Surface Structure, Interface Morphology, and RITD performance in the 6.1 Å Compound Semiconductors

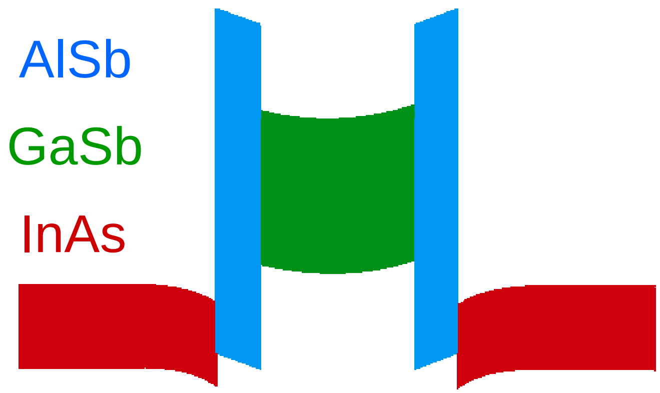
Allan Bracker, W. Barvosa Carter, B.R. Bennett,
J.C. Culbertson, R. Magno, B.Z. Nosho,
B.V. Shanabrook, M. Twigg, L.J. Whitman, M.J. Yang

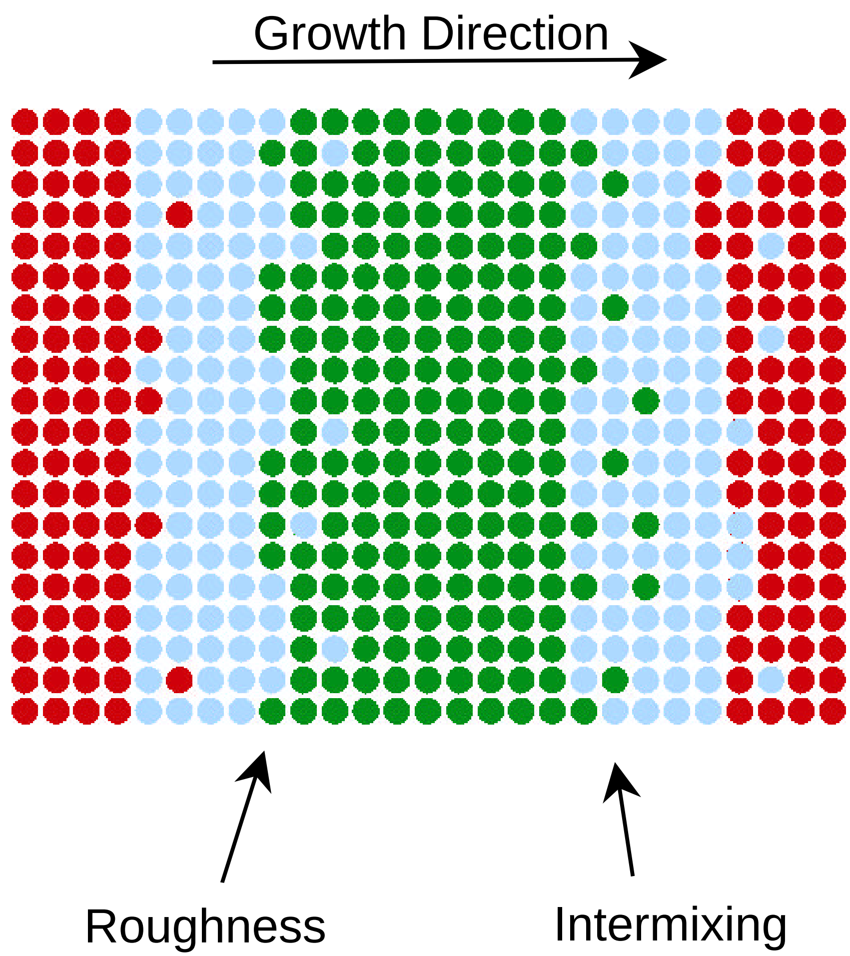
Naval Research Laboratory
Washington, DC

Funded by ONR and DARPA

3rd Workshop on the Fabrication, Characterization,
and Applications of 6.1 Å III-V Semiconductors
31 July - 2 Aug 2001

High "Interface to Volume Ratio"

