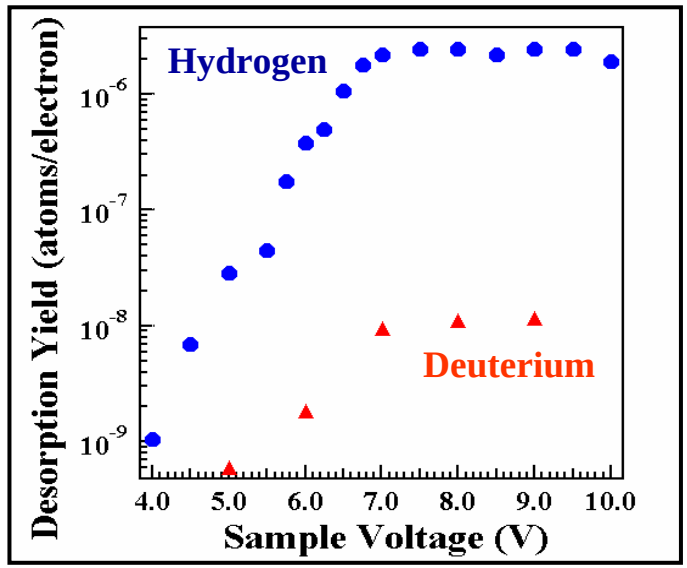
Hydrogen Desorption Mechanisms





Electron Stimulated Desorption Isotope Effect





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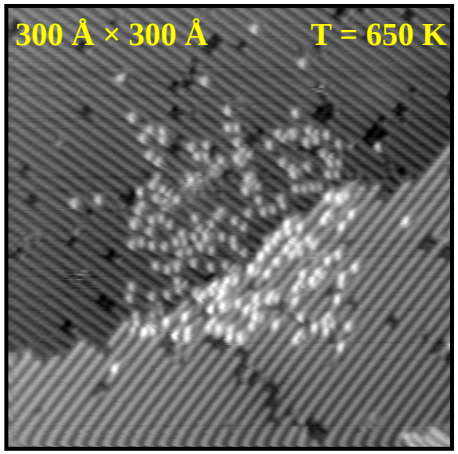
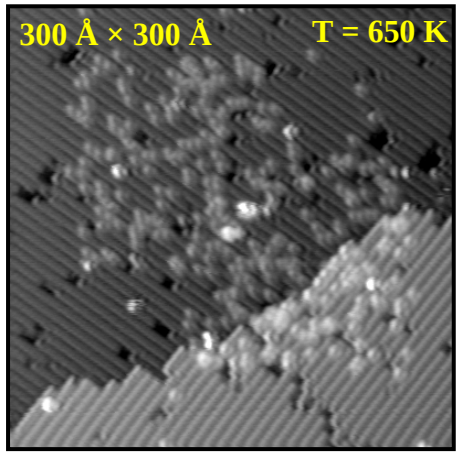
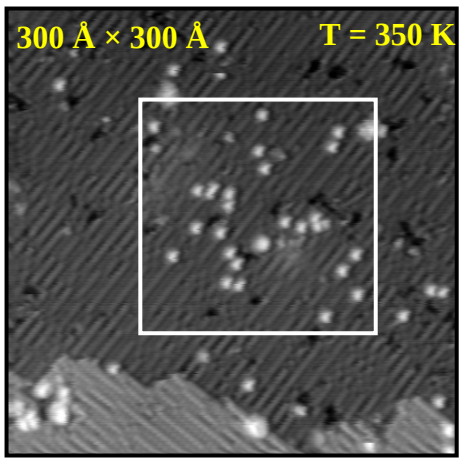
Ph. Avouris, *et al.*, *Chem. Phys. Lett.*, **257**, 148 (1996).

