나노 기술의 이해
(Understanding Nanotechnology)

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Lecture 14.
A brief summary of nanotechnology

1. Nanotechnology: Definition

- “Research and technology development at the atomic, molecular or macromolecular level in the length scale of approximately 1 - 100 nm range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices and systems that have novel properties and functions because of their small and/or intermediate size.” *www.nano.gov*

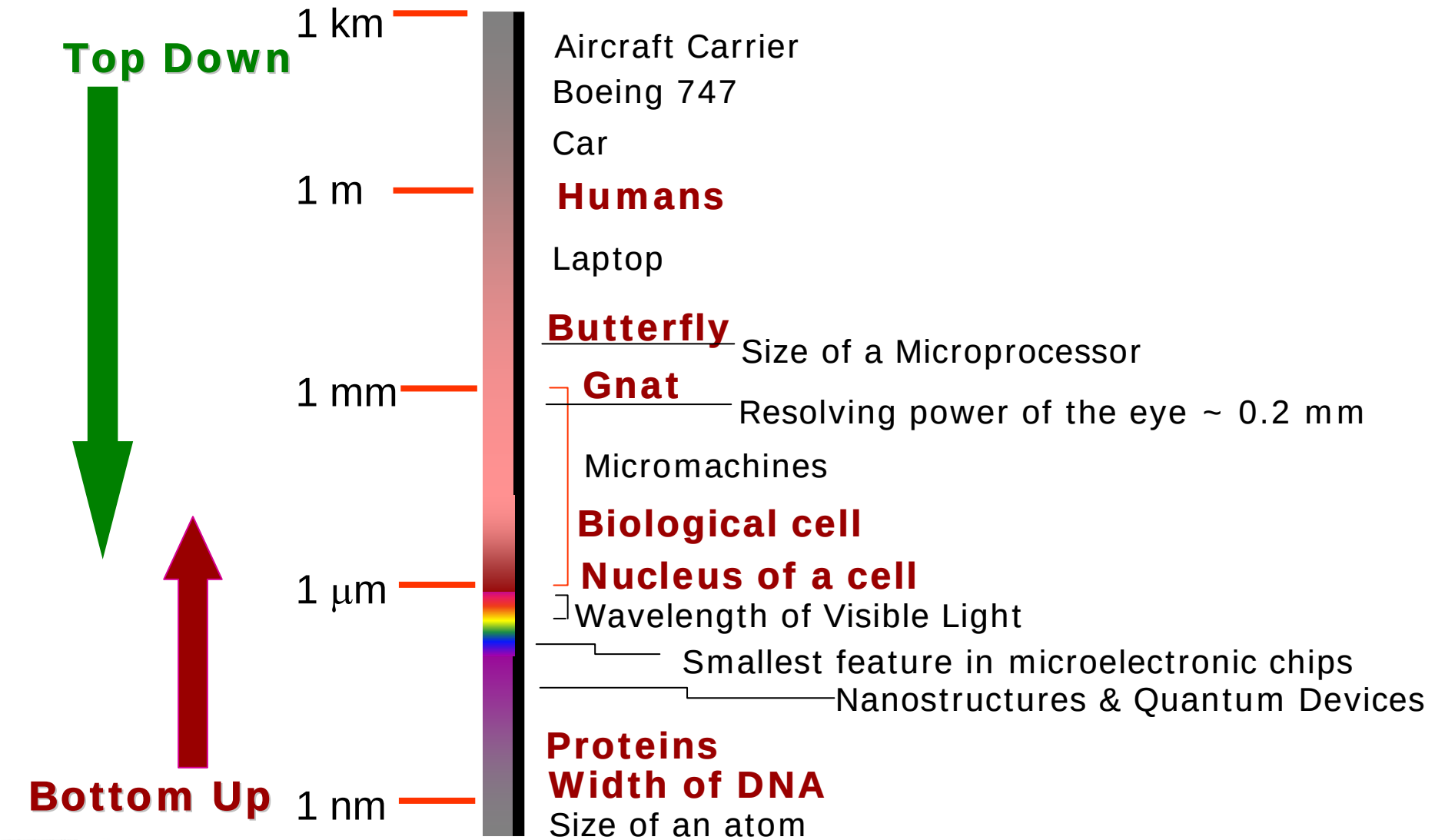
- “The development and use of devices that have a size of only a few nanometers.” *physics.about.com*

