Evolution of InAs/AlSb/InAs Resonant Tunneling Dio
Interfaces Studied by Scanning Tunneling Microscop

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Funded by: *Office of Naval Research*
QUEST, a Center for Quantized Electronic Structures (NSF)
DARPA/NSF

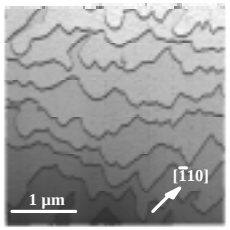
InAs/AlSb/InAs Quantum Wells

- Component of resonant tunneling device (RTD)
  - Potential device for high-speed oscillators and switches
    - Prototypes approaching terahertz frequencies
  - Device perfomance dependent on atomic-scale morphology: barrier thickness variations, interface roughness, etc.
- Interesting system for modeling MBE growth
  - Multiple group III and V species
  - Small lattice mismatch (1.6%)

Experimental Setup

- Multi-chamber MBE-surface analysis system
  - Riber 32P MBE with Al, Ga, In, and cracked As and Sb sources (Sb_2 flux ~ 3x10^{-6} Torr)
  - Custom-modified PSI Autoprobe STM
- Easy MBE-to-STM transfers (~5 min)
- STM done at room temperature

InAs(001)-(2×4): Starting Surface



- 3-D rendered image
- Terrace widths indicate ~0.05° miscut

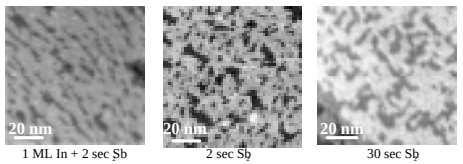
MBE GROWTH

- 1 ML/s at 500 °C with 30 sec interrupts every 90 sec
- 10 min interrupt after ~1 µm

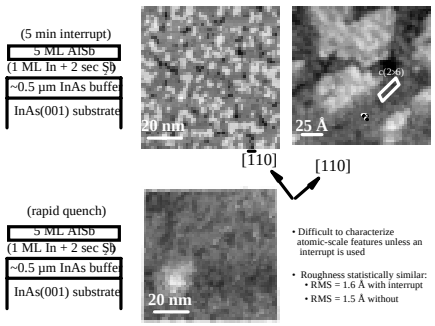
Perfect Step-Flow Growth - Atomically flat terraces

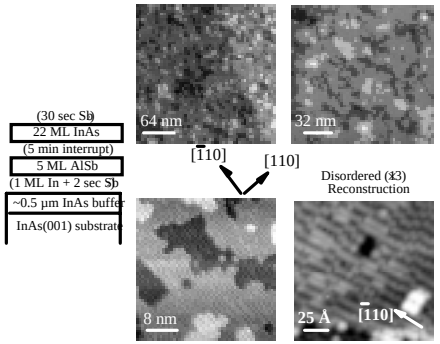
Preparation of InAs/AlSb interface

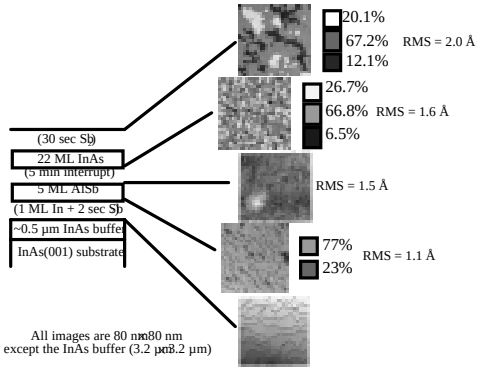
- Form InSb-like bonds at the interface by either:
  - 1 ML In followed by 2 sec Sb_2 (MEE)
  - Simple Sb_2 exposure for various times



In all cases vacancy islands cover ~25% of the surface







Summary

- Sb_2 is very reactive with the InAs(001)-(2×4) surface.
  - Initial deposition of Sb_2 disrupts the terraces, producing multi-level surfaces.
  - A disordered (1×3) reconstruction is observed on all levels of the surface by both RHEED and STM.
  - ~25% of the surface is covered by vacancy islands.
- The RMS roughness was found to be less than 1 ML (~3 Å) on all surfaces studied, but increased as each material layer was added due to the multi-level starting surface combined with incomplete step-flow during growth.

