The Structure of Sb-Terminated GaAs(001) Surfaces*

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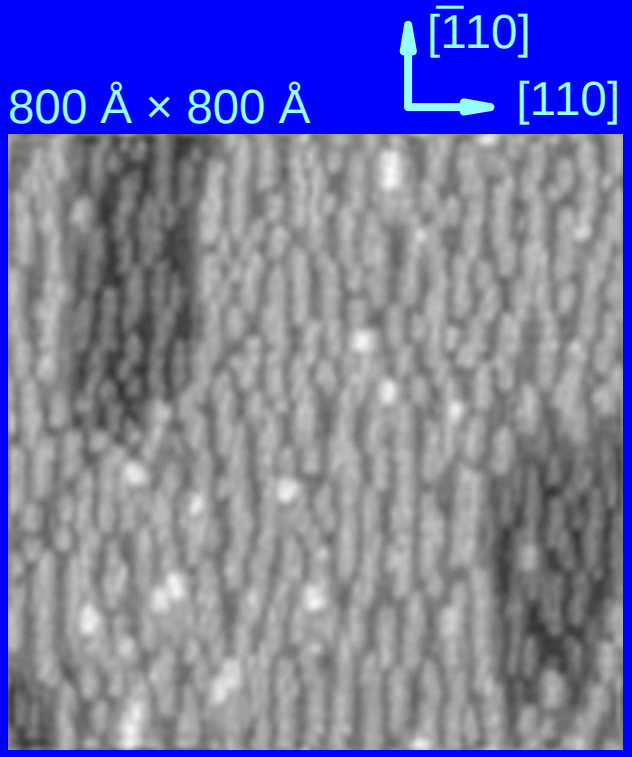
Sb on GaAs(001)-(2×4): Background

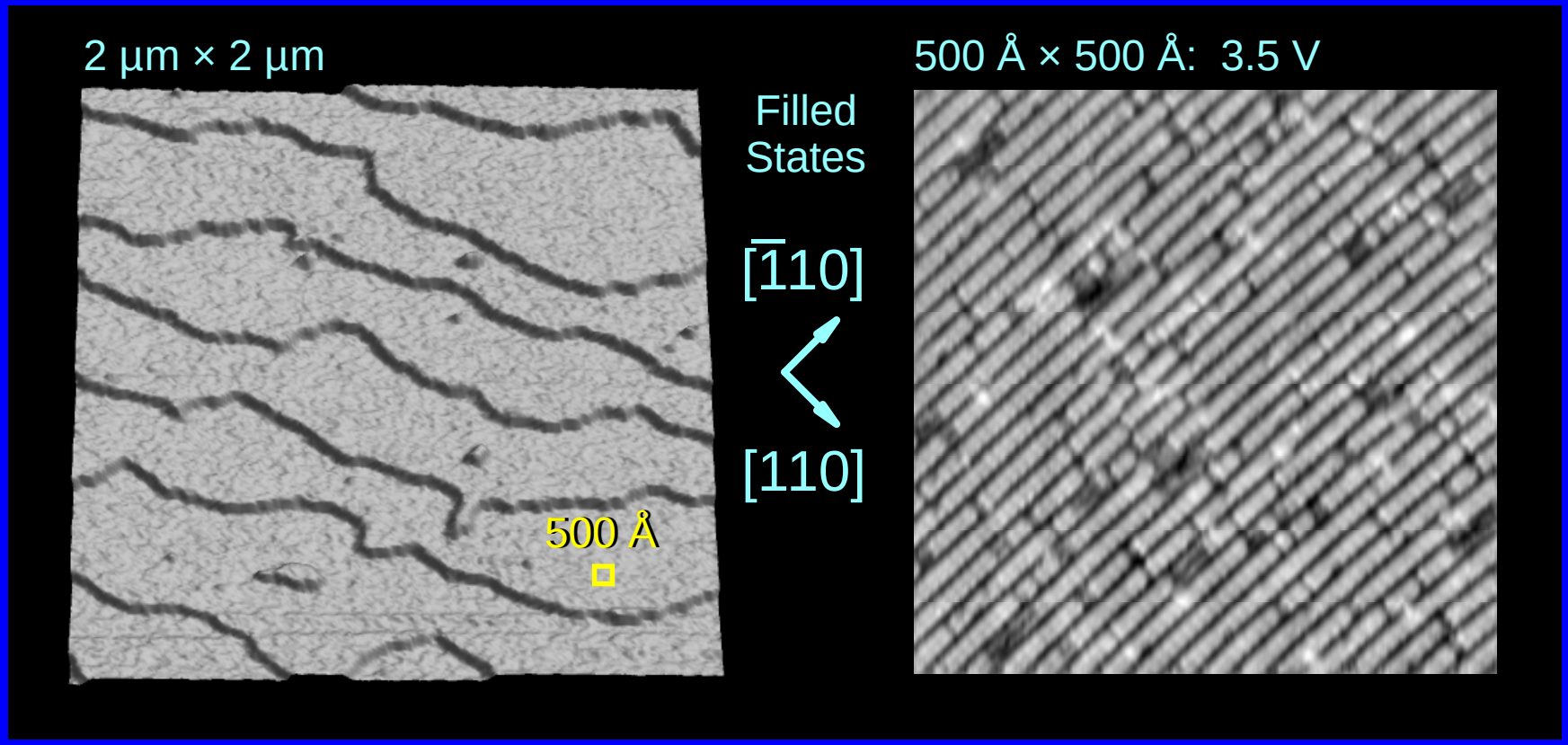
- GaSb, AlSb, InSb/GaAs for novel superlattice, quantum well electronics
  - Structure of interfaces related to "starting surface"
- Starting surface for III-Sb Quantum Dots/GaAs
- Two reconstructions reported: 2×8, 2×4
  - One STM study and one theory study of 2×4



