Introduction to Nanotechnology

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What is “nano”

10^{-1}m
10^{-2}m
10^{-3}m

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Perspective

Narrower than my pinky!
Nanotechnology, a definition

- American Heritage Dictionary
  “The science and technology of building electronic circuits and devices from single atoms and molecules.”

- Wordnet
  “the branch of engineering that deals with things smaller than 100 nanometers (especially with the manipulation of individual molecules)”

Definitions continued

- M. Rocco, NSF
  “the ability to work at the molecular level, atom by atom, to create large structures with fundamentally new properties and functions”

- NASA
  “the creation of functional materials, devices and systems through control of matter on the nanometer length scale (1-100 nanometers), and exploitation of novel phenomena and properties (physical, chemical, biological) at that length scale”

Ancient History of Nanotech?

- ~400BC, Atoms [Democritus of Abdera]
- ~500AD, glazes [artisan in Mesopotamia]
- 1661, elements [Boyle]
- 1803, atomic theory [Dalton]
- 1869, periodic table [Mendeleyev]
- 1915, Bohr Model [Bohr]
- 1920, carbon black

Modern history of nanotech

- 1959, Feynman’s talk “There is plenty of room at the bottom”
- 1965, Moore’s original paper
- 1981, Drexler began popularizing
- 1984, invention of STM [Binning]
- 1985, discovery of fullerens [smalley]
- 1990, IBM written in Xenon
Moore’s Law

What Comes Next?

Technology Shifts

• Size of Devices
  ⇒ Inches to Microns to Nanometers

• Type of Interconnect
  ⇒ Rods to Lithowires to Nanowires

• Method of Fabrication
  ⇒ Hammers to Light to Self-Assembly

• Largest Sustainable System
  ⇒ $10^1$ to $10^8$ to $10^{12}$

• Reliability
  ⇒ Bad to Excellent to Unknown
Commercialization

- By 2015 predicted to be $10^{12}$ dollars
- Everything from nanoparticles to nanorobots

Rutt, Foley, and Lardner, 2002

One Course Goal

- Understand what is important to you
  - Read literature in related fields
  - Understand relevance to your research
- Understand importance to others

Biology

- DNA/RNA
  - 2-3nm per base pair
  - $10^9$ base pairs for human genome
- Proteins
  - 100K different in human
  - “self-assembles”
- DNA-computing
- DNA-based self-assembly
- ATP motors
Chemistry

- Molecular diodes
- Molecular switches
- Block Polymers
- Fluidic self-assembly
- Molecular design

Physics

- Quantum mechanics
- Scattering

Materials

- Carbon Nanotubes
- Multifunctional materials
- Smart materials
- Nanostructured catalysts

Electrical Engineering

- VLSI
- Lithography
  - Top-down assembly
  - Easily to 65nm, controlled gates to 15nm,
  - Thicknesses to sub-1nm!
- Transistor
- Electronic nanotechnology
- Nanocomputing
Robotics

• Integration
• Actuation (e.g., surface tension)
• Power systems
• Sensing
• Emergent behavior

Sociology

• Disruptive technology
• Changes in social fabric
• Work habits
• Life expectancy
• Understanding fear

Policy

• Controlling & aiding research
• Risk of accidental or intentional harm
• Training and education
• Environmental impact
• What to fund

What is Nanotechnology?

• Does anyone really know?
• Another goal of the course, determine precisely what nanotech is
What is “nano”

- Surface to volume ration is different
- Individual atoms are important
- Forces/effects are new
  - Quantum
  - Van der Walls
  - Brownian
  - Electrostatic
- E.g., how fast is the speed of sound

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Is this nano?

- A motion controller for nanoassembly

Building a Computing Crystal

Or, is this nano?
Building a Computing Crystal

Defining Nanotechnology

• Why?
  - Asilomar conference of 1975 for biotech
  - Funding priorities

• How?
  - First, describe design space
  - Then, linearize

The Nano design space

• Length scale
• Dimensions controlled
• Types of materials used
• Dynamic or static end-product
• Assembly method
  - bottom-up
  - Top-down
  - Deterministic or self-assembly
• Forces harnessed

Course Structure

• Lectures
• Participation
• Readings
• Reviews
• Projects
Topics Covered

• General nanotechnology
• Electronic nanotechnology
• Bottom-up/self-assembly
• Tools
• Nanorobotics
• Self-organization
• Policy

For Next Time

• Read Feynman’s lecture “There is plenty of room at the bottom”
  www.zyvex.com/nanotech/feynman.html
• Write ½ page about above
• Email pdf to seth@cs.cmu.edu before Wed Midnight

• Email me brief background and what you want to get out of this course