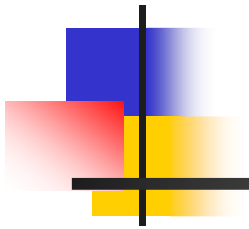
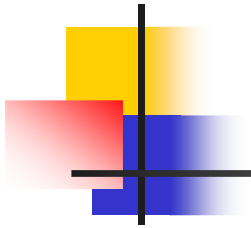


Moore´s future is more!

Jarmo Määttänen,Ph.D

Paavo Jalonen,Ph.D

The 1st European Conference on
Science, Art and Technology
in the Service of Man
September 7th - 9th, 2006
Main Building, University of Helsinki, Finland



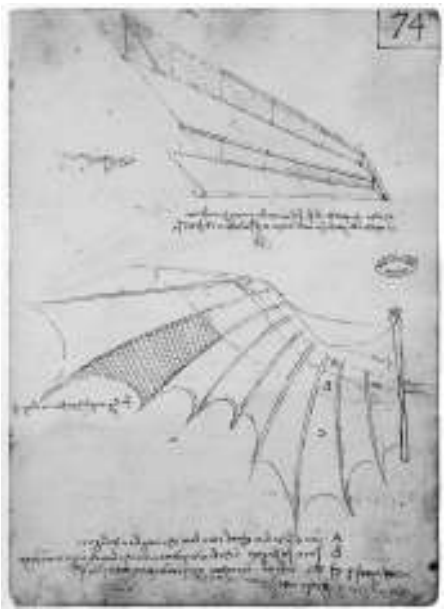
Outline

- Introduction
- Predictions and Gordon Moore
- Physical limits of microcircuits
- 3D integration
- Nanotechnology
- How the art can help us

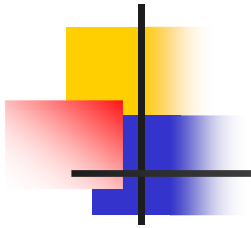
Leonardo da Vinci (1452-1519)

A man of Renaissance

Science , Art & Technology

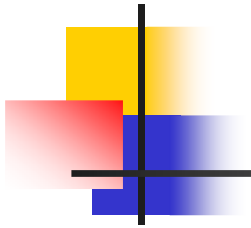


Famously Wrong Predictions



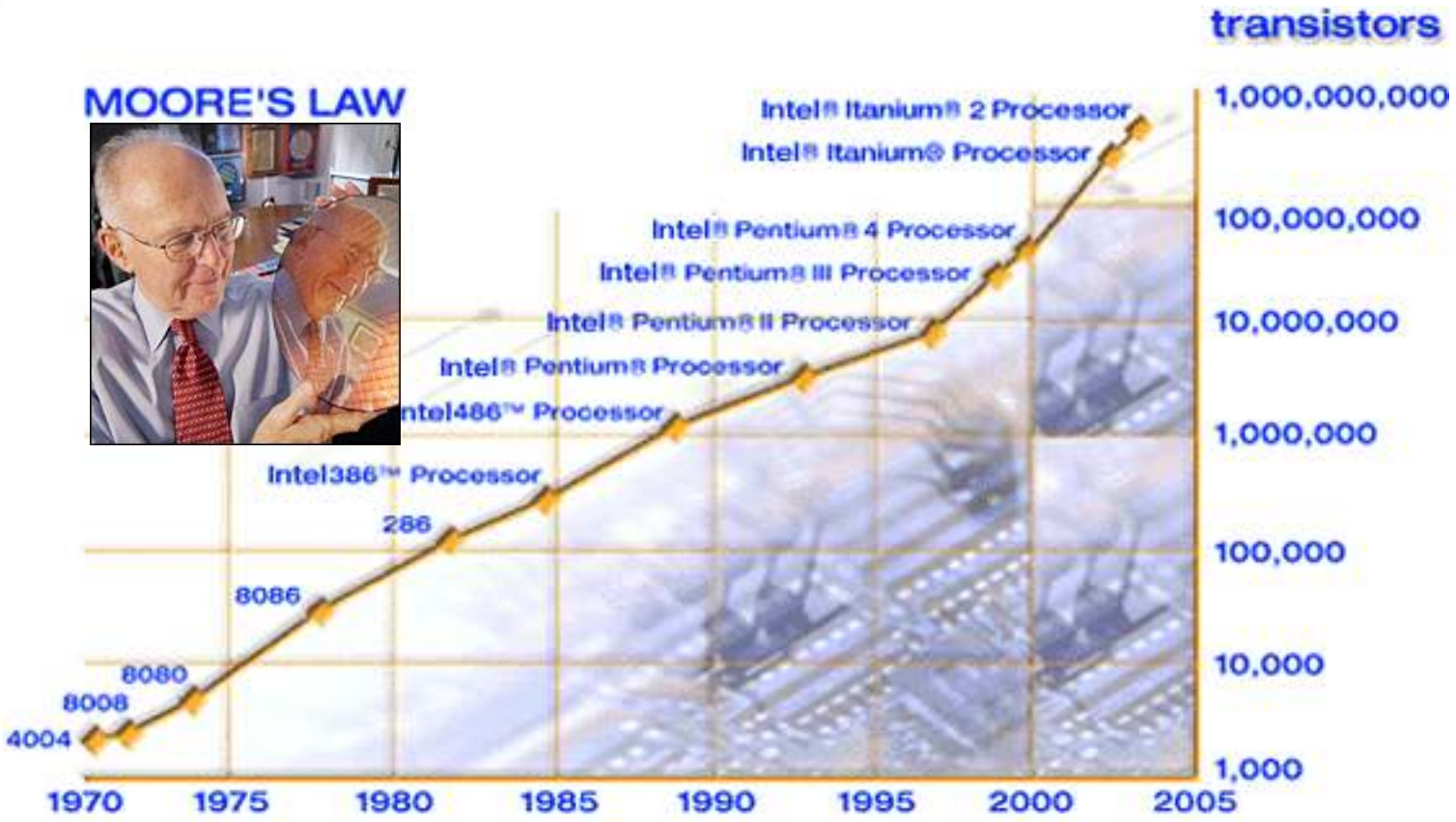
- *Inventions have long since reached their limit, and I see no hope for further developments," Roman engineer Julius Sextus Frontinus, A.D. 10.*
- *Everything that can be invented has been invented."*
  - *-- Charles H. Duell, Commissioner, U.S. Office of Patents, 1899.*
- *"Despite the trend to compactness and lower costs, it is unlikely everyone will have his own computer any time soon," Reporter Stanley Penn, The Wall Street Journal, 1966*
- *"By the turn of this century, we will live in a paperless society," Roger Smith, chairman of General Motors, 1986.*