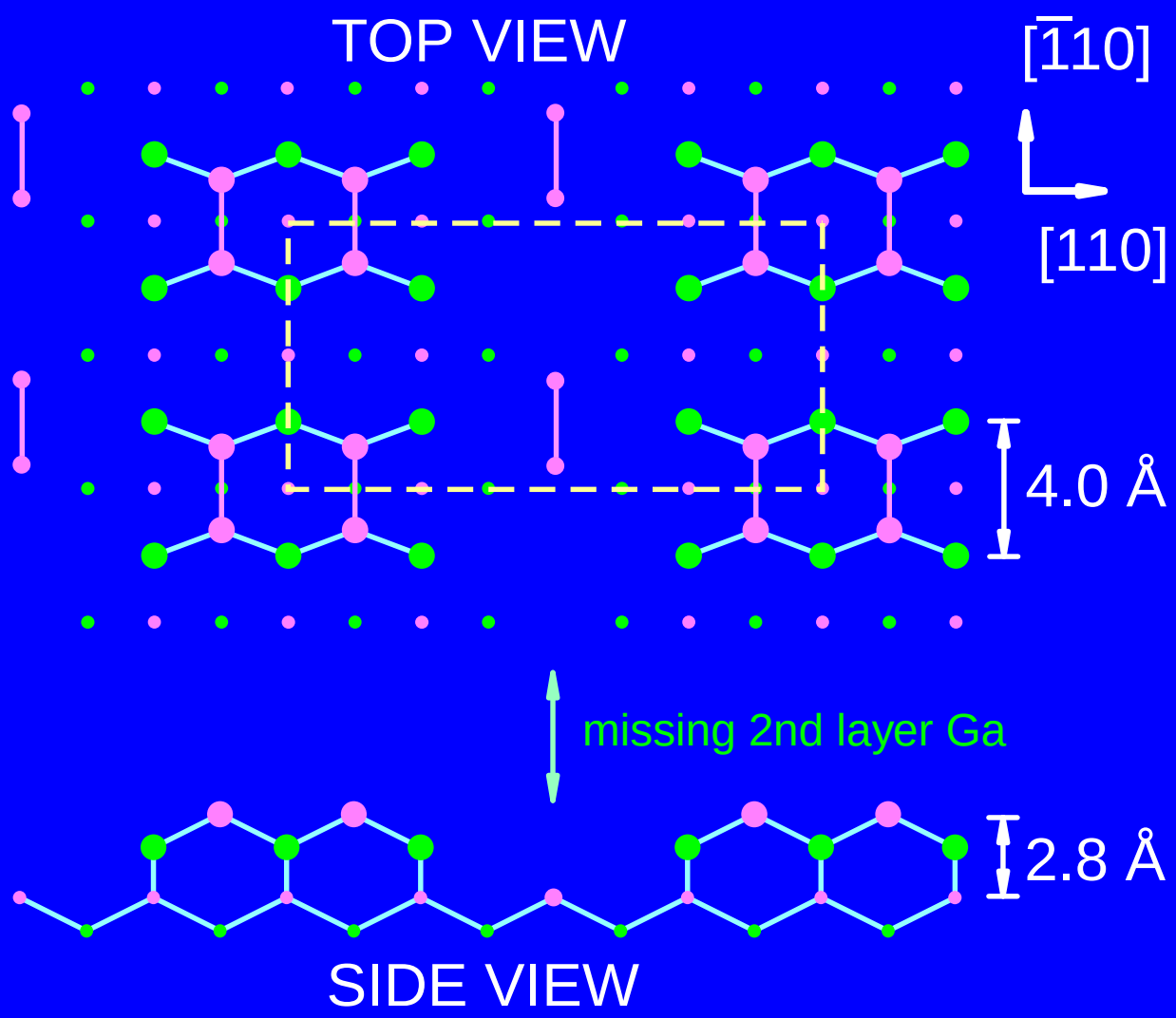
1.5 ML InSb on GaAs(001)-(2×4)

