



# Moore's future is more!

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in the Service of Man  
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# Outline

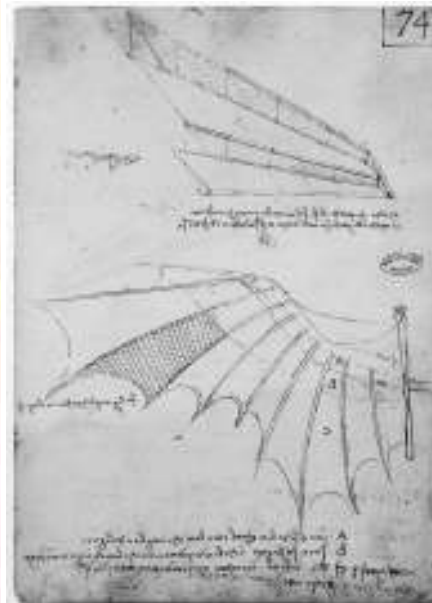
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- Introduction
- Predictions and Gordon Moore
- Physical limits of microcircuits
- 3D integration
- Nanotechnology
- How the art can help us

# Leonardo da Vinci (1452-1519)

A man of Renaissance

Science, Art & Technology





# Famously Wrong Predictions

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- *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.*

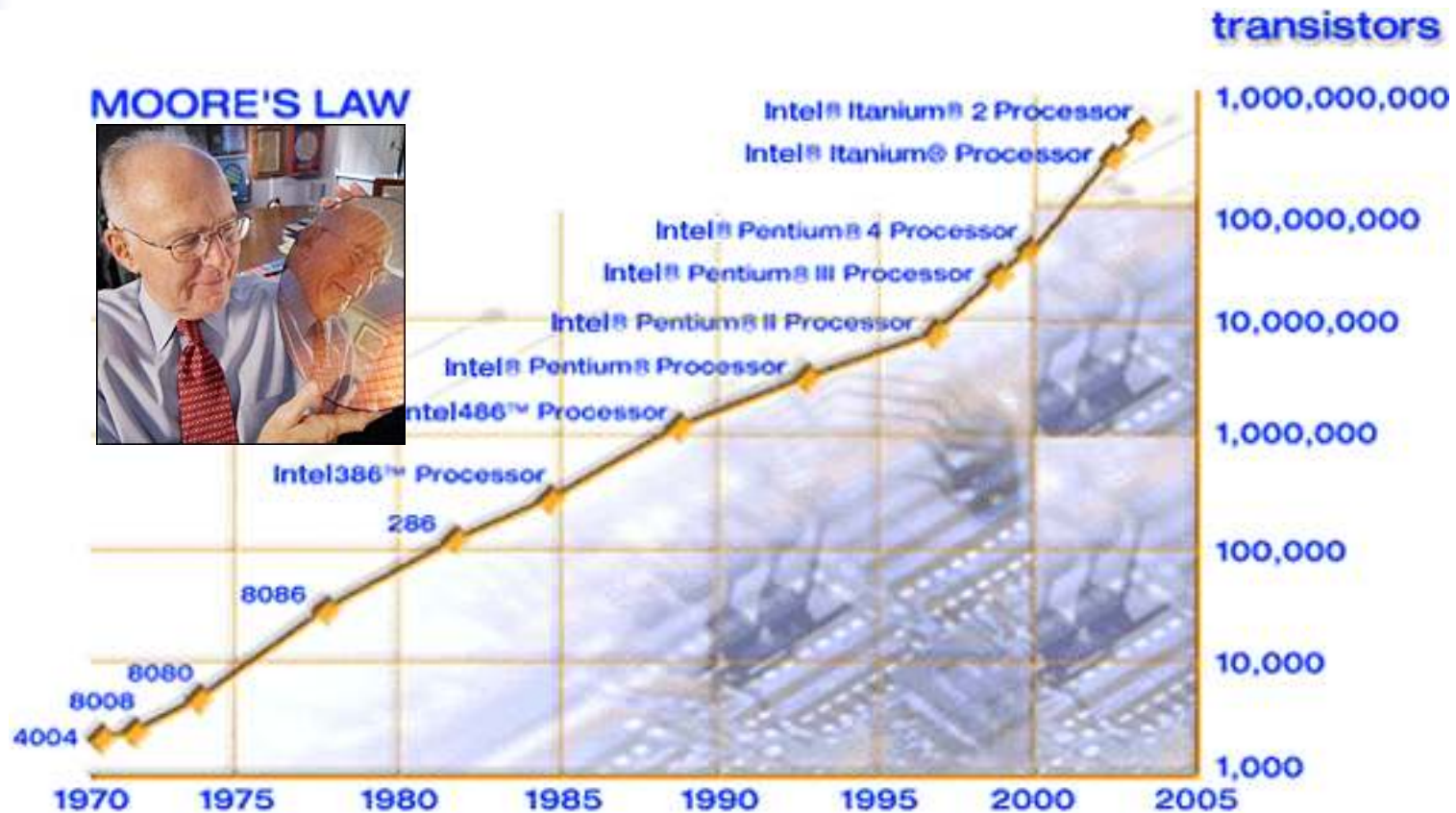


# Famously Wrong Predictions

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- *"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\_II 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

