Some Aspects of Nano-Science & Technology

前沿奈米科學與技術

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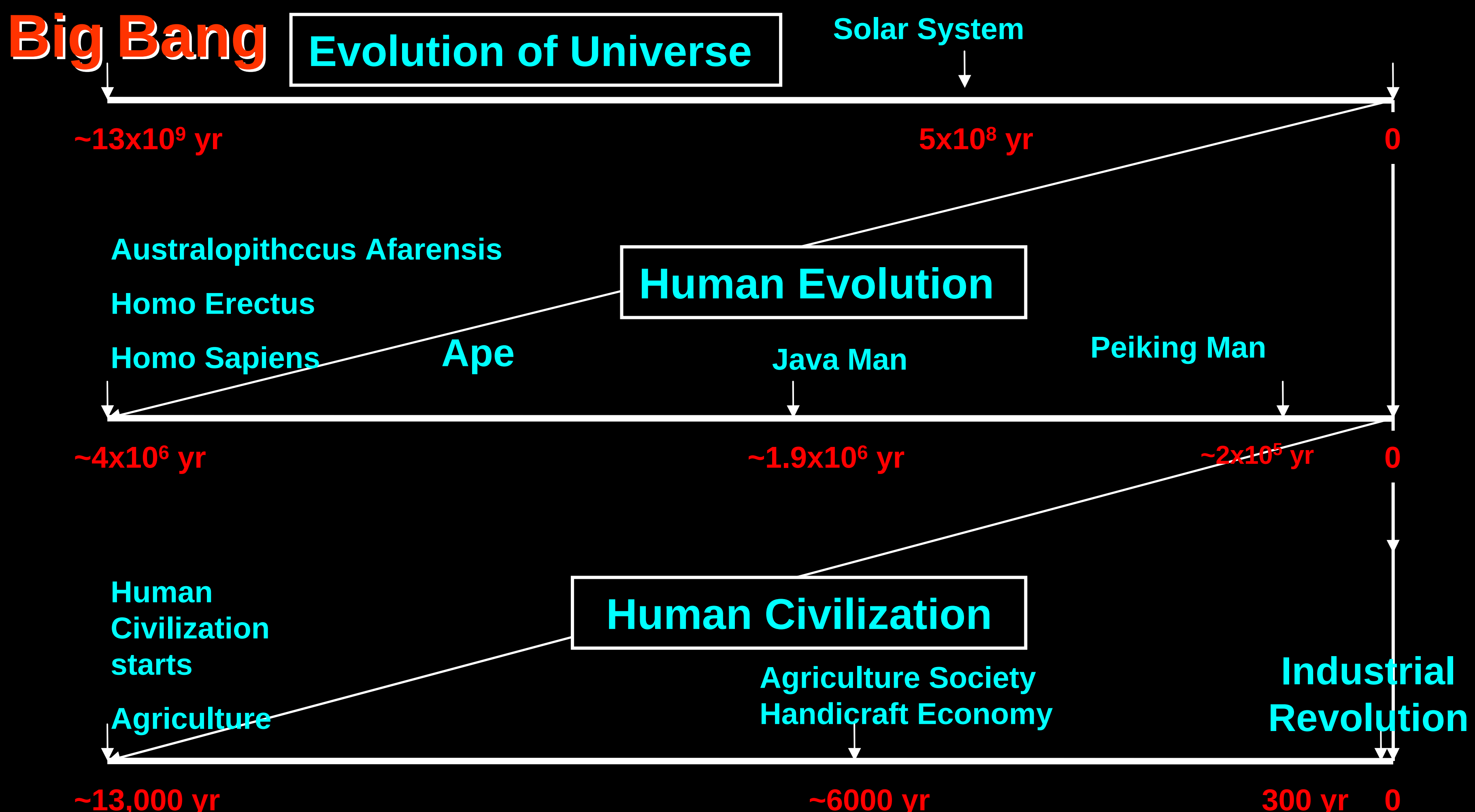


- ✓ **Handicraft Economy: Based on experiences, human & animal power, small scale, little science**
- ✓ **Industrial Revolution: Started 1760-1840, based on experiences & simple science. Materials: iron & steel. Motive power: engine, electricity. System: factories. Transportation: automobile, train & ship. Knowledge: A little physics & chemistry. Industry stimulated progress in science.**

Physics and Science & Technology: A Time Spectrum

1604: Galileo, Science is based on experimental facts!

1609, 1618: Brache, Kepler laws of planet mo.

1687: Newton, Principia

1690: Huygens, optics
1704: Newton, Optics

1770: Black, calorimetry

1600 — 1700 — 1800

1698 1712
Steam engine
Savery, Newcomen

1769
Automobile
Cugnot

Iron industry

Industrial Revolution (1760 – 1840)

1824: Carnot cycle
1831: Faraday, field & em induction

1849: Kelvin temp.
1850: Clausius laws of thermodynamics
1875: Gibbs

1873: Maxwell em-wave

1905: Einstein, th. relativty

1900-1926 QM: Planck, Einstein, Bohr, Heisenberg, Schroedinger

1957, DNA: Watson & Crick

Molecular Biology

1948: transistor. 1950: laser. 1980: STM

Nuclear, Atom & mole. H.E. & Solid state phys.

Surf. Sci., Materials Sci. Cosmology, Nano Sci.

1800 — 1900 — 2000

1803: Train (Trevithick)
1803-1807: Steam boat (Symington, Fulton)

1875-1876: Bell Telephraph telephone

Steel indu.

1901-1907: Wireless comm. Edison, Marconi Fleming, Forest
1903: Airplane, Wright brother, etc.

1936: EM,
1951: FIM

1957: Sputnik, 1960: laser,
1969: moon landing, 1947-now, solid state electronics & computer & information tech.

1900-1950: modern industry
1950-now: high tech. industry

Modern Physics and Science & Technology

1) Electromagnetic Waves

   1831: Faraday, Induction & Field

   1873: Maxwell, EM waves

2) Relativity, Einstein

   1905: Special Th. Space & Time,
   Mass & Energy

   1915: General Th. Acceler. & Gravity

3) Quantum Mechanics

   1900: Planck, Quantization of Energy

   1905: Einstein, Photon

   1913: Bohr, H-Model, Appl. Of QM

   1924: de Broglie, Matter Wave

   1925: Heisenberg, Quantum Mech.

   1926: Schroedinger, S-Equation

Atom & Molec. Phys.: Laser,

Optical Trap, BE-Condens.

Condensed Matt. Phys.:

Solid state electronics,

Computer, Informat. tech.

Chemistry: Chem. bond, Chem.

Indus. Pharmaceutical ind.

Biology: Double helix,

Molecular biology,

Genetic engineering

Surface Sci. : Thin films,

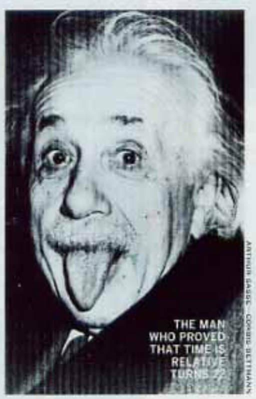
Electronic materials,

Catalysis, **Nanoscience**

Materials Sci.: Interdisciplinary

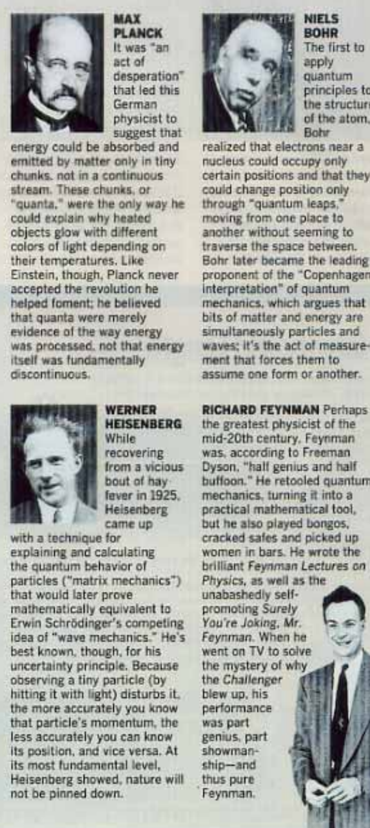
Time Man of the 20th Century

World Year of PHYSICS 2005



self "satisfied with the mystery of life's eternity and with a knowledge, a sense, of the marvelous structure of existence."

In embracing Einstein, our century took leave of a prior universe and an erstwhile God. The new versions were not so rigid and deterministic as the old Newtonian world. Einstein's God was no clockmaker, but he was the embodiment of reason in nature—"subtle but malicious he is not." This God did not control our actions or even sit in judgment on them. ("Einstein,



PLAYING DICE WITH THE UNIVERSE

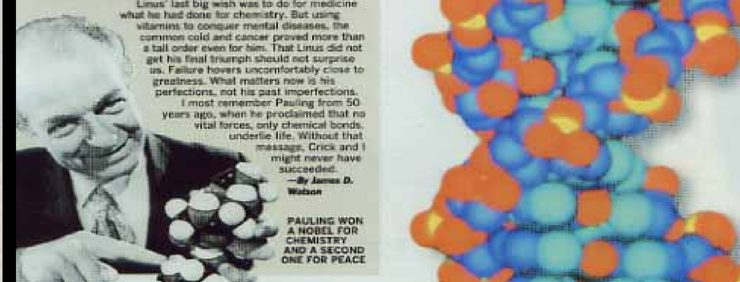
Quantum theory turns common sense on its ear. It suggests, among other things, that a beam of light is at once a fluttering wave of electromagnetism and a spray of bulletlike particles; that effects like radioactive decay occur without cause; that particles move from one point to another without traversing the space between; that the world is, at the smallest scales, grainy and discontinuous, like a roomful of dancers under a strobe; and that despite Einstein's dogged insistence that "God does not play dice," the most fundamental characteristic of the subatomic realm is its ultimate unpredictability. Yet quantum theory has proved indispensable in the invention of such applications as the laser, the atom bomb and the semiconductor, and in understanding the basic functioning of organic molecules, including DNA. The architects of this powerful yet counterintuitive theory were among the most brilliant minds of the century.

MAX PLANCK It was "an act of desperation" that led this German physicist to suggest that energy could be absorbed and emitted by matter only in tiny chunks, not in a continuous stream. These chunks, or "quanta," were the only way he could explain why heated objects glow with different colors of light depending on their temperatures. Like Einstein, though, Planck never accepted the revolution he helped foment; he believed that quanta were merely evidence of the way energy was processed, not that energy itself was fundamentally discontinuous.

NIELS BOHR The first to apply quantum principles to the structure of the atom, Bohr realized that electrons near a nucleus could occupy only certain positions and that they could change position only through "quantum leaps," moving from one place to another without seeming to traverse the space between. Bohr later became the leading proponent of the "Copenhagen interpretation" of quantum mechanics, which argues that bits of matter and energy are simultaneously particles and waves; it's the act of measurement that forces them to assume one form or another.

WERNER HEISENBERG While recovering from a vicious bout of hay fever in 1925, Heisenberg came up with a technique for explaining and calculating the quantum behavior of particles ("matrix mechanics") that would later prove mathematically equivalent to Erwin Schrödinger's competing idea of "wave mechanics." He's best known, though, for his uncertainty principle. Because observing a tiny particle (by hitting it with light) disturbs it, the more accurately you know that particle's momentum, the less accurately you can know its position, and vice versa. At its most fundamental level, Heisenberg showed, nature will not be pinned down.

RICHARD FEYNMAN Perhaps the greatest physicist of the mid-20th century, Feynman was, according to Freeman Dyson, "half genius and half buffoon." He retooled quantum mechanics, turning it into a practical mathematical tool, but he also played bongos, cracked safes and picked up women in bars. He wrote the brilliant *Feynman Lectures on Physics*, as well as the unabashedly self-promoting *Surely You're Joking, Mr. Feynman*. When he went on TV to solve the mystery of why the *Challenger* blew up, his performance was part genius, part showman-ship—and thus pure Feynman.



In 1931, when he was 30, Linus Pauling knew he was the world's best chemist. Ten years later his peers agreed. By then, *The Nature of the Chemical Bond* (1939) was already on its way to becoming the most influential chemistry book of the century. His biggest biological success came from his 1951 proposal of the alpha-helical fold for protein molecules, which everybody else thought were too large and complex to study. His findings were quickly verified, and Linus' confidence was never higher.

Then, unexpectedly, he struck out when he proposed an implausible, three-chain helix for DNA. Several months later, in Cambridge, England, Francis Crick and I, apprehensive that Linus might bat again, found the double helix. Why Linus failed to hit this home run will never be known. His wife Ava Helen is said to have told Linus that he should have worked harder. I believe the decade following World War II may have had too many agonizing moments for the Pauling family.

They arose chiefly from his opposition to nuclear weapons. After the first atom bombs were used, he began giving speeches expressing his concern that our nation's growing anticommunist fears were forcing us into an insane nuclear-weapons race. He was broadly labeled a pink, if not a red. J. Edgar Hoover personally pursued him. Senator McCarthy called him a security risk, and the State Department took away his passport.

Linus' last big wish was to do for medicine what he had done for chemistry. But using vitamins to conquer mental diseases, the common cold and cancer proved more than a tall order even for him. That Linus did not get his final triumph should not surprise us. Failure hovers uncomfortably close to greatness. What matters now is his perfections, not his past imperfections.

I most remember Pauling from 50 years ago, when he proclaimed that no vital forces, only chemical bonds, underlie life. Without that message, Crick and I might never have succeeded.