Current and Future Work

- Further study of the atomic-scale origin of the multi-level surfaces
- Perform AES and/or XPS to compare relative Sb coverages
- Study relationship between the multi-level morphology of Sb:InAs(001) and the subsequent AlSb surfaces
- Explore the effects of growth interrupts:
  - smoother surfaces during growth
  - possible interdiffusion at interfaces
- Measure dependence of device performance on interface morphology
- Cross-sectional STM studies of buried interfaces

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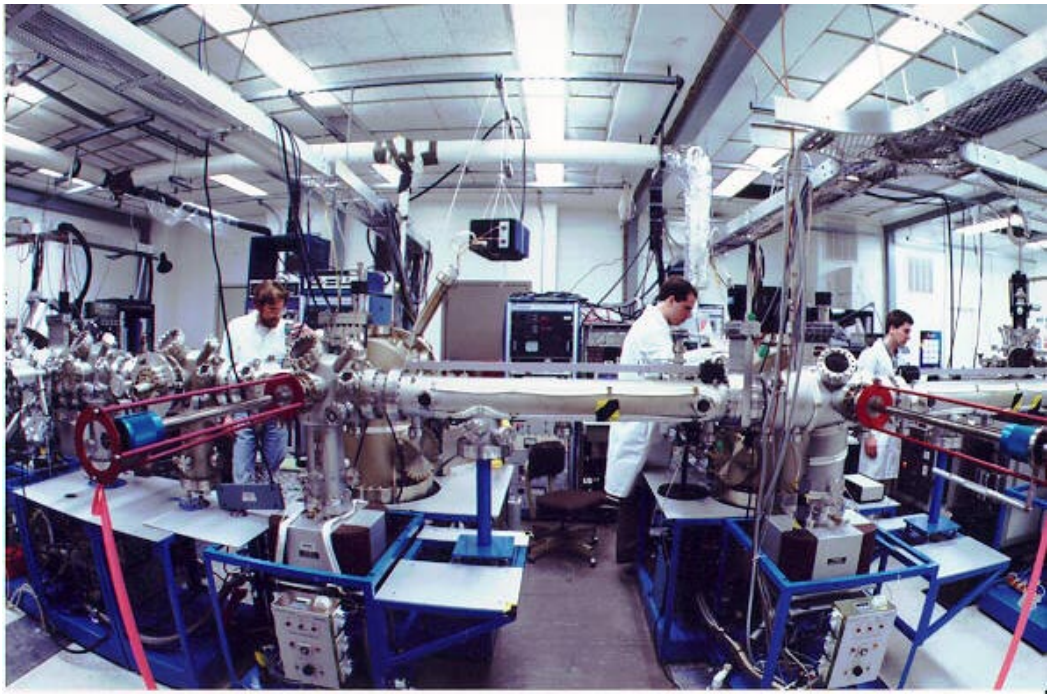

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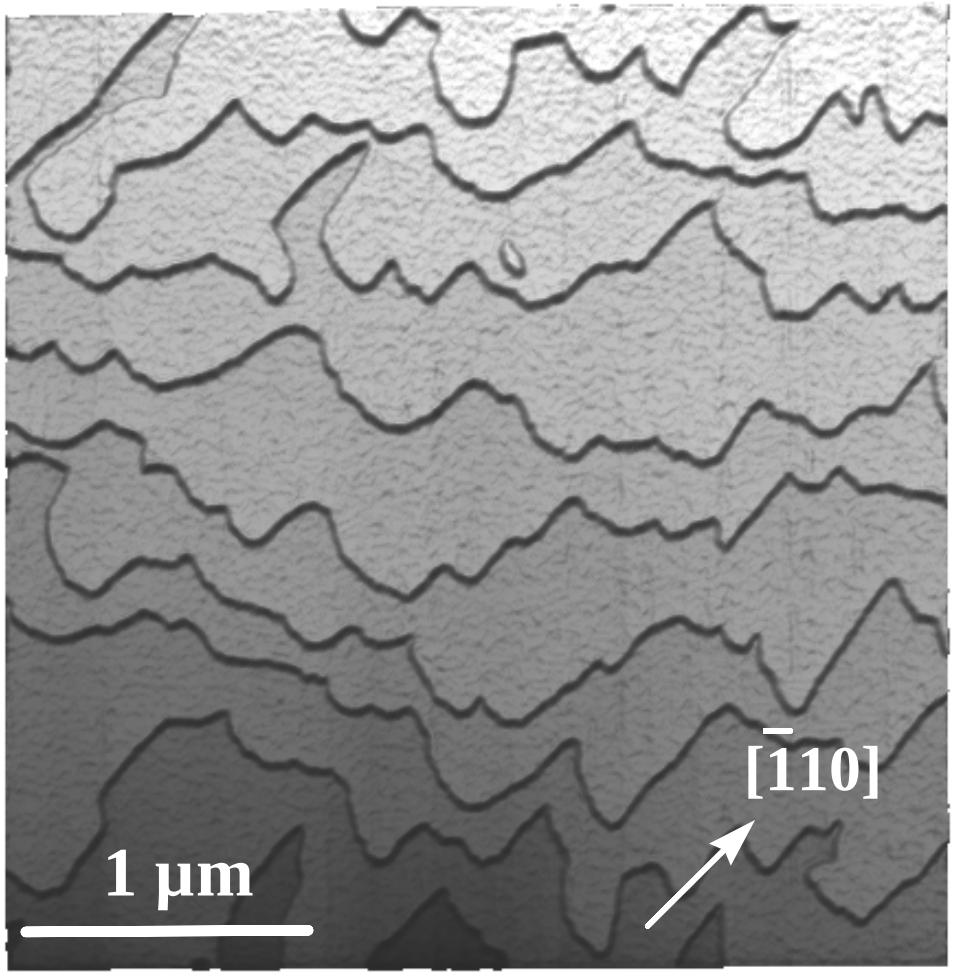