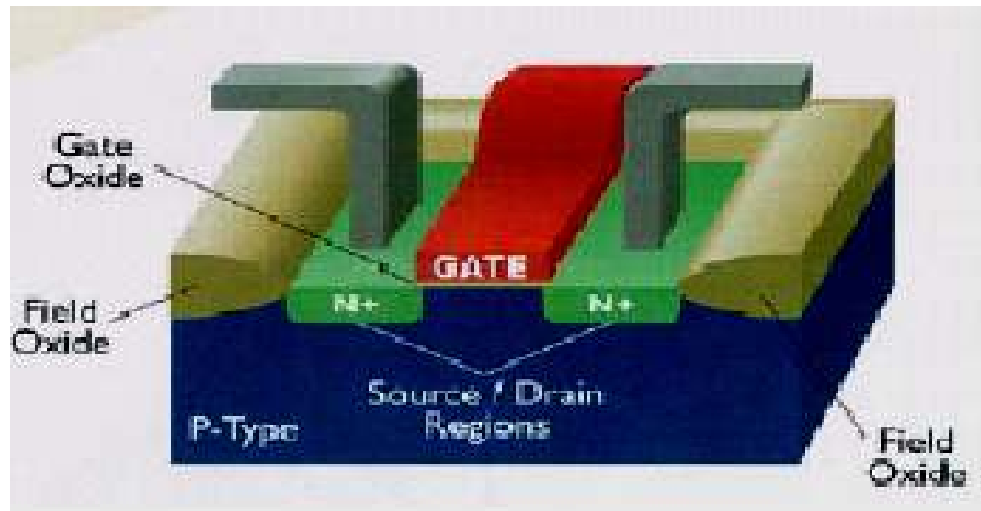
**Gordon Moore** (inventor of Intel); he predicted that the number of transistors the industry would be able to place on a computer chip would double every year [i]. In 1975, he updated his prediction to once every two years but later on it was found out that it doubles every 18 months



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

# Physical 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 always finds the way...”

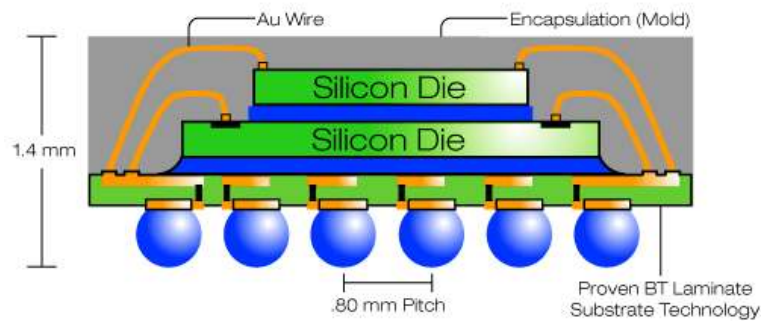
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- Integration with 3D solutions :
  - All functions cannot be integrated into 2D-silicon → 3D-silicon → wafer level integration
  - Solution is to optimize the system with 3D miniaturisation
- Nanotechnology (<100 nm)
- Molecule size solutions