Direct Measurement of D:H Ratio

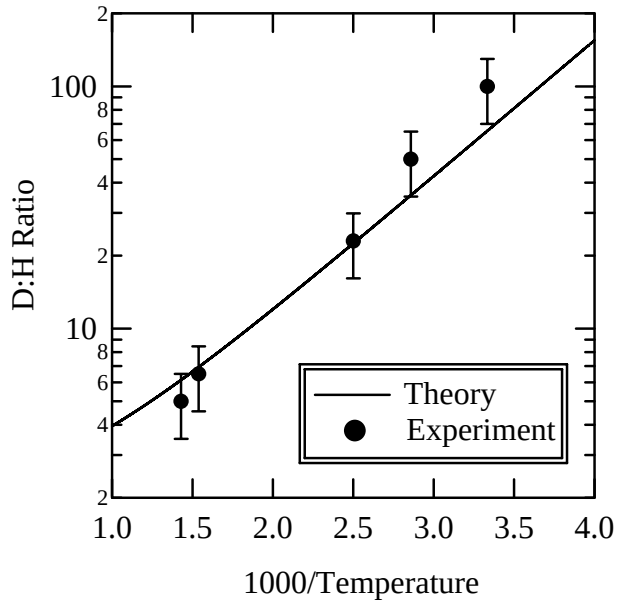






Reducing the thermal budget of CMOS processing should lead to greater deuterium incorporation and longer device lifetimes.

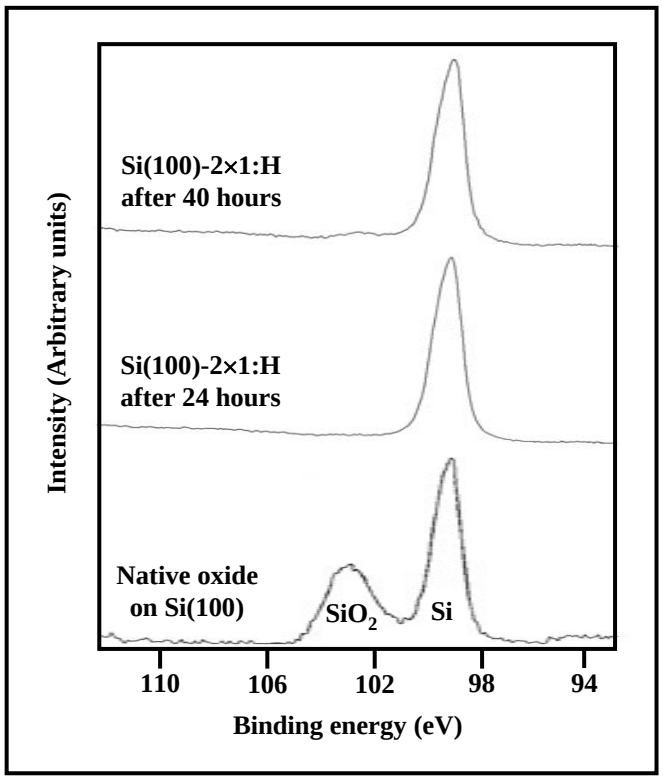
Passivation at 650 K ⇒ D:H Ratio ~ 5
Passivation at 350 K ⇒ D:H Ratio ~ 50