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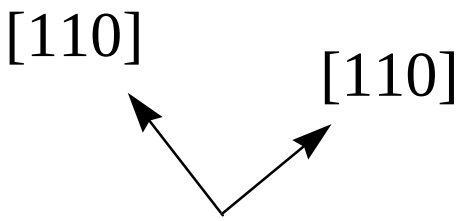
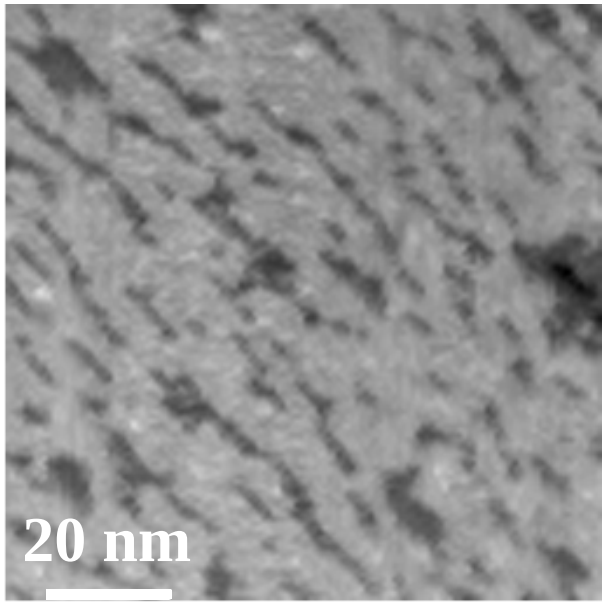
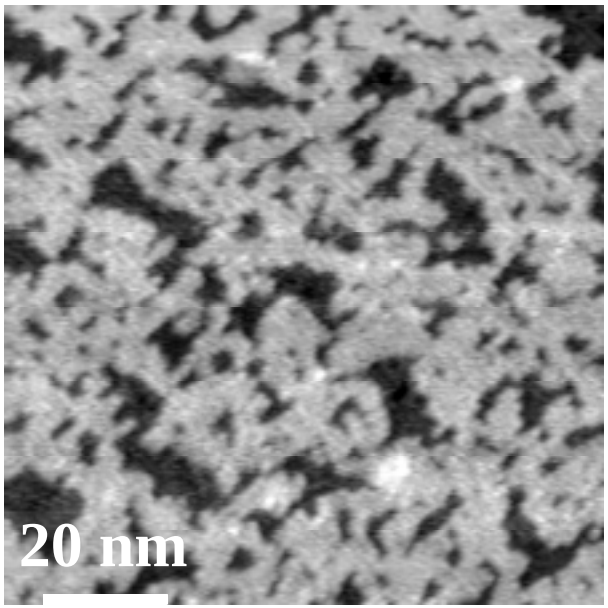
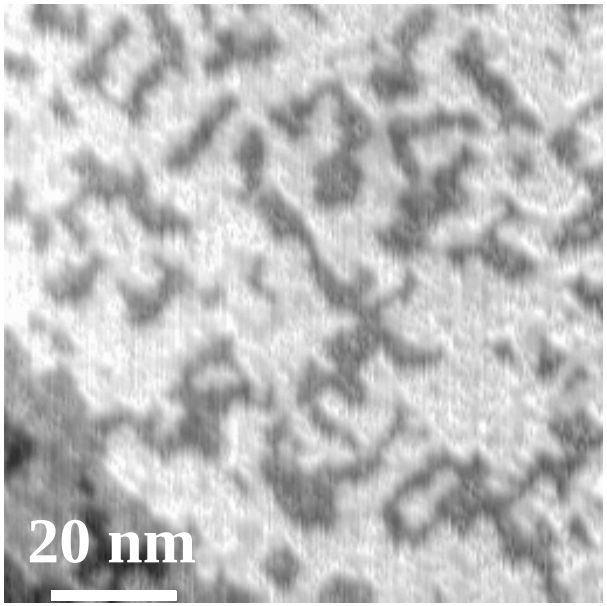




