Research exercise: Quantum Dot Formation Using Nano-patterned Planar InAs

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Quantum Dot Formation Using Nano-patterned InAs

Dan Esposito
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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

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

\[ \Gamma = \gamma_e \csc \theta - \gamma_s \cot \theta \]

\[ A = \sigma_0^2 (1-\nu) / (2\piG) \]

\[ V = h^3 \tan ^2 \theta \]

\[ R = D_e e^{\Delta E^* / kT} \]

\[ \Delta E^* = \frac{1}{2} (4\Gamma^2/9A)^2 \cot \theta \]

\[ V' = (4\Gamma/9A)^2 \cot ^2 \theta \]

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

Smaller Patterns
• 75 line grid ~460Å x 460Å, 120Å high
• 100 line grid ~300Å x 300Å, 70Å high

Grain Analysis

<table>
<thead>
<tr>
<th>Pattern</th>
<th>75 line grid</th>
<th>100 line grid</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area ± Stand. Dev. [nm]</strong></td>
<td>1636 ± 563</td>
<td>704 ± 325</td>
</tr>
<tr>
<td><strong>Height ± Stand. Dev. [nm]</strong></td>
<td>12.3 ± 3.7</td>
<td>7.0 ± 2.9</td>
</tr>
</tbody>
</table>