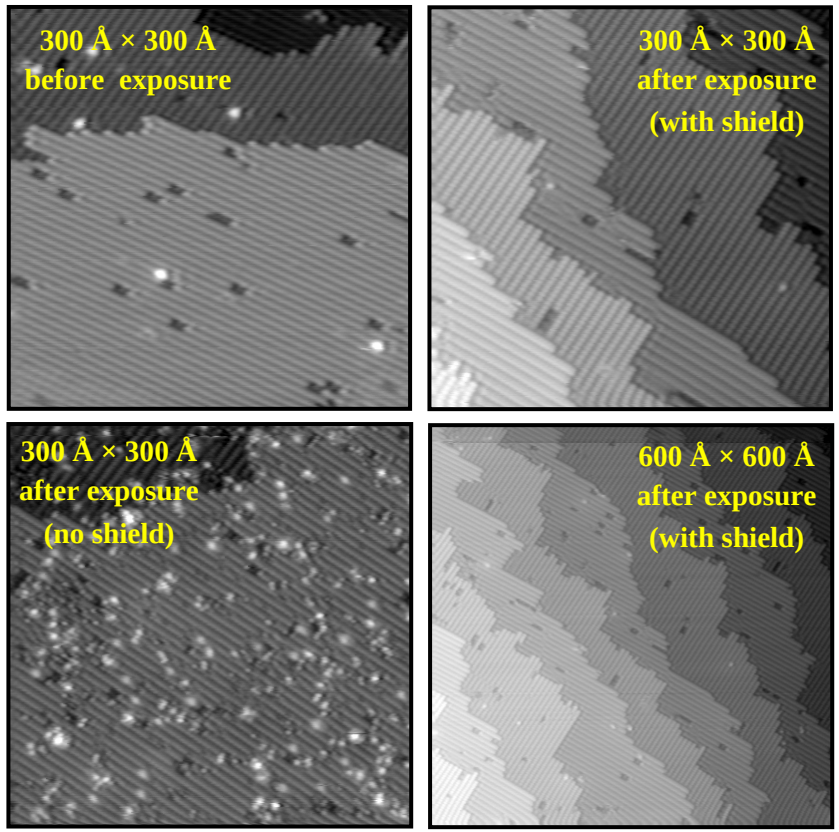
Statistical thermodynamics model confirms experimental results.