—*By James D. Watson*

PAULING WON A NOBEL FOR CHEMISTRY AND A SECOND ONE FOR PEACE

My Men of Science of the 20th Century

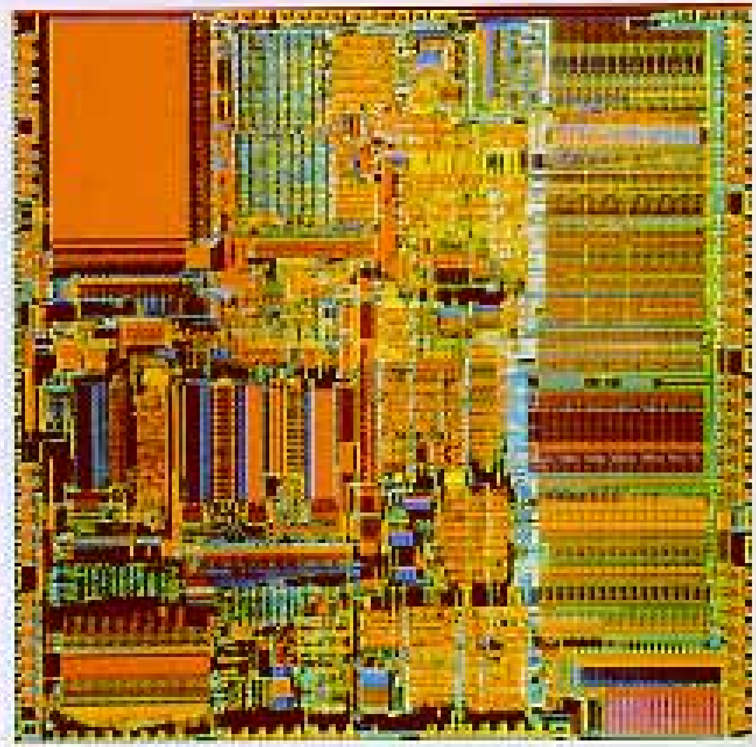
There's Plenty of Room at the Bottom

by Richard Feynman

A talk given by Richard Feynman on December 29th 1959 at the annual meeting of the American Physical Society at the California Institute of Technology (Caltech)

- There is plenty of room at the bottom. Rearranging atoms. New structures, new physics, new possibilities.
- *Why cannot we write the entire 24 volumes of the Encyclopedia Brittanica on the head of a pin?*
- Let us represent a dot by a small spot of one metal, the next dash, by an adjacent spot of another metal, and so on. Suppose, to be conservative, that a bit of information is going to require a little cube of atoms 5 times 5 times 5---that is 125 atoms. All human books can be stored in a cube of .01 inch in size!

Nanodevice: CPU



Computer CPU:

~2x2 cm^2

Pentium II

~14 M transistors

180 nm

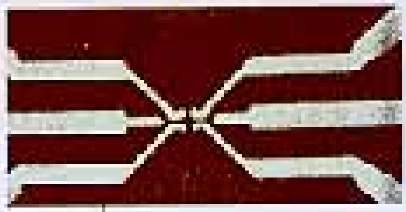
Pentium IV

~42 M transistors

130 nm

Centrino & Xenon: ~90 nm

over 60 M transistors



Moore's Law:

(Bits per square inch) ∞ $2^{(t/t_{0.5} - 1962)}$

Density increases twice every 18 months

The end of the road for silicon?

Nature 1999

Max Schulz

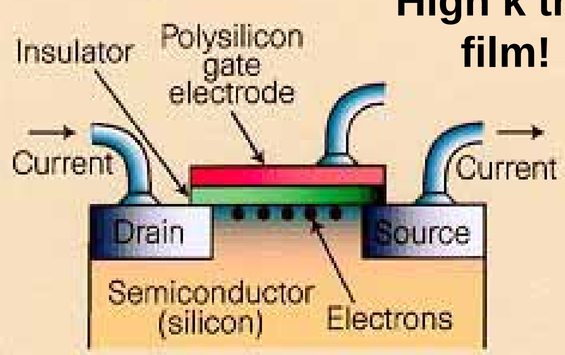
Computer chips continue to shrink. But the discovery that a layer of silicon dioxide must be at least four to five atoms thick to function as an insulator suggests that silicon-based microchips will reach the physical limits of miniaturization early next century.

Electron Tunneling Effect

...con atoms, current will penetrate through the gate oxide causing the chip to fail.

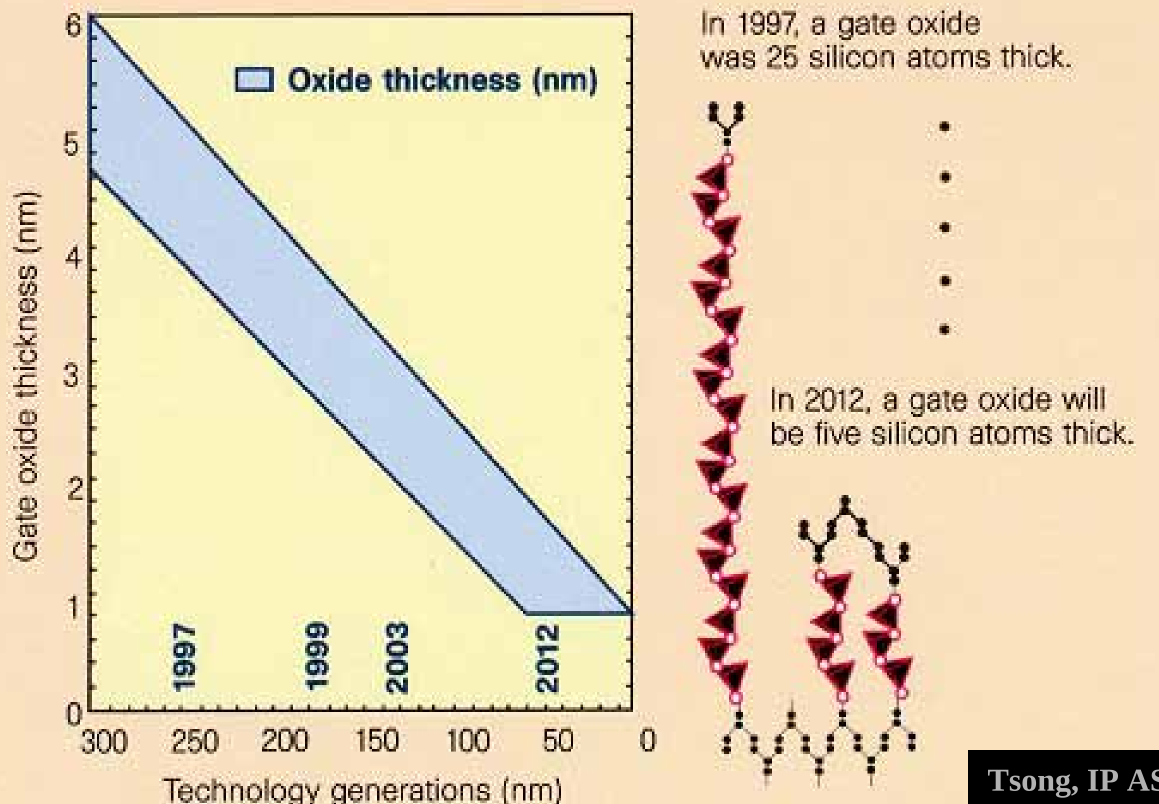
In 1925, Lilienfeld patented[2] the first field-effect device (one where current flow is modified by applying an electric field) based on silicon, but he probably never got it to work. It wasn't until 1960 that Kahng and Atalla[3] demonstrated the first metal-oxide semiconductor field-effect transistor

High k thin film!



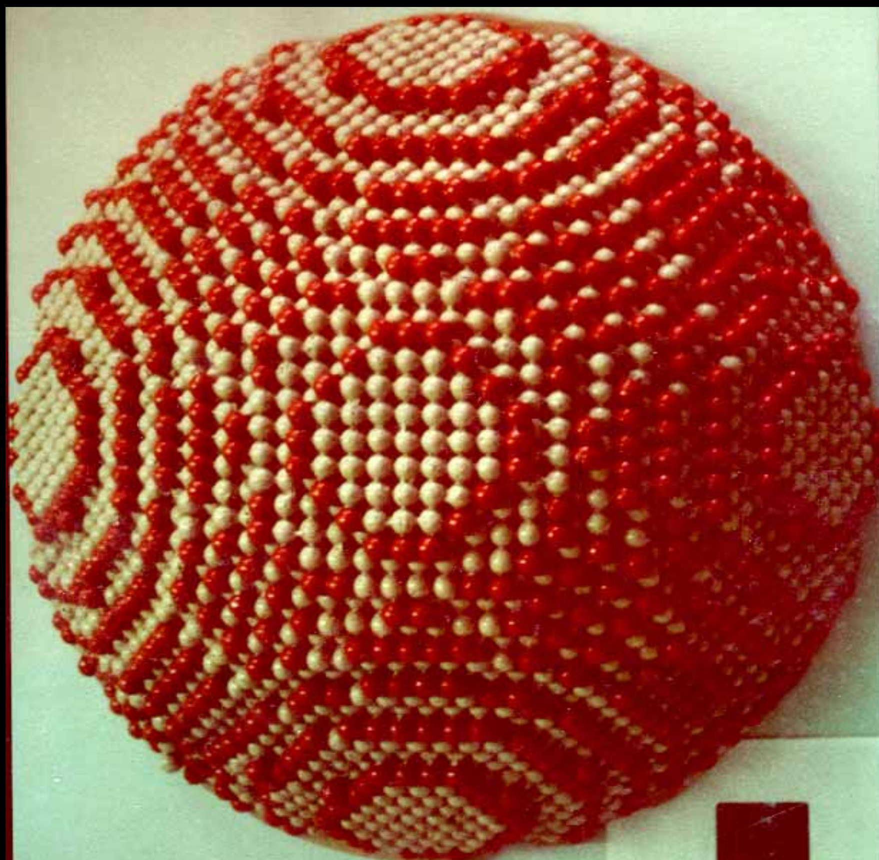
Field-effect transistor

Figure 1 A field effect transistor (FET), such as

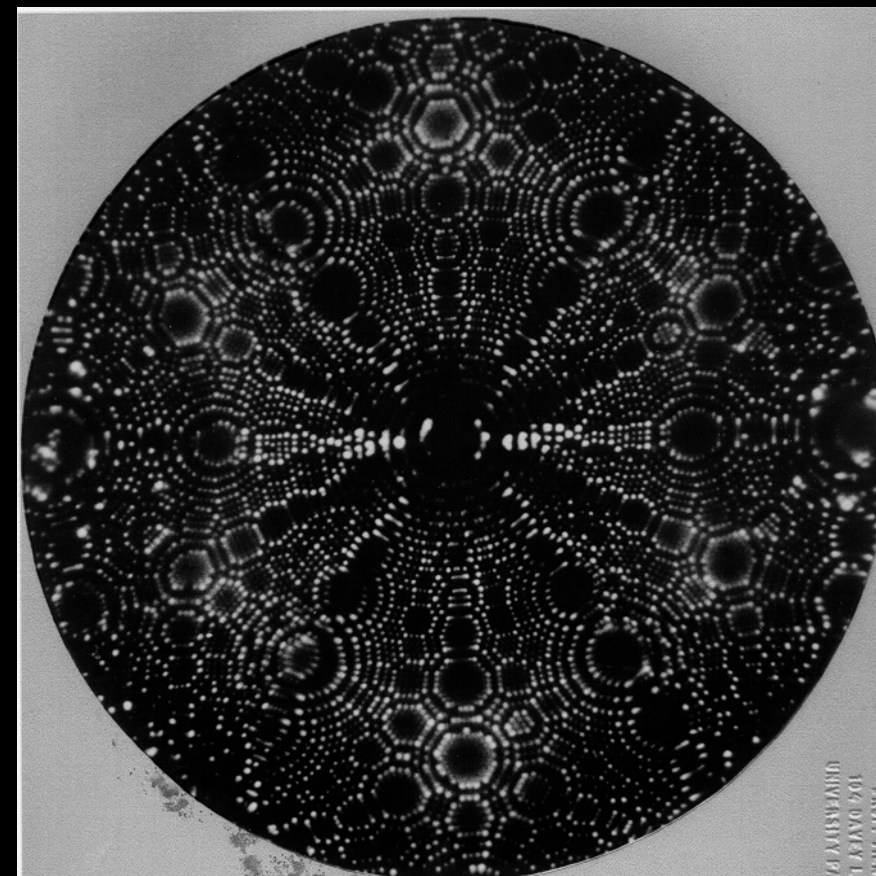


Tsong, IP AS

Atomic Model
R: 10 nm



FIM Image of a W tip
25 nm



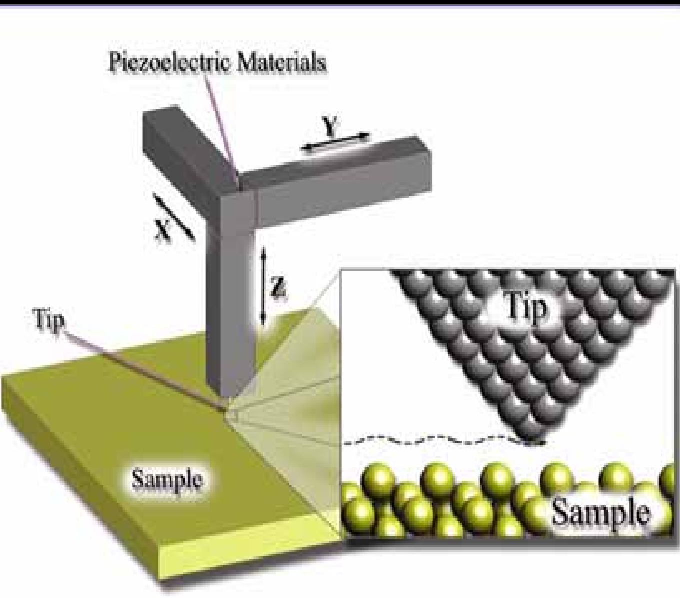
E. W. Müller & T. T. Tsong, *Field Ion Microscopy*, Elsevier 1969