- “Branch of engineering that deals with things smaller than 100 nm (especially with the manipulation of individual molecules).” *www.hyperdictionary.com*

- “Nanotechnology, or, as it is sometimes called, *molecular manufacturing*, is a branch of engineering that deals with the design and manufacture of extremely small electronic circuits and mechanical devices built at the molecular level of matter.” *www.whatis.com*

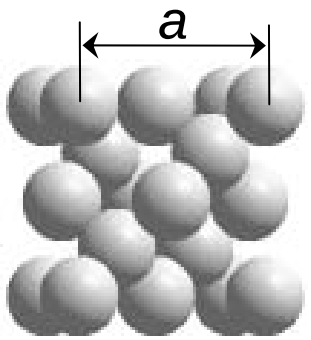
- “The art of manipulating materials on an atomic or molecular scale especially to build microscopic devices.” *Miriam Webster Dictionary*

Perspective of length scale



Surface vs. Volume

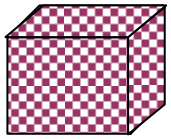
Si has a diamond structure with a = 5.43 Å



Diamond unit cell

A Si nanocube 10 nm on a side is composed of:
- ~6250 unit cells
- ~50,000 atoms

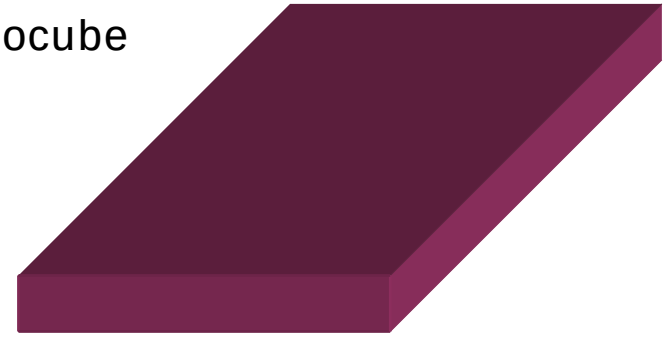
Each nanocube face is composed of:
- ~340 unit cells per face
- ~680 surface atoms per face



Si nanocube

Total surface area is:
- ~4080 atoms (~10% surface atoms)

A bulk Si film 1 μm thick on a 10 cm square:
- ~6.3×10^{19} unit cells
- ~5×10^{20} atoms
- ~1.4×10^{17} surface atoms (~0.03% surface atoms)