# 3D –integration on portable devices

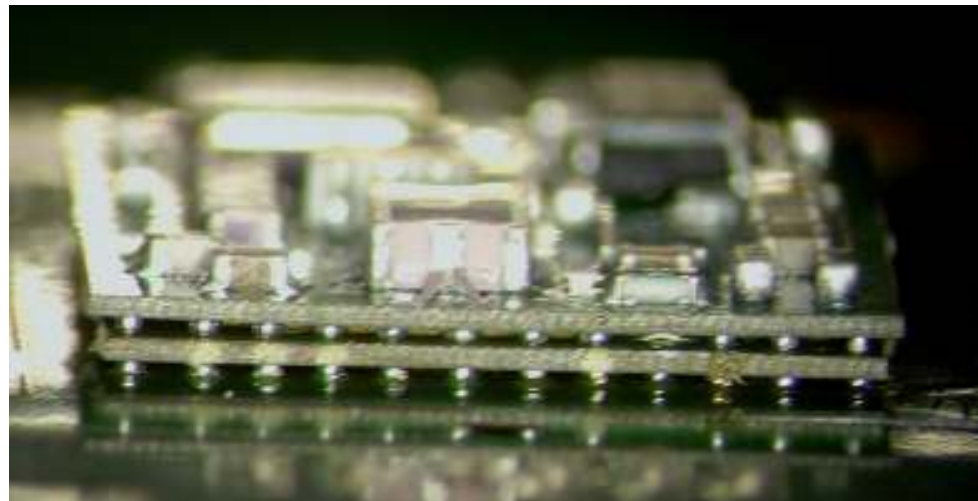
The Intel® Stacked-CSP



PoP (package on package)



SIP (System in Package)







## Richard Feynman (1918-1988)

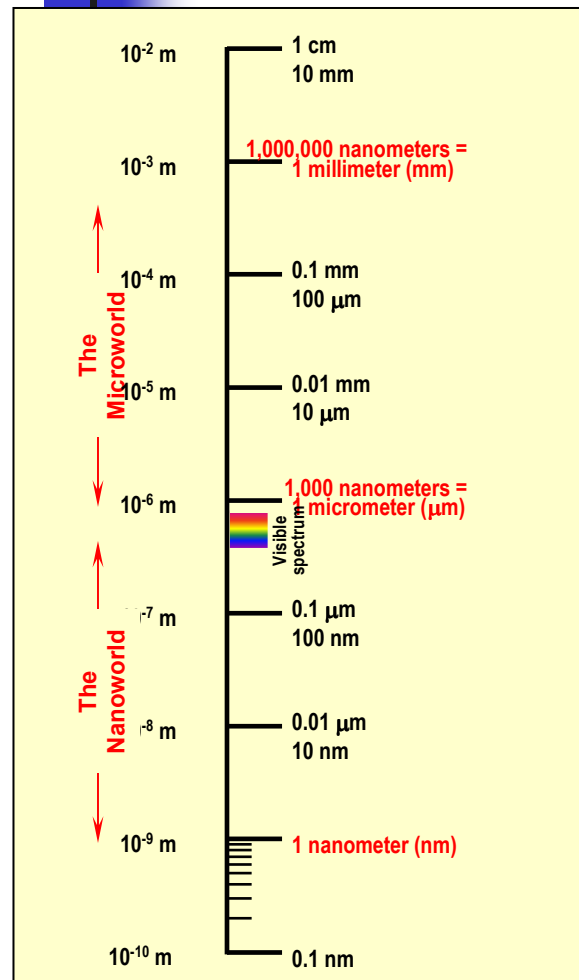


*"Hullun runnun" äänien modulointia Ralph Leightonin kanssa vuonna 1984.  
(Faustin Bray)*



