Nanomaterials

Lecture 11: Scanning Probe Lithography
Quantum Corrals

Fe atoms on Cu(111)

Quantum Mirage (Kondo Resonance)

Topography:

Co atoms on Cu(111)

dI/dV:

Room Temperature Manipulation of Si(111)

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

Department of Materials Science and Engineering, Northwestern University
Field Evaporation of Gold

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

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Hydrogen Passivated Si(100)
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.

Hydrogen Desorption Mechanisms

**Si-H(D) \( \sigma \rightarrow \sigma^* \) Transition**

**Heating & Cooling Compete**

- Vibrational Up Pumping due to Current
- Cooling due to Phonon Coupling
- Hot Ground State

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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.

Hydrogen Desorption Mechanisms

![Graph 1: Si-H(D) \( \sigma \rightarrow \sigma^* \) Transition](image)

- **Excitation Energy (eV)**
- **Si-H Bonding Distance (Å)**
- **t = 0**

![Graph 2: Heating & Cooling Compete](image)

- **Excitation Energy (eV)**
- **Si-H Bonding Distance (Å)**
- **Vibrational Up Pumping due to Current**
- **Cooling due to Phonon Coupling**
- **Hot Ground State**

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Direct Measurement of D:H Ratio

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

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

Statistical thermodynamics model confirms experimental results.


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Robustness of Si(100)-2×1:H

XPS results after ambient exposure

Selective Molecular Adsorption of Norbornadiene on Silicon


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Feedback Controlled Lithography

Hydrogen Desorption Event

\[ \Delta Z \sim 1.5 \, \text{Å} \]

Use FCL to create template of Si dangling bonds