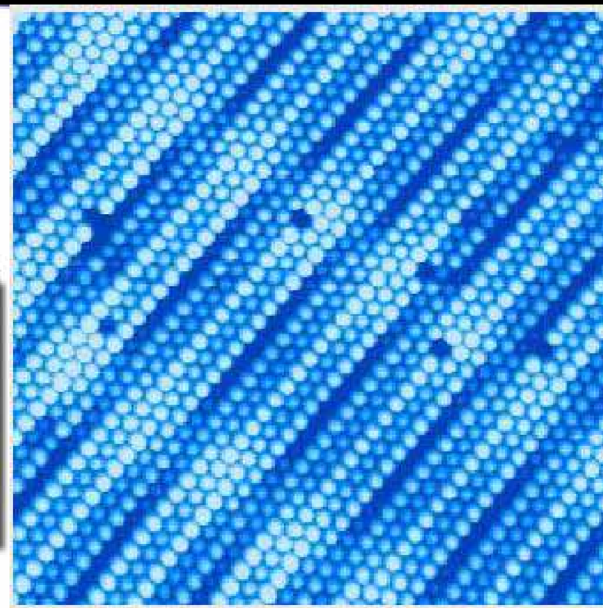
T. T. Tsong, *Atom-Probe Field Ion Microscopy*, Cambridge Univ. Press, 1990

Scanning Tunneling Microscope

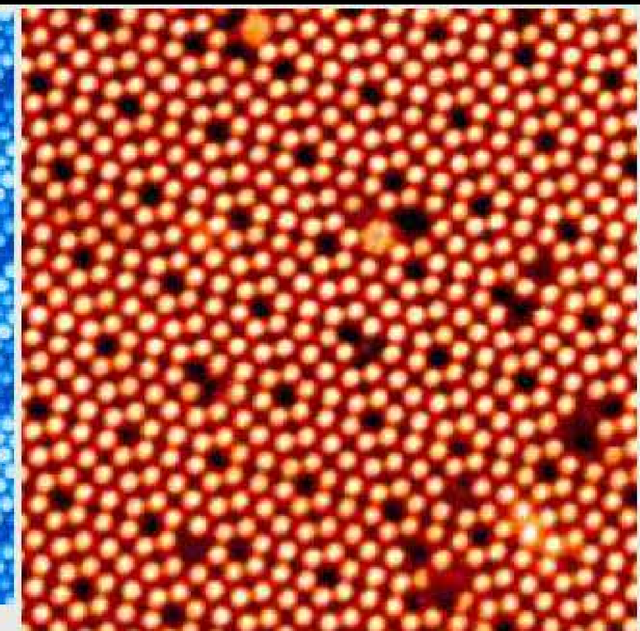
Binnig & Rohrer et al. 1981

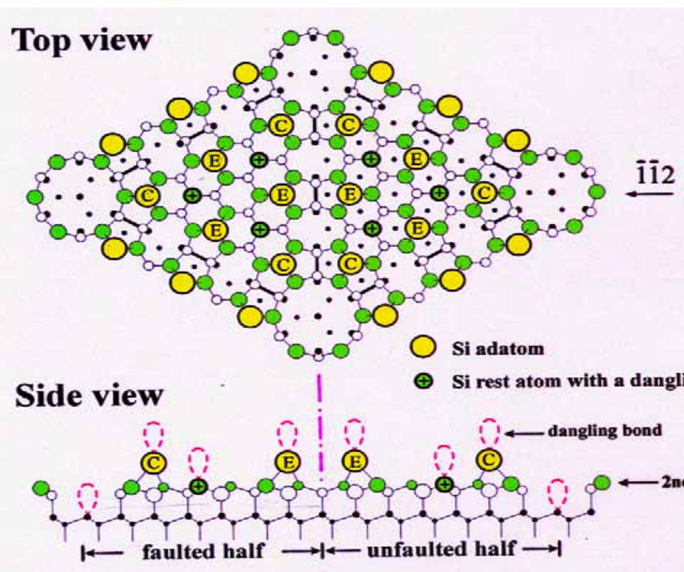
STM images：Atomic arrangement of Si & Au surfaces, etc.

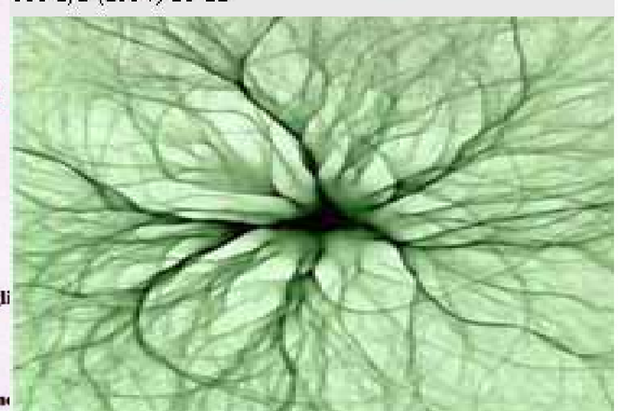




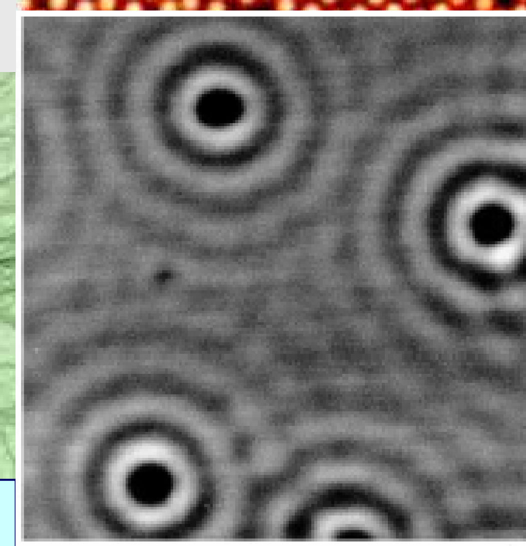
Atomic Resolution on Pt(100)
E. Bergene, Trondheim, Norway; *Published in Surf. Sci. 306 1/2 (1994) 10-22*







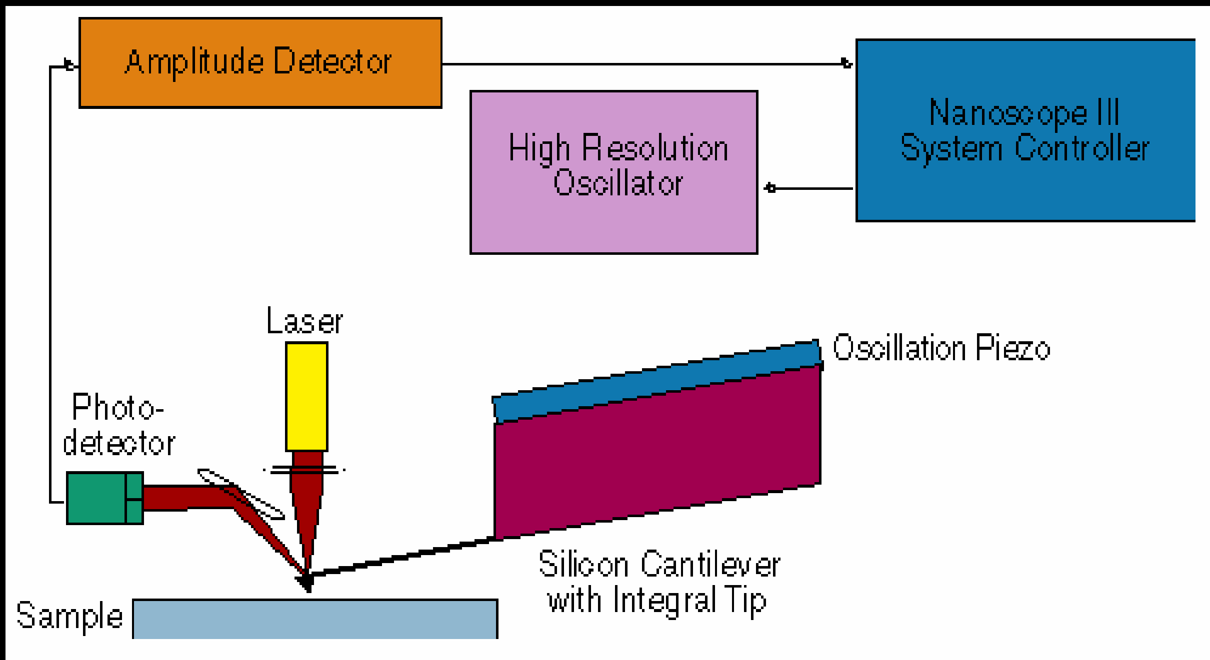
Current density R. Westervelt

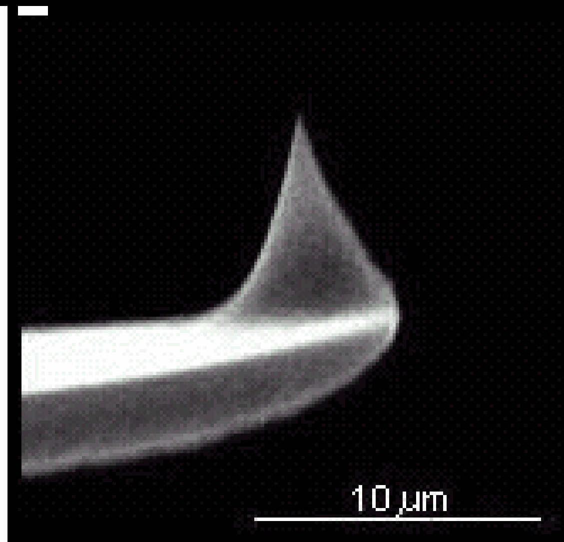


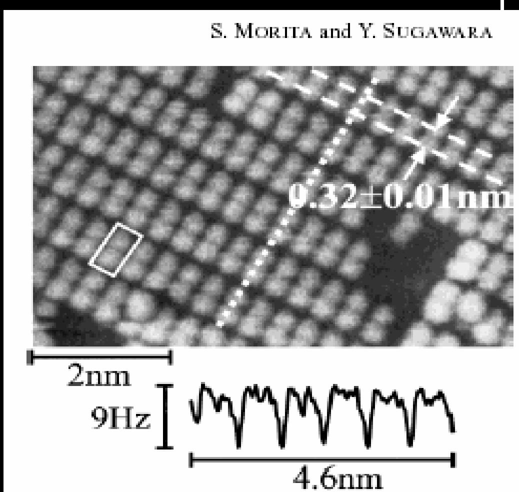
Electronic density

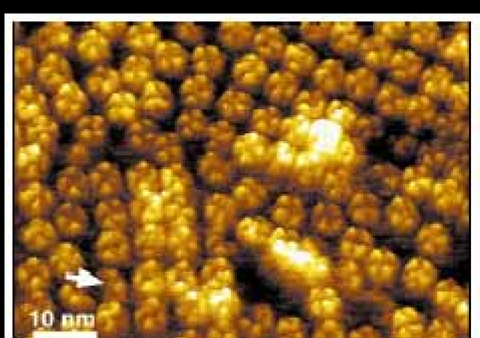
原子力顯微儀 (Atomic Force Microscopy)