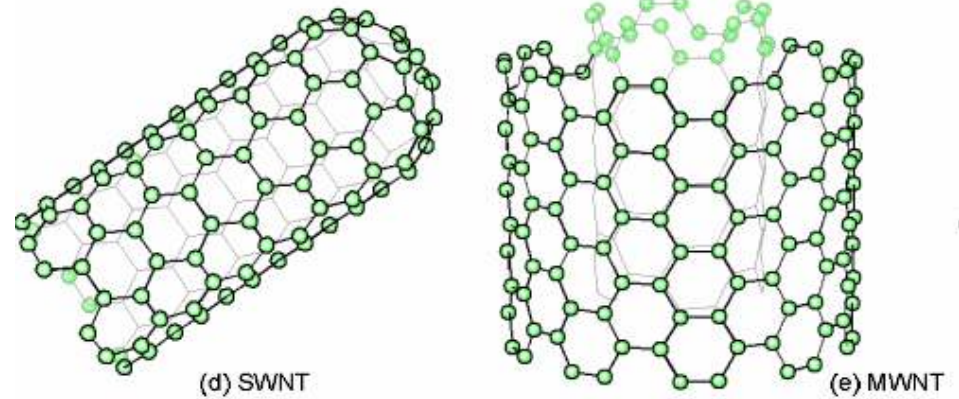
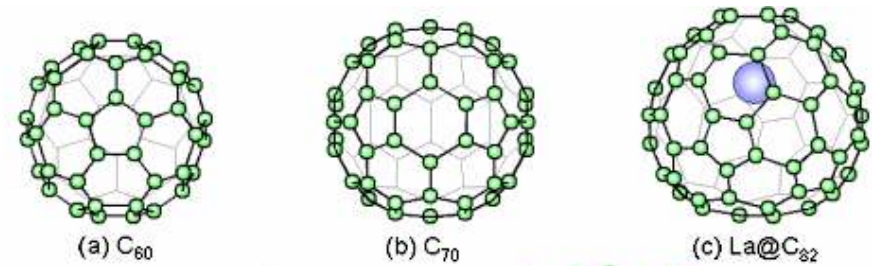
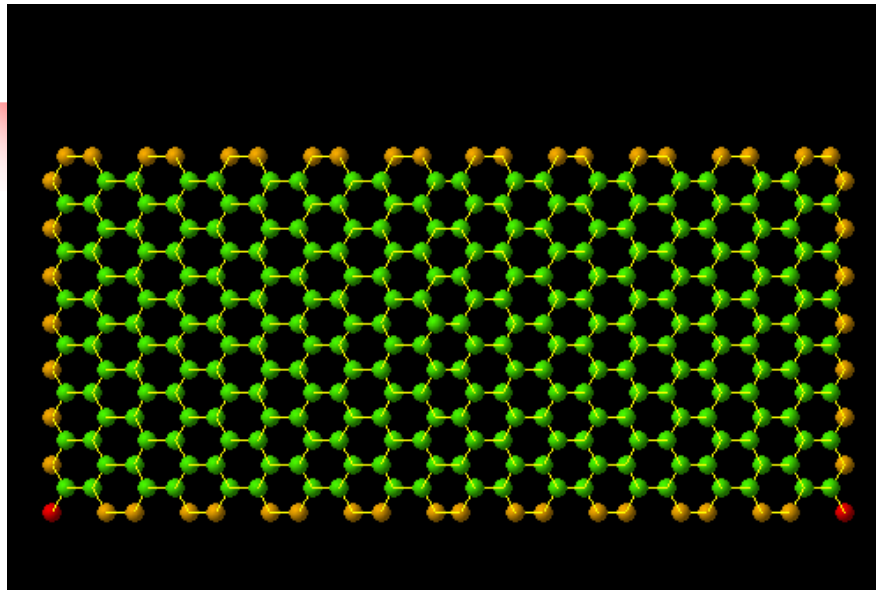
“Small is beautiful” and “there is lot of space at the bottom”, said Richard Feynman already 1959 (Nobel price same year) → nanotechnology is a specific sort of manufacturing technology, which allows for building things from bottom up.

