나노 기술의 이해
(Understanding Nanotechnology)

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Lecture 2.
Introduction to Nanotechnology

Standard Decimal Prefixes

Multiplier Prefix		Abbreviation	Size examples (in meter)
10^{12}	tera	T	?
10^{9}	giga	G	Sun
10^{6}	mega	M	Earth
10^{3}	kilo	k	Animals
10^{-1}	deci	d	
10^{-2}	centi	c	Ant
10^{-3}	milli	m	Frog egg Paramecium
10^{-6}	micro	μ	Eukaryotic cells Bacteria
10^{-9}	nano	n	CMOS Nanotubes, proteins Molecules
10^{-12}	pico	p	?
10^{-15}	femto	f	
10^{-18}	atto	a	
10^{-21}	zepto	z	

What does Nano mean?

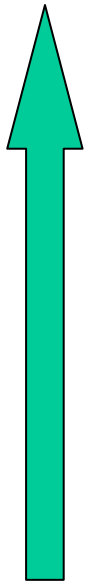
- "Nano" – Derived from an ancient Greek word 'Nanos' meaning DWARF.
- "Nano" = One billionth of something (10^{-9}).
- "A Nanometer" = One billionth of a meter.
- 10 hydrogen atoms shoulder to shoulder
- There are twenty five million nms in a single inch.

From NATIONAL NANOTECHNOLOGY ACT, OCTOVER 2003

Size matters

Sizes of biological systems are at the nanoscale

Atom	0.1 nm
Water	0.2 nm
DNA (width)	2 nm
Protein	5 nm
Cell membrane	5 nm thick
Virus	75 – 100 nm
Materials internalized by cells	< 100 nm
Bacteria	1,000 – 10,000 nm
White Blood Cell	10,000 nm

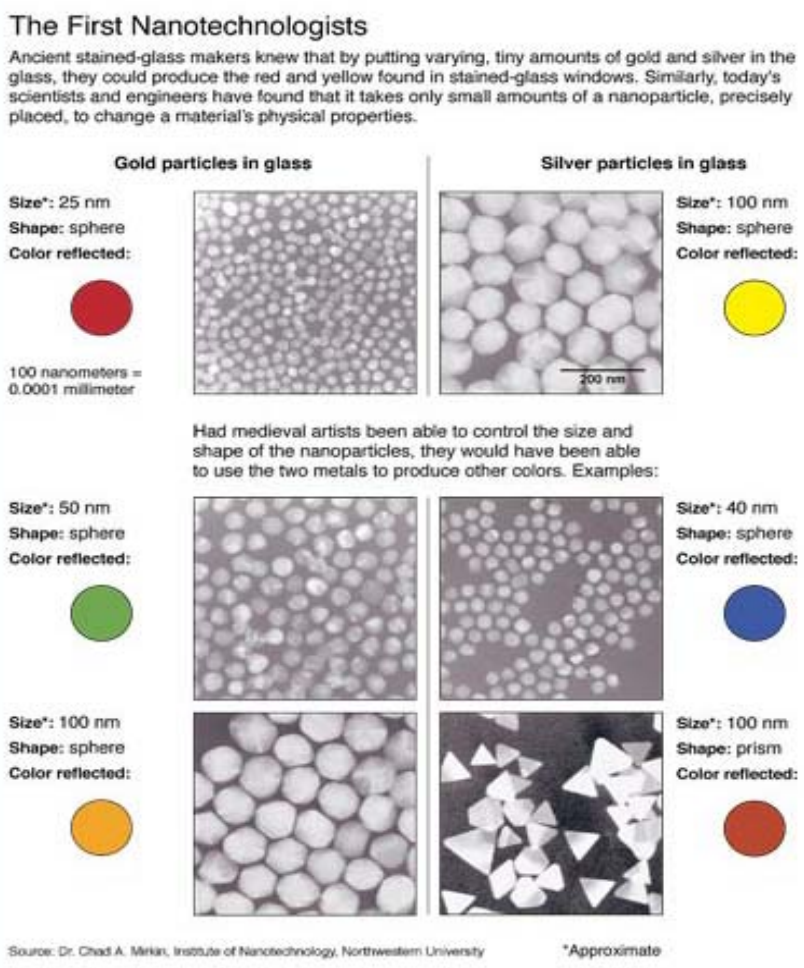


Definition of Nanotechnology

- **A definition of what nanotechnology is, is not clear.**
- **Scientists and engineers have varied opinions what nanotechnology is.**
- **Further, people have been working at the nano scale well before the word "nanotechnology" became popular.**

It depends on whom you ask. Some folks apparently reserve the word to mean whatever it is they do as opposed to whatever it is anyone else does.