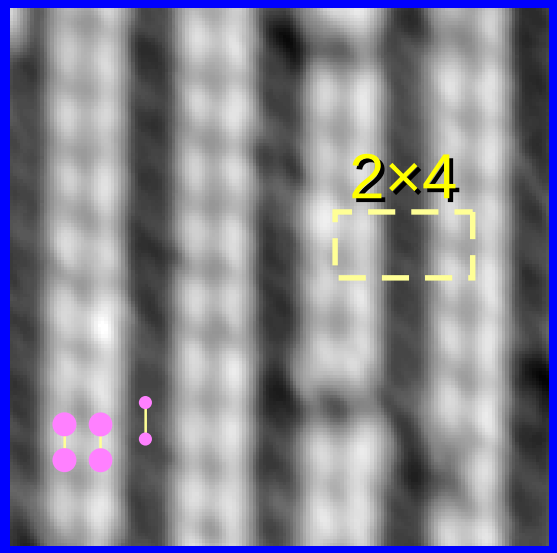
GaAs(001)-(2×4) Surface Morphology

- MBE: 1 ML/s at 600 °C, with 30 s interrupts every 90 s
- After ~1 µm, 10 min interrupt to finish



GaAs(001)-(2x4): "α-1" Model





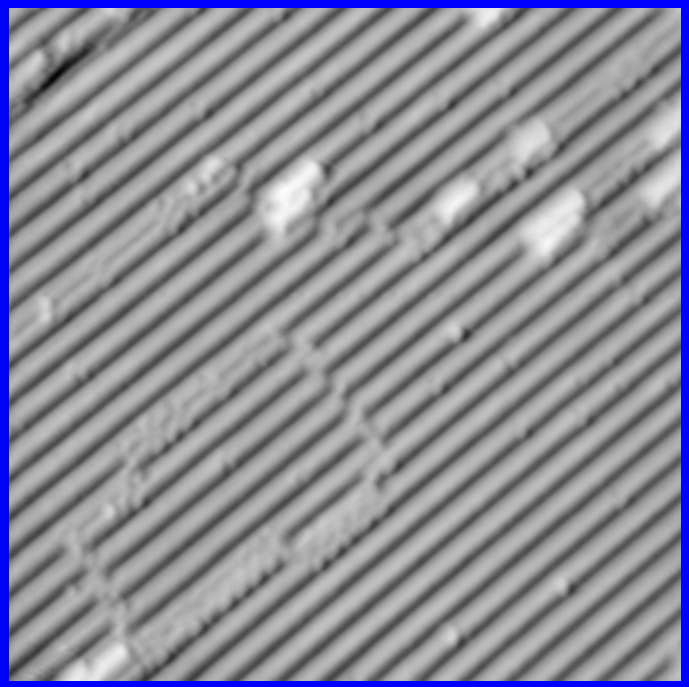
z-range ~ 3 Å

- 1st layer As
- 2nd layer Ga
- 3rd layer As
- 4th layer Ga

Sb:GaAs(001)-(2×8)

