Nanotechnology in our Daily Life

Iridescent car paint: Based on interference colors (like a butterfly, no bleaching after 5 years Miami)
Nanotechnology on our Desktops

Quantum Well Laser

Well 6 nm

Transistor

Gate oxide 4 nm

Gate

Source Drain

Switching layer 5 nm

Hard Disk

Sensor Medium

Magnetic grain 10 nm
Quantum Well Laser: Designing the Perfect Trap

6 nm: Optimum Thickness
Nanocrystals

Quantum effect: Crystal size determines the color
(blue-shifted when smaller)
When does silicon cease to be silicon?

The band gap of silicon nanoclusters

3 nm: Gap begins to change
Transistor

Gate Oxide

Power consumption by a leaky gate oxide
A show-stopper for silicon technology?
Hard Disk Reading Head

- Optimum Sensing Layer Thickness: 5 nm
- Diagram showing components and signal vs. Sensing Layer Thickness graph
The Physicist’s View: Fundamental Length Scales

Energy $\rightarrow$ Length

Room temperature operation requires energies larger than the thermal energy: $k_B T = 25 \text{ meV}$

<table>
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<th>Quantum</th>
<th>Electric</th>
<th>Magnetic</th>
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<td>Quantum Well:</td>
<td>Capacitor:</td>
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Energy Levels

\[ E = \frac{3h^2}{8m} l^2 \]

Charging Energy

\[ E = \frac{2e^2}{\varepsilon} d \]

Spin Flip Barrier

\[ E = \frac{1}{2} M^2 a^3 \]

\[ l < 7 \text{ nm} \]  
\[ d < 9 \text{ nm} \]  
\[ a > 3 \text{ nm} \]
Biological Length Scales

DNA

- 3.4 nm pitch
- 10 base pairs

Virus (TMV)

- 300 nm

- 18 nm
- 11 nm
- 2 nm
Functional Supramolecular SYSTEMS

- Life Science
- Molecular Selforganization
- Molecular Recognition

- Enzymes
- Guest - Host
- Catalyst
- Surfaces
- Multilayers
- Liquid Crystals

- Function via Organization
- Synthetic Materials

- Order and Mobility
Knitting with Polymers
New Concepts: Molecular Electronics, Self-Assembly, Self-Correcting

Hewlett-Packard molecular memory, teramac computer
In Pursuit of the Ultimate Storage Medium:

1 Bit = 1 Atom

Silicon Surface

CD-ROM

1.6 nm Track

Density \times 1\,000\,000
- Speed is sacrificed as density increases (less signal per bit)
- Density and speed in silicon are comparable to those in DNA
When will we be down to atoms?

Using Moore's Law...

250 Terabit/inch²
Year 2038
"Disruptive technologies" start at the low end

Clayton Christensen, Harvard Business School

Figure 3. Successful disruptors target smaller, “green space” markets instead of stretching toward existing, larger markets.