Famously Wrong Predictions



- *"Heavier-than-air flying machines are impossible."*
  - *-- Lord Kelvin, president, Royal Society, 1895.*
- *"I think there is a world market for maybe five computers."*
  - *-- Thomas Watson, chairman of IBM, 1943*
- *Computers in the future may weigh no more than 1.5 tons."*
  - *-- Popular Mechanics, forecasting the relentless march of science, 1949*
- *Who the h_ll wants to hear actors talk?"*
  - *-- H.M. Warner, Warner Brothers, 1927.*
- *We don't like their sound, and guitar music is on the way out."*
  - *-- Decca Recording Co. rejecting the Beatles, 1962.*
- *640K ought to be enough for anybody."*
  - *-- Bill Gates, 1981*

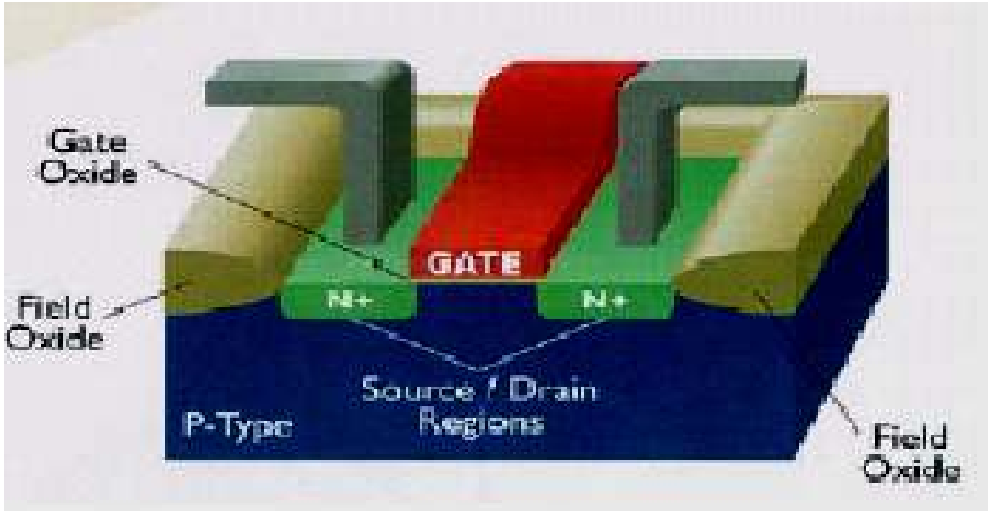
Gordon Moore (inventor of Intel); he predicted that the number of transistors the industry would be able to place on a computer chip would double every year[i]. In 1975, he updated his prediction to once every two years but later on it was found out that it doubles every 18 months



[i] Moore G., "Cramming more components onto integrated circuits", *Electronics Magazine* 19 April 1965

Fysical Limitations of microcircuit technology (Top down strategy)

CMOS=Complementary metal oxide semiconductor



- Heat Dissipation will be a problem (3 GHz microprocessor emits about 100 watts- more than a stove-top cooking surface)
- Thickness of gate isolation is going down to only few atom layers (3 nm)
- The photolithography to copy very small structures is limited because of diffraction of light
- The channel length smaller than 10 nm makes the transistor unstable!!