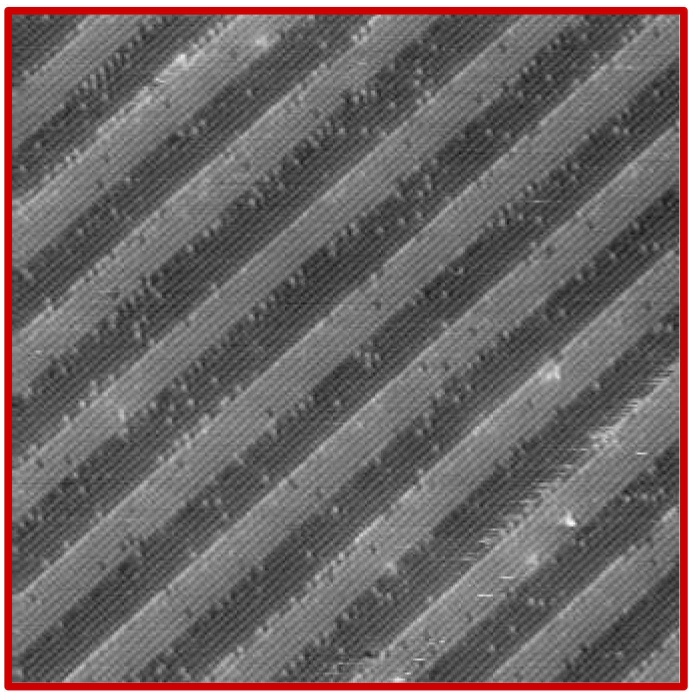




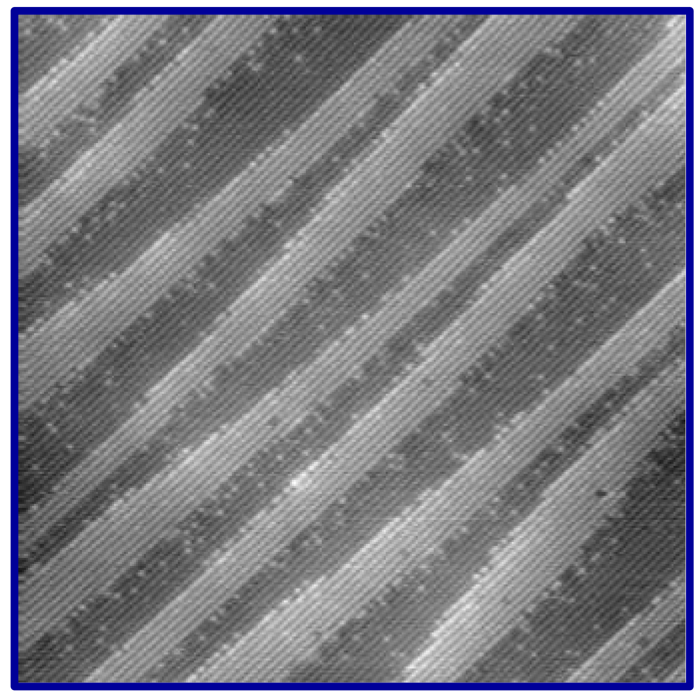
The importance of growth parameters

GaSb / InAs superlattice

10 nm



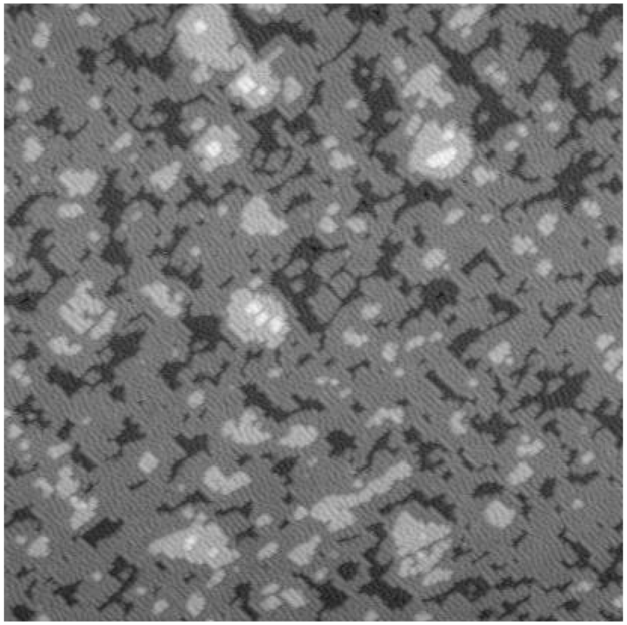
grown with As_2



grown with As_4

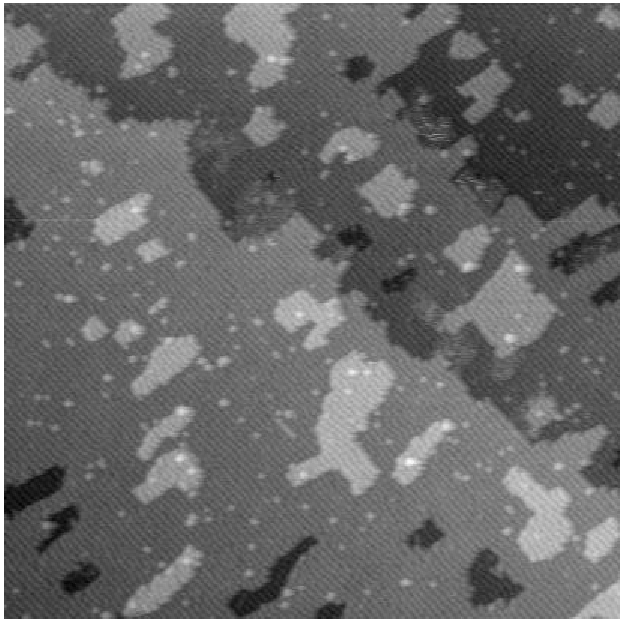
Lower AlSb barrier in RITD-like structure at two growth temperatures

