Self-Growth Mechanisms for Silicon and Germanium Nanostructures  
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Nanostructures are proposed for many applications, from quantum computing to photonics. For their potential applications to be realized, building these structures must be done quickly or cheaply enough. In the case of silicon and germanium, “top-down” methods, such as lithography, have been proposed. But most forms of lithography are too coarse and too slow to be an ideal method in producing these structures, which can sometimes be as small as 2nm wide, and often well below 100nm. Thus, “bottom-up” methods seem to be more favorable due to their relative speed and resolution. Using molecular beam epitaxy, nanostructures in the sub-ten to hundred nanometer range can be built at a much higher efficiency. However, self-growth methods are comparatively more random in terms of the structure formation, and can have less size uniformity. This poster seeks to explore a couple of the nanostructure growth methods being researched today and the potential resolves offered in terms of growth uniformity.
Abstract
In the case of silicon and germanium, “bottom-up” methods in growing nanostructures have been proposed. Using molecular beam epitaxy, nanostructures in the sub-ten to hundred nanometer range can be built.

Motivation
Nanostructures are proposed for many applications, from quantum computing to photonics. For their potential applications to be realized, building these structures must be done quickly or cheaply enough. In the case of silicon and germanium, “top-down” methods, such as lithography, have been proposed. But most forms of lithography are too coarse and too slow to be an ideal method in producing these structures, which can sometimes be as small as 2nm wide, and often well below 100nm. Thus, “bottom-up” methods seem to be more favorable due to their relative speed and resolution. However, self-growth methods are comparatively more random in terms of the structure formation, and can have less size uniformity. This poster seeks to explore a couple of the nanostructure growth methods being researched today and a potential resolve offered in terms of growth uniformity.

Concept
• 3D shapes with Ge/Si Deposit on Si.
  • Structure shape controlled by deposit amount, substrate temperature, deposition rate, shape of substrate.

Ge Growth on Si(001)
• Stranski-Krastanov growth mode: 4ML Ge wetting layer on Si(001).

Germanium Structures Grown via S-K Method

• Si(111)7x7 reconstructed surface (DAS structure)
• dangling bonds (94919)
• F half & U half

Ge on Si(111)flat surface
Post growth: Ge/Si = 100° C, Sub @ RT. 20 min., Post Annealed 30 min. at 400° C.

• Hut clusters: oriented along [110] directions, high density.
• Nanowire from further deposition of Ge or higher temperature.

Ge on Si(111)flat surface
Post growth: Ge/Si = 100° C, Sub @ RT. 20 min., Post Annealed 30 min. at 400° C.

• Octagonal, Dome-Shaped Islands: further deposition of Ge or higher temperature.

• Bigger shapes have slower growth rates. This limits size of islands.
• Heated atoms move to islands with lower chemical potential.
  (chemical potential = change in E of an island/change in # of particles).
• Chemical potential is lower for larger shapes.
• Increasing temperature makes larger average size, less size distribution.
• Temperature affects Si concentration.
  (approximately 50% on the top, ~100% on the bottom).
• Concentration of Si depends on shape.
  Pyramid dots have more Si (~50% on the top, ~100% on the bottom).

• Deposition rate affects the size and density of deposits.
  Faster rates allow for more nucleations and form more, smaller dots.
• Deposition amount influences island size and size uniformity.
  Greater deposition amounts increase average dot size and size distribution.

• Concentration of Si depends on shape.
  Pyramid dots have more Si (~50% on the top, ~100% on the bottom).
  Decrease in Si from bottom to top is more linear than island.

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Concept
• Ge deposition through MBE at heater temp. = 1160° C and surface temp. = 500-800° C.
• Three shapes can be formed:
  2. Pyramids: caused by further deposition of Ge or higher temperature. Pyramid dots and dome dots can coexist.
  3. Octagonal, Dome-Shaped Islands: further deposition of Ge or higher temperature.