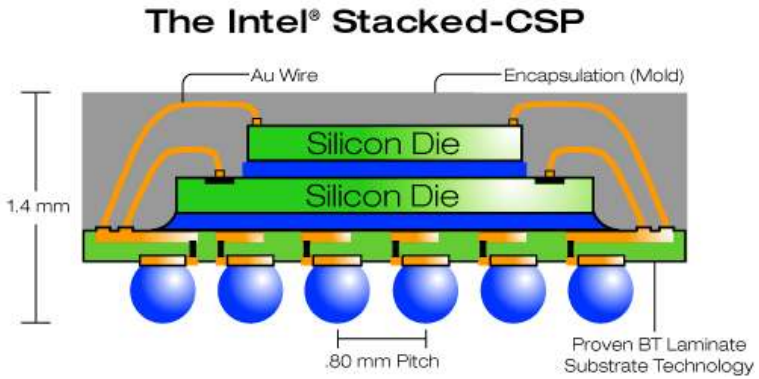
- These facts gives to Moore´s law only 10 more years to survive

What is More than Moore

”Man allways finds the way…”

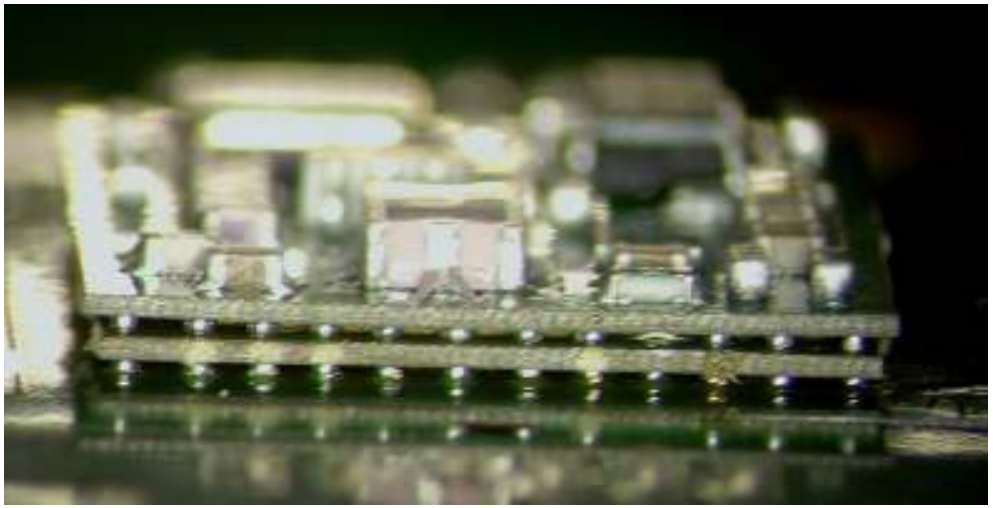
- Integration with 3D solutions :
  - All functions cannot be integrated into 2D-silicon→ 3D-silicon→wafer level integration
  - Solution is to optimize the system with 3D miniatyrisation
- Nanotechnology (<100 nm)
- Molecule size solutions

3D –integration on portable devices



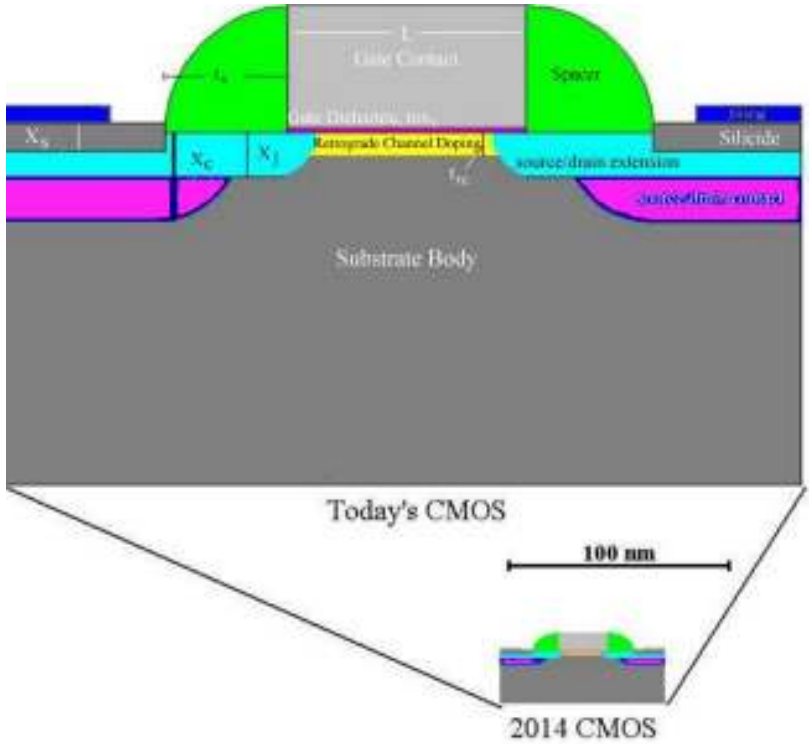
PoP (package on package)