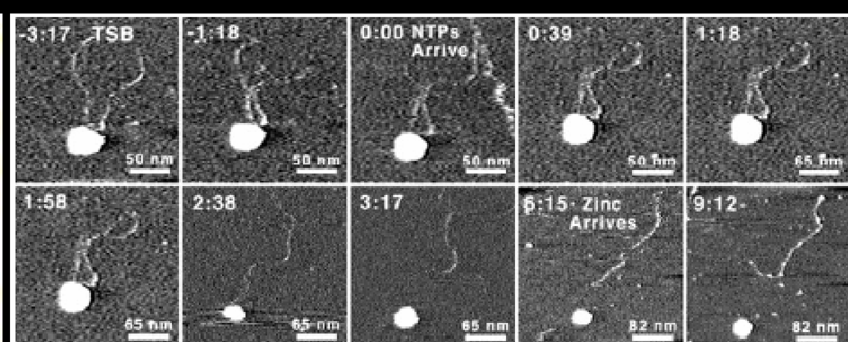
Atomic resolution achieved recently











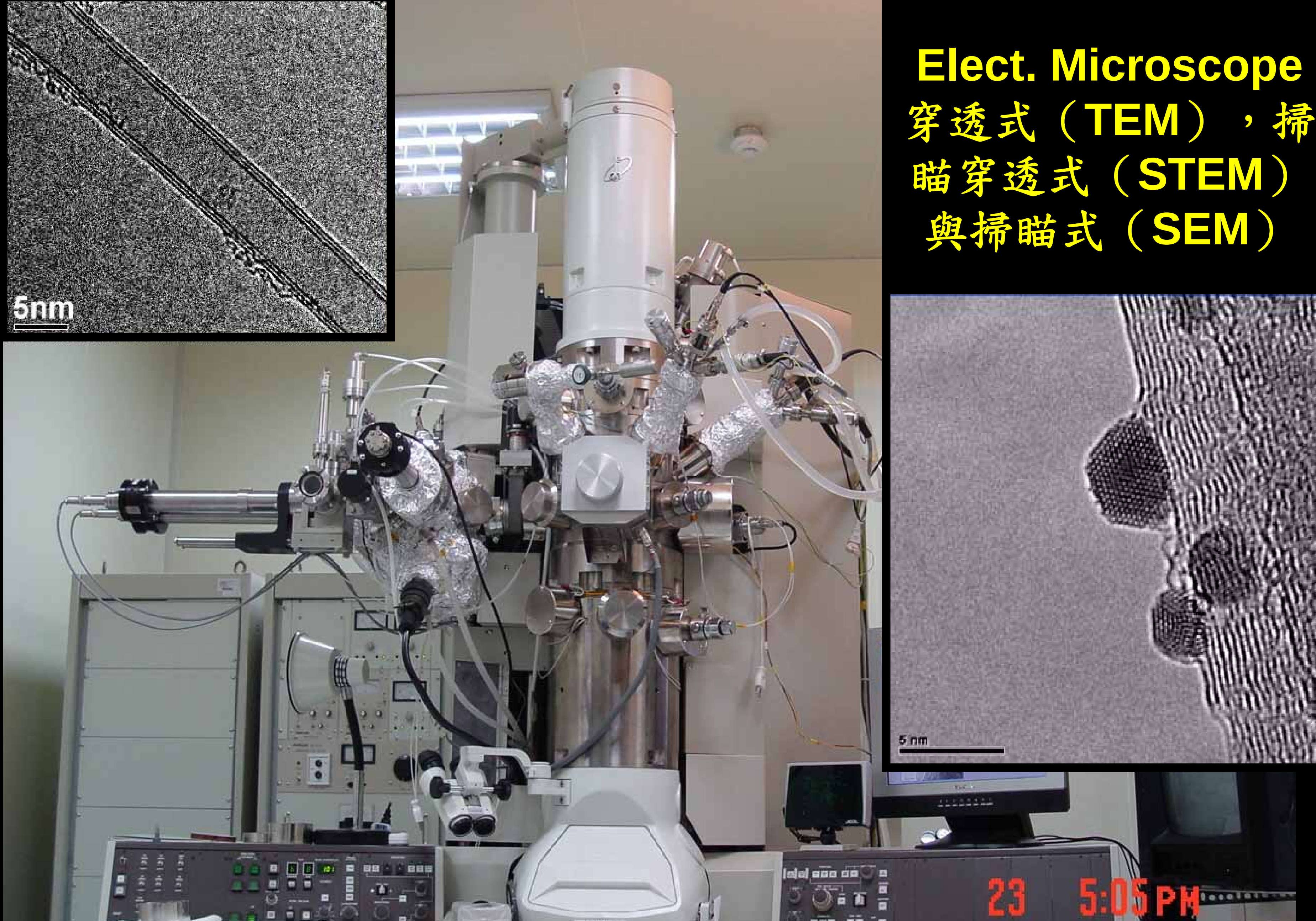
Protein Molecule (MIP)

Dynamics of Polymerase DNA

Si(100)-2x1 surf.

鄭天佐 IP AS

Elect. Microscope
穿透式（TEM），掃瞄穿透式（STEM）與掃瞄式（SEM）



UHV TEM in Nano-science Lab. of Institute of Physics, AS

Physical Properties of Nanostructures

Surface Effects: Fraction of Surface Atoms Increases, Effects Enhanced

Quantum Properties Dominate

- Discrete Quantum Levels
- Dot: Atom-Like, Sharp Energy Levels
  - A Set of Quantum Numbers, 2D & 3D Quantum Dots
- Wire: Ballistic Regime, Quantized Conductivity, No heat generation
  - Resistance is a Wrong Concept, 1+1=1, ax1=1, Wrong Logic
  - How about superconducting nanowire, what are the differences?
- Quantum Confinement Effects: Wave properties
- Quantum Tunneling: Insulation Problem,..

Spin Effects: Spintronics

Atom & Molecular Dynamics: Dynamic Behavior, Growth Phenomena

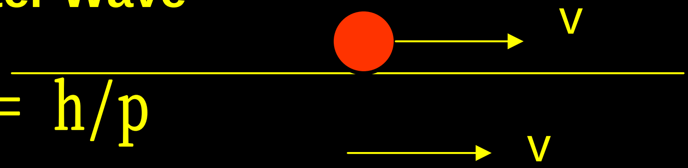
- Electronic Effects in Island Growth
- Thermal Stability: Diffusion, Size & Shape Fluctuation

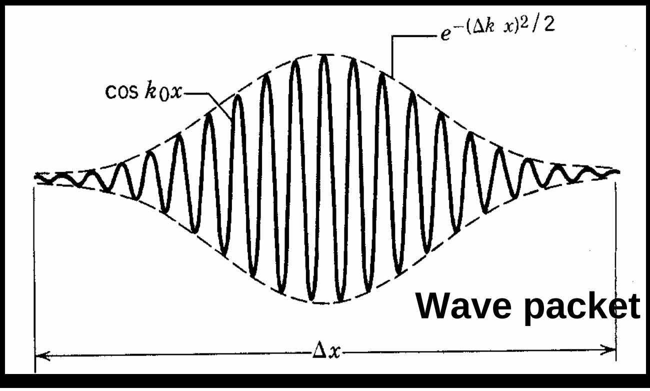
Coulomb Blockade: Small Capacitance, Single Electron Electronics

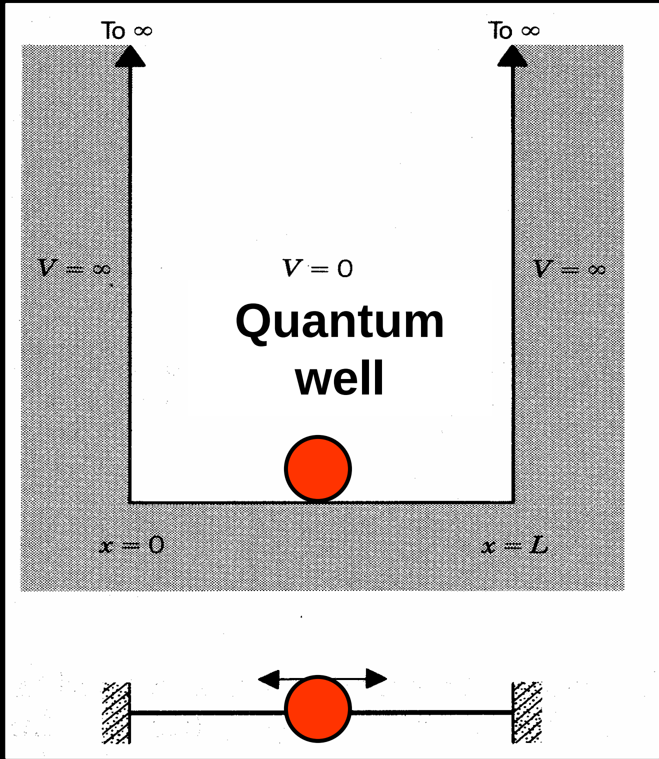
Chemical Stability: Oxidation & Corrosion Resistive Materials

1 Matter Wave

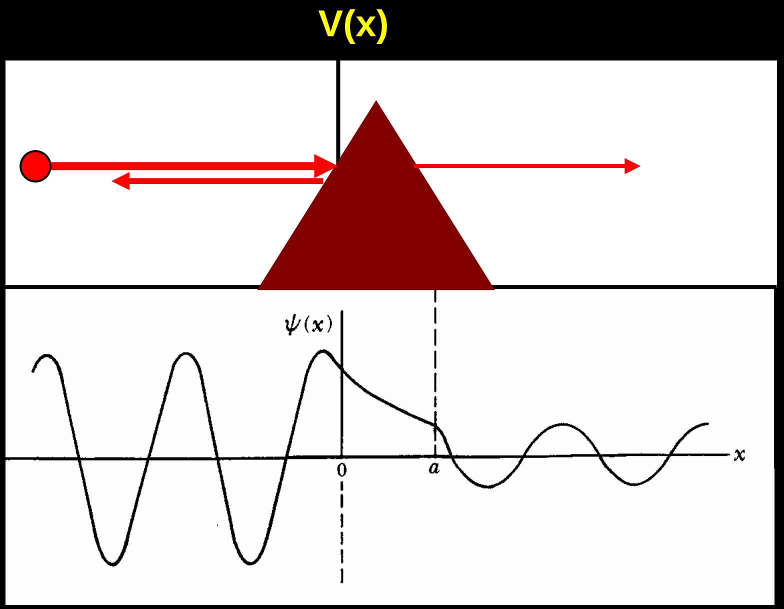
$\lambda = h/p$





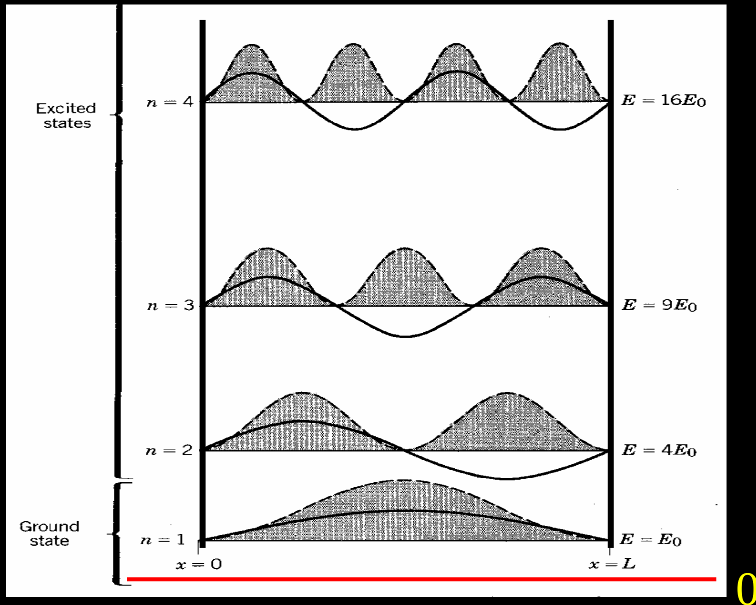


Quantum Properties



2 Particle tunneling

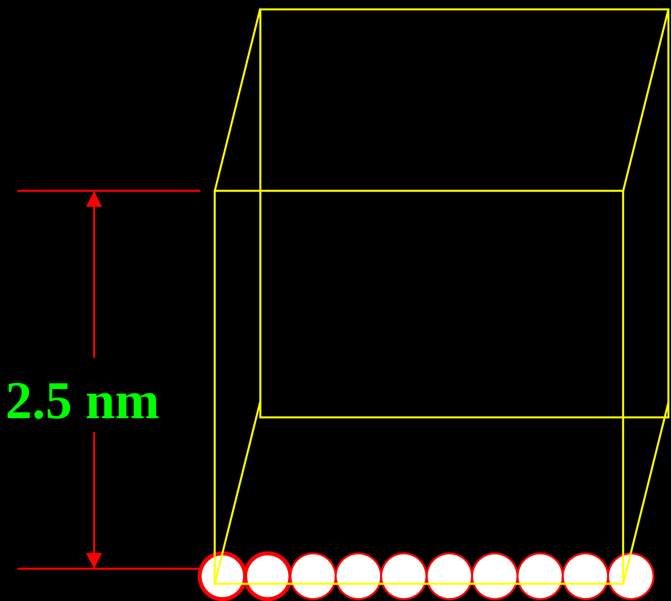
Quantum Dot



3 Energy Quantization

Particle Size → Energy Levels → Color

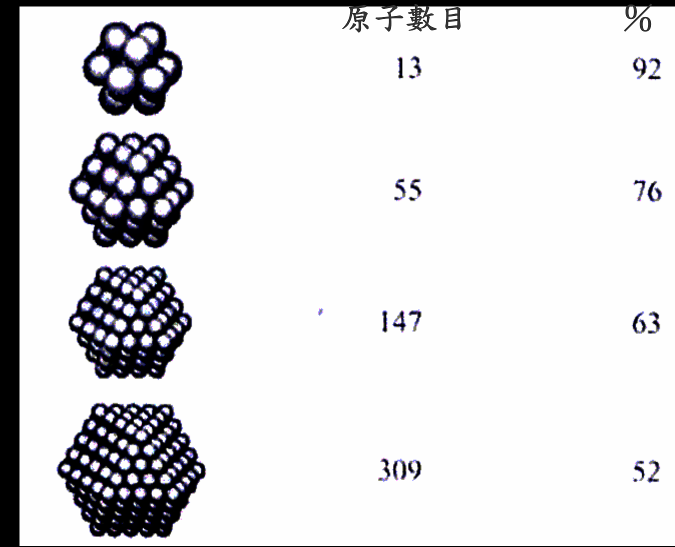
鄭天佐 IP AS

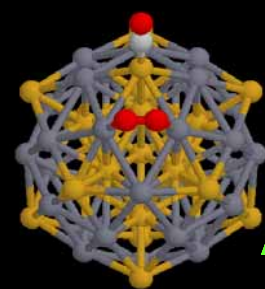


Variety of atom configurations

Surface Effects:

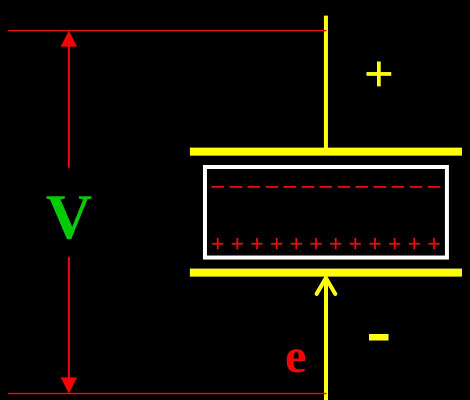
Size	1 nm	2.5 nm
No.	64	1000
Surf.	56	488
Ratio	87.5%	48.8%