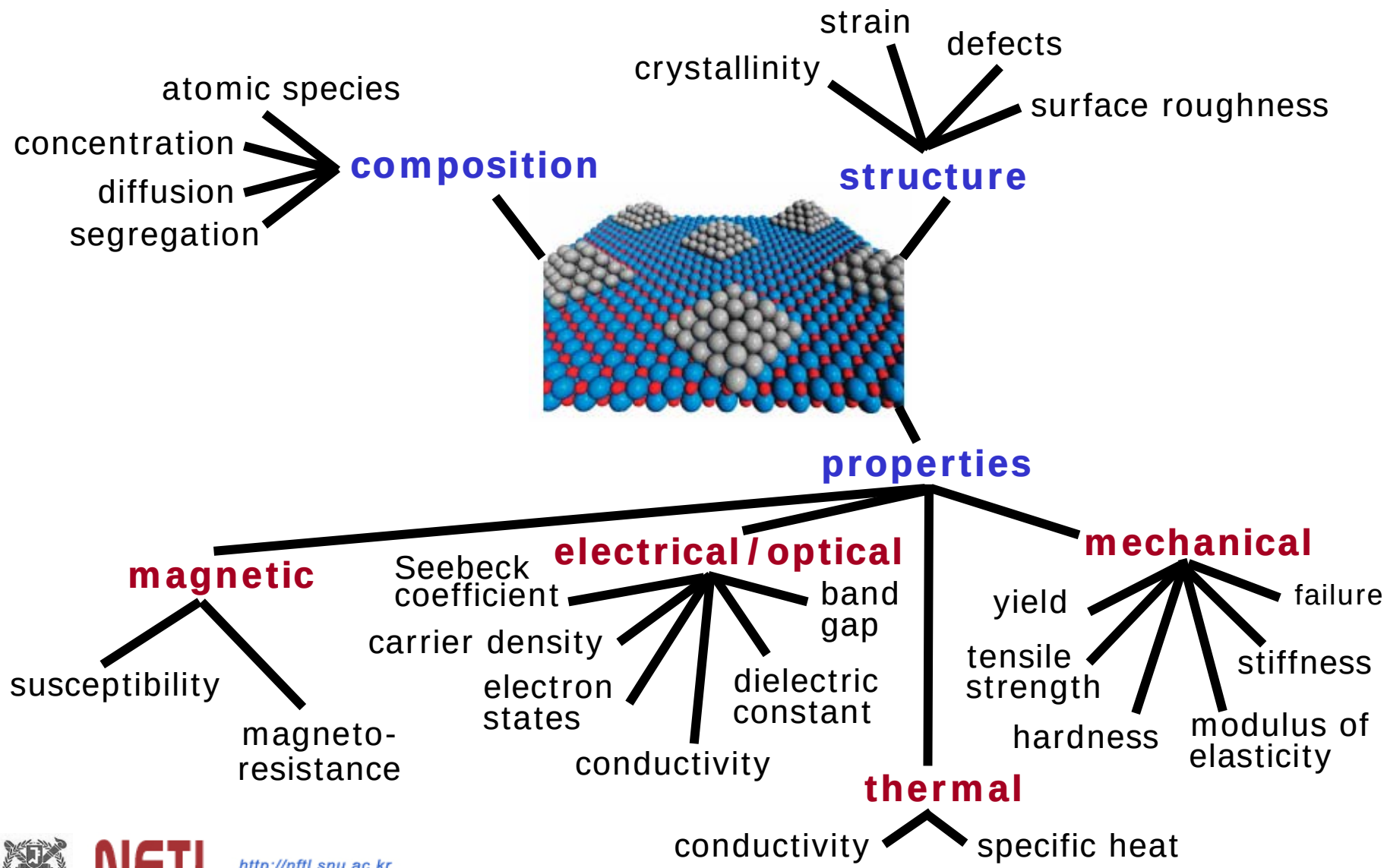


Bulk Si film

In a nanoscale material,

the surface / boundary / interface plays an important role!

What can we measure?



2. Nanotechnology: Nanomaterials

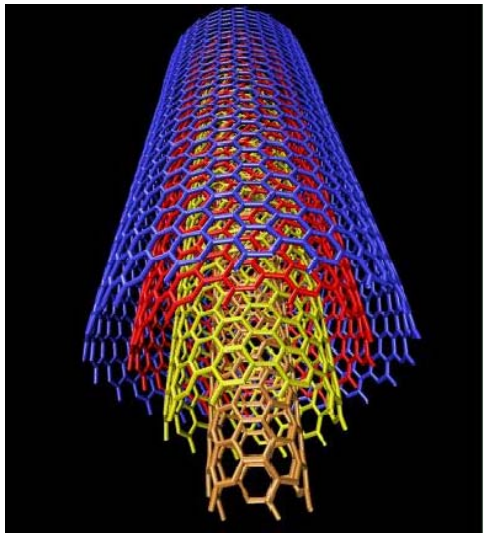
At least one dimension is between 1 - 100 nm

2-D structures (1-D confinement):