- Expose GaAs(001)-(2×4) at 530 °C to Sb_4
- First reported by Ludeke in 1977

800 Å × 800 Å

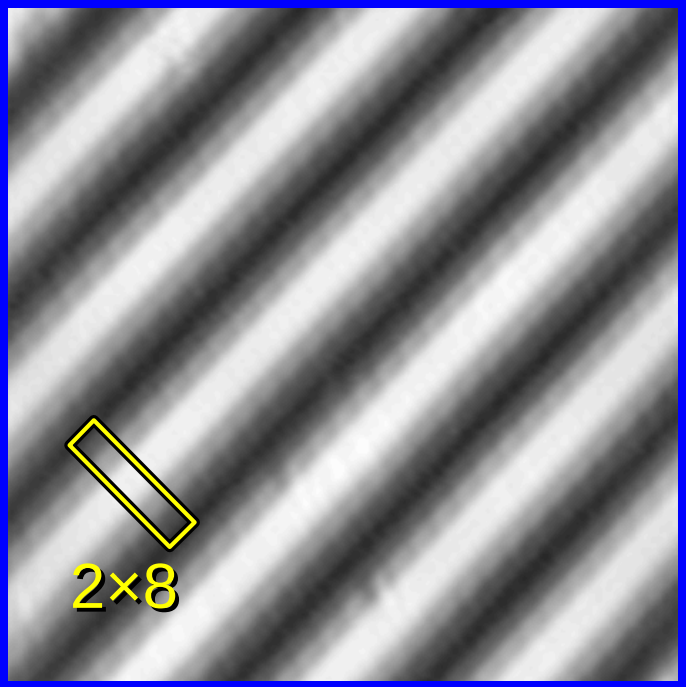


Filled States

[$\bar{1}$10]

[110]

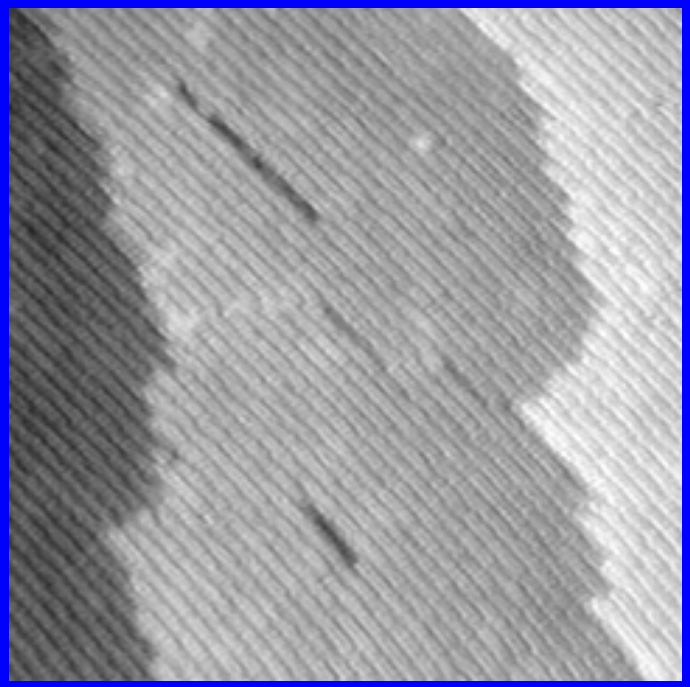
150 Å × 150 Å: 3.2 V



Sb:GaAs(001)-(2×4)

- Heat Sb:GaAs(001)-(2×8) to 460 °C
- XPS => ~ half the Sb as on (2×8)

