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Title:

CHARACTERIZATION OF Si(100) HOMOEPITAXY GROWN IN THE STM AT LOW TEMPERATURES

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We explore the growth of low-temperature bulk-like Si(100) homoepitaxy with regard to microscopic surface roughness and defects. We characterize films grown at different temperatures up to 500K in-situ by means of an effusion cell added to our UHV-STM. The development of novel architectures for future generation computers calls for high-quality homoepitaxial Si(100) grown at low temperature.[1] Even though Si(100) can be grown crystalline up to a limited thickness,[2] the microstructure reveals significant small-scale surface roughness[3] and defects specific to low-temperature growth.[4] Both can be detrimental to fabrication and operation of small-scale electronic devices.

[1] **B. Kane, Nature 393, 133 (1998)**

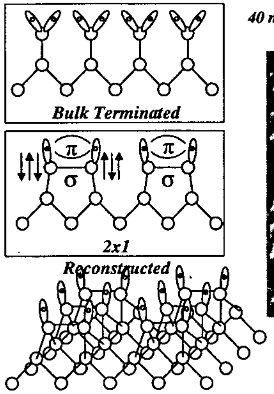
[2] **DJ Eaglesham, J. Appl. Phys., 77, 3597 (1995)**

[3] **RJ Hamers et al., J. Vac. Sci. Technol. A 8, 195 (1990)**

[4] **MJ Bronikowski et al., Phys. Rev. B, 48, 12 361 (1993)**

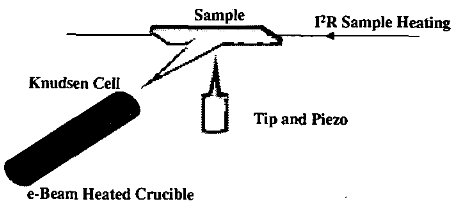
Silicon Based Quantum Computer

- **Arrays of Spin Centers in Silicon Matrix**
  B. Kane, *Nature* 393, 133 (1998)
- **High Quality Epitaxial Layer**
  - ***Isolate Spins from Environment***
- **Low Temperature Silicon Epitaxy**
  - ***Preserve Atomic Arrangement***
- **Manufacture in the STM**
  - ***Facilitate Positioning between Process Steps***



40 nm x 40 nm. Filled States $V_{sample} = -3$ V

Unit Cell
3.85 Å x 7.70 Å



- Tip Retracted during Growth
- Sample at Room Temperature during Imaging

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- Crystalline Growth up to a Temperature Dependent Thickness
- Surface Roughness Increases with Epitaxy Thickness

DJ Eaglesham, J. Appl. Phys., 77, 3597 (1995).

- Surface Roughness Increases with Background Hydrogen

JE Vasek et al., Phys. Rev. B, 51, 17 207 (1995).

- Preferred Nucleation at Antiphase Domain Boundaries

P Bedrossian et al., Phys. Rev Lett., 70, 2589 (1993).
MJ Bronikowski et al., Phys. Rev. B, 48, 12 361 (1993).

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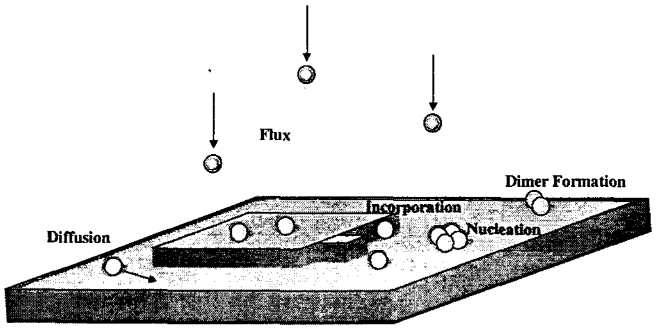

Sample

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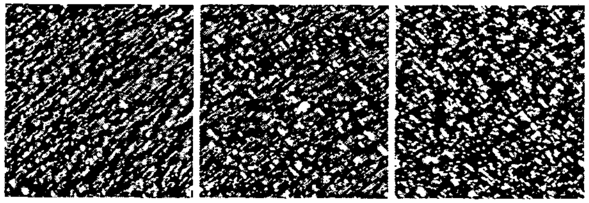
100nm x 100nm STM scans -1.5V sample bias, 150pA. Epitaxy grown at 100°C