M. C. Hersam, *et al.*, *Appl. Phys. Lett.*, **80**, 201 (2002).

Robustness of Si(100)-2×1:H

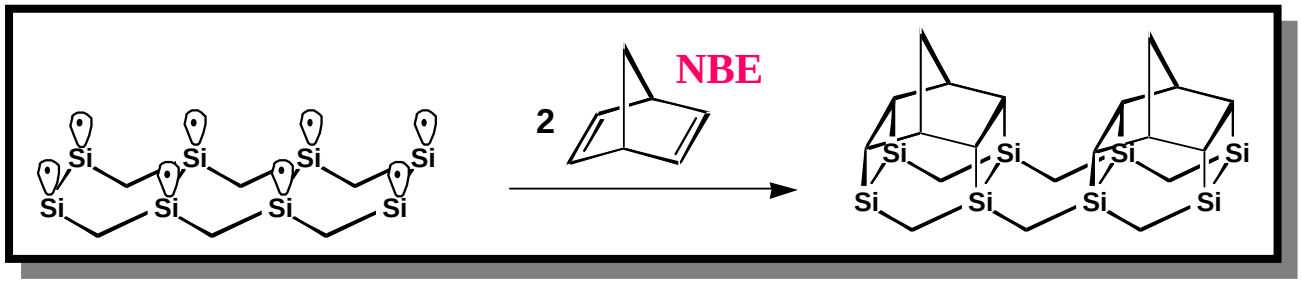


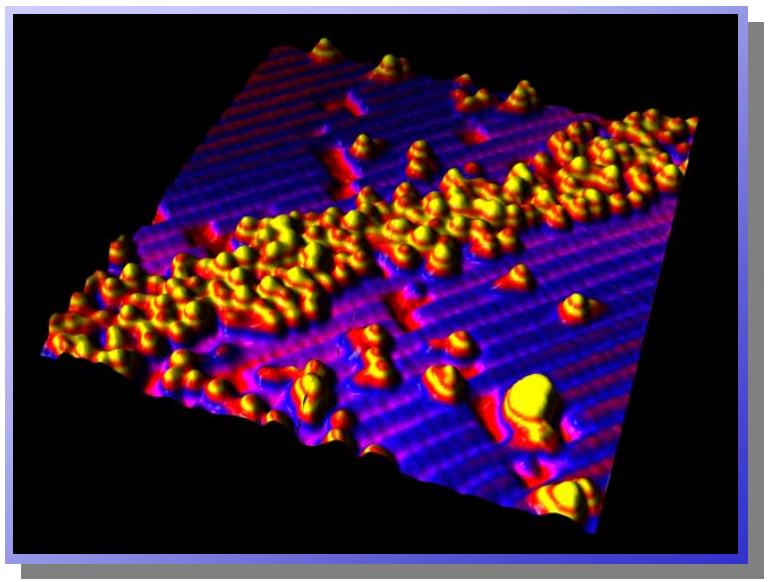
XPS results after ambient exposure

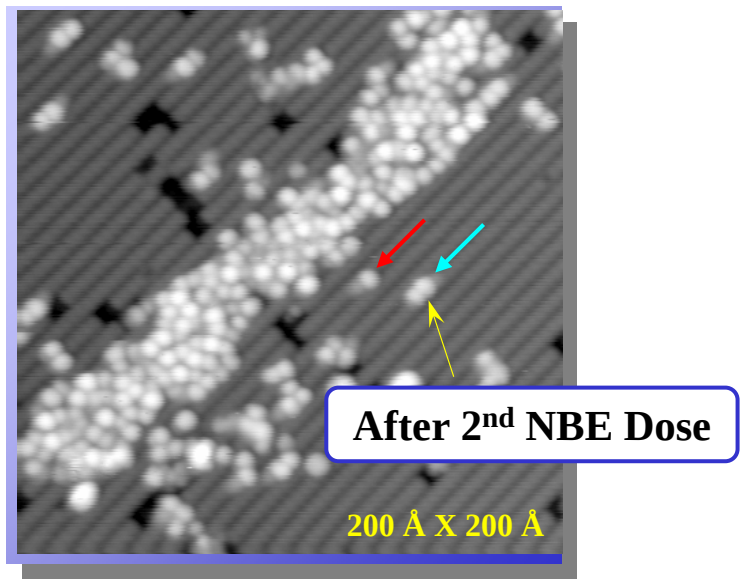


M. C. Hersam, *et al.*, *Appl. Phys. Lett.*, **78**, 886 (2001).