700 Å × 700 Å

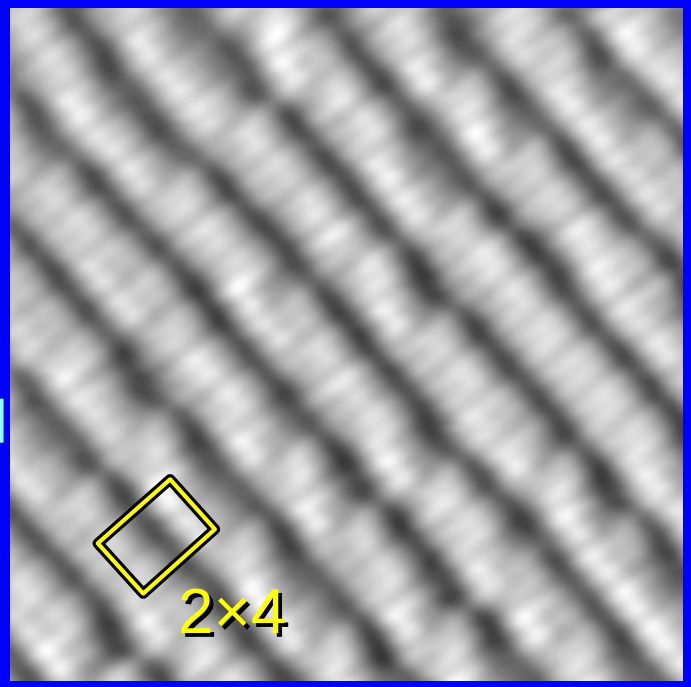


Filled States

[110]

[$\bar{1}$10]

120 Å × 120 Å: 3.0 V



Images similar to Moriarty et al. (PRB 6/15/96)

Absolute Sb Coverages via XPS and XRF

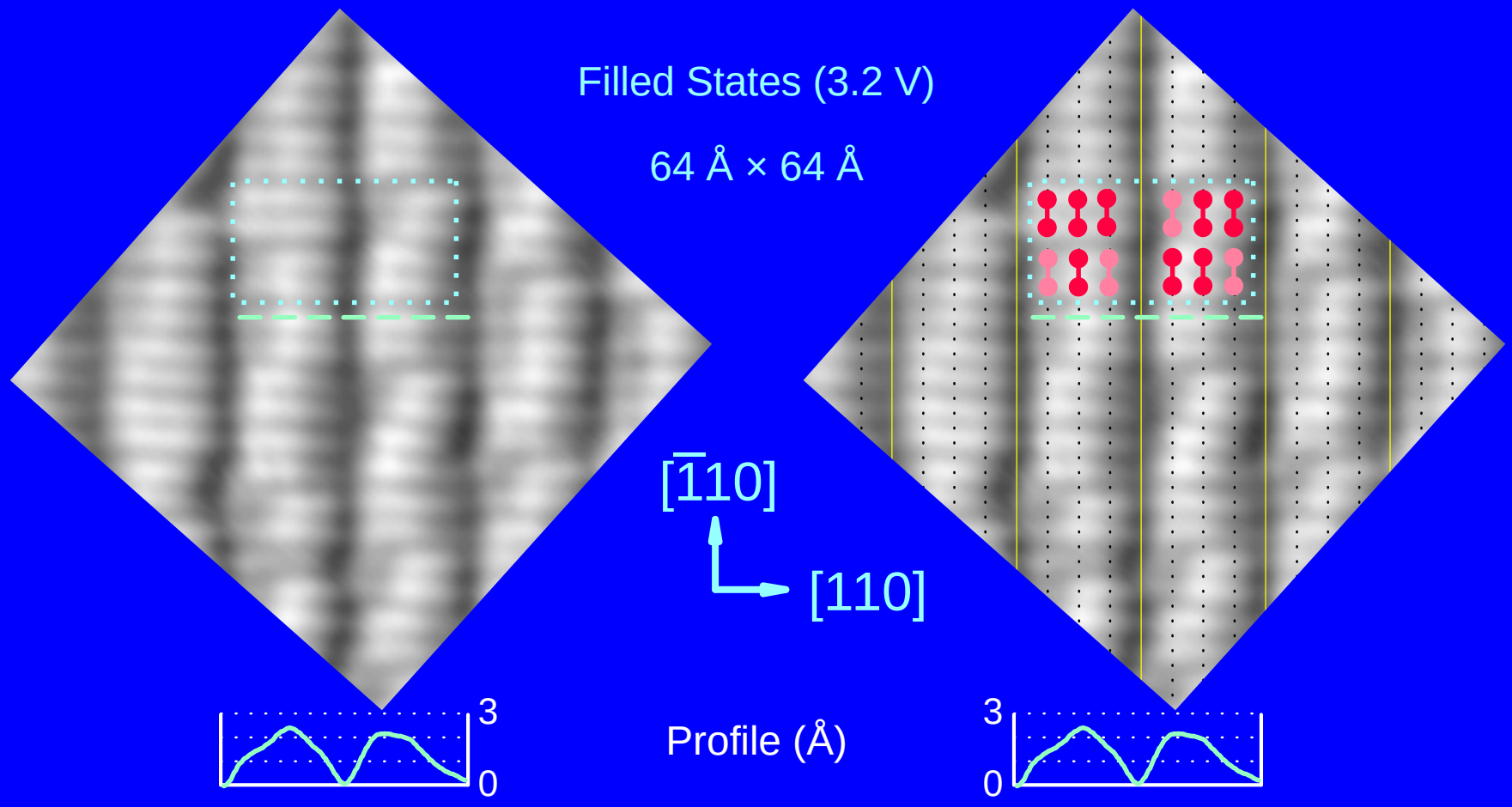
- Relative Sb coverages from XPS
  - Integrate intensity of Sb 4*d* core level (normal emission)
- Sb flux calibrated via x-ray fluorescence (XRF)
  - Use 1000 Å-thick Sb film on room-temp. GaAs-oxide