20 nm



400 °C

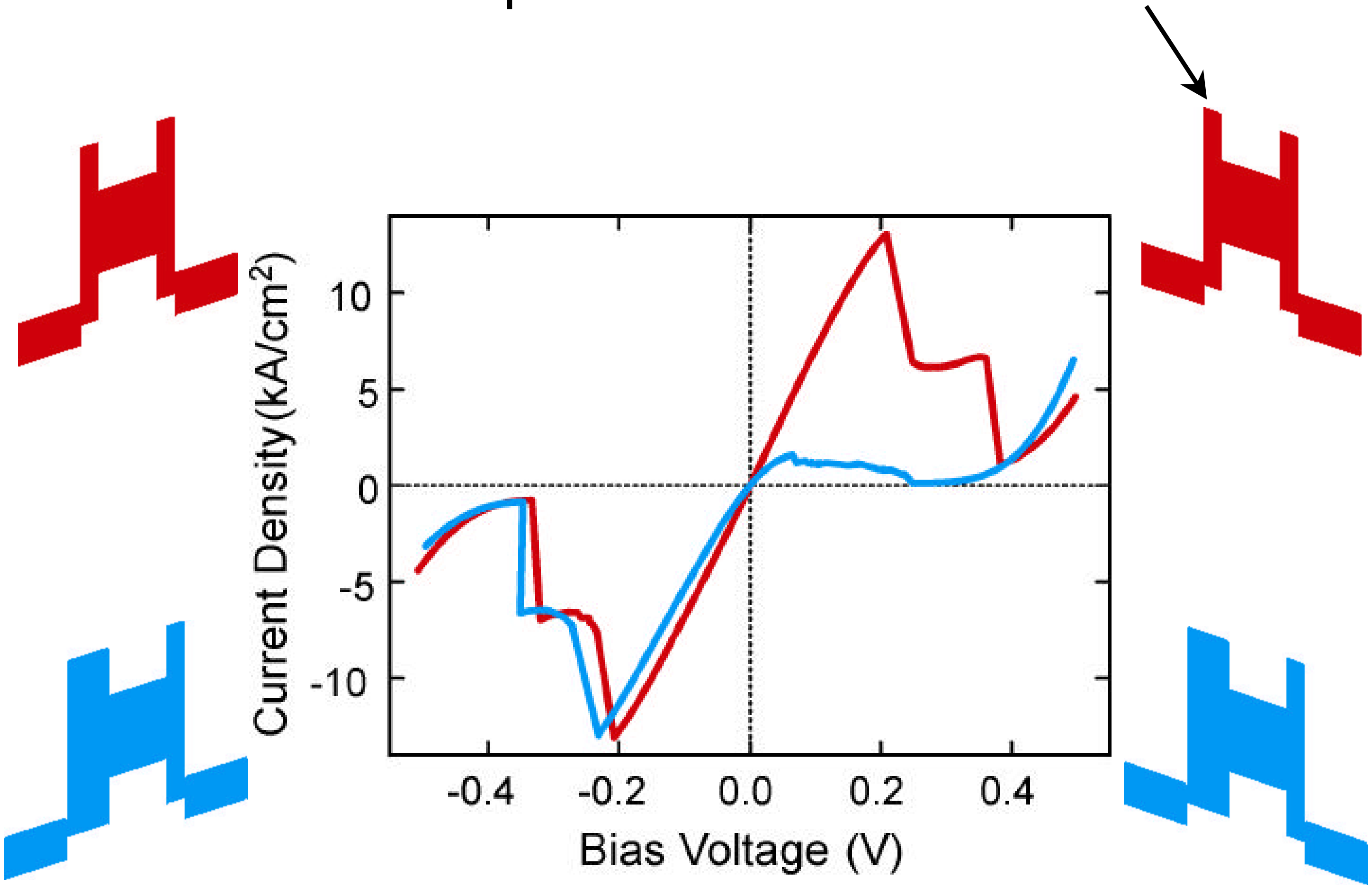
20 % lower monolayer



470 °C

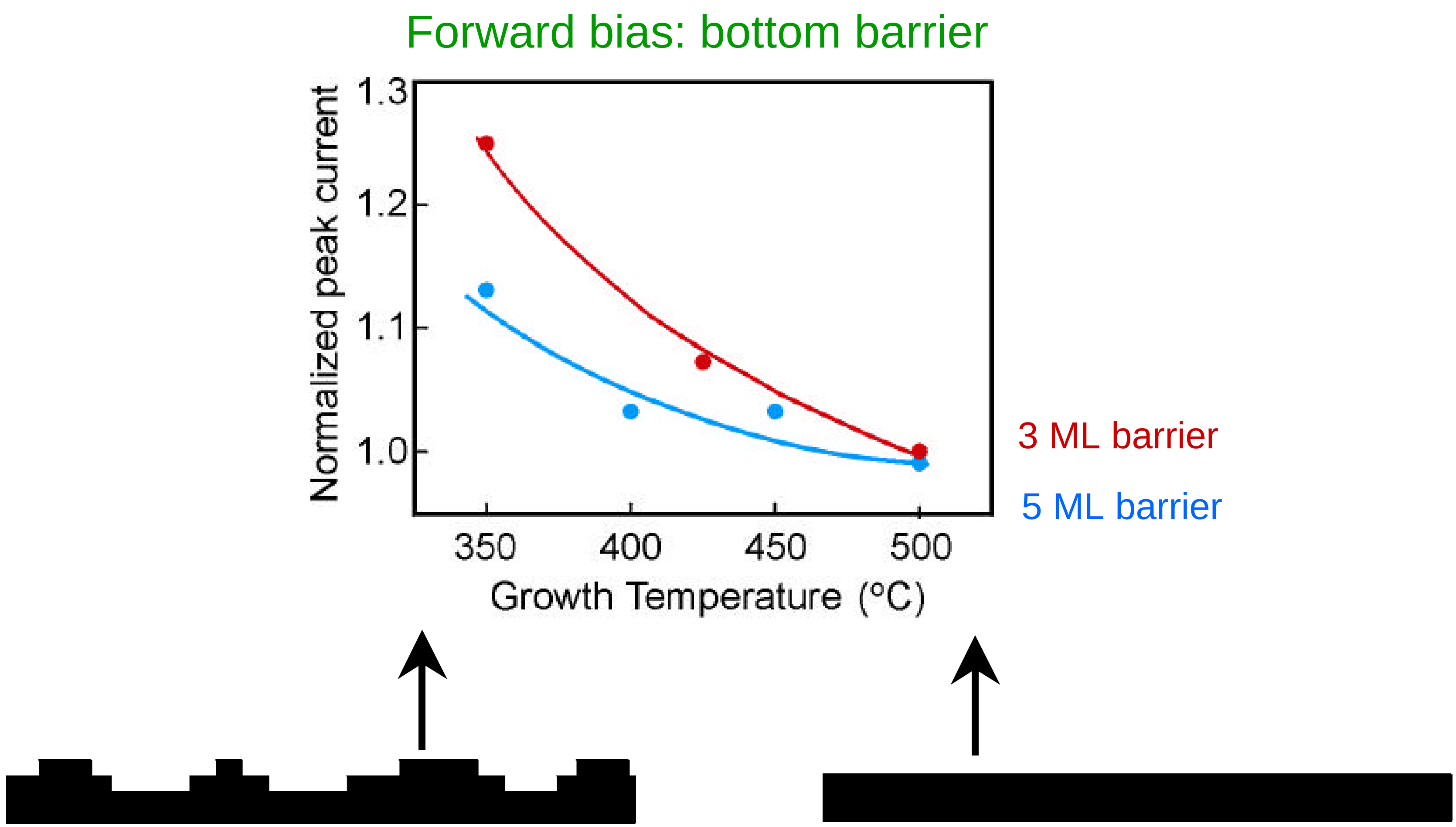
5 % lower monolayer

Forward bias I-V peak is sensitive to bottom barrier



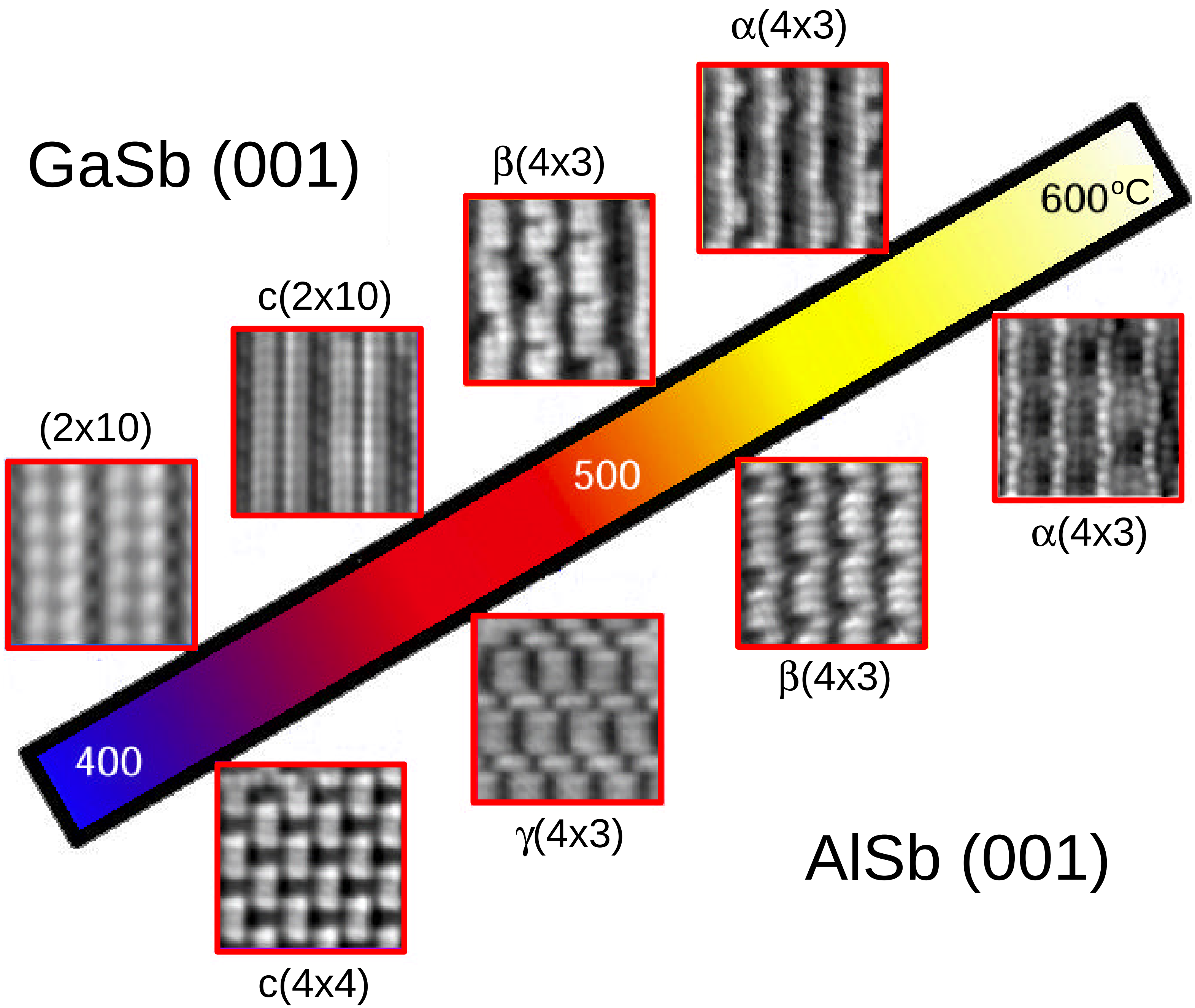
Simplifies interpretation of interface effects