$Au_{25}Ag_{30}$

C. M. Wei et al



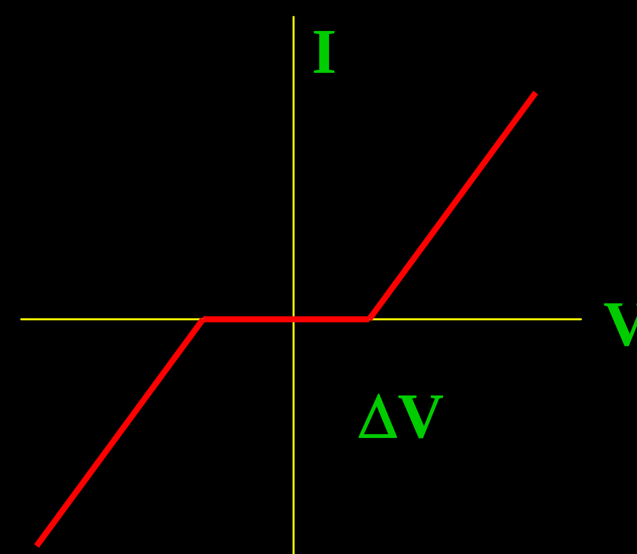
Single electron transistor：

Coulomb Blockade

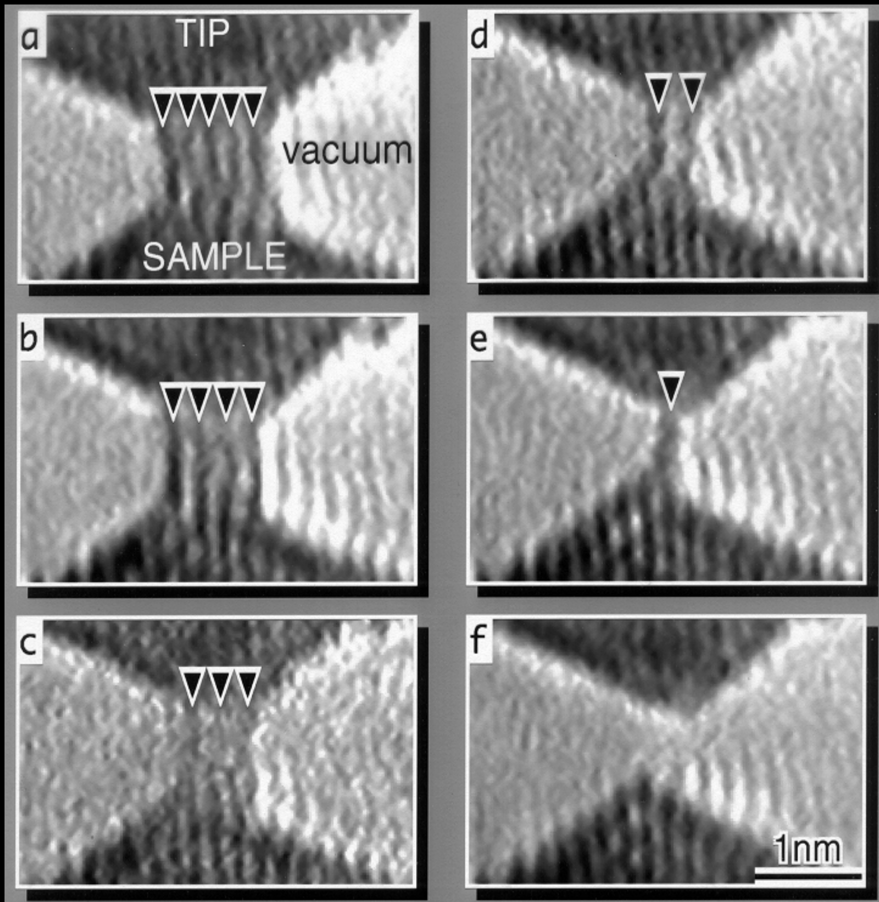
$$V = Q/C$$

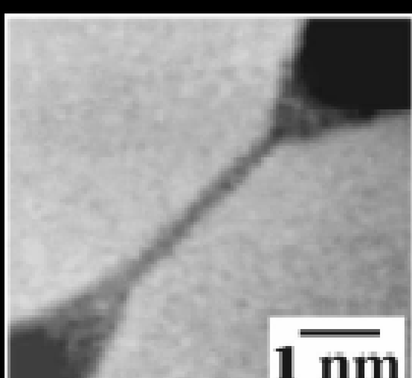
$$\Delta V = \Delta Q/C = e/C$$

$$\gg kT/e$$



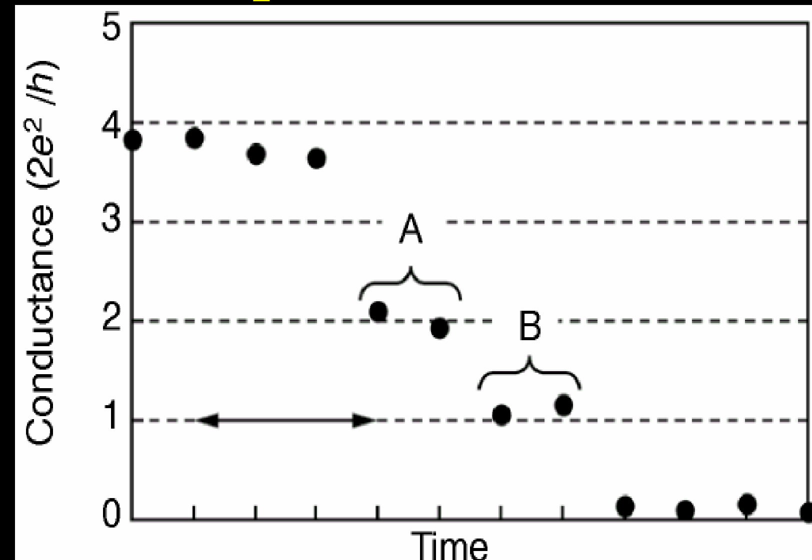
Conductance quantization of quantum wire

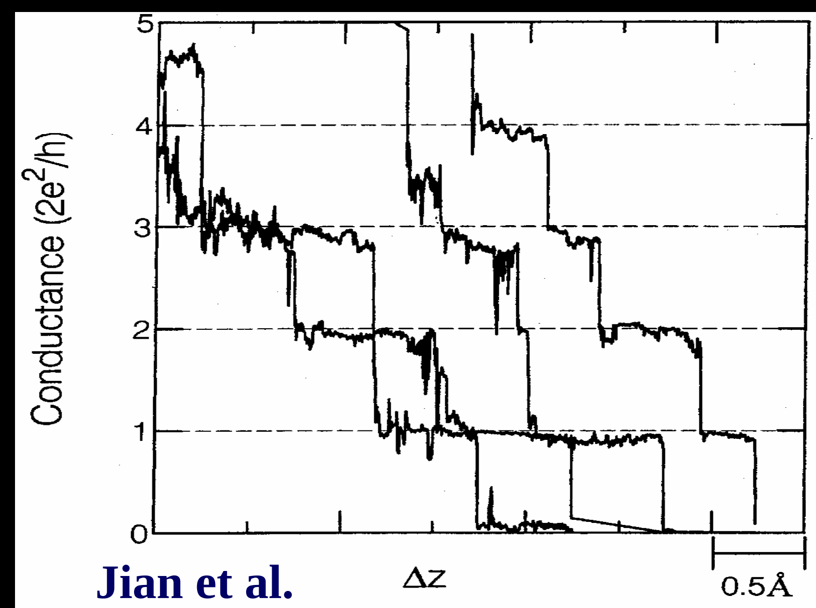




TEM images, Takayanagi et al.

11-atom gold chain

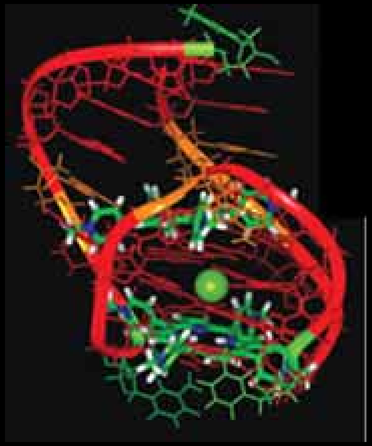




Jian et al.

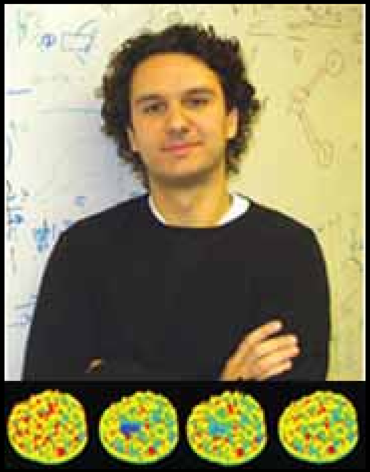
Life Originates from Dynamic Behavior of Biomolecules

Single molecule techniques: trace molecular dynamics by fluorescence of QD



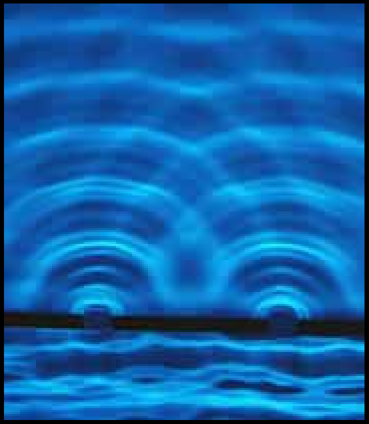
這個特別的 DNA 結構（紅色）可能會防禦癌症基因的形成

© H. Vankayalapati / Univ. Arizona

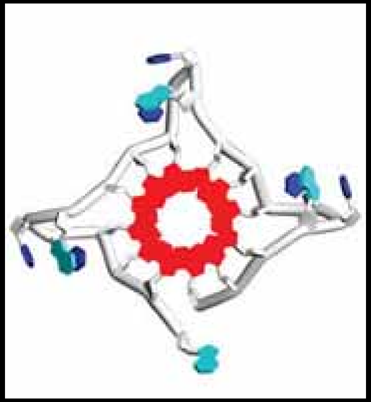


細胞核中蛋白質的動態

© T. Misteli / NCI/NIH

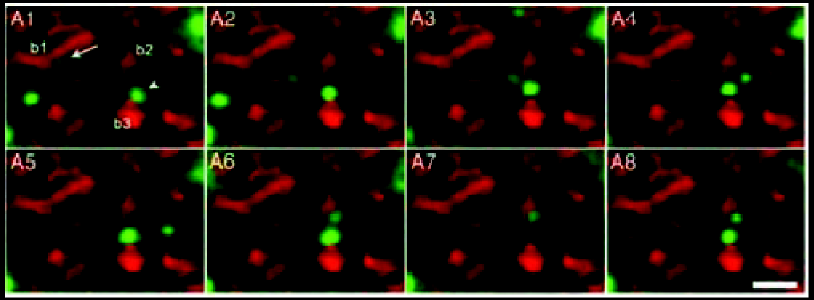


Penrose et al. Life originates from wave properties of electrons in bio-molecules