Structure	**Sb (ML)***
1 sec Sb_4/GaAs-oxide	***≡ 1.5***
clean GaAs(001)-(2×4)	0.05 ± 0.02
Sb:GaAs(001)-(2×4)	1.5 ± 0.1
Sb:GaAs(001)-(2×8)	3.2 ± 0.2

**1 ML ≡ 1 Sb per GaAs(001)-(1×1)*

Sb:GaAs(001)-(2×4): Atomic Resolution

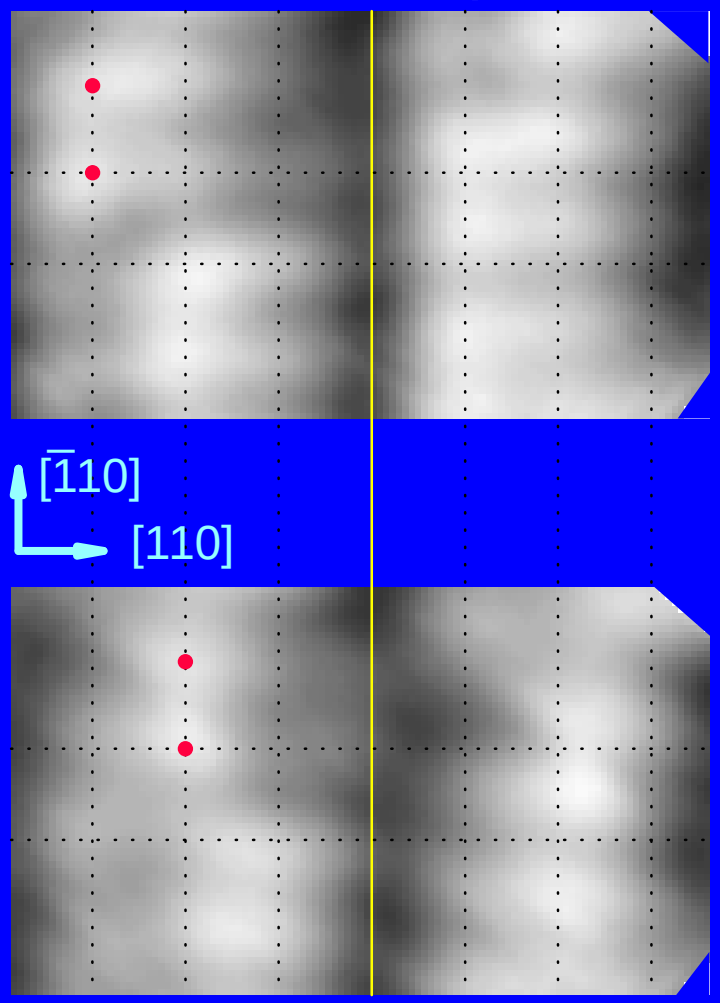
- Looks like mixture of dimer types
- ~2/3 dimers "bright," 1/3 "dim" (~1 Å lower)