SIP (System in Package)

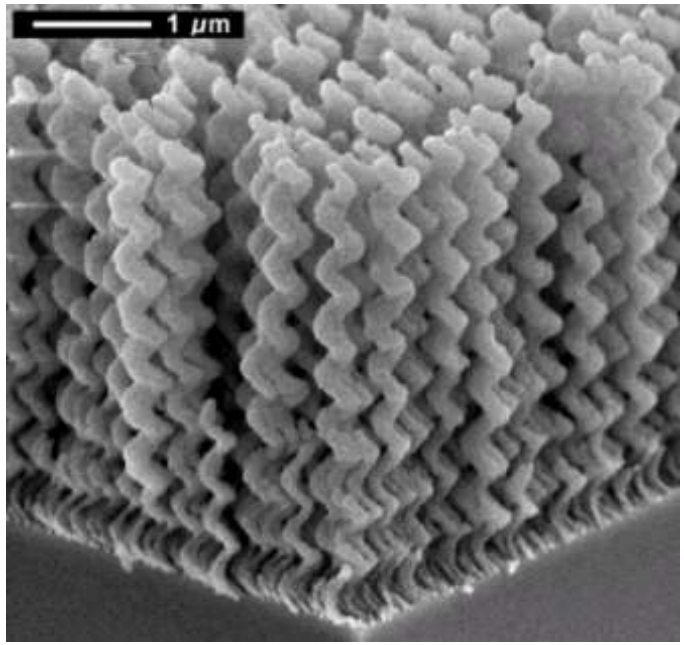


Electronic development strategies

Top down (current technology)



Bottom up (atom level)

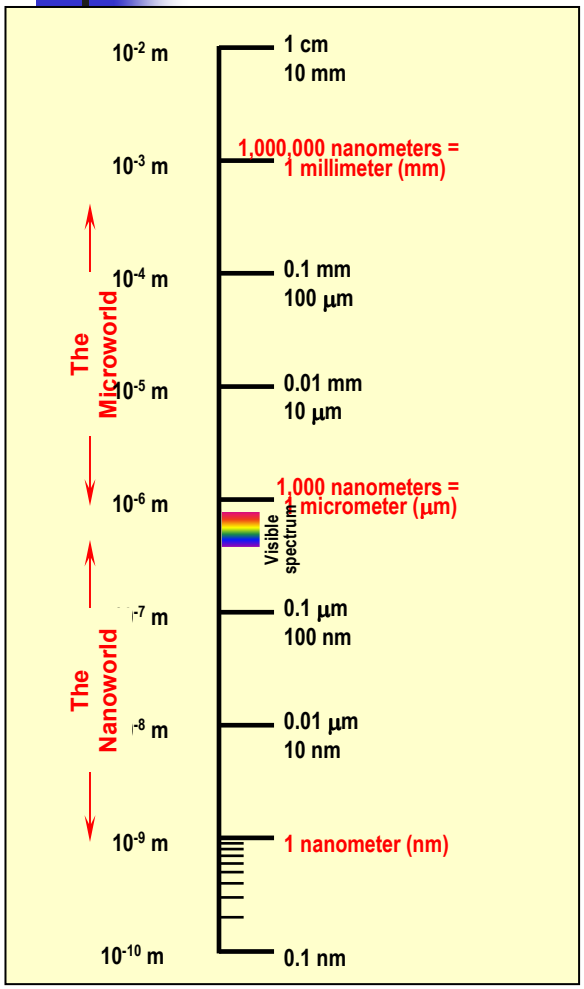


Richard Feynman (1918-1988)

"Hullun rummun" äänien modulointia Ralph Leightonin kanssa vuonna 1984.
(Faustin Bray)