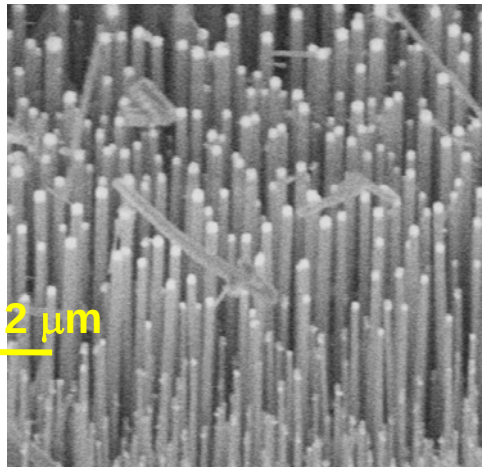
- Thin films
- Planar quantum wells
- Superlattices

1-D structures (2-D confinement):

- Nanowires
- Quantum wires
- Nanorods
- Nanotubes



Multi-wall carbon nanotube



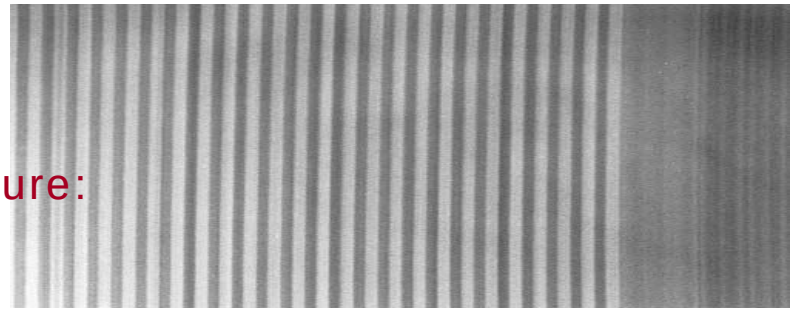
Si Nanowire Array

0-D structures (3-D confinement):

- Nanoparticles
- Quantum dots

Dimensionality, confinement depends on structure:

- Bulk nanocrystalline films
- Nanocomposites



$Si_{0.76}Ge_{0.24}$ / $Si_{0.84}Ge_{0.16}$ superlattice

3. Nanotechnology: Nanofabrication

Nanofabrication can generally be divided into two categories based on the approach:

"**Top-Down**": Fabrication of device structures via monolithic processing on the nanoscale.

"**Bottom-Up**": Fabrication of device structures via systematic assembly of atoms, molecules or other basic units of matter.