Influence of Roughness on Peak Current

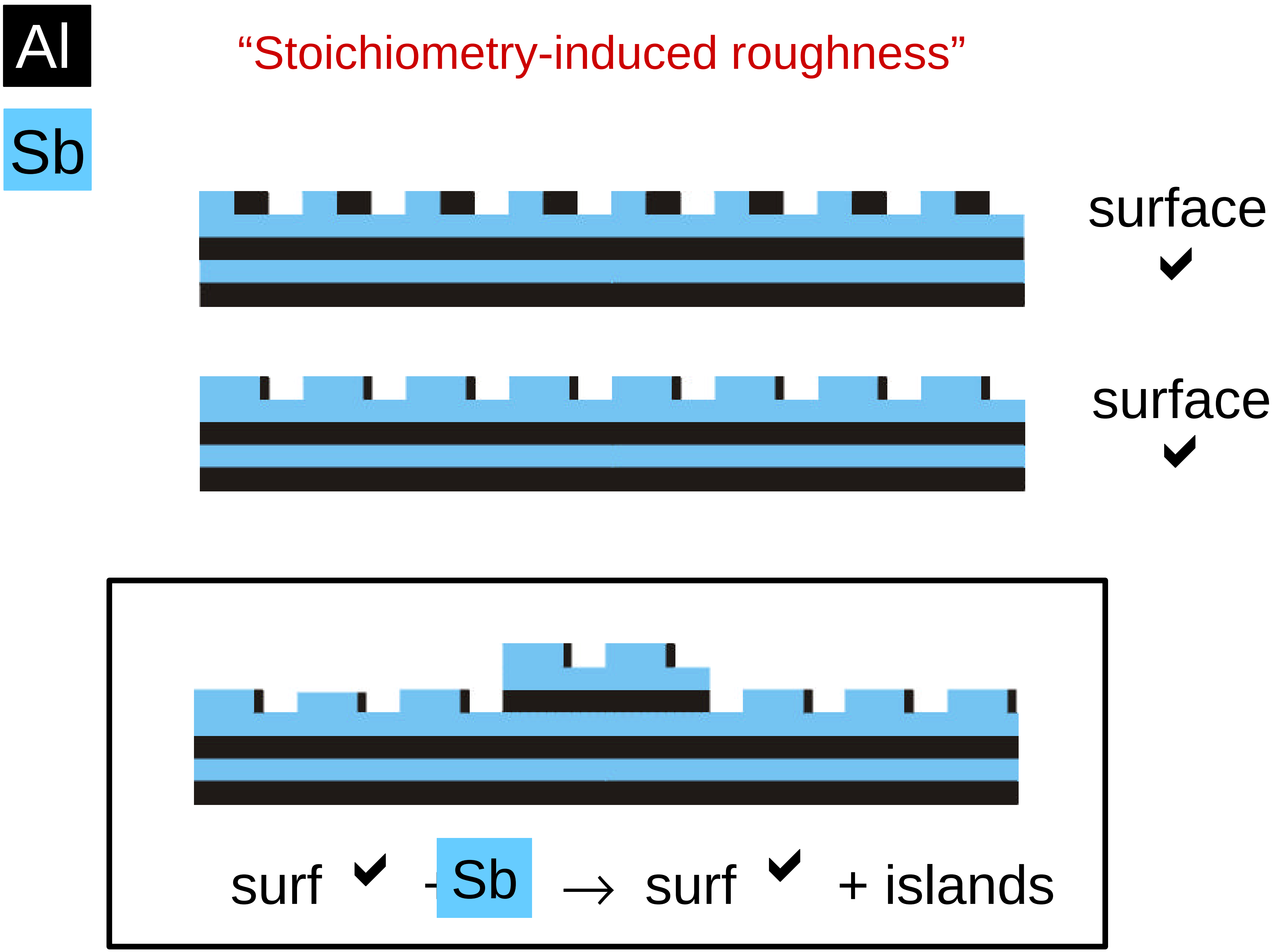


Rough barrier: same volume, smaller effective thickness

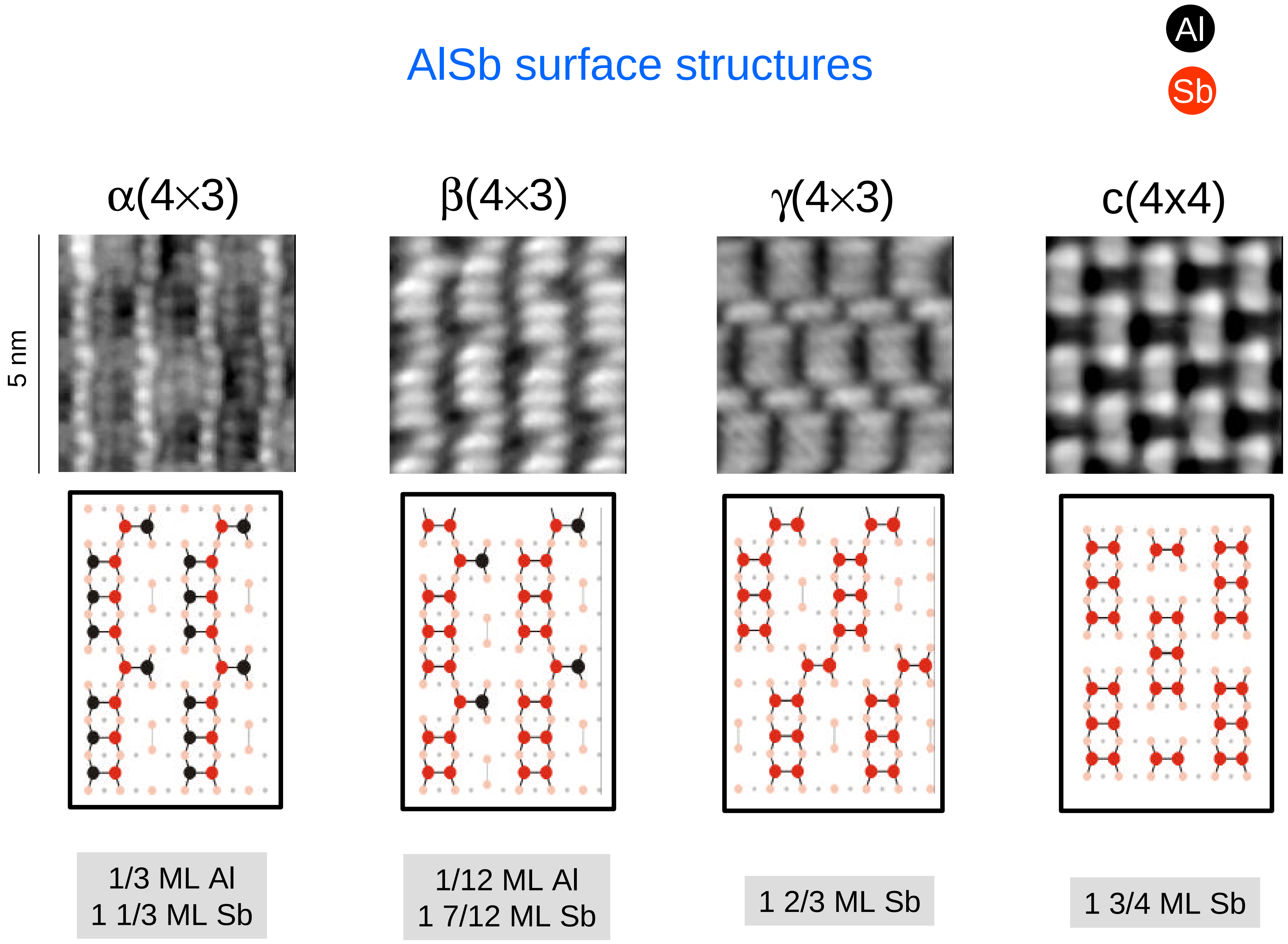
Ideal barrier



GaSb (001)
α(4x3)
β(4x3)
c(2x10)
(2x10)
600°C
500
400
α(4x3)
β(4x3)
γ(4x3)
c(4x4)
AlSb (001)


Al
Sb
“Stoichiometry-induced roughness”
surface
surface
surf + Sb → surf + islands