1 ML In + 2 sec Sb_2



2 sec Sb_2

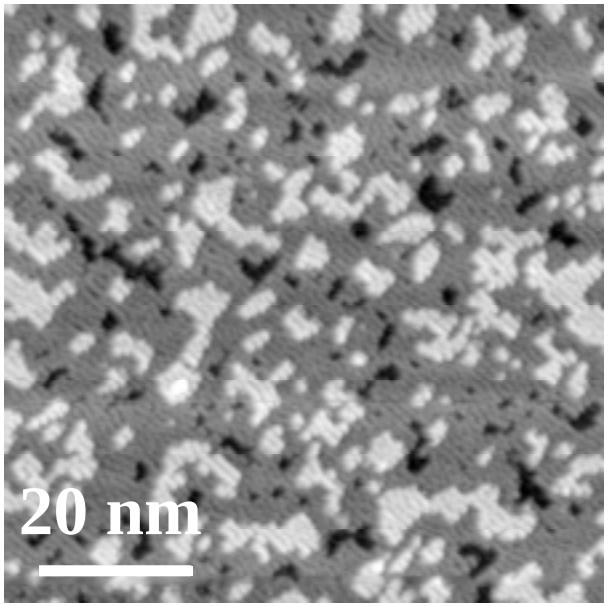


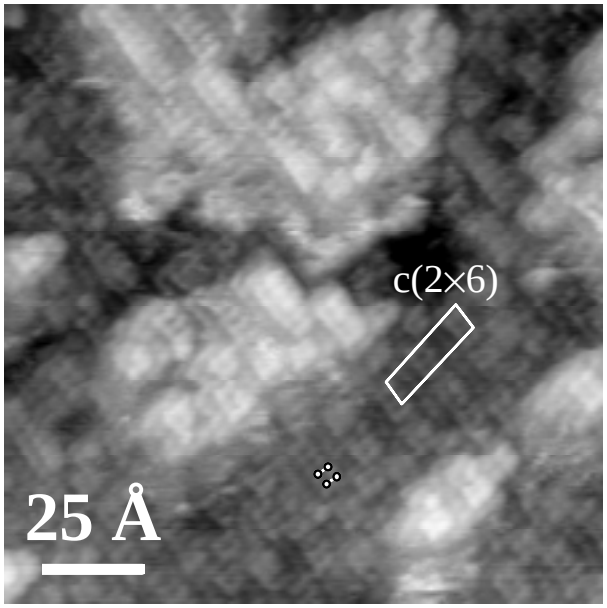
30 sec Sb_2

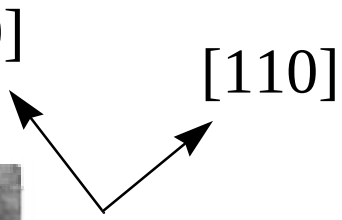
In all cases vacancy islands cover ~25% of the surface.