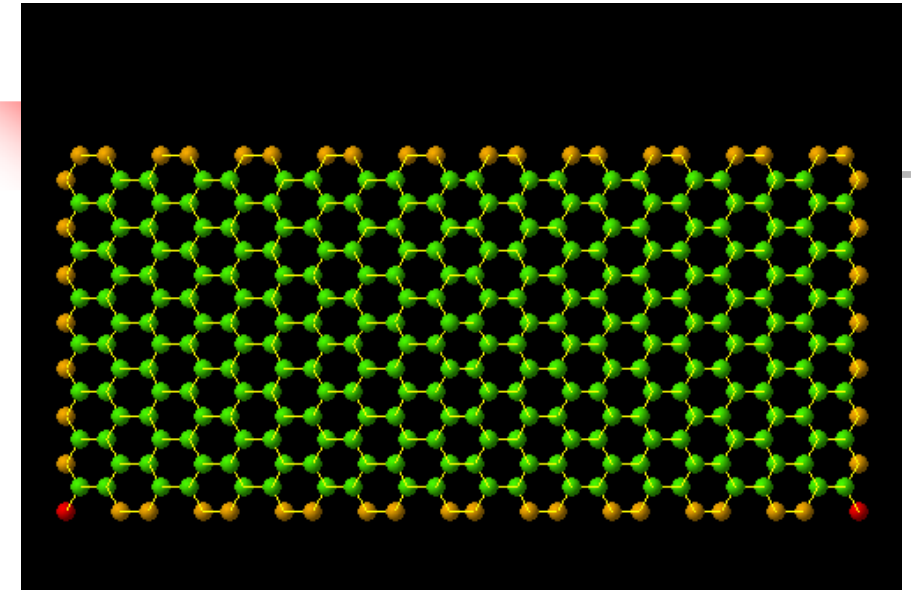
"Small is beautiful" and "there is lot of space at the bottom", said Richard Feynman already 1959 (Nobel price same year)→ nanotechnology is a specific sort of manufacturing technology, which allows for building things from bottom up.

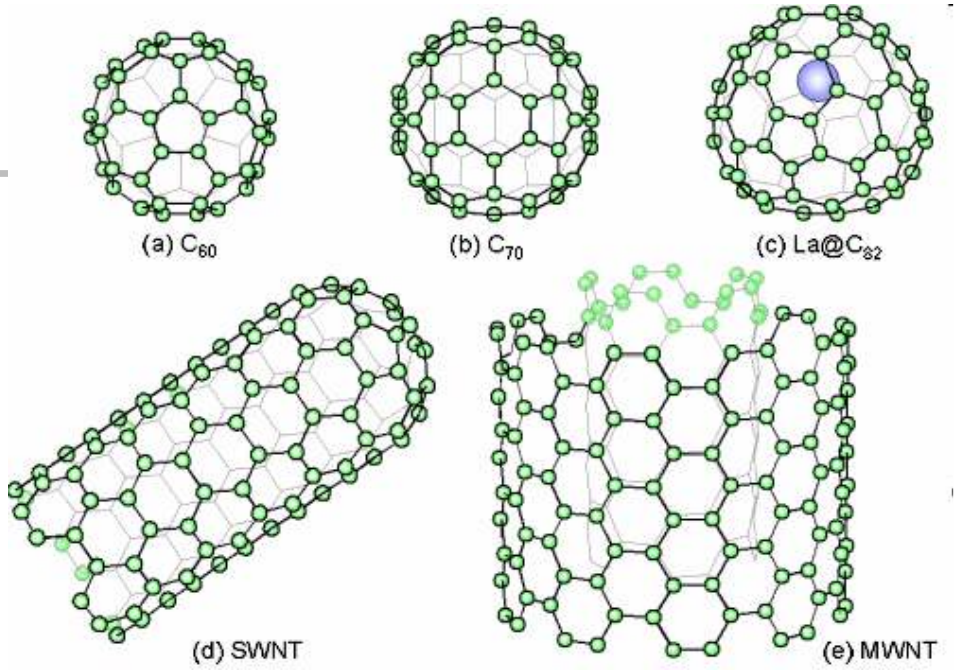
Nanotechnology < 100 nm =0, 000 000 1 m
1 nm =0, 000 000 001 m