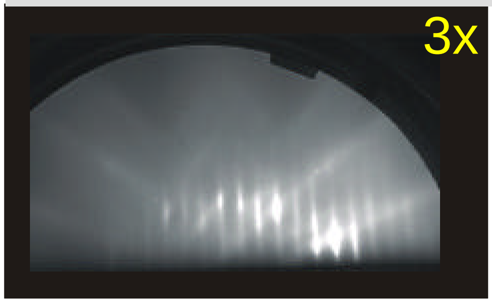
AlSb surface structures



Preparation of flat β(4×3) and α(4×3) surfaces

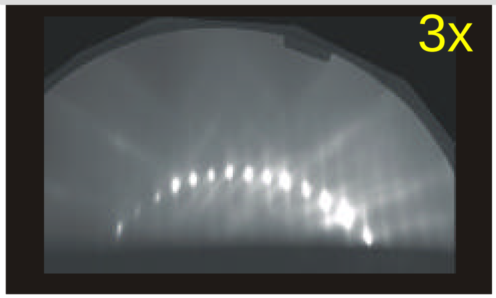
β(4×3)

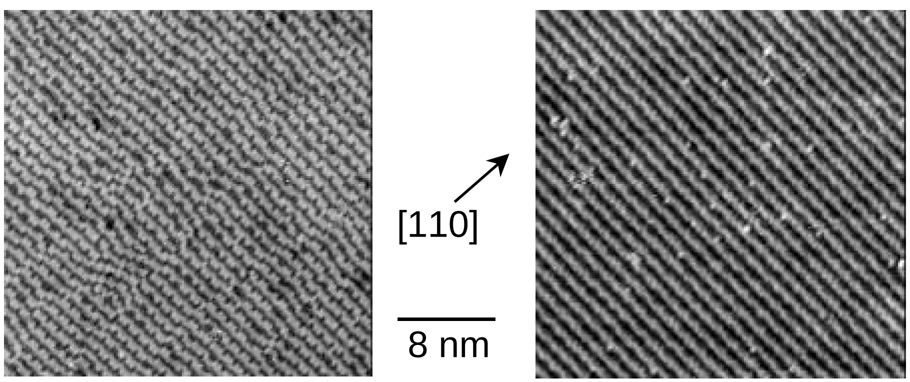
- Grow at 1 ML/s;
- T_{sub} = 550-600 °C
- Anneal under Sb

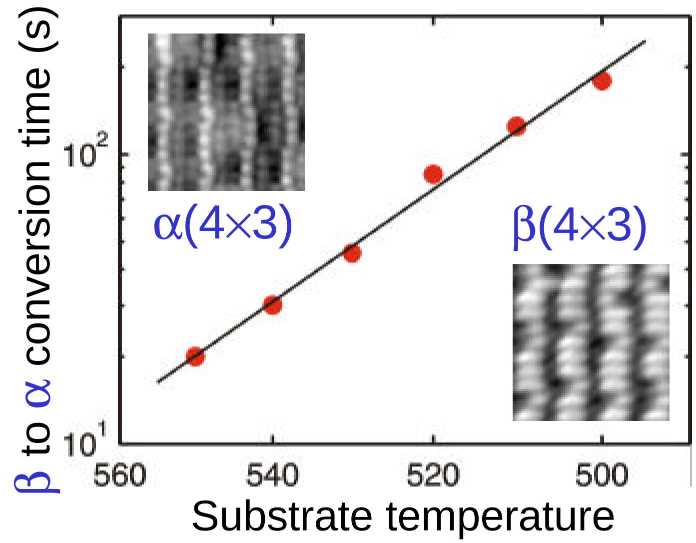


α(4×3)

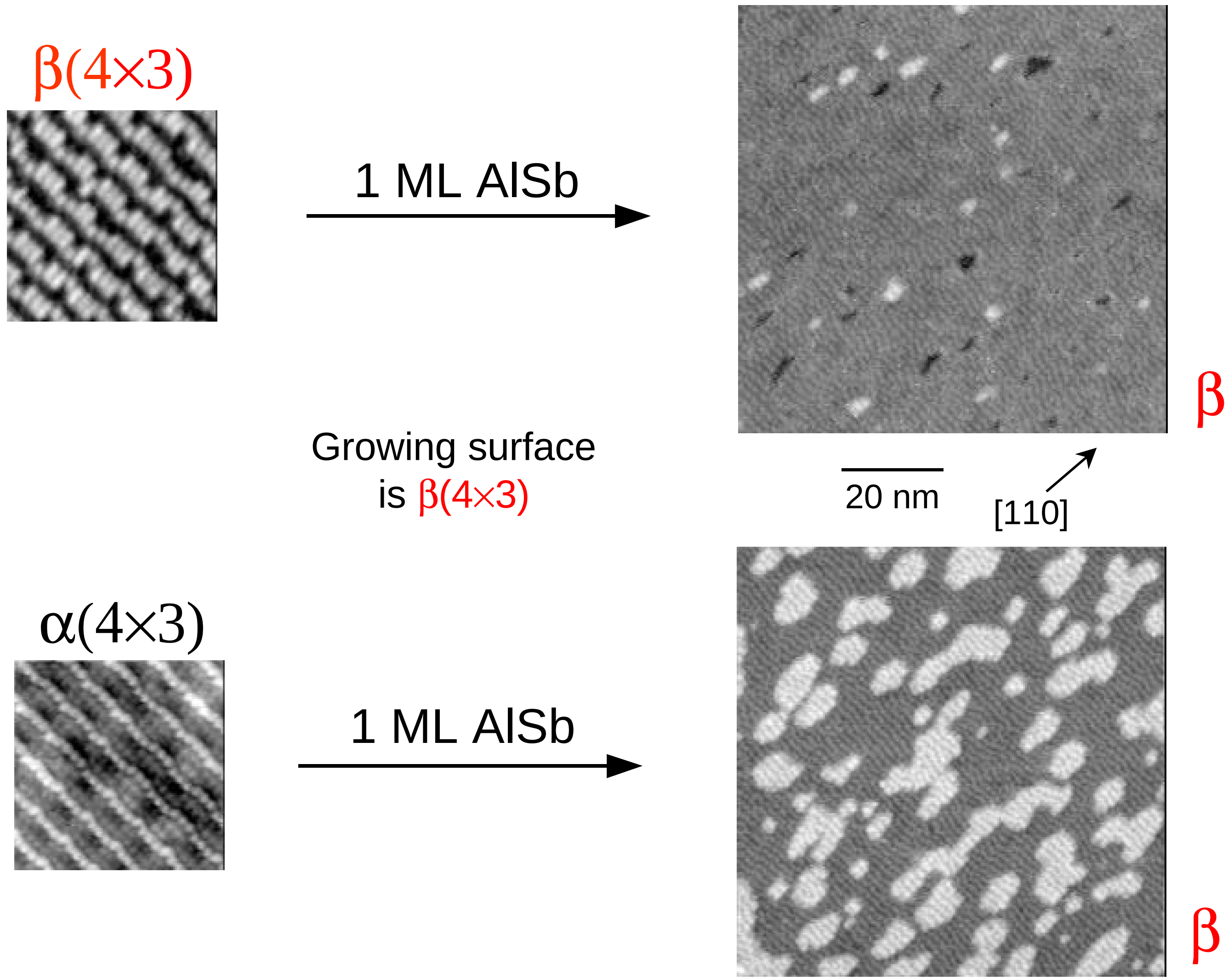
- Prepare flat β(4×3);
- Anneal without Sb