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  $\leftrightarrow$  nanotube
- Molecyles 0,1-1 nm
- Atoms 0,1 nm

# Carbon nanotubes and fullerenes



$n,m=[10,10]$  -- metallic  
 $n,m=[10,0]$  -- semiconducting

B.I. Yakobson and R.E. Smalley  
American Scientist, 85 (1997) 324

STM image  
1.0 nm

20 nm

S. Iijima, Nature 354 (1991) 56

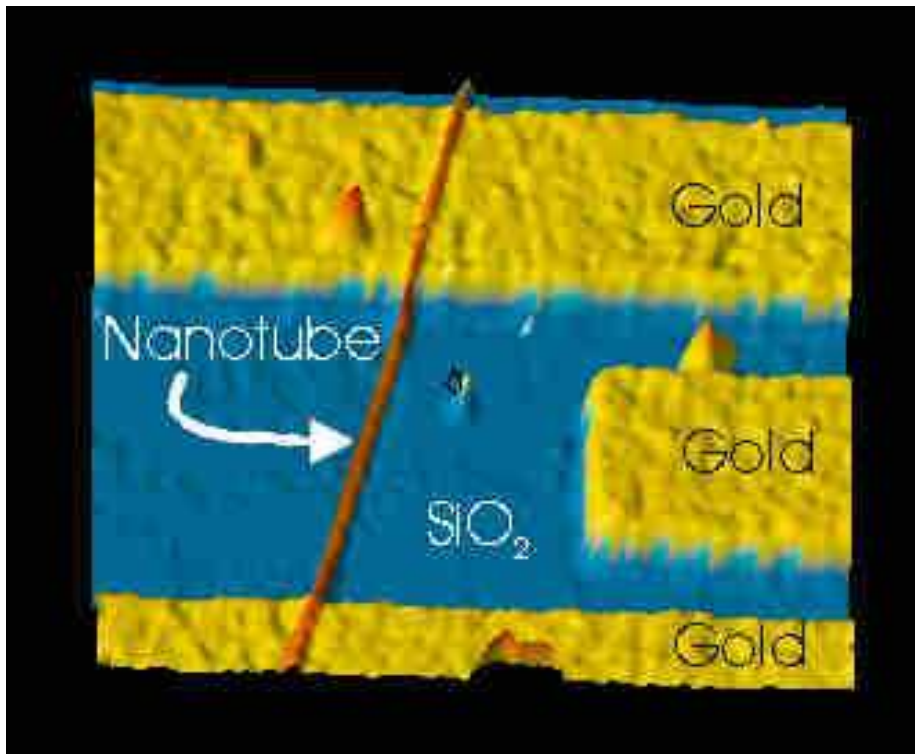


# Properties of carbon nanotubes

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- 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  $\mu\text{m}$
- 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)