(5 min interrupt)

5 ML AlSb
(1 ML In + 2 sec Sb_2)
~0.5 µm InAs buffer
InAs(001) substrate

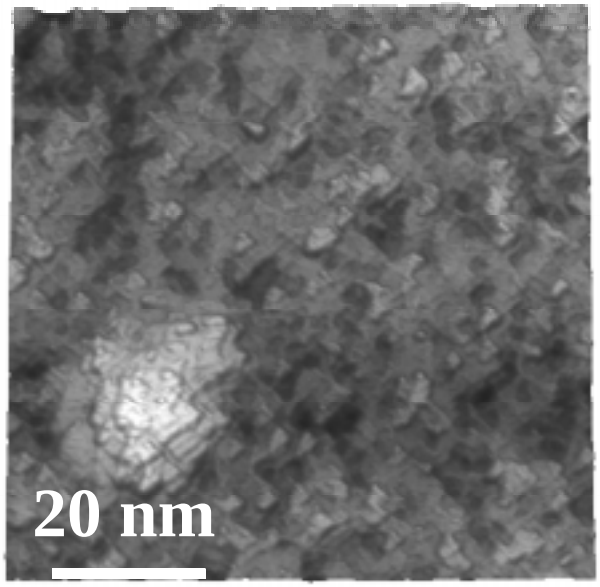






(rapid quench)

5 ML AlSb
(1 ML In + 2 sec Sb_2)
~0.5 µm InAs buffer
InAs(001) substrate



- Difficult to characterize atomic-scale features unless an interrupt is used
- Roughness statistically similar:
  - RMS = 1.6 Å with interrupt
  - RMS = 1.5 Å without

(30 sec Sb_2)

22 ML InAs

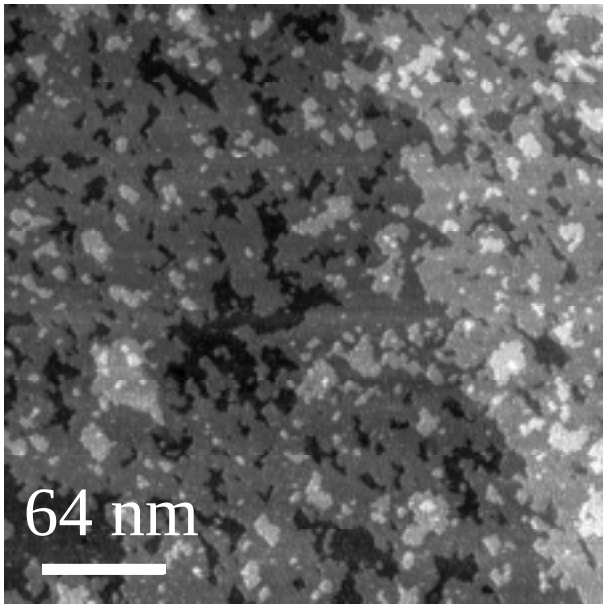
(5 min interrupt)

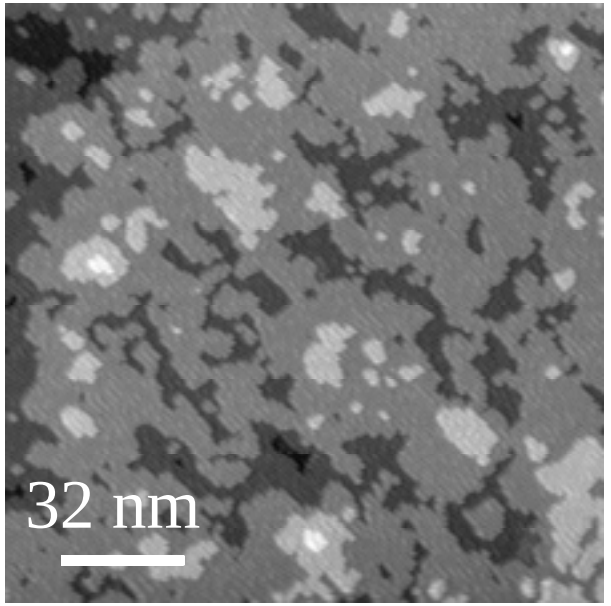
5 ML AlSb

(1 ML In + 2 sec Sb_2)