4. Nanotechnology: Nano device

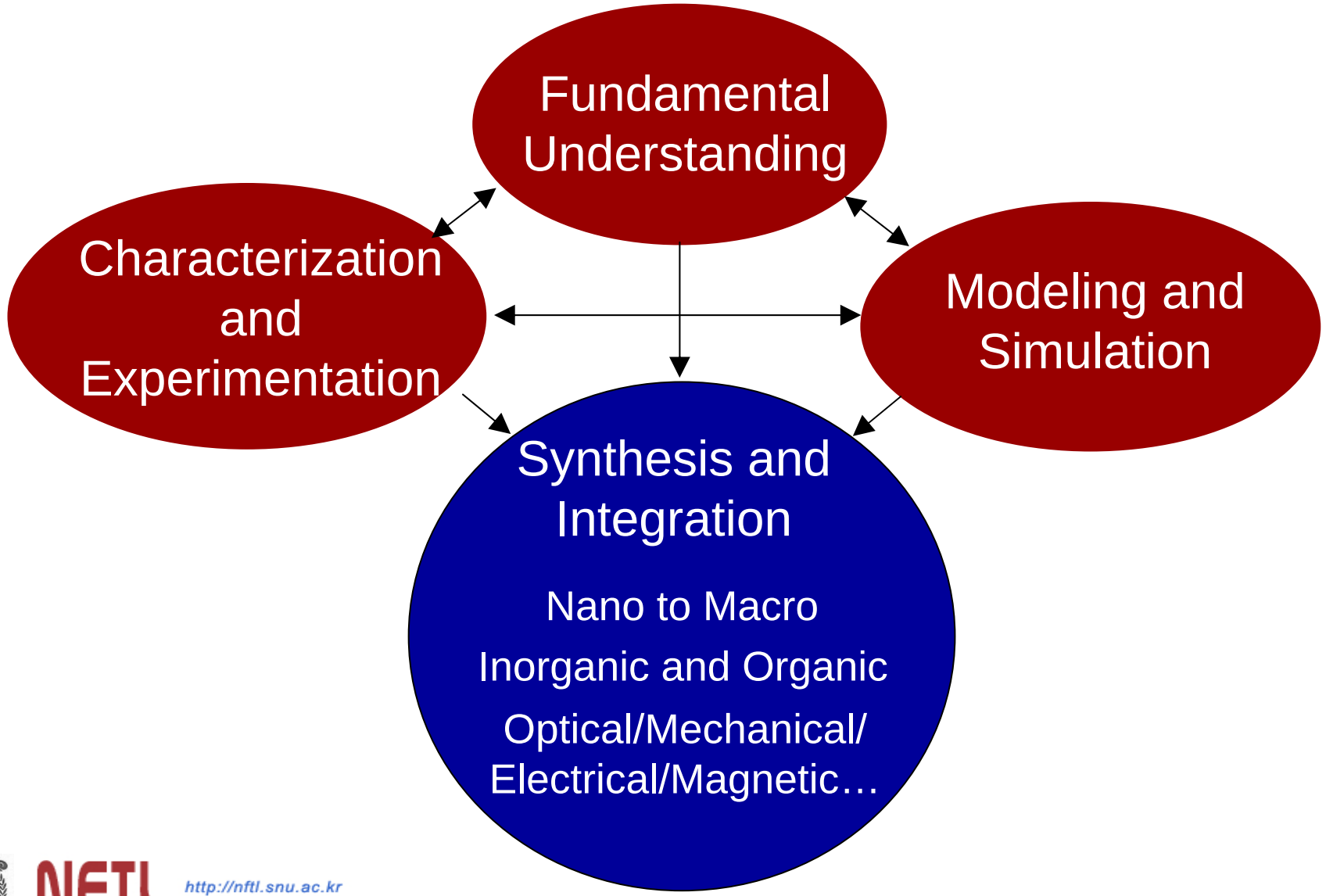
NT-BT:

Nanobiochip (DNA, Protein, Cell chip, Lab on a chip), Drug delivery, Tissue engineering, Nano robots, Biomimetics…

NT-IT:

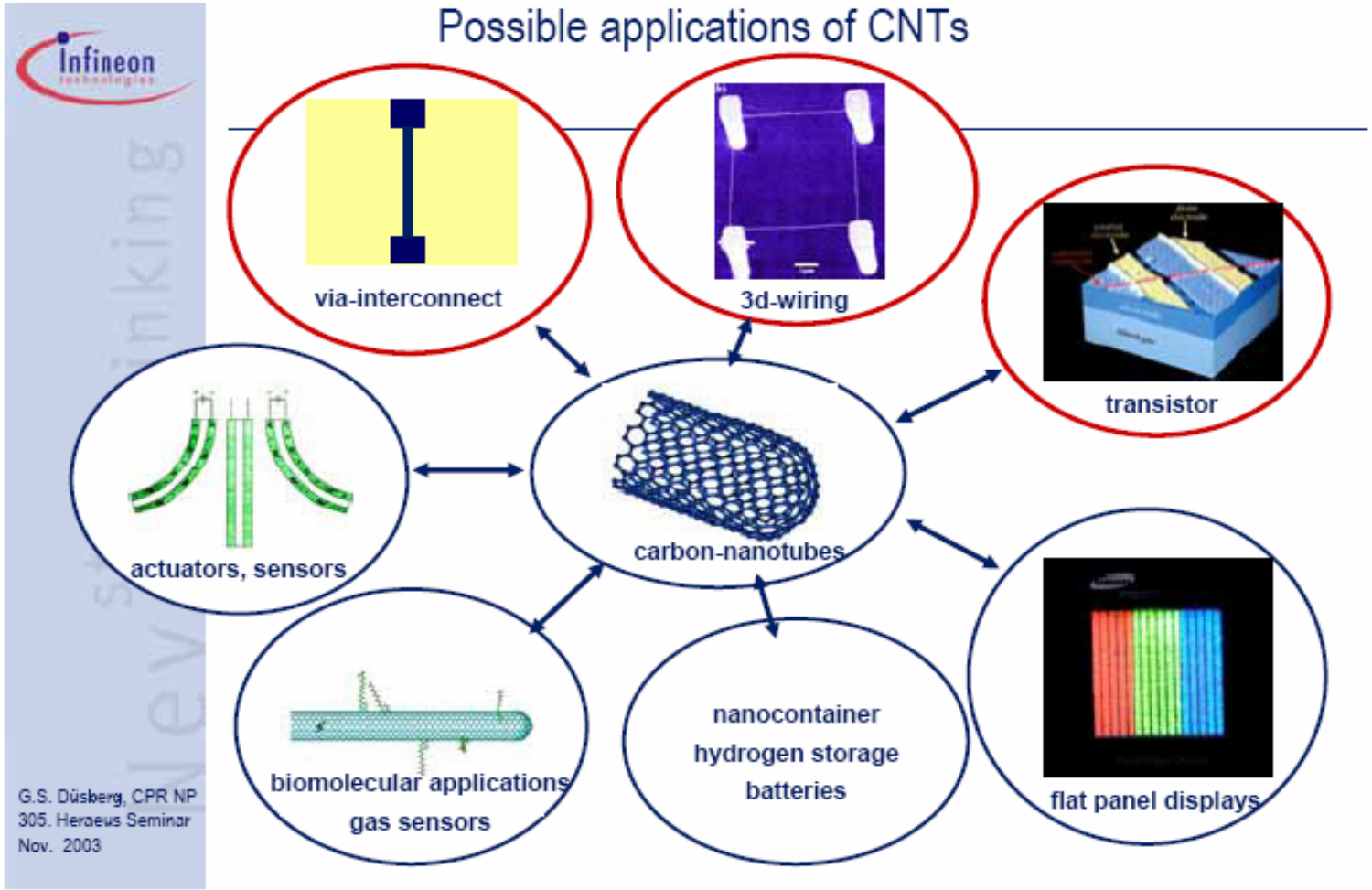
Nanocomputer (single electron transistor, molecular transistor), Display, Data storage