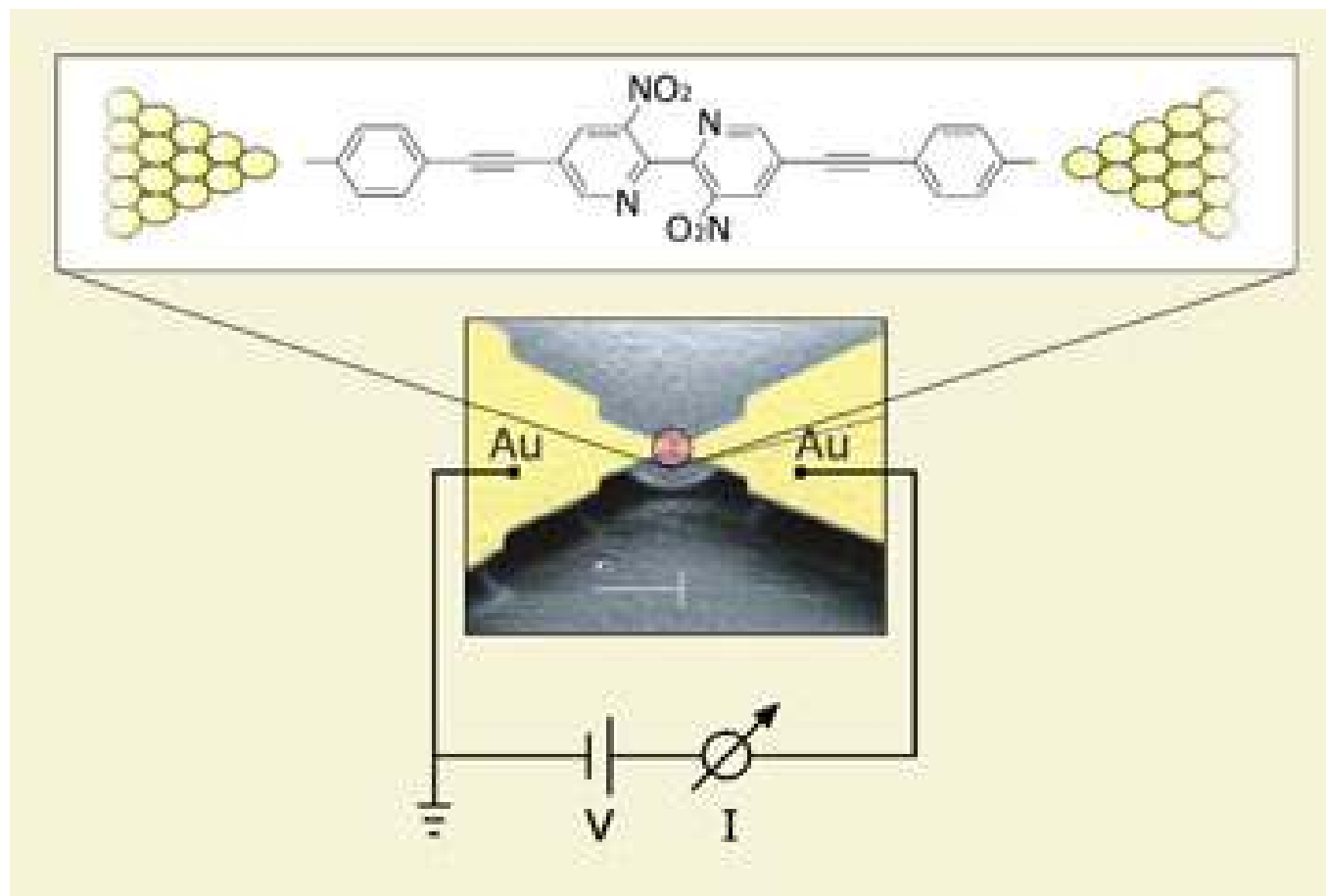
# Transistor based on nanotube (2 nm)



- + Possible to grow the gate oxide under the carbon nanotube (active channel)
- How to arrange the nanotubes on silicon wafer

