STM manipulation and dynamics of phason on Si(001)

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Open-Minded

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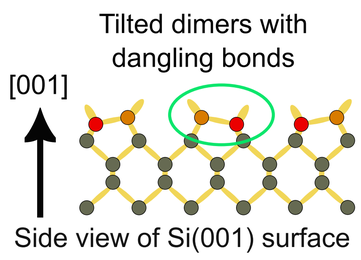
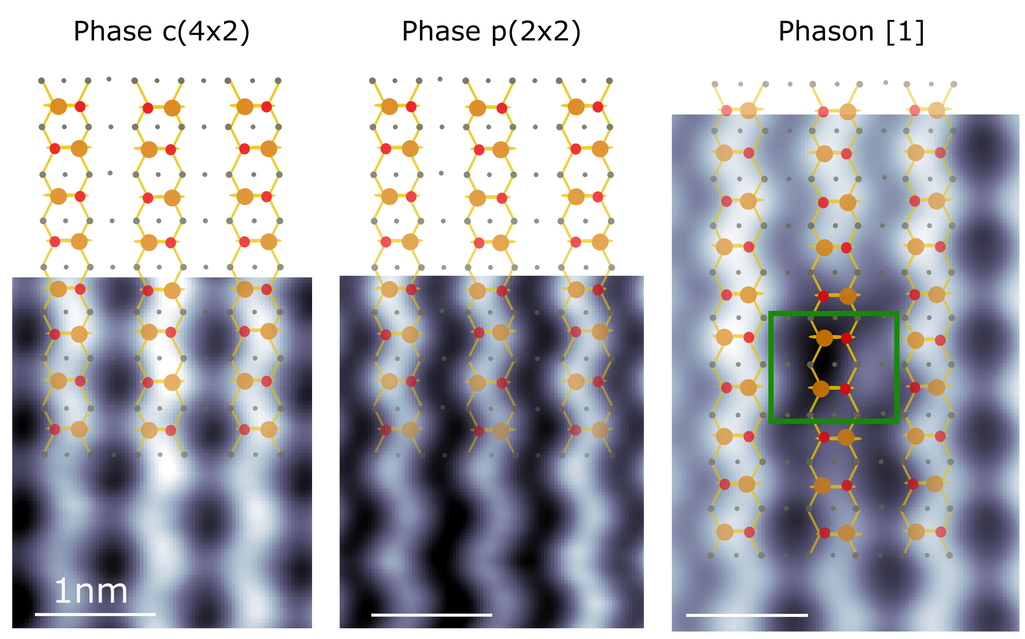
Motivation

- Si(001) is an essential surface in technological applications.
- Better understand the role of structural atomic defect, so-called phasons, for phase transition of Si(001) superstructure.
- Scanning tunneling microscope (STM) as suitable tool to access and manipulate individual phasons on Si(001).
- Investigate the phason dynamics under electron injection and understand the phason propagation.
- Influence of the local environment (*e.g.* defect) on the phason dynamics/propagation.

Si(001) surface and reconstruction



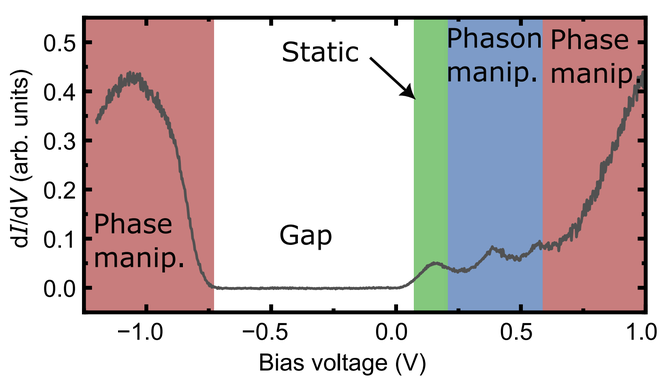
- Reconstruction of Si(001) surface: Rows of tilted Si dimers.
- Within rows: Alternating orientation of buckling angle.
- Between adjacent rows: Buckling alternation in or out-of phase.