Sb:GaAs(001)-(2×4): Bias Dependence

<u>Filled States</u>

3.0 V, 50 pA

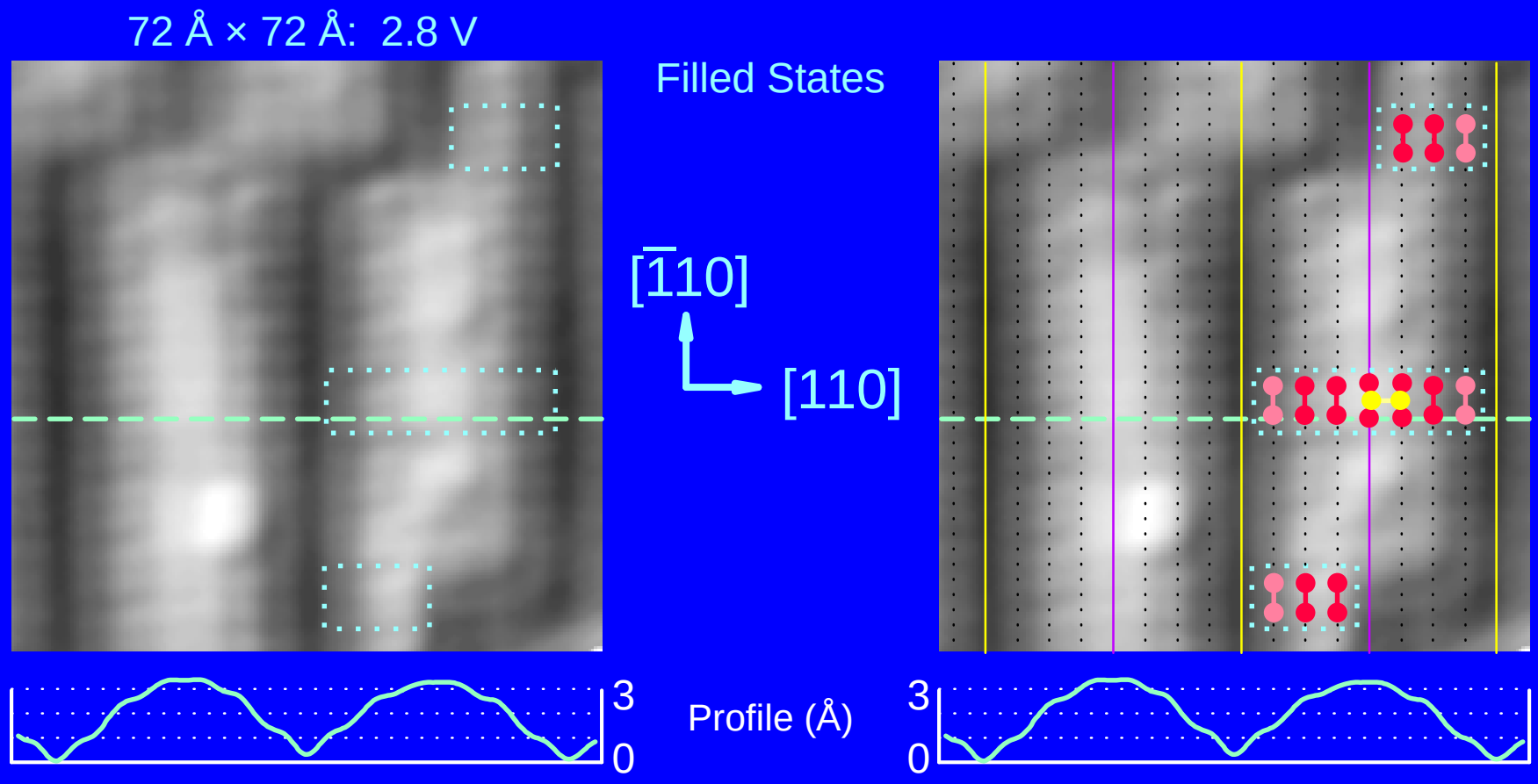


2.0 V, 50 pA

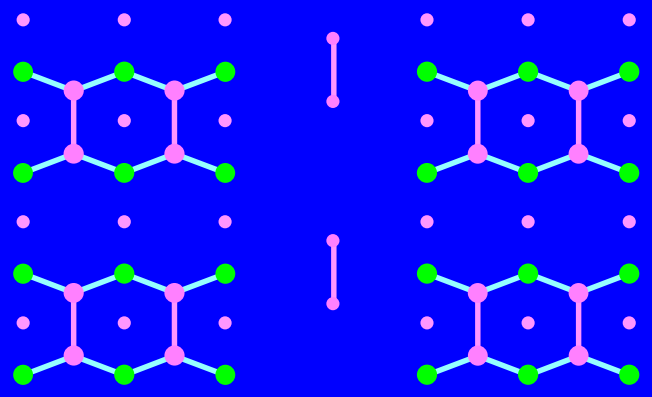
- Noticable filled-state bias dependence
- Highest dimer changes with bias
- Different atoms (Sb vs As)?
- Bonded to different atoms below (Ga vs Sb_{Ga})?

Sb:GaAs(001)-(2×8): Atomic Resolution

- Bias-dependent structures similar to Sb:(2×4)
- Slightly asymmetrical across [$\bar{1}$10]

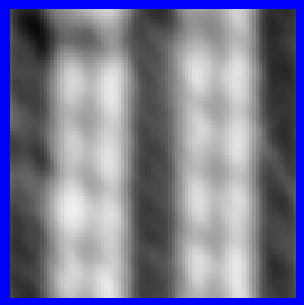


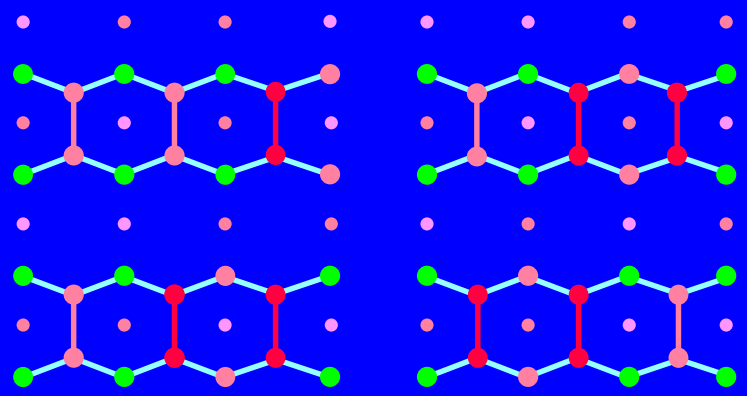
Possible Structures of Sb:GaAs(001)



Clean (2×4)

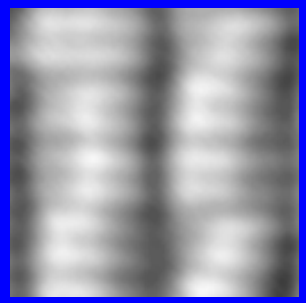
- 0.5 ML As on 0.75 ML Ga





Sb-(2×4)

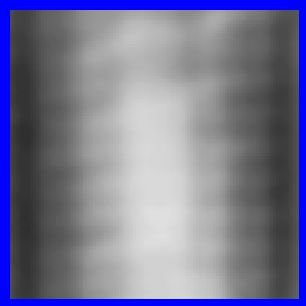
- Multilayer As-Sb intermixing
- Sb in Ga sites



??????

Sb-(2×8)

- Multilayer, multi-component



Sb-Stabilized GaAs(001) Surfaces

- Atomic-resolution STM images of (2×8), (2×4)
  - Considerable bias-dependence
  - Multiple atom and bond types, e.g. mixed As-Sb, Sb_{Ga}
- Calibrated XPS indicates multilayer Sb incorporation, $\theta_{(2\times8)} \sim 2\theta_{(2\times4)} \sim 3$ ML
- Previous models of Sb:(2×4) (including ours) clearly WRONG!

humble pie →

There's hope: mulitcomponent structures, BUT well-ordered and periodic