# Molecules size transistor (IBM)

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

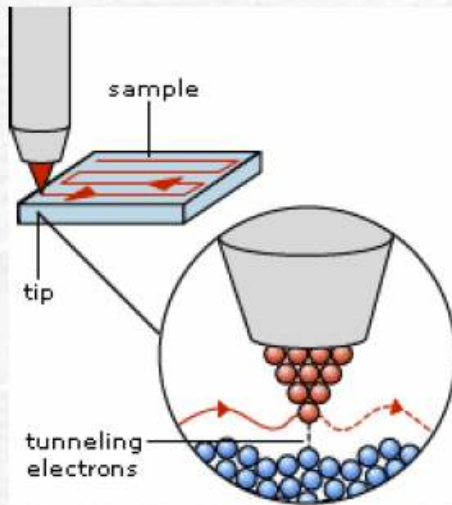




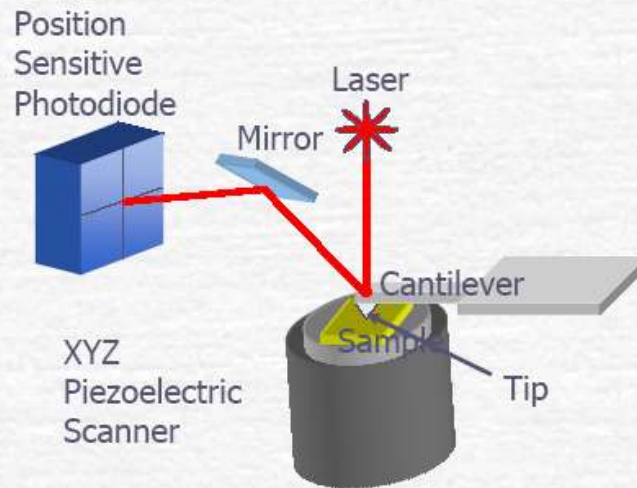
# New instruments : SEM (Scanning electron microscope)

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

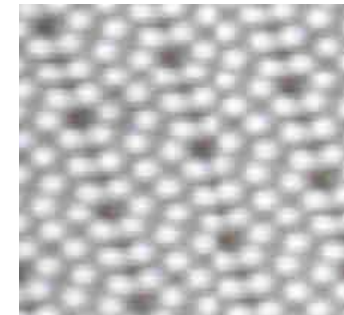
## Scanning Tunneling Microscopy (STM)



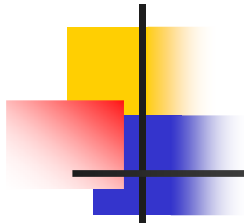
## Atomic Force Microscopy (AFM)



## Si (111) 7x7

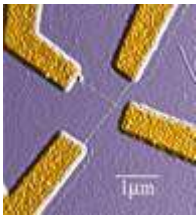


# Nanotechnology needs co-operation between science, art & technology – one man cannot do everything like Leonardo da Vinci

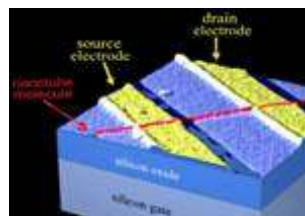


## Material Science

### Electronics/technology

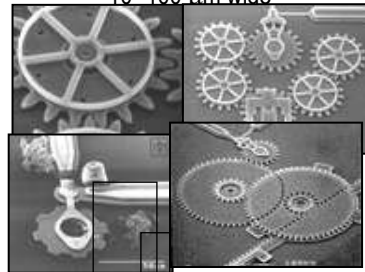


Nanotube electrode



Nanotube transistor

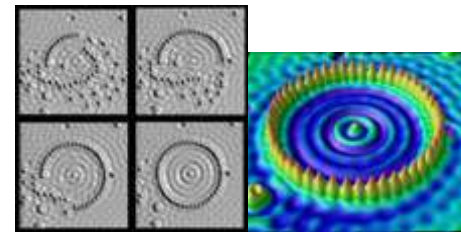
### MicroElectroMechanical Devices 10 -100 $\mu\text{m}$ wide



### Mechanics

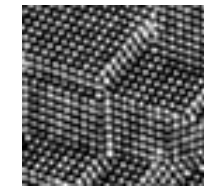
Red blood cells  
Pollen grain

### Computing

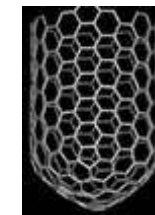
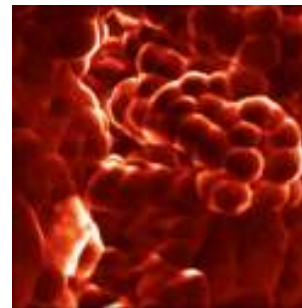


Quantum corral of 48 iron atoms on copper surface  
positioned one at a time with an STM tip  
Corral diameter 14 nm

### Physics

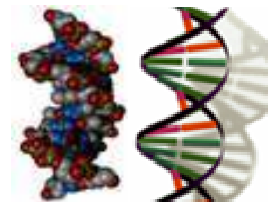


Atoms of silicon  
spacing  $\sim$  tenths of nm



Carbon nanotube  
 $\sim$ 2 nm diameter

### Chemistry



DNA  
 $\sim$ 2-1/2 nm diameter

### Biosciences



# How the art can help us?

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- 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