STM topographs on Si(001), 0.2 V, 20 pA

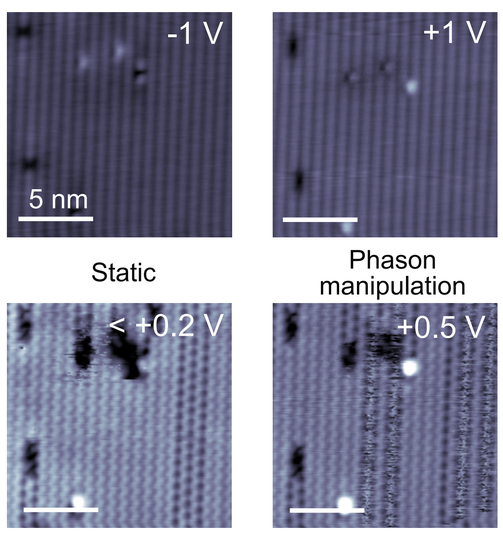
Sample characteristics

- Highly doped Si(001), (As doped, 0.003 -004 Ω.cm)
- Flashed at 1200 °C in UHV
- STM measurements at 4.5 K

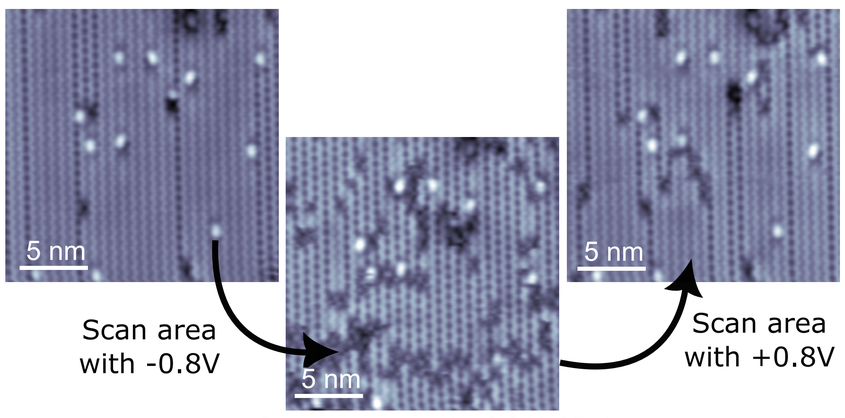


Tunneling spectroscopy (STS) on Si(001)

Phase manipulation



Phase manipulation



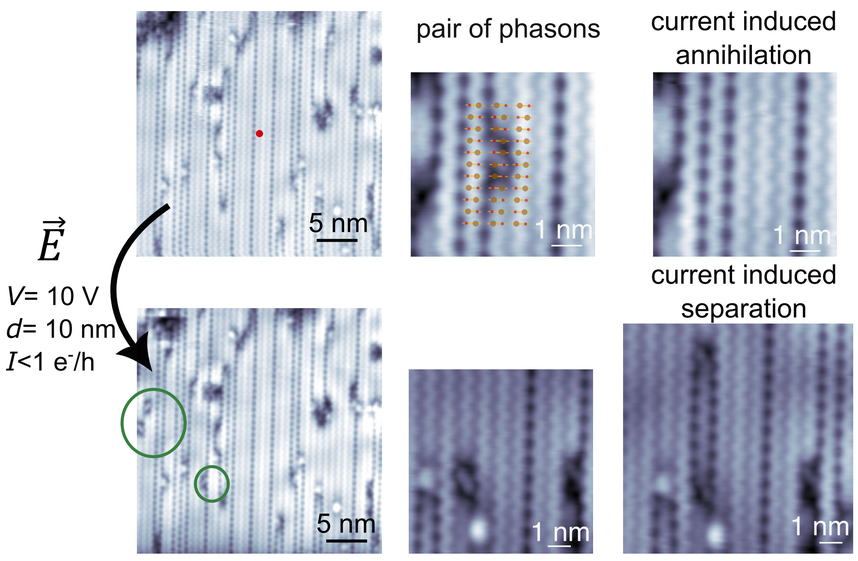
Scans recorded with 0.3 V, 25pA

- Bias polarity influence the stability of the phase [2]:

  Negative bias voltage favors the c(4x2) phase.

  Positive bias voltage favors the p(2x2) phase.
- High phason concentration after phase manipulation.