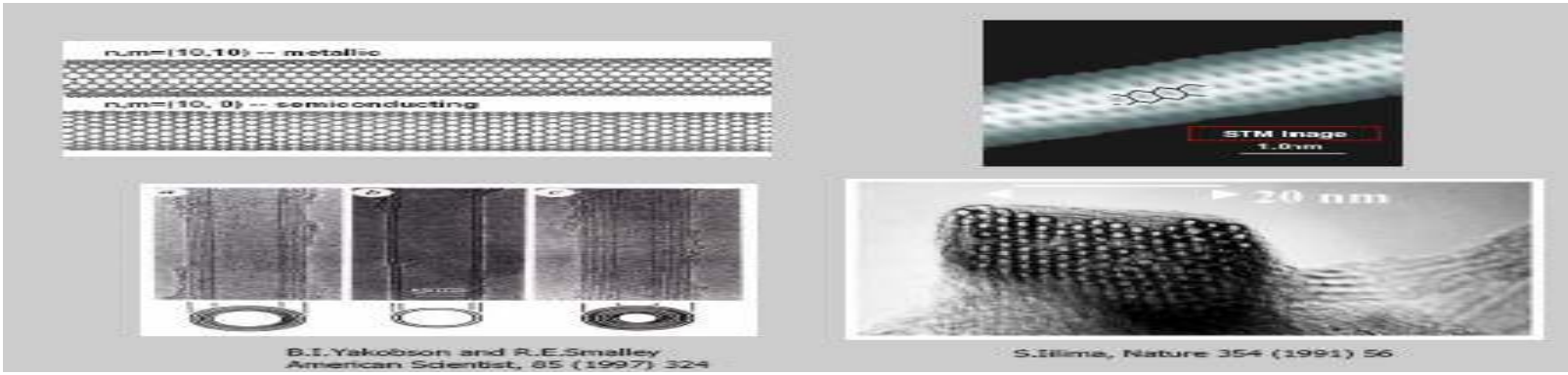


- Human hair 50 000- 100 000 nm
- White blood cell 10 000nm
- Bacteria 1000-10 000nm
- Living cells <100nm
- Virus 75-100 nm
- Protein 5-50 nm
- DNA (width) 2 nm ←→ nanotube
- Molecyles 0,1-1 nm
- Atoms 0,1 nm

Carbon nanotubes and fullerenes



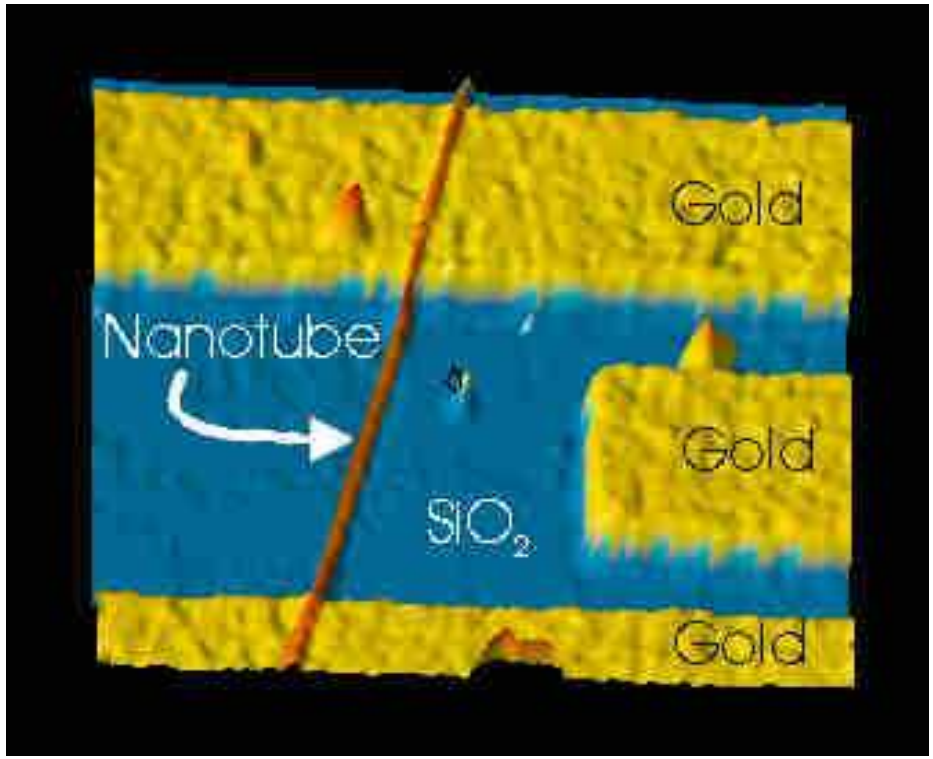




Properties of carbon nanotubes

- Carbon nanotubes can have a single wall (SWNT) or multiwall structure (MWNT)
- Typically SWNT is 2 nm in diameter and the length up to 100 μm
- It can be used as a detector for gases
- It can storage hydrogen
- It has a high mechanical strength (100 x steel)
- It has a high thermal conductivity (better than diamond)
- It can be a conductor or semiconductor
- It can have high conductivity (1000 x Cu)

Transistor based on nanotube (2 nm)