Development of Nanotechnology



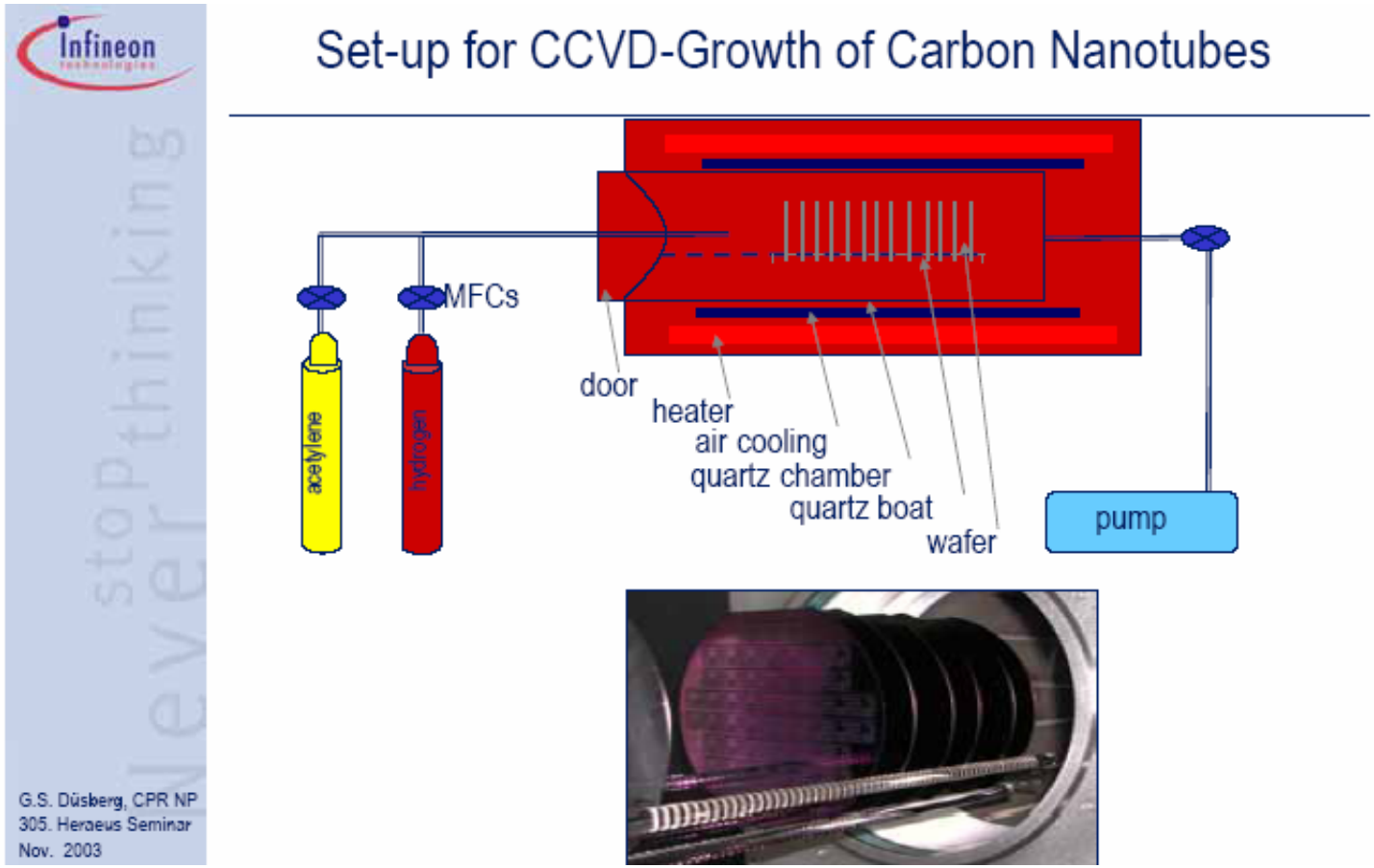
An example of device fabrication

Material? - CNT



An example of device fabrication

Process? – Bottom up + Top down (NT + BT + IT)



An example of device fabrication

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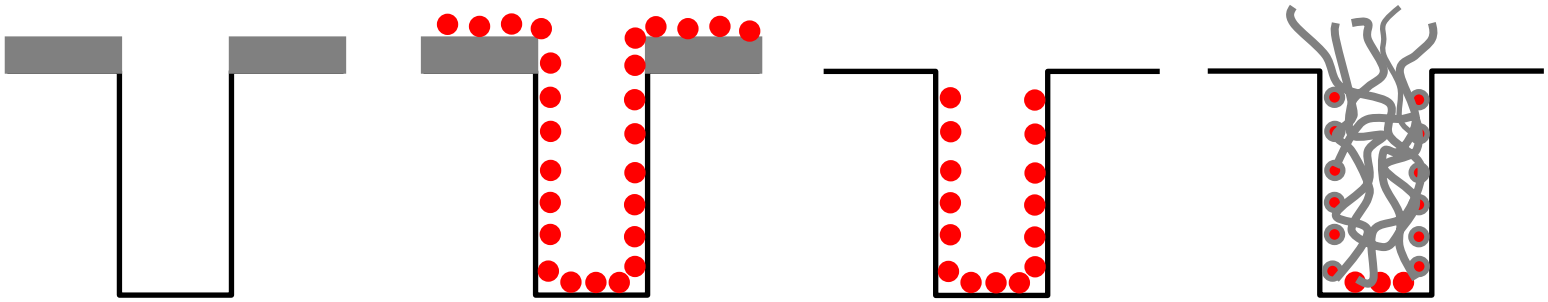

Via etch

Sputter deposit Fe catalyst

Lift-off

MWNT growth by CVD using H_2,C_2H_2 at 700 ^oC

F. Kreupl et al., Microelectronic Eng., 64, 399 (2002).