The First Nanotechnologists



Chad Mirkin, Northwestern University, in NYTimes article by K. Chang - 2005

What is nanotechnology?

You may ask me, "What is Nanotechnology?"

My answer is this.

"Nanotechnology is the collaboration of chemistry, biology, physics, computer, and material sciences integrated with Engineering, Application and Education entering the Universe of Nanoscale. This means science and engineering focused on creating materials, devices, and systems at the atomic and molecular level."

Dialogues for The Cookie Jar by Dr. Anthony F. Laviano

What is Nanotechnology?

- **It comprises any technological developments on the nanometer scale, usually 1 to 100 nm.**
- **One nanometer equals one thousandth of a micrometer or one millionth of a millimeter.**
- **It is also referred as nanoscopic technology.**

The term "nanotechnology" refers to the conception and creation of functional structures, devices, and systems with dimensions ranging from 1-100 nanometers (nm).

McGraw-Hill Access Science

A possible definition

US National Nanotechnology Initiative (NNI):

- **Technology and research development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 to 100 nanometer 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.**

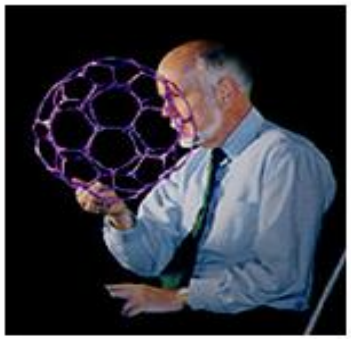
Contributors

Richard P. Feynman
1965 Nobel Laureate in Physics for fundamental work in quantum electrodynamics, with deep-ploughing consequences for the physics of elementary particles.
1959 – "There's Plenty of Room at the Bottom".

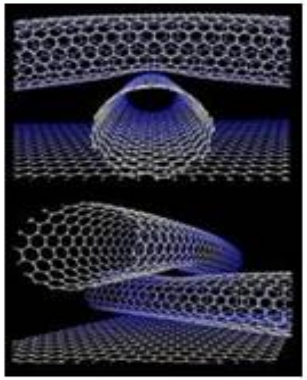
Sir Harry Kroto
1996 Nobel Prize for Chemistry for the discovery of buckministerfullerenes

Gerd Karl Binnig
Heinrich Rohrer
Invented (1981) Scanning Tunneling Microscope

Contributors



Dr. Richard Smalley - Buckyball



Dr. Sumio Iijima - Carbon Nanotubes

Dr. Anthony F. Laviano
17 August 2001 Team White Paper, a paradigm shift in the design and manufacture of RF Systems and Energy Modules using Nanotechnology.

Contributors

K.E. Drexler (1986) **“Engines of Creation: The Coming Era of Nanotechnology”**

D.M. Eigler (1989) **Writes IBM’s name with individual xe non atoms**

C. Dekker (1998) **Creates transistor from carbon nanotube**

J.M. Tour and M.A. Reed (1999) **Single molecules can act as molecular switches**