Selective Molecular Adsorption of Norbornadiene on Silicon

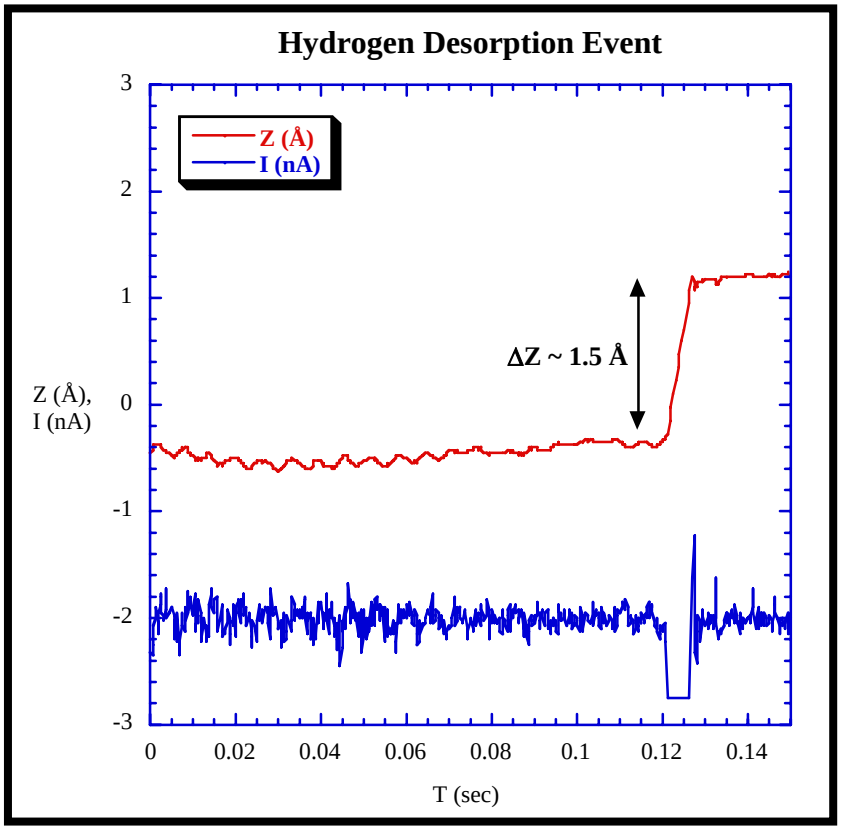


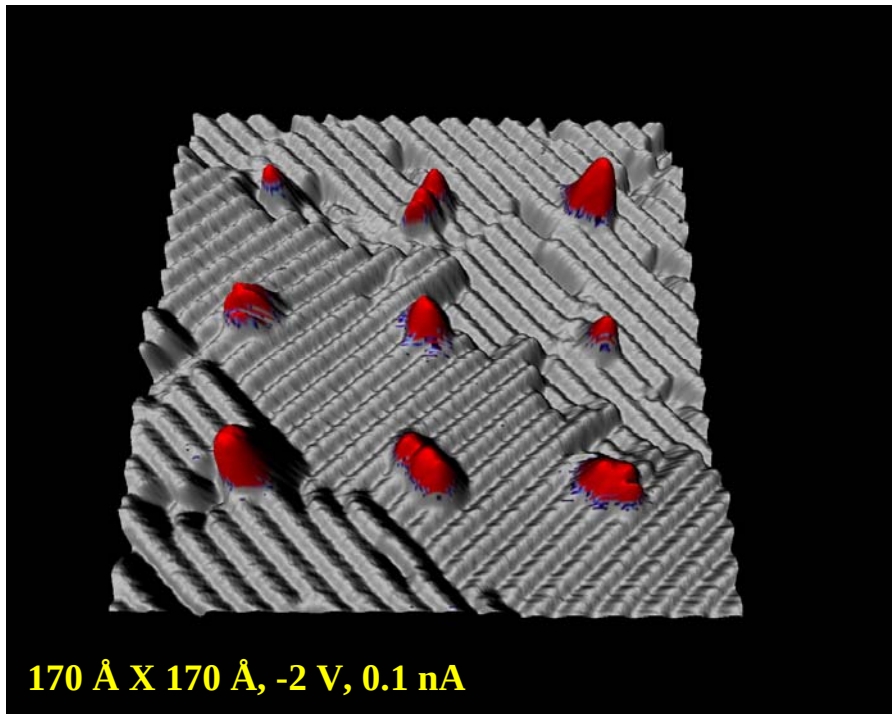




G. C. Abeln, *et al.*, *J. Vac. Sci. Technol. B*, **16**, 3874 (1998).

Feedback Controlled Lithography