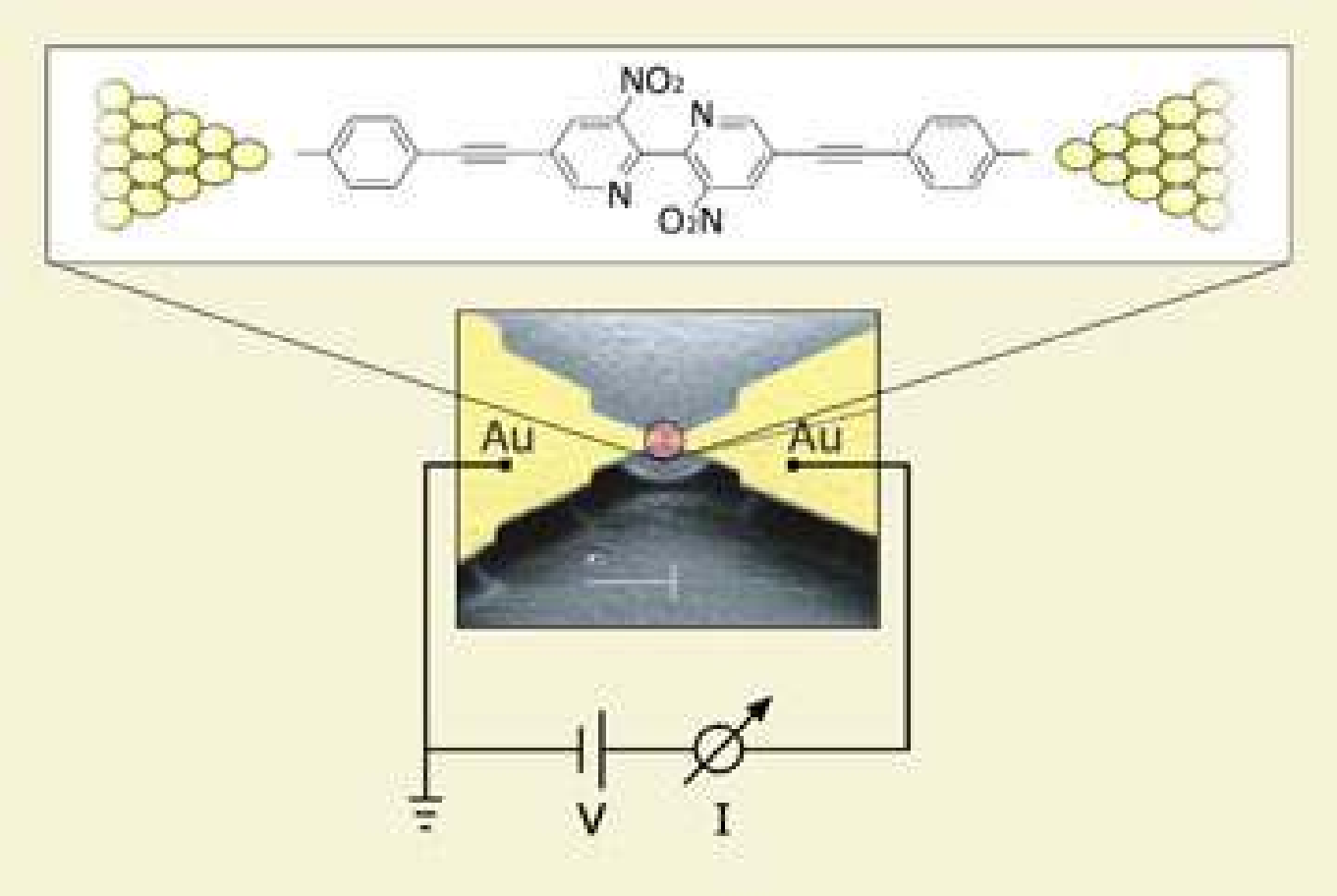


+**Possible to grow the gate oxide under the carbon nanotube (active channel)**

- **How to arrange the nanotubes on silicon wafer**

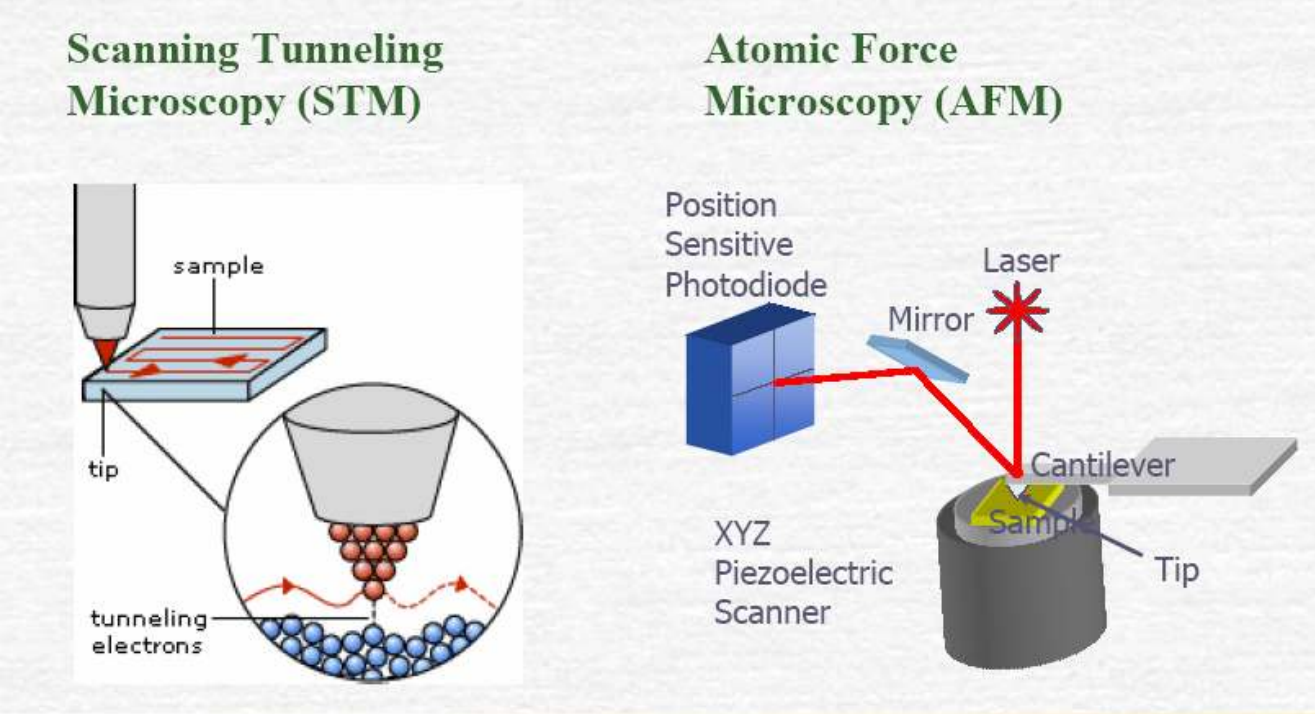
Molecyles size transistor (IBM)