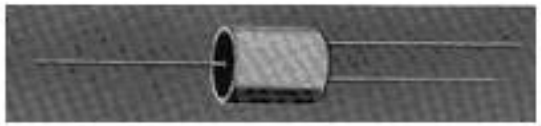
Technologies in the 1950's

Lasers

Programmable Systems

ENIAC

Transistor

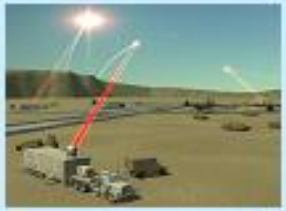


Atomic Clock

DNA

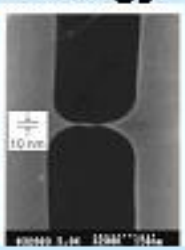
Today for 2015 and beyond…

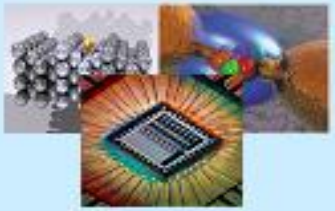
Directed Energy



Robotics

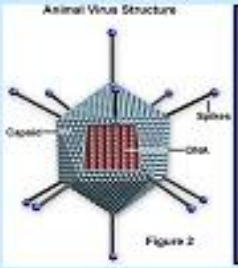
Nanotechnology

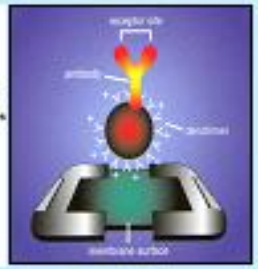




Advanced Computing

Immersive Environments

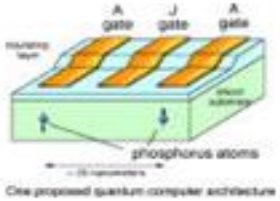


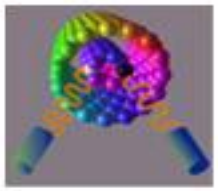


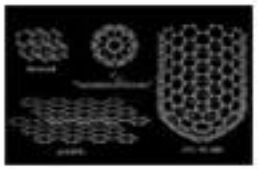
Biotechnology

1996 – 2002 Nano-Patents

"Nano" in the patent:	2812
"Quantum" in a claim:	1469
"Nano" in a claim:	195
"Nanotechnology" in the patent:	148
"Nanoparticle" in the claim :	60
'Nanowire" in a claim:	90
"Nanotube" in a claim:	7





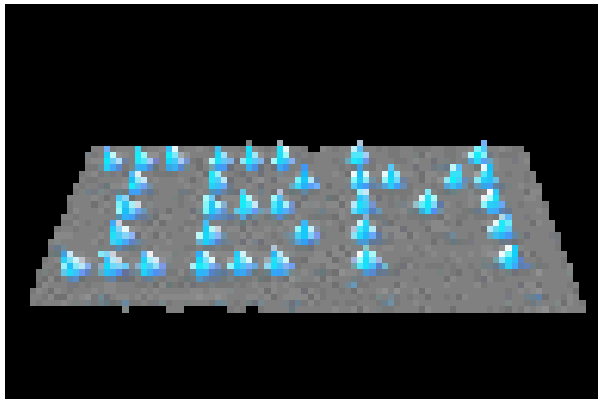


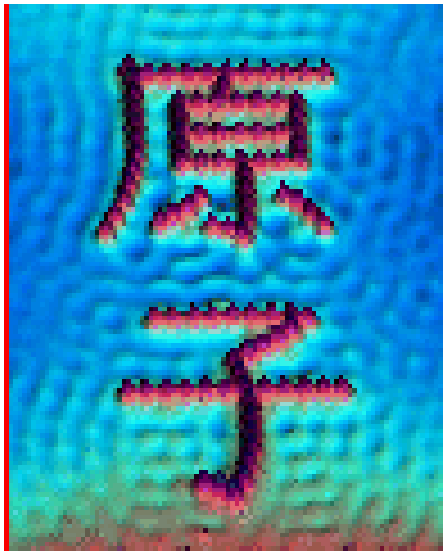
….and Growing !

A pin head is 1/16 inch across

- 1 inch approx. 2.45cm (this is a rough estimate)
- Magnify the pin head 25,000 times
- Area of pin head is then equal to the area of all the pages of the Encyclopedia Britannica.
- All you have to do is reduce the size of the writing by 25,000 times- that's all !
- Each dot on a page of the Encyclopedia has a diameter 1/120 inch roughly or 0.204mm. De-magnify 25,000 times gives us a diameter 8.2nm or about 30 atoms across in a typical metal (which they use for pins).
- So there's plenty of room to write Britannica on a pin head. No problem!!

That is fact!