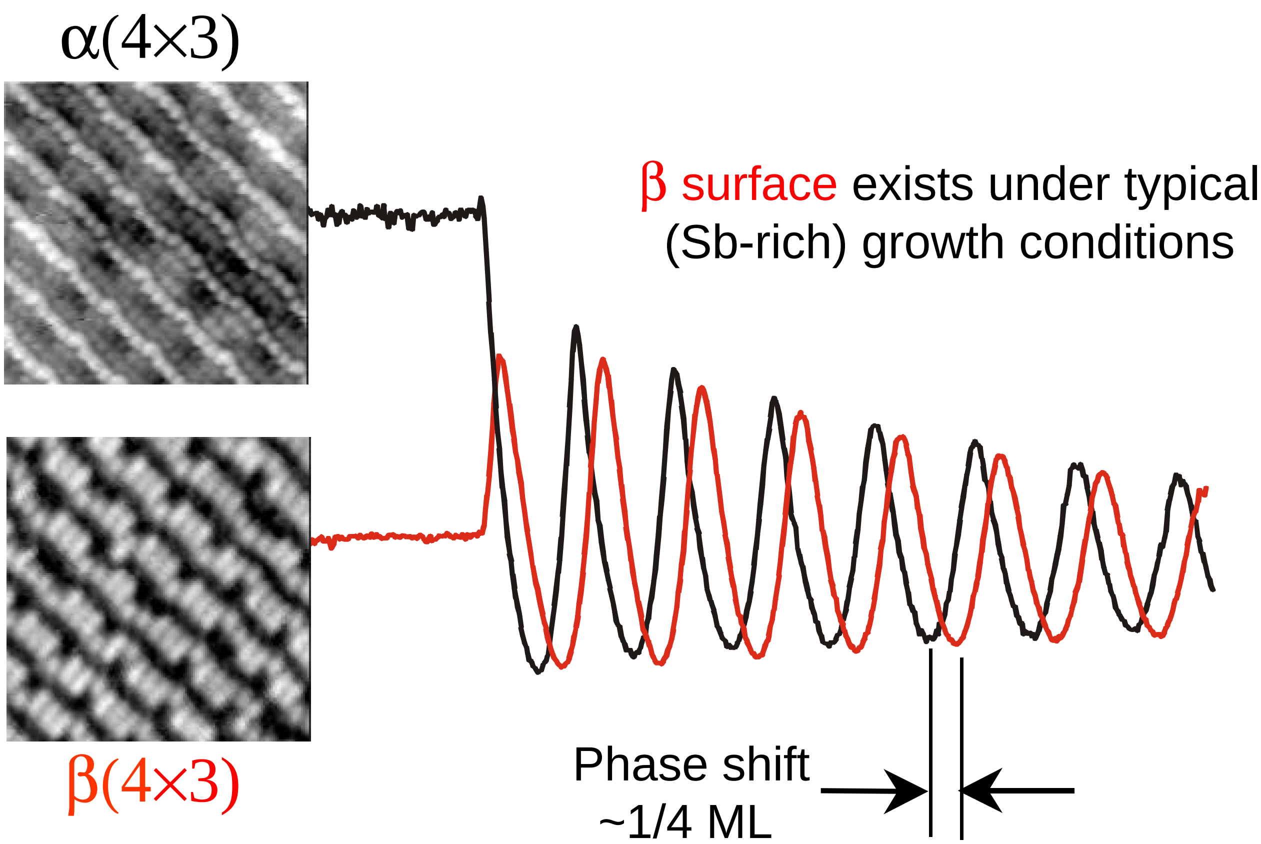


Add 1 ML AlSb to flat β(4×3) and α(4×3) surfaces



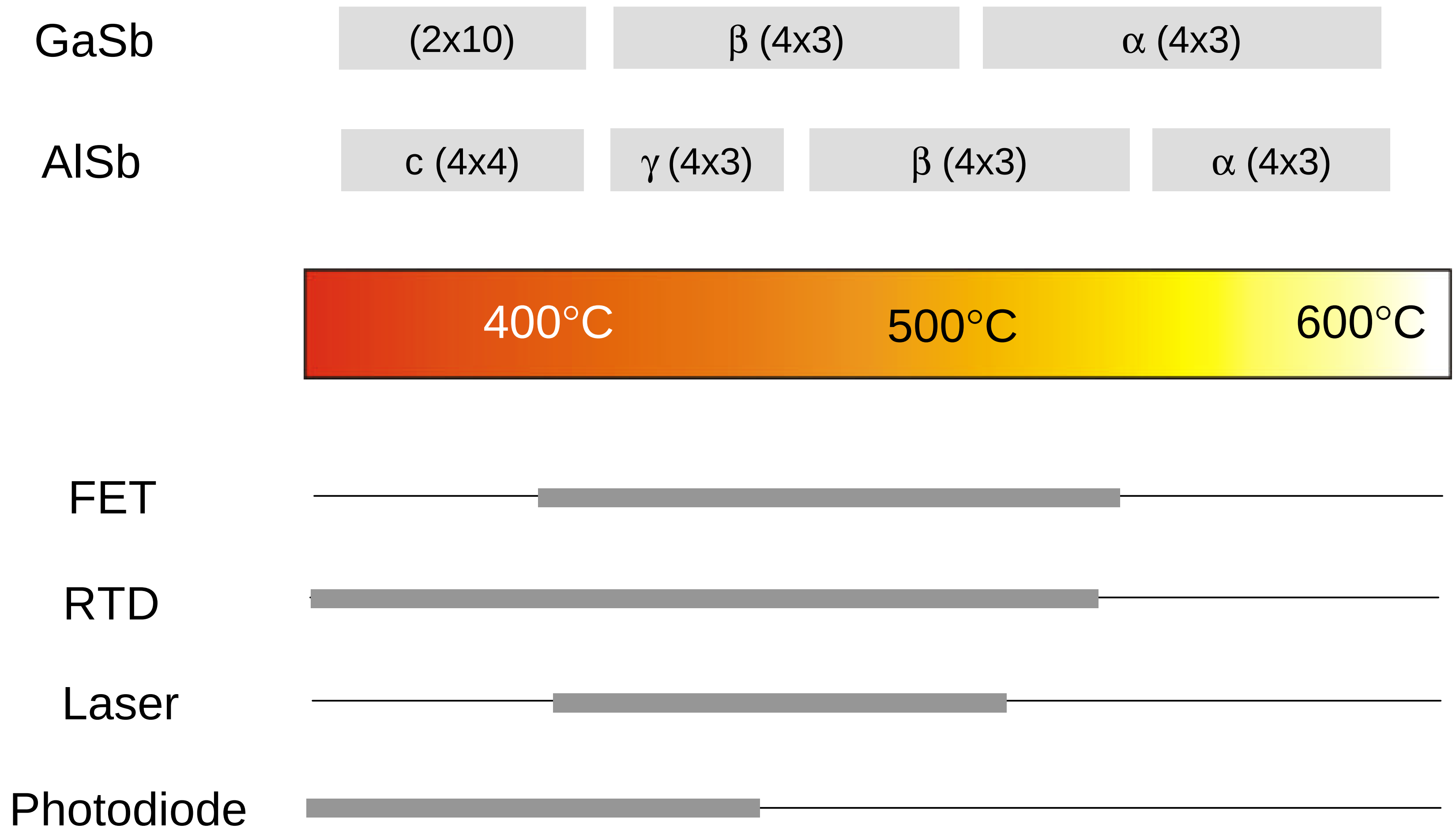
Islands form due to extra aluminum in α(4×3)