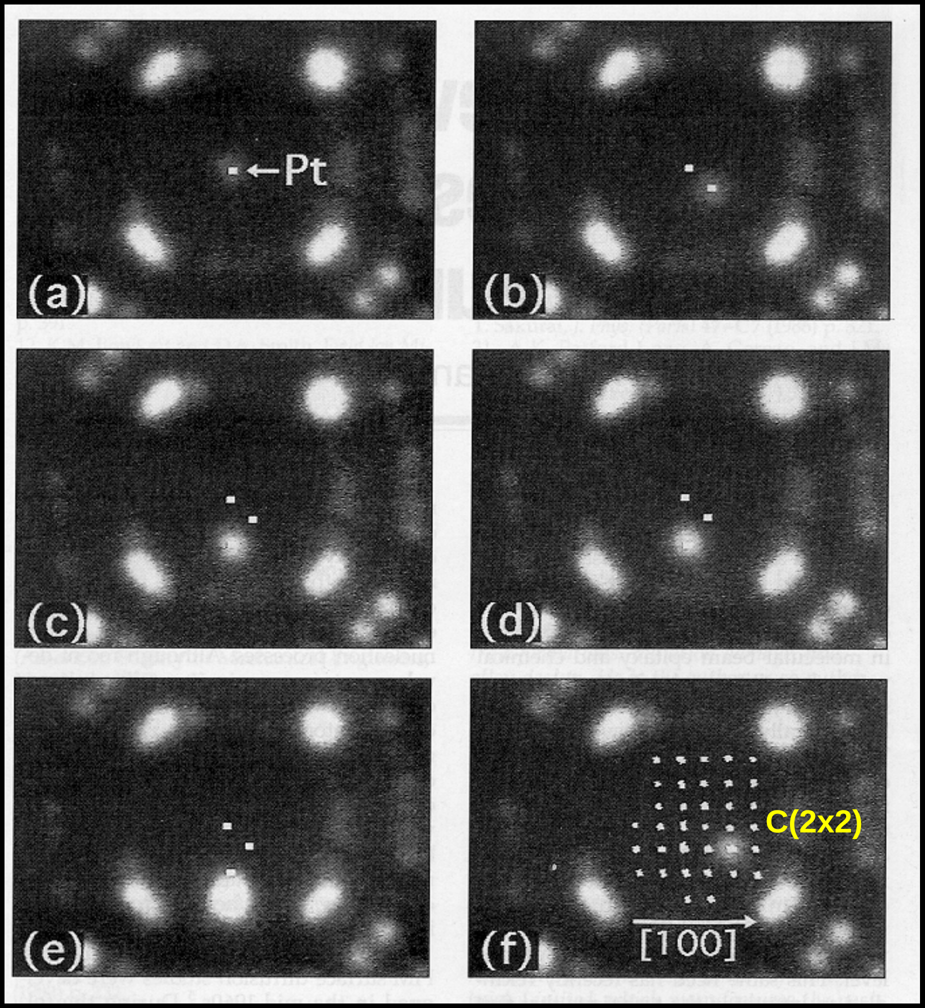
Propeller shape biomolecule

© S. Neidle

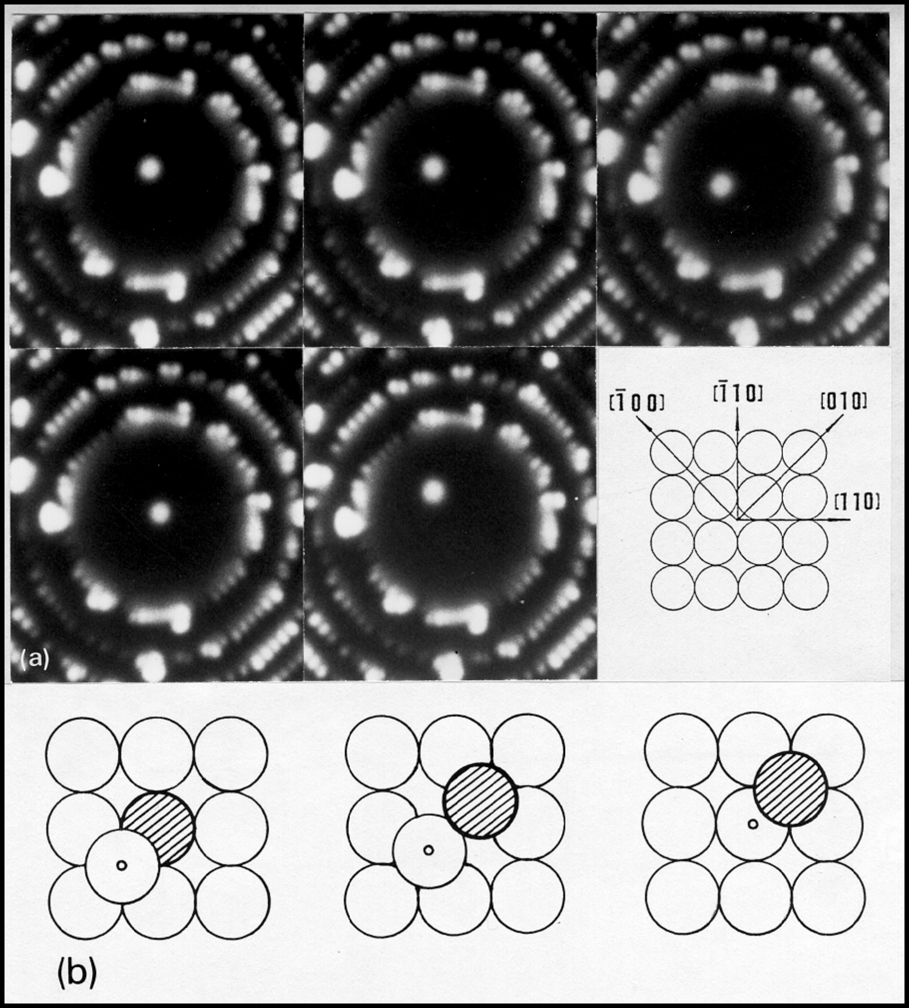


以量子點螢光追蹤 Glycine Receptors 的擴散動態, Triller et al. Science '03

Atom-exchange diffusion mechanism: Ir/Ir(001)

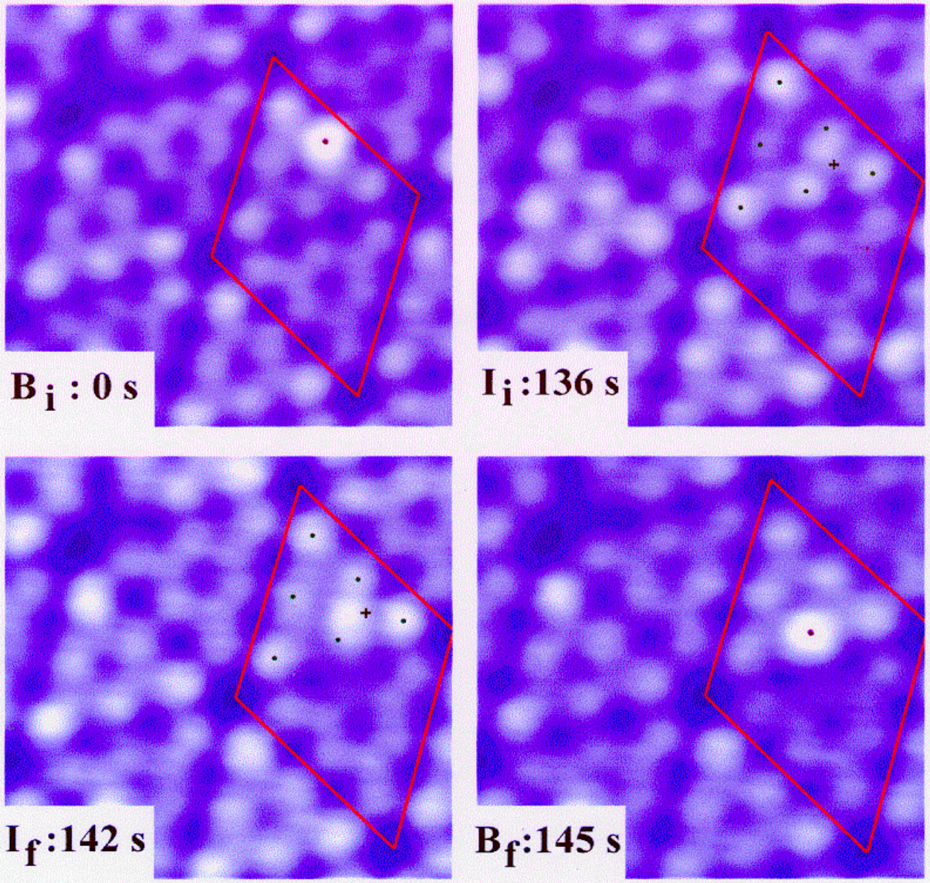


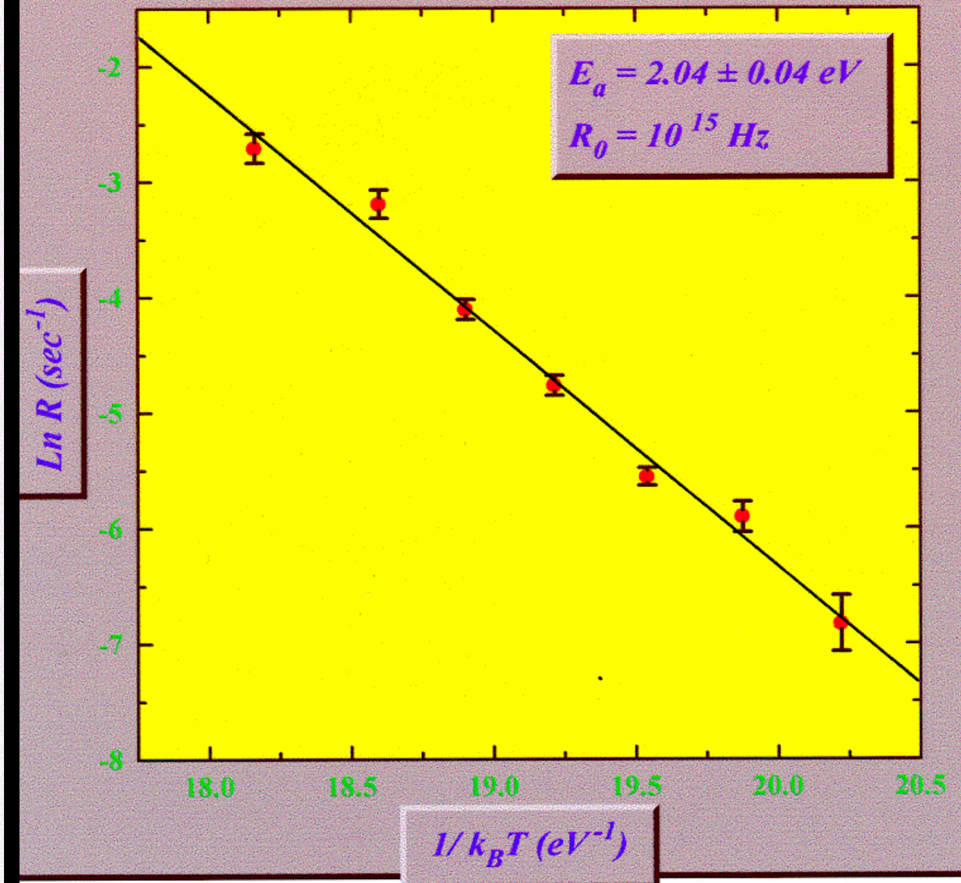
Tracking the movement of one surface atom