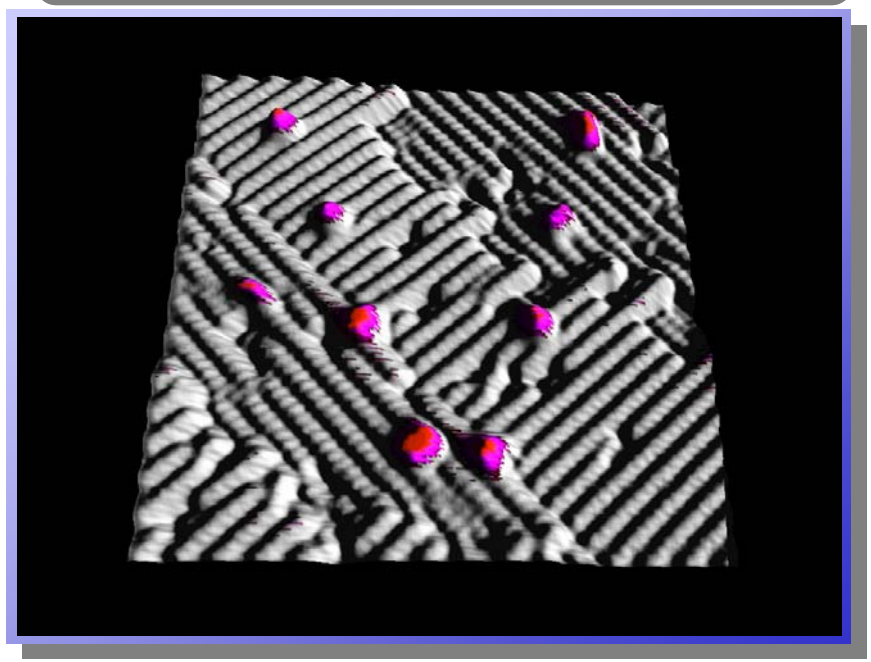


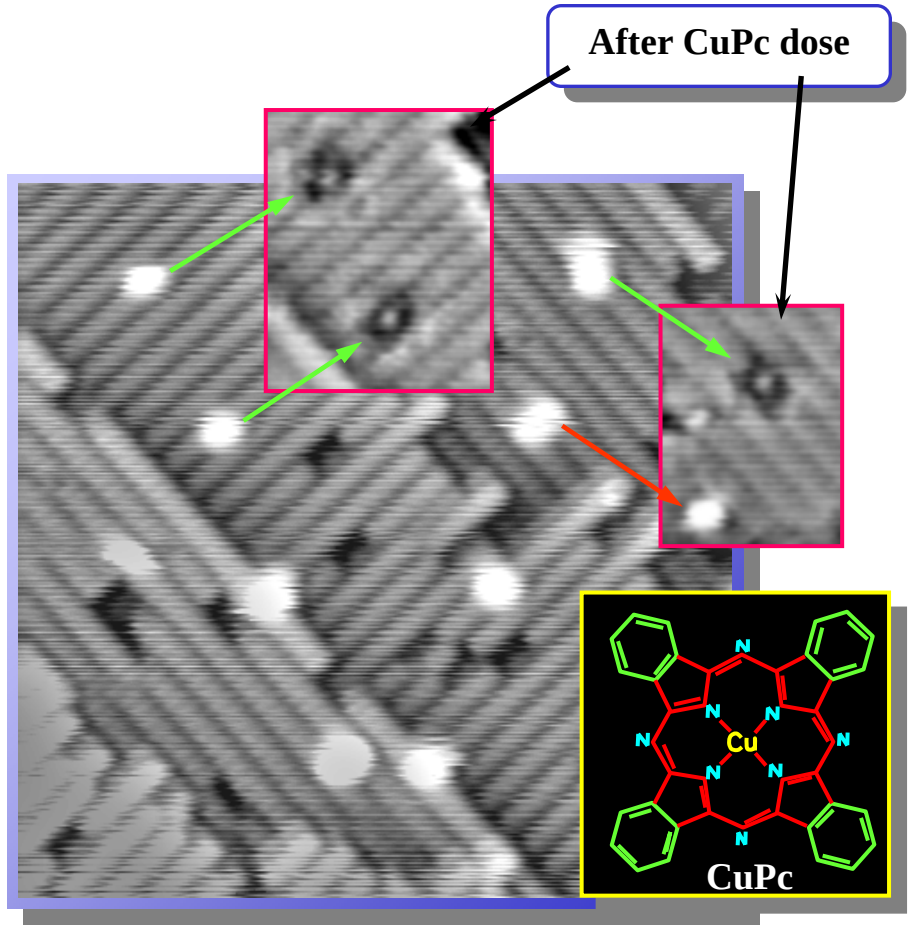


M. C. Hersam, *et al.*, *Nanotechnology*, **11**, 70 (2000).

Patterning Individual Molecules with FCL

Use FCL to create template of Si dangling bonds





M. C. Hersam, *et al.*, *J. Vac. Sci. Technol. A*, **18**, 1349 (2000).