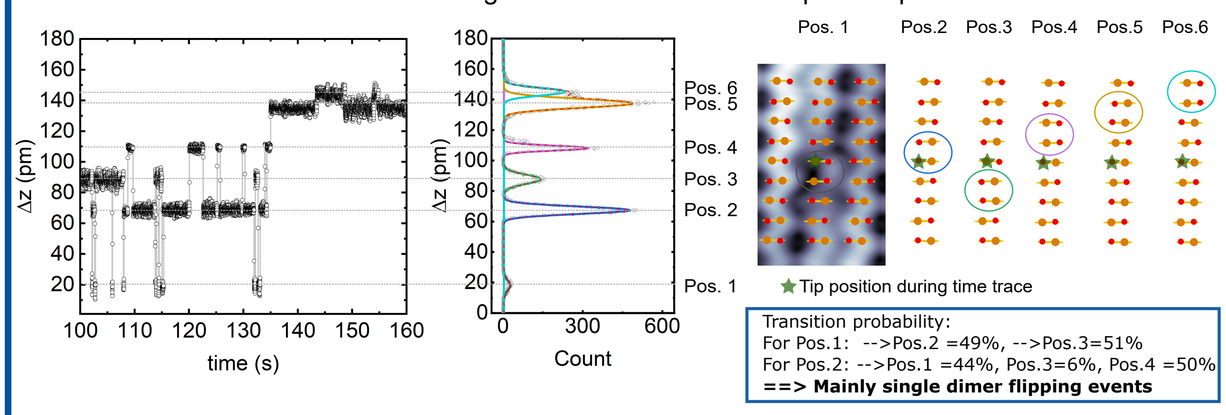
Formation and annihilation of phasons

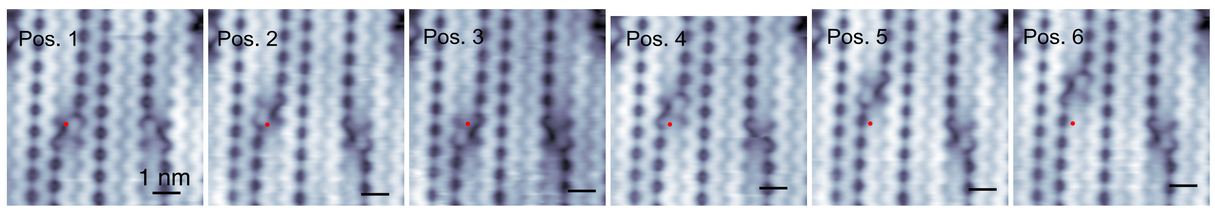


- Formation of pairs of phasons with large electric field (no current involved).
- Pair of phasons can be annihilated or separated in two individual phasons.
- Phason pair creation (tip-approach-induced) previously shown in AFM experiment [3].

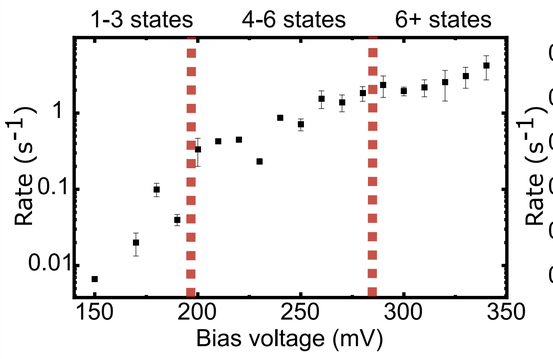
Displacement dynamics of an individual phason

Tip height (Δz) time trace over a phason at 240 mV, 30 pA
→ Multilevel switching associated with different phason positions.



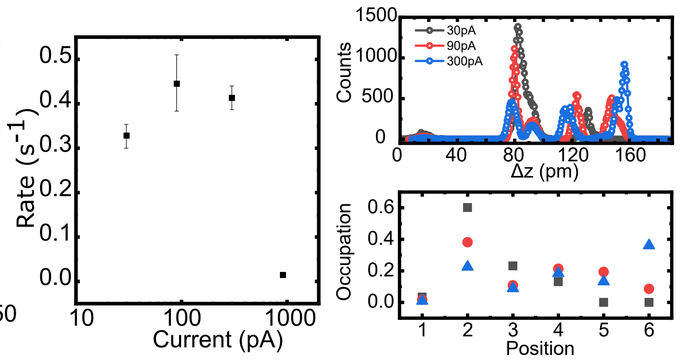


Voltage dependency of switching



- Increase of switching rate with voltage. ➡ electron induced switching.
- Increase of observed levels with voltage.
- Does the switching rate depends on the phason distance? (further analysis in progress)

Current dependency of switching



- No clear current dependency of total switching.
- Quasi-quenching of the switching at high current. ➡ Other sources of influence (tip interaction?)
- Evolution of the level occupation with current ? ➡ More statistics required

Conclusion-Outlooks

- Fine adjustements of the experimental conditions (bias voltage, tip surface distance) allows for the selectivity of the surface manipulation, phase or phason (propagation or creation).
- Propagation of phason measured with atomic precision
- More statistics and deeper analysis on phasons manipulation should bring new insights in dimer flipping dynamics.
- Implementation of faster measurements methods (ultrashort voltage pulse, stochastic resonance) to study dynamics at higher at higher voltages

References:

[1] Y. Pennec et al, Phys. Rev. Lett., 96, 026102, (2006)

[2] K. Sagisaka et al, Phys. Rev. Lett., 91, 146103, (2003)

[3] A. Sweetman et al, Phys. Rev. B, 84, 085426 (2011)

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