Chen & Tsong, PRL' 90, Nature' 91

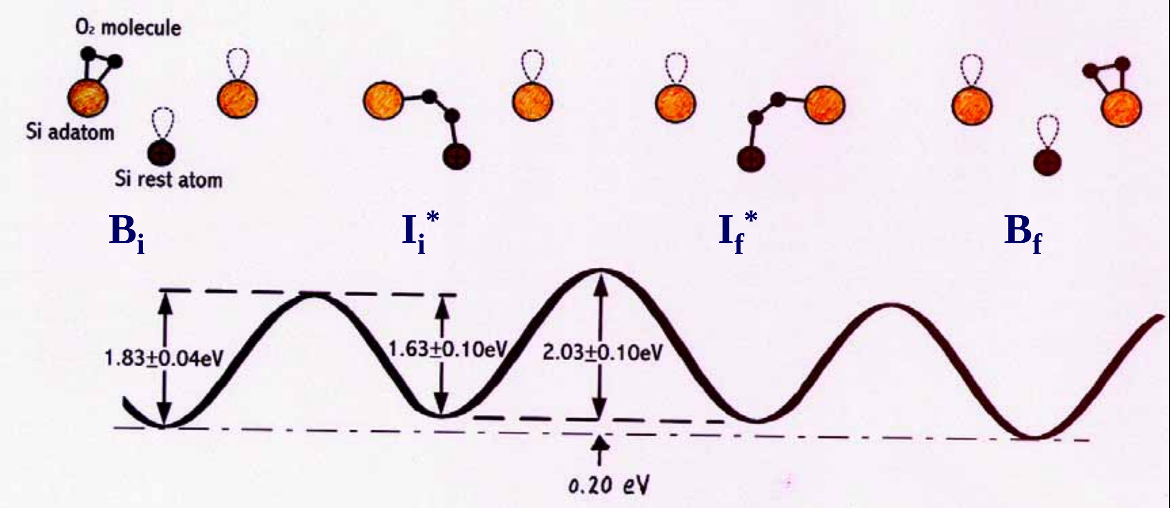
Kellogg & Feibelman, PRL'90



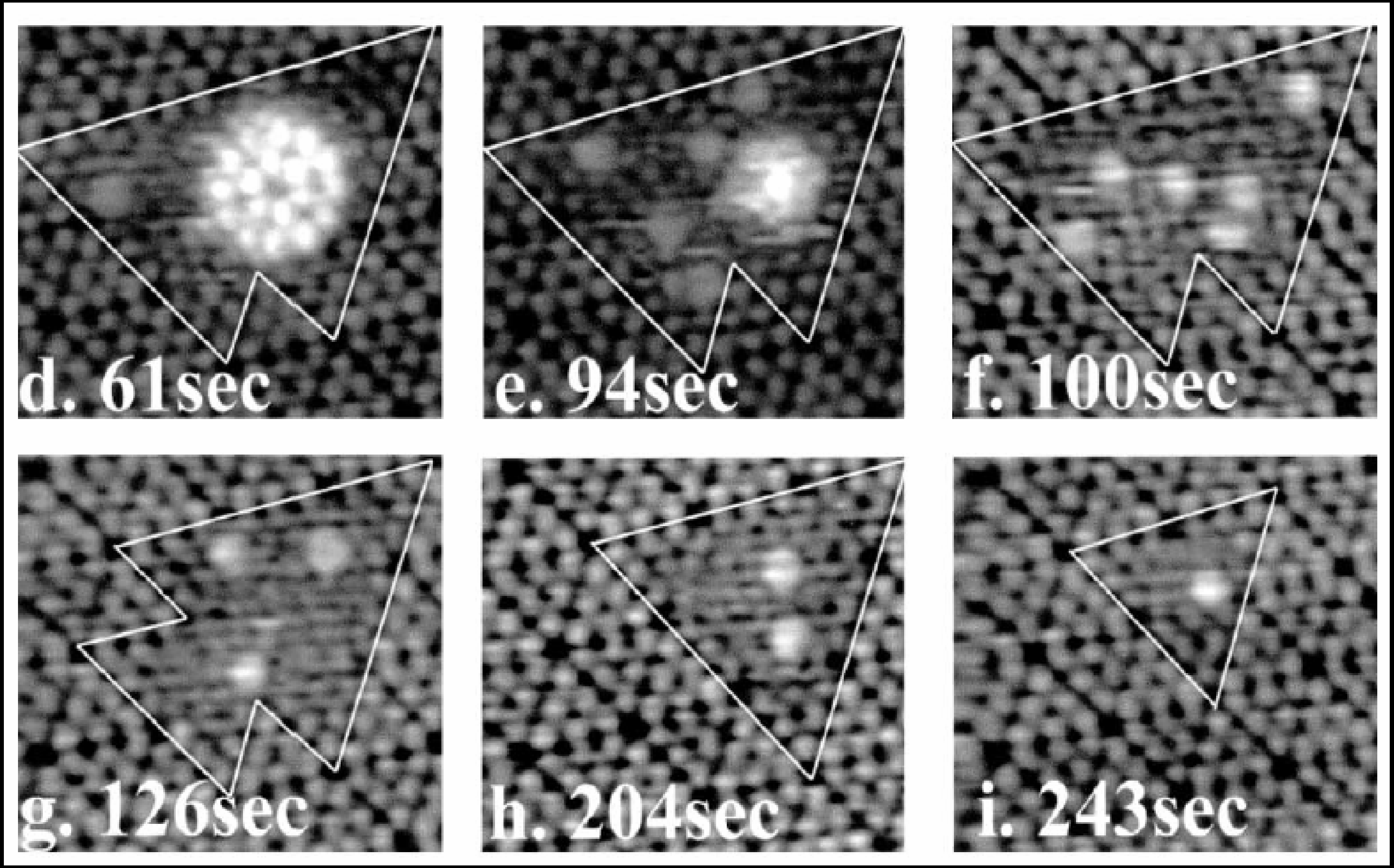


O_2/Si(111)-7x7, 300 C
Hwang et al. ‘97

Jumping Mechanism of a O_2 molecule on Si(111)-surface

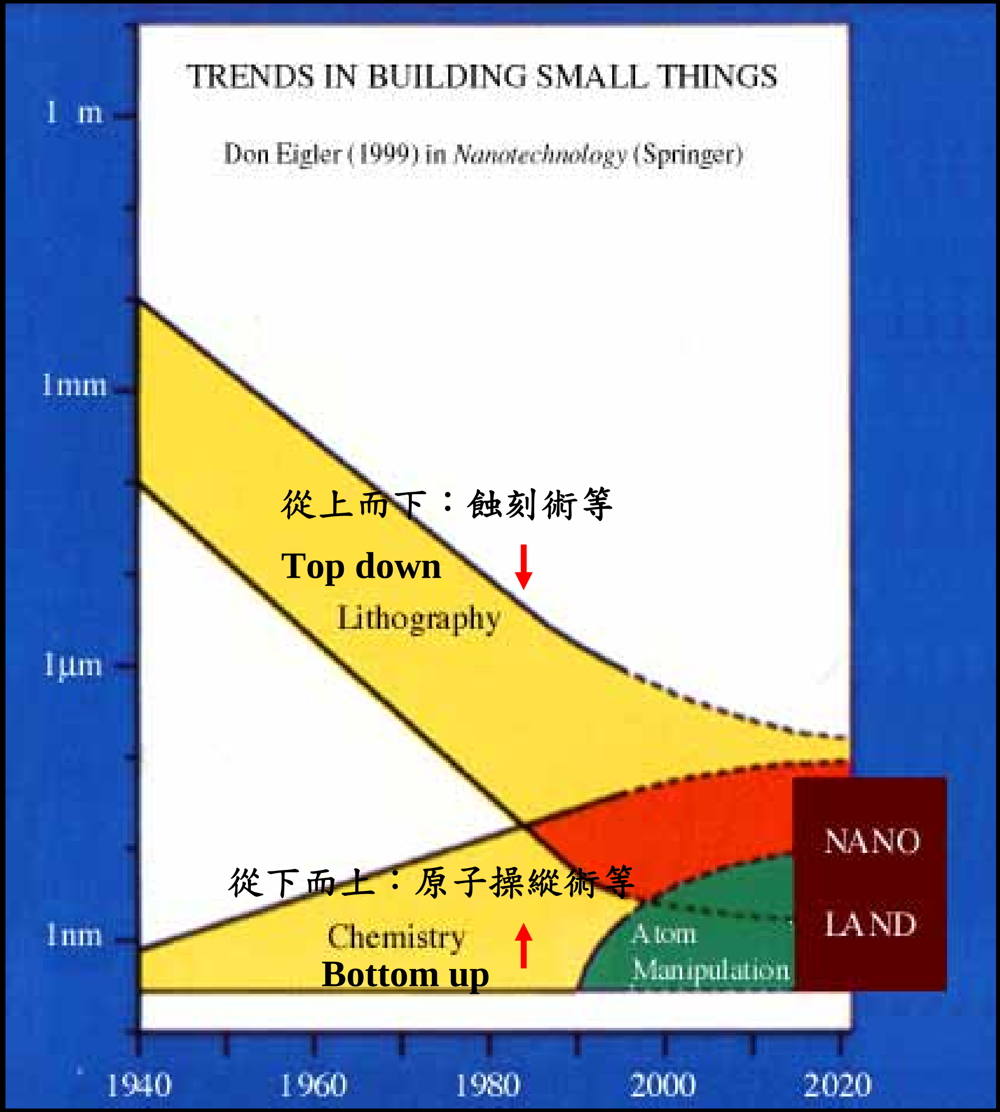


Dynamics of Si magic clusters on a Si surface
A time-lapse movie



何孟書等人 '99

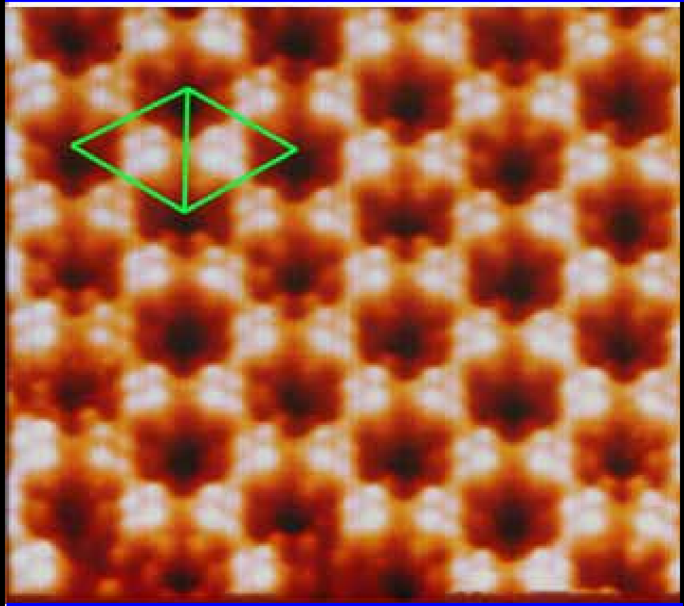
奈米科技 Nanotechnology



- **Rearrange atoms to create a man-made nanostructure**
- **Study the physical properties of such a structure**
- **Utilize the new properties to make new devices**

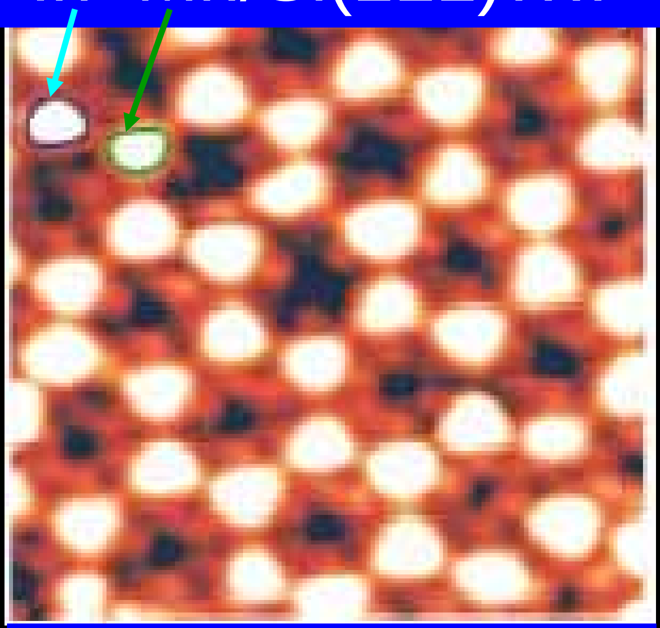
Substrate atomic structure as a template for self-organized growth

Ga/Si(111)7x7



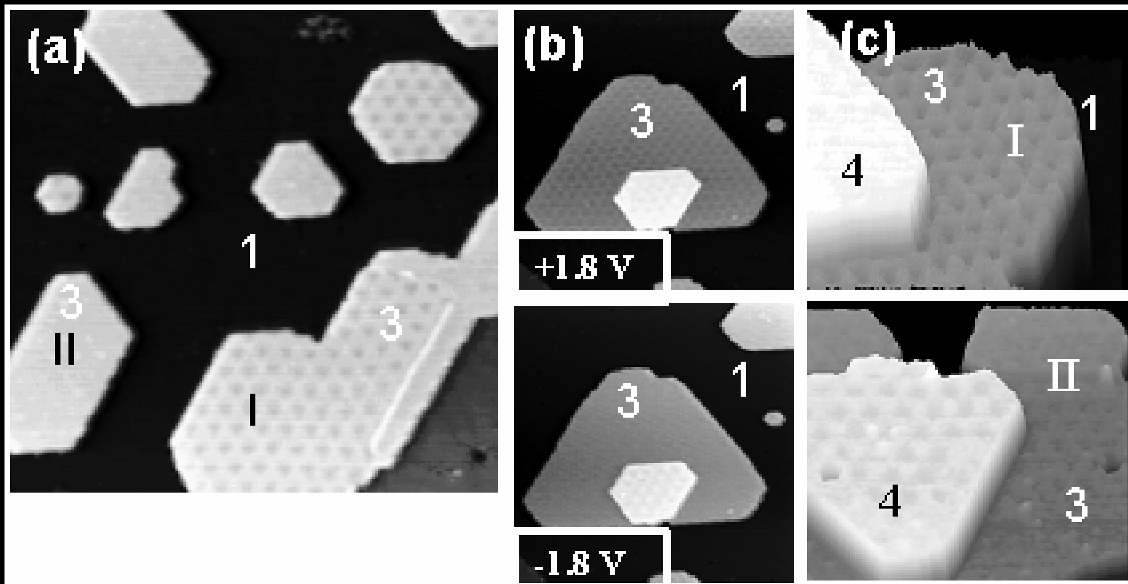
M.Y. Lai and Y. L. Wang
Phys. Rev. Lett. 81 (1998) 164

In+Mn/Si(111)7x7



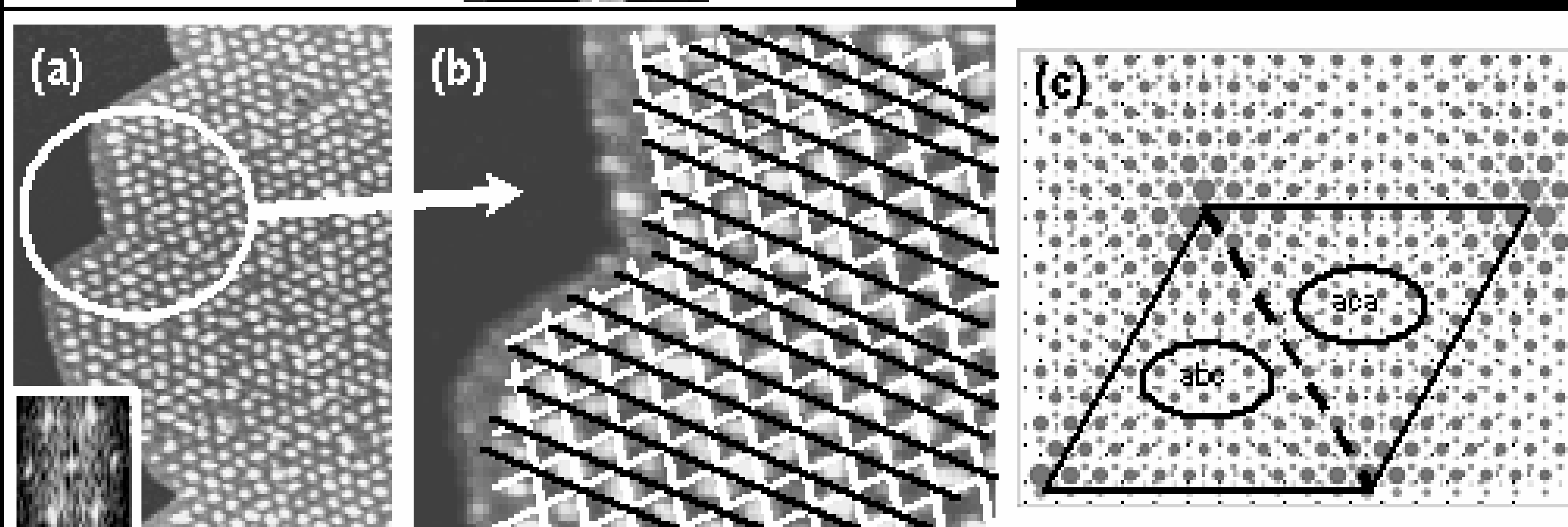
Jian-Long Li *et al.*
Phys. Rev. Lett. 88 (2002) 066101

e-Density pattern as a template for self-organized growth

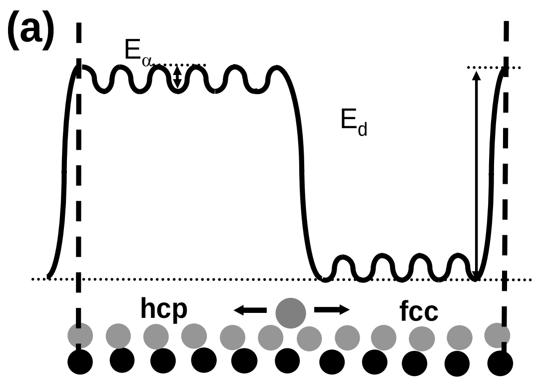


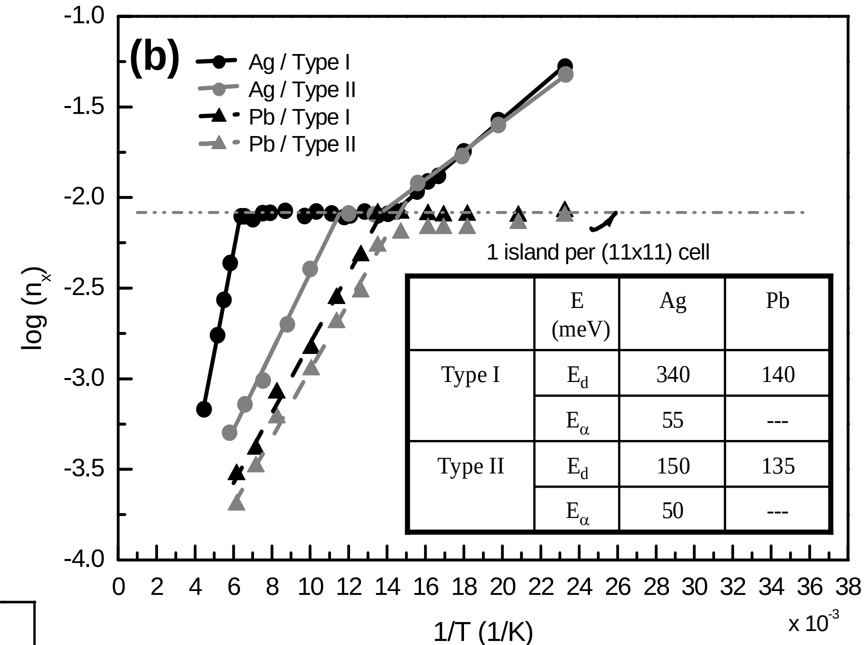
Pb nano quantum islands of types I & II on the Si(111)-7x7 surface