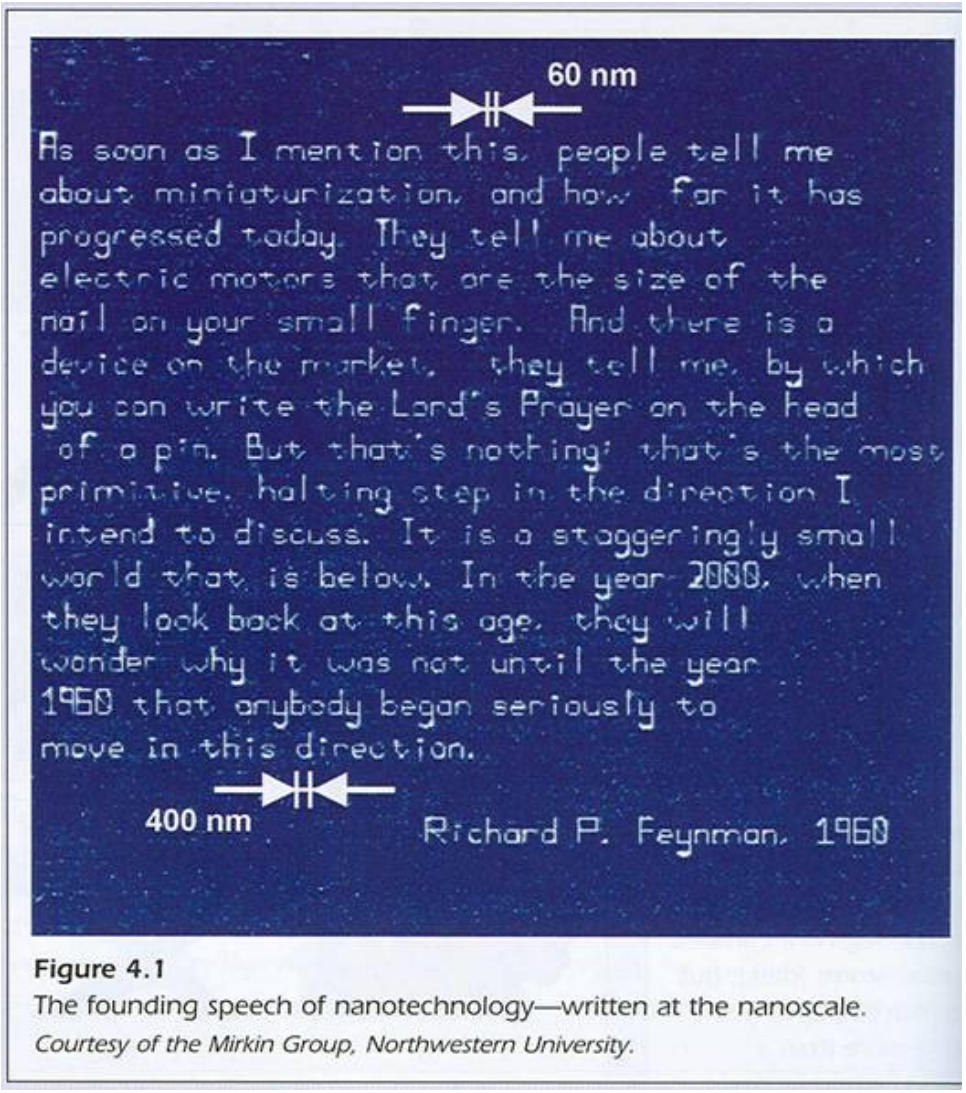


Figure 4.1
The founding speech of nanotechnology—written at the nanoscale.
Courtesy of the Mirkin Group, Northwestern University.

Why nano differs from bulk?

- **Surface tension**
  - Weight scales as l^3 whereas surface tension force as l^1
  - More difficult to empty liquids from a capillary than to spill coffee from a cup
  - Ex) Water strider
    - 10 mg mosquito ~ 1 mm^2 foot area, 60 kg man ~ 8000×8000 m^2 foot area

- **Animals in Nature**
  - African elephant of 3.80 m on land vs. a whale of 20 m long in sea
  - Foxes in cold or warm regions
  - No warm-blooded animal smaller than a shrew or a hummingbird
  - A smaller creature finds weight less troublesome

Next Lecture..
Then,
How do we WRITE small?
How do we READ small writing?