bipyridyl-dinitro-oligophenylene-ethynylene dithiol (BPDN-BT)

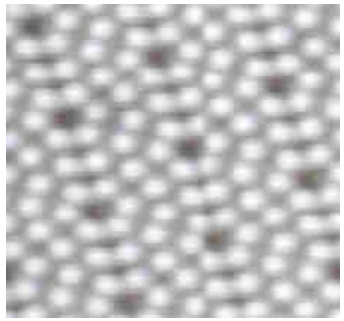


New instruments : SEM (Scanning electron microscope)

→ STM (Scanning Tunneling microscope)
AFM (Atom Force Microscope)



Si (111) 7x7

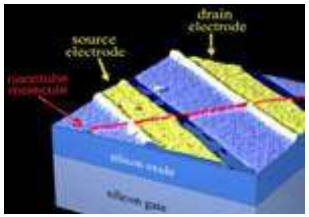


Nanotechnology needs co-operation between science, art & technology – one man cannot do everything like Leonardo da Vinci

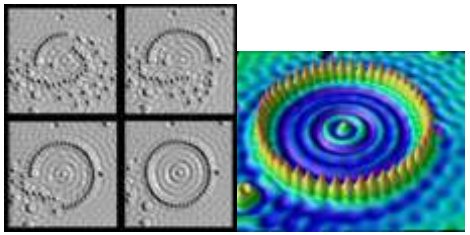
Material Science

Electronics/technology

Nanotube electrode



Nanotube transistor



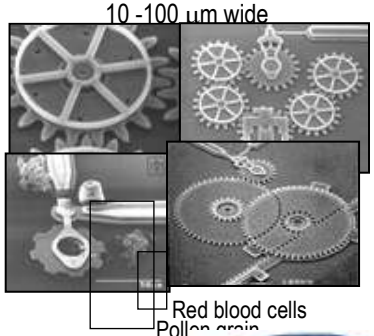
Quantum corral of 48 iron atoms on copper surface positioned one at a time with an STM tip
Corral diameter 14 nm

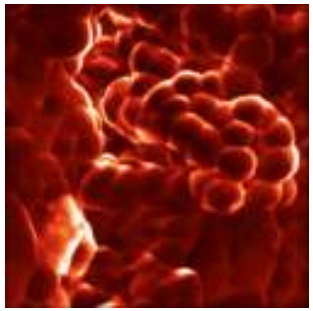
Physics

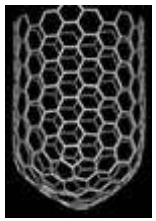
Atoms of silicon
spacing ~tenths of nm

MicroElectroMechanical Devices
10 -100 μm wide

Mechanics



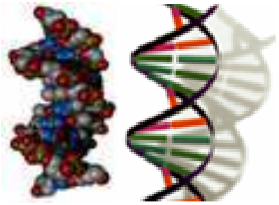




Carbon nanotube
~2 nm diameter

Chemistry

Computing



DNA
~2-1/2 nm diameter

Biosciences

How the art can help us?

- Activating our imagination and widening our view of life
- Important source of creativity
- Has a great mission in helping the mankind to survive and find the creative answers to our problems
- Helps to understand and develop the science and technology - especially in the field of nanotechnology where new views and ideas are needed
- Helps in co-operation between the people having different standpoints and opinions