~0.5 µm InAs buffer

InAs(001) substrate

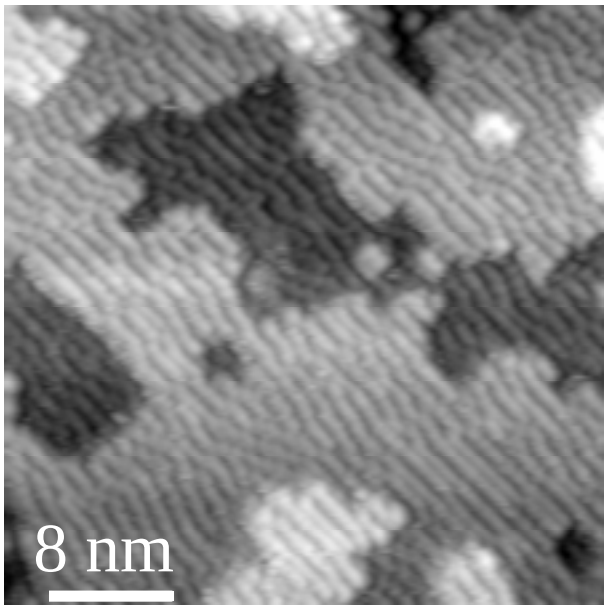


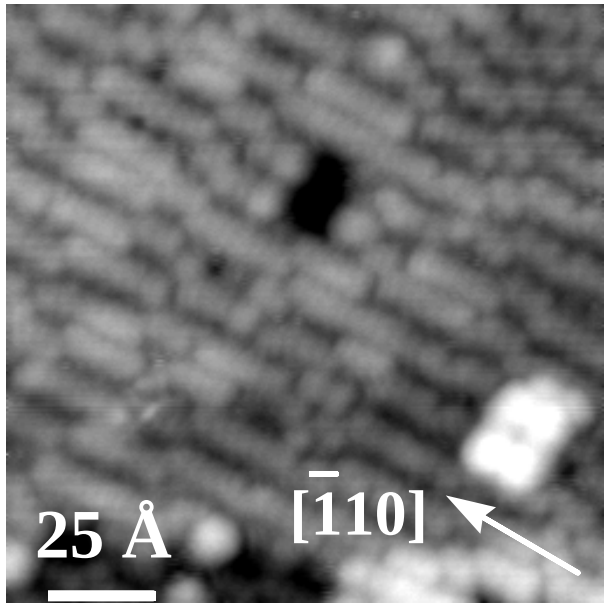


[$\bar{1}$10]

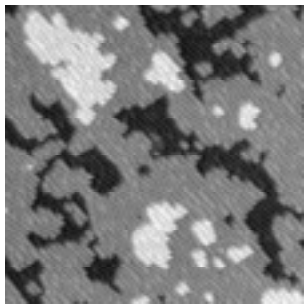
[110]

Disordered (1×3) Reconstruction





B. Z. Nosho, UCSB

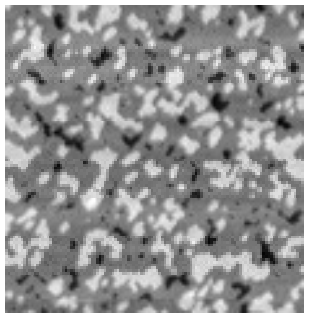


20.1%

67.2%

12.1%

RMS = 2.0 Å



26.7%

66.8%

6.5%

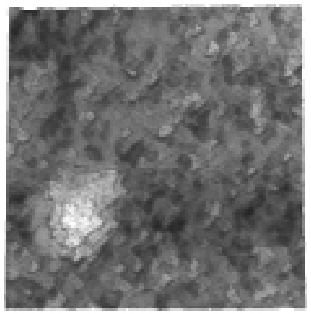
RMS = 1.6 Å

(30 sec Sb_2)

22 ML InAs

(5 min interrupt)

5 ML AlSb

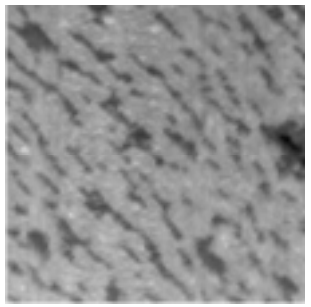


RMS = 1.5 Å

(1 ML In + 2 sec Sb_2)

~0.5 µm InAs buffer

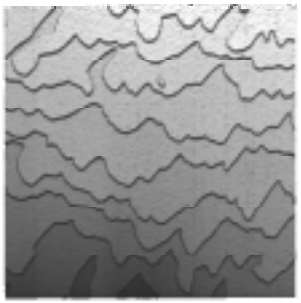
InAs(001) substrate



77%

23%

RMS = 1.1 Å



All images are 80 nm × 80 nm
except the InAs buffer (3.2 µm × 3.2 µm)

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