Phase shift of RHEED oscillations

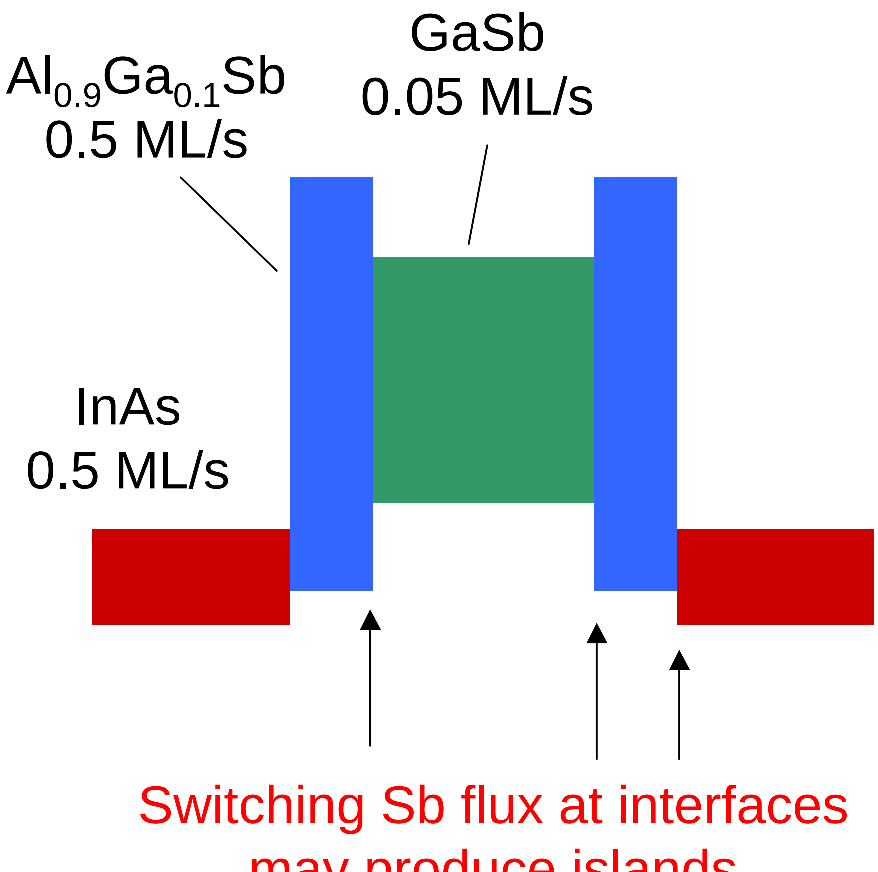


1/4 ML extra aluminum in α(4×3) gives head start in oscillations

Device growths and surface reconstructions



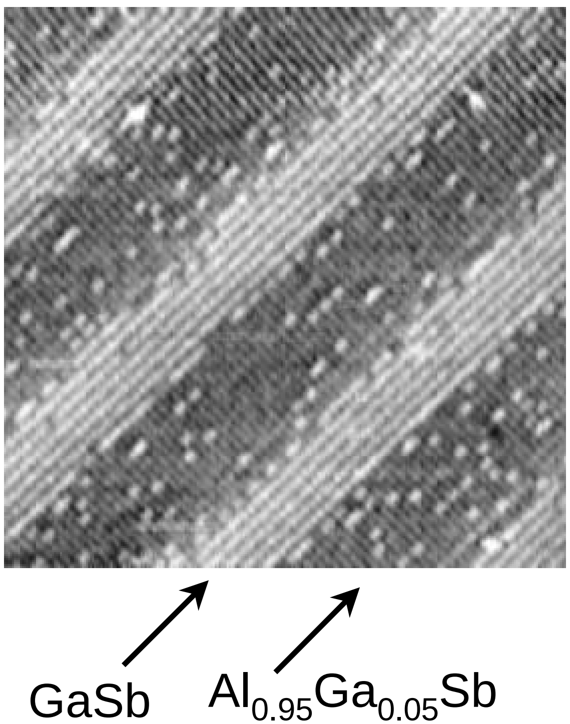
A growth scenario: RITD with alloy barriers



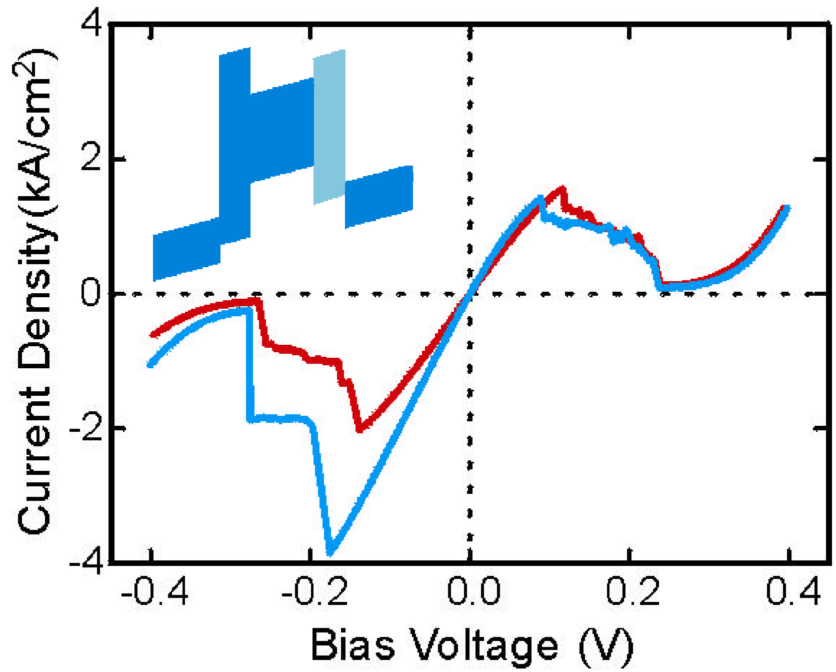
Two Sb cells for two growth rates.