0.66 ML, 3.6% 2nd layer | 0.81 ML, 10% 2nd layer | 1.05 ML, 22% 2nd layer

Early Onset of Second Layer Nucleation at submonolayer coverages

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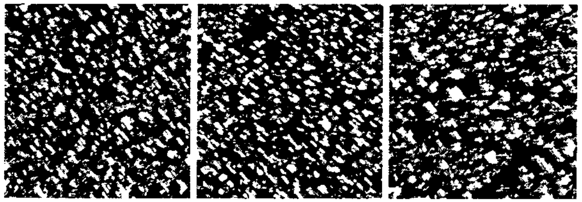
100nm x 100nm STM scans -1.5V sample bias, 150pA. 100°C Epitaxy Annealed

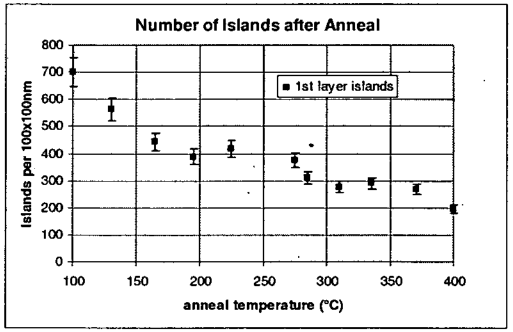


Anneal to 195°C
344 Islands

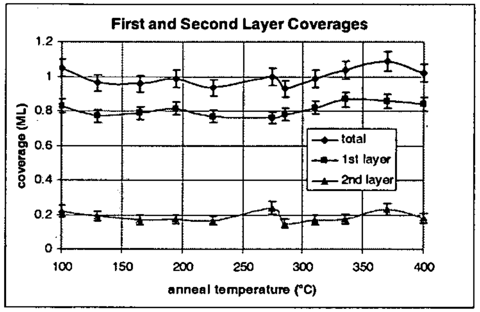
Anneal to 335°C
293 Islands

Anneal to 400°C
196 Islands

Coarsening of First and Second Layer

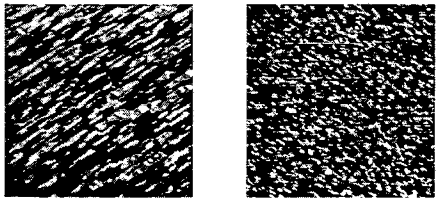


No Mass Transport between Layers



No Mass Transport between Layers

100nm x 100nm STM scans -1.5V sample bias, 150pA. Epitaxy grown at 150°C



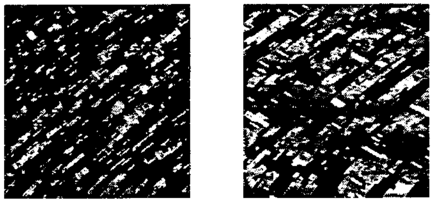
0.47 ML, 5.7% 2nd layer

0.96 ML, 8% 2nd layer

Reduced Second Layer Nucleation at submonolayer coverages

Smoother Epitaxy near monolayer coverage than Grown at 100°C

100nm x 100nm STM scans -1.5V sample bias, 150pA. Epitaxy grown at 200°C

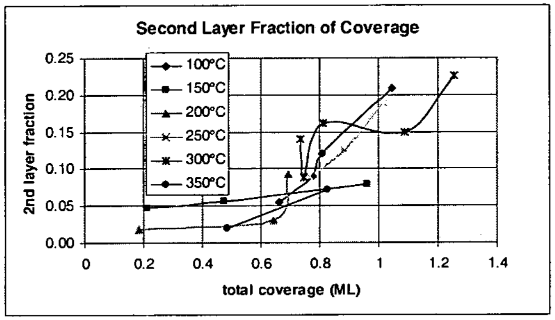


0.18 ML, 1.8% 2nd layer

0.64 ML, 3.1% 2nd layer

Reduced Second Layer Nucleation at submonolayer coverages

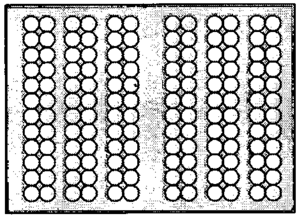
Smoother Epitaxy than Grown at 100°C or 150°C



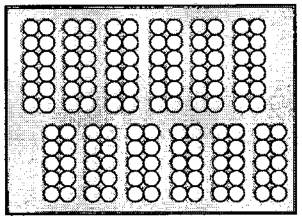
Higher Growth Temperatures Lead to Smoother Epitaxy

High Quality Thin Homoepitaxy on Silicon (100)

- Considerable Small Scale Surface Roughness
- Postanneal at Moderate Temperatures Ineffective
- Smoother Epitaxy at Higher Temperatures
- In Situ STM Study



AP1



AP2