Quantum Dot Formation Using Nano-patterned InAs

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Research Objective: To control the size and uniformity of quantum dots using nano-patterned planar InAs.

Motivation

- Tunable energy levels
- Orbital overlap
- Quantized phonon and electron levels

Self-Assembly Process

- A balance between surface effects and bulk effects determine when nuclei become stable
- Nucleation is random over surface area and time

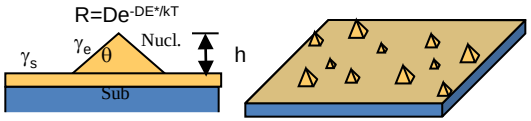
Surface *Bulk*

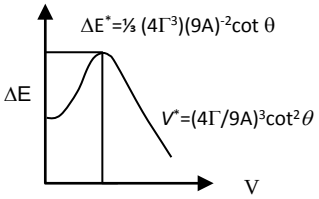
$$\Delta E = 4\Gamma V^{2/3}\tan^{1/3}\theta - 6AV\tan\theta$$

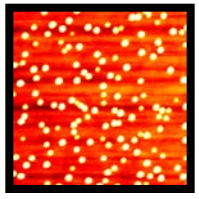
$$\Gamma=\gamma_e \csc\theta-\gamma_s\cot\theta$$

$$A=\sigma_{\square}^{\,2}(1-\upsilon)/(2\pi G) \quad \textit{Strain}$$

$$V=h^3\tan^2\theta$$

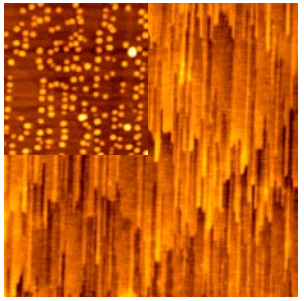


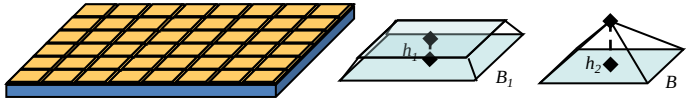




Fabricated Nucleation

- Surface tension can cause the surface of planar InAs to spontaneously reconstruct
- Nano-patterning allows us to adjust and control the surface tension; subsequent annealing under high arsenic overpressure causes the material to pull up and form quantum dots

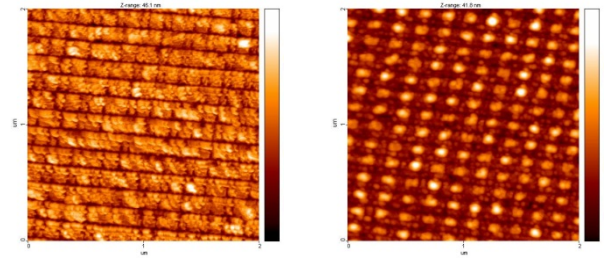




- Size of squares are chosen so that the volume of material is larger than the critical nuclei size

2μ x 2 μ AFM images

Before Annealing | After Annealing ~500ºC

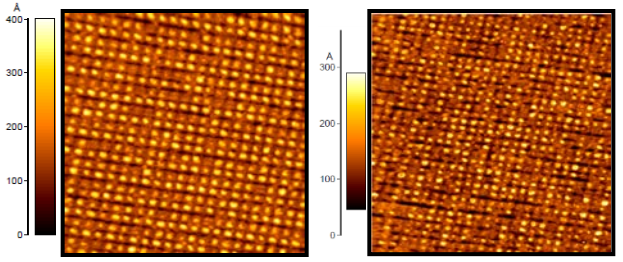


- Initial pattern ~1600Å x 1600Å , 45-50Å high
- Final structure 800Å x 800Å , 400Å high

Smaller Patterns

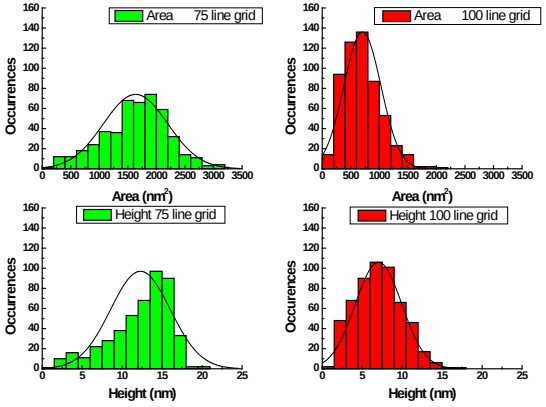
2μ x 2 μ AFM images after annealing

75 line grid | 100 line grid



- 75 line grid ~460Å x 460Å , 120Å high
- 100 line grid ~ 300Å x 300Å , 70Å high

Grain Analysis



Pattern	75 line grid	100 line grid
Area ± Stand. Dev. [nm]	1636 ± 563	704 ± 325
Height ± Stand. Dev [nm]	12.3 ± 3.7	7.0 ± 2.9

This work was sponsored by AFOSR with Kitt Reinhardt as the manager