AlGaSb Alloy barriers

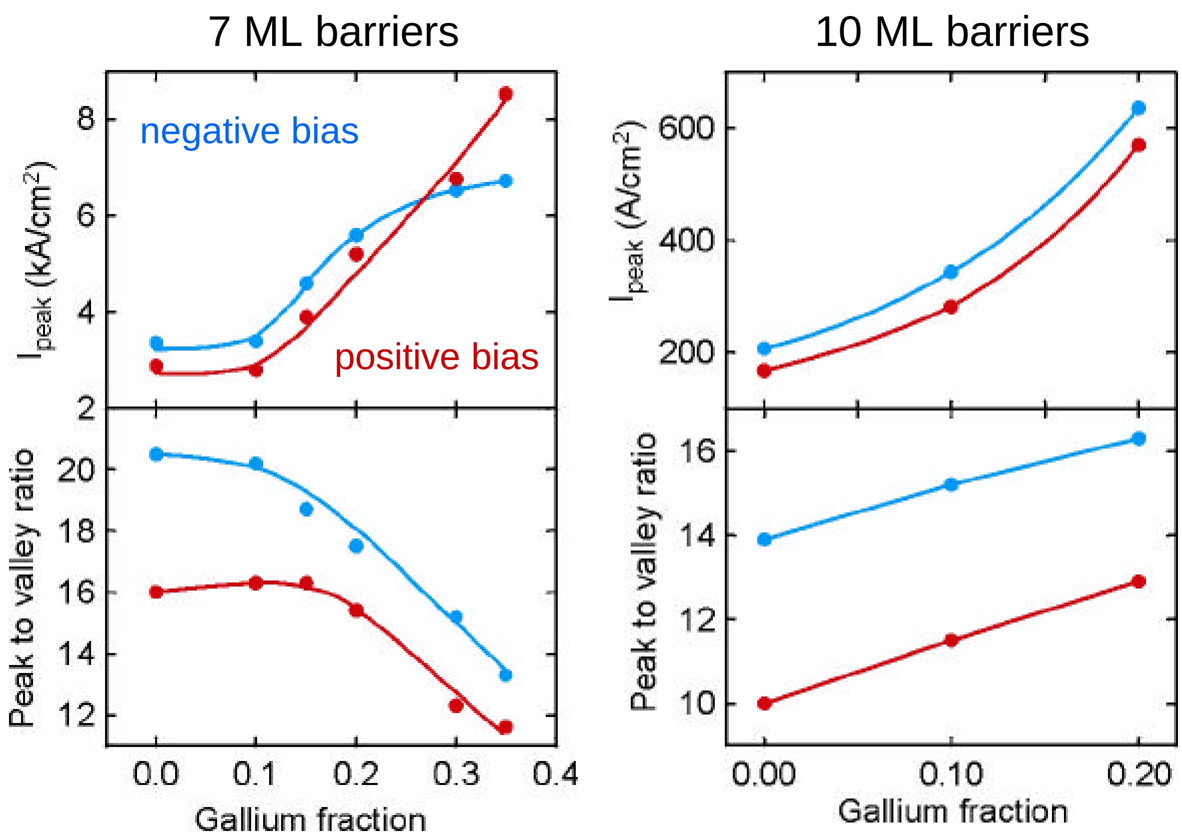
GaSb / AlGaSb superlattice



Symmetric (both barriers AlSb)
Asymmetric (top barr. Al$_{0.7}$Ga$_{0.3}$Sb)



Performance Advantages of AlGaSb barriers



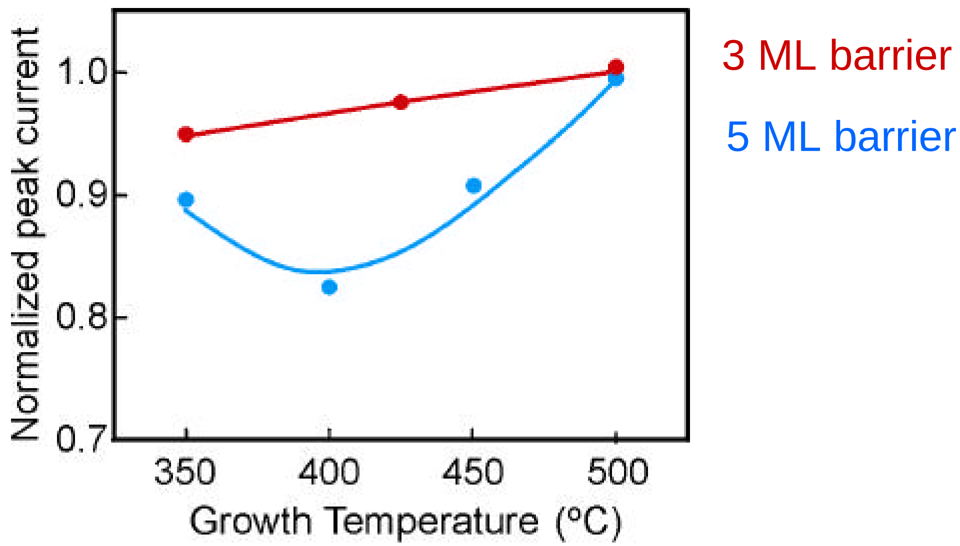
2-3 times boost in peak current

P/ V suffers little if at all

Opportunity for high currents with thicker barriers that are less sensitive to interface effects.

Influence of Ga segregation on Peak current

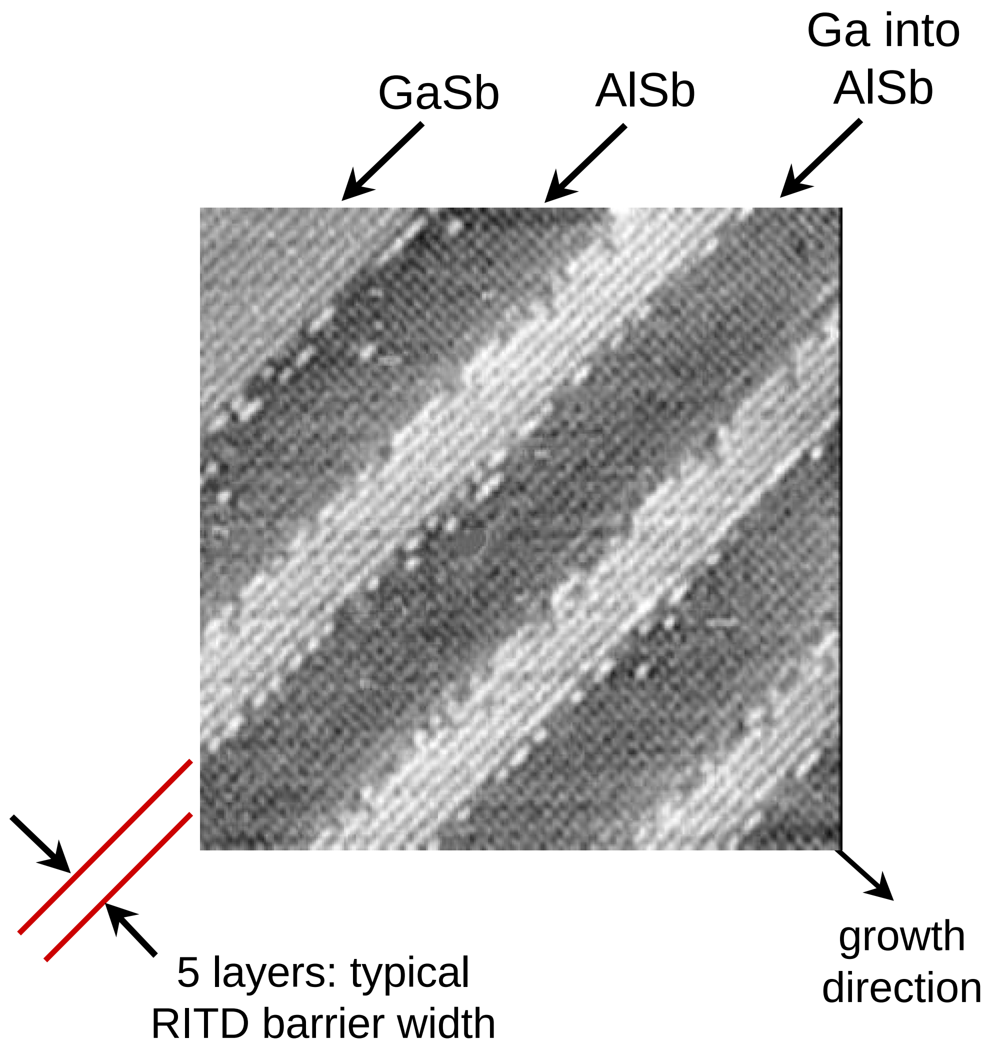
Reverse bias: top barrier



Segregation reduces top barrier gap
to increase reverse bias current.

Roughness will also contribute (with opposite
temperature dependence), complicating interpretation.

Ga segregation into AlSb



Conclusions

- Higher peak currents result from
  1. Interface roughness at low growth temperature
  2. Gallium segregation at higher growth temperature

- Sudden reconstruction changes can lead to island formation with antimonides

- Barrier alloying permits higher peak currents with possible reduced sensitivity to interface flaws

.