Self-organized growth of Ag nano-pucks on the island surface

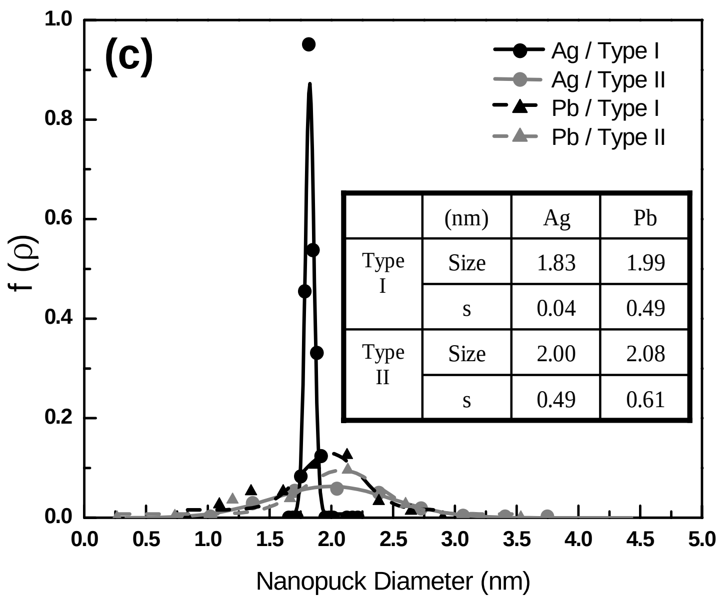


Chiu et al. '04





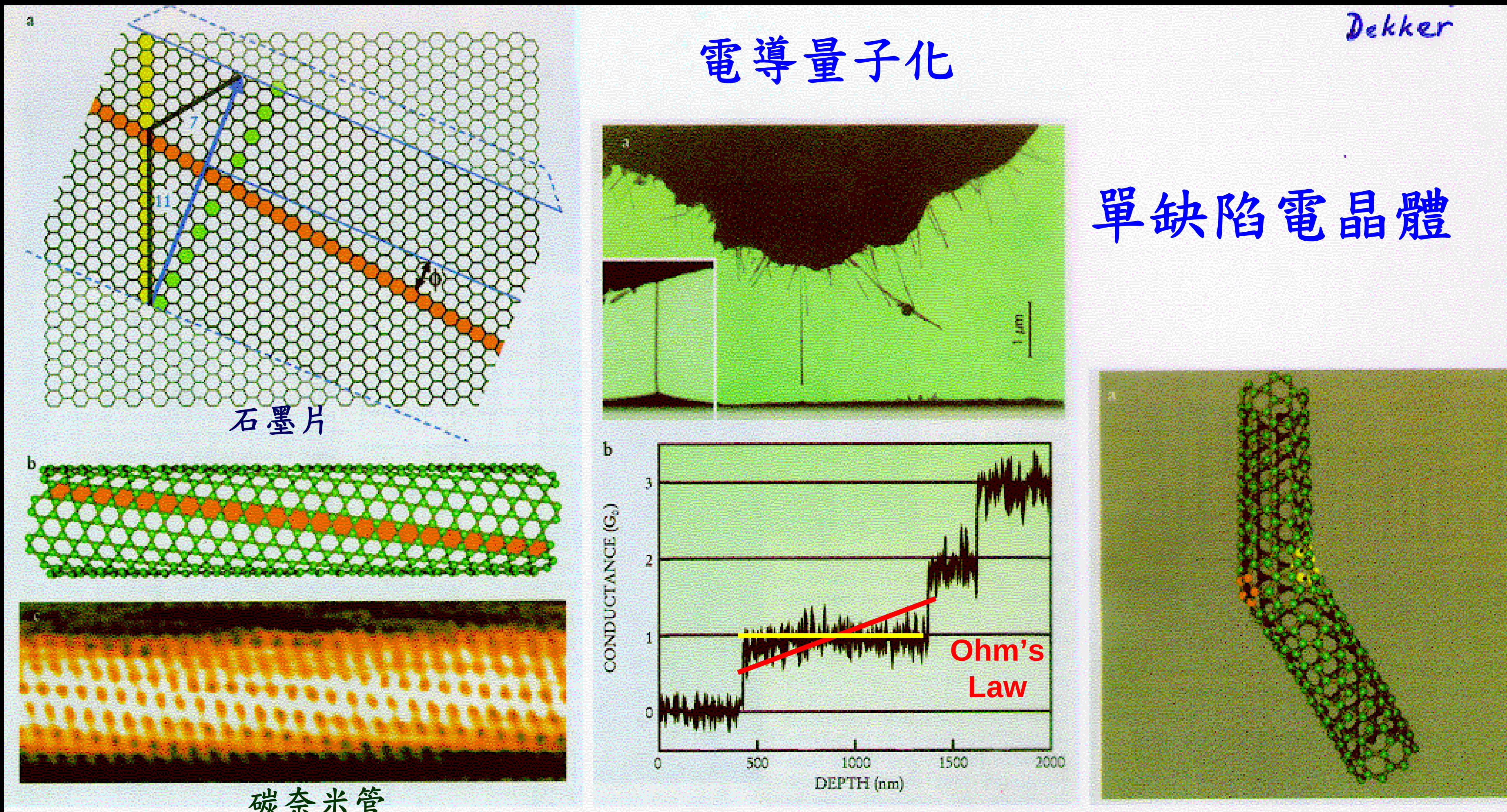
	E (meV)	Ag	Pb
Type I	E_d	340	140
	E_α	55	---
Type II	E_d	150	135
	E_α	50	---

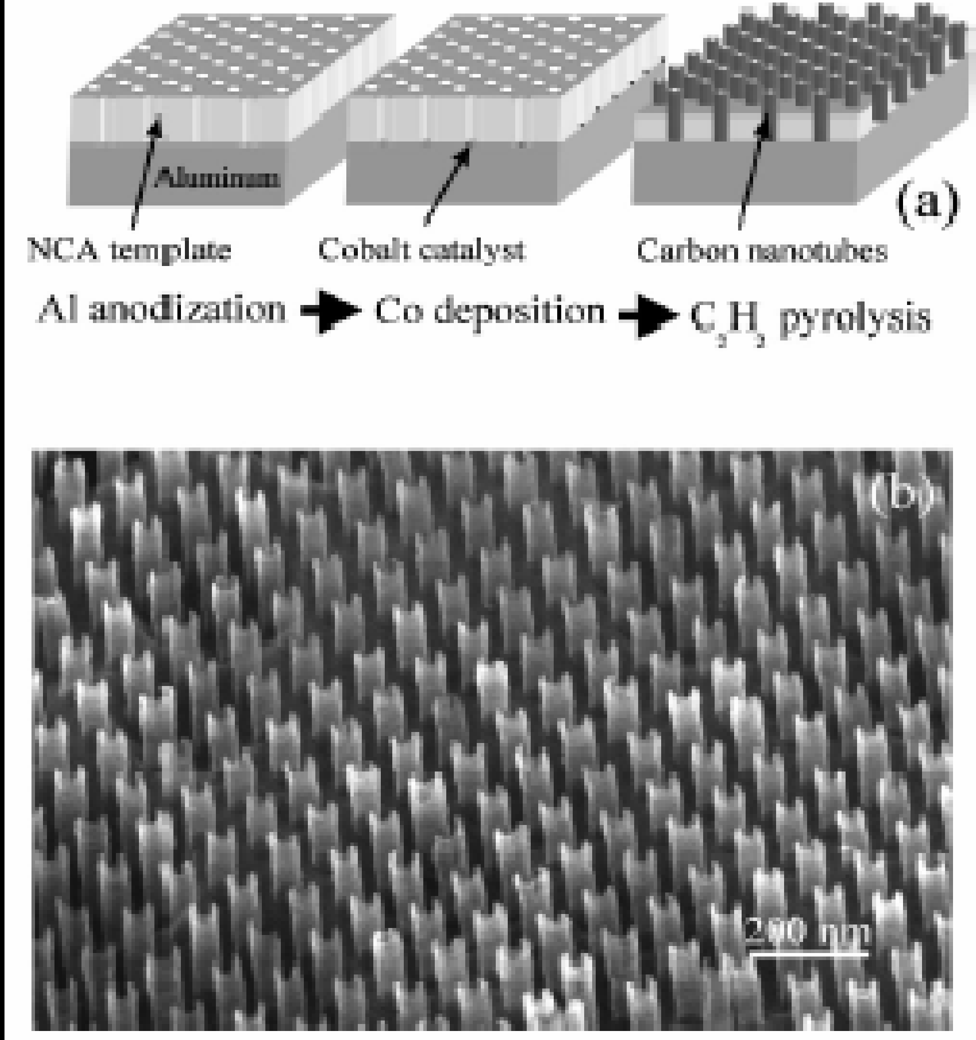


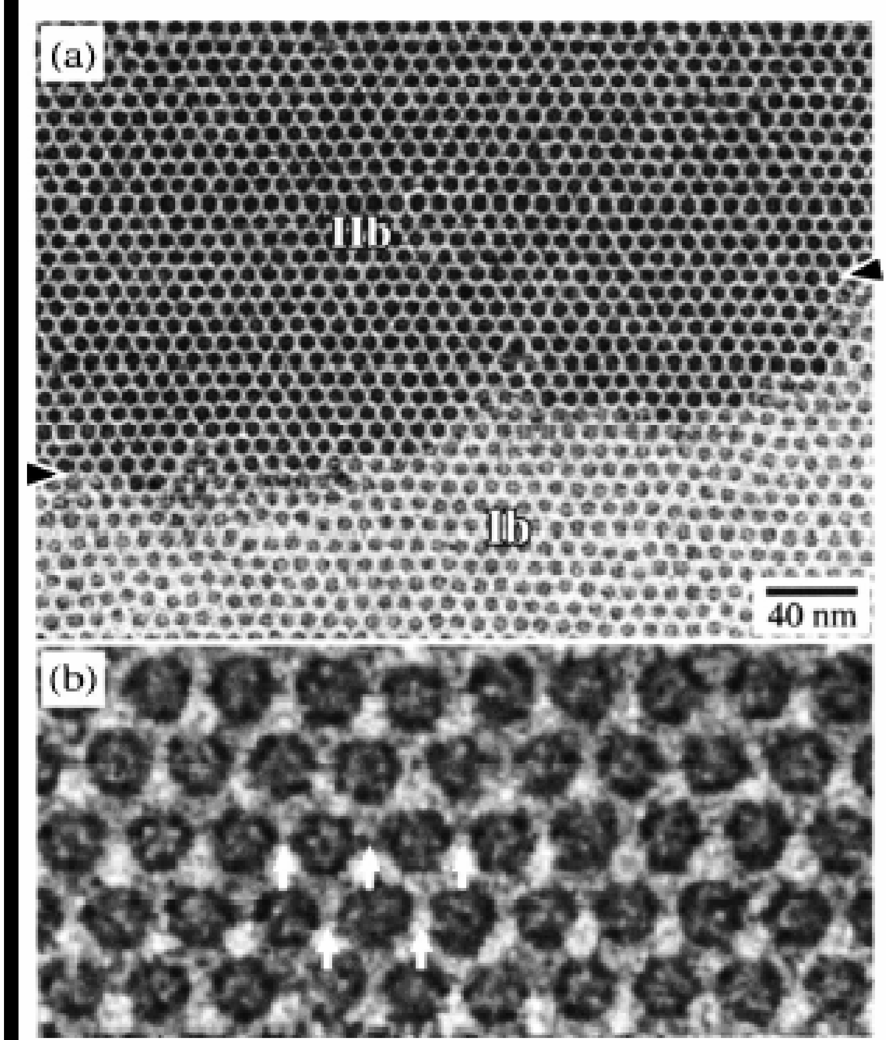
	(nm)	Ag	Pb
Type I	Size	1.83	1.99
	s	0.04	0.49
Type II	Size	2.00	2.08
	s	0.49	0.61

Based on a theory of nucleation and growth, the activation energies involved can be derived

By Chemical Synthesis & Growth (Self-Assembly): Single Wall Carbon Nanotube







Highly-ordered carbon nanotube arrays for electronics & FEFPD applications

J. M. Xu et al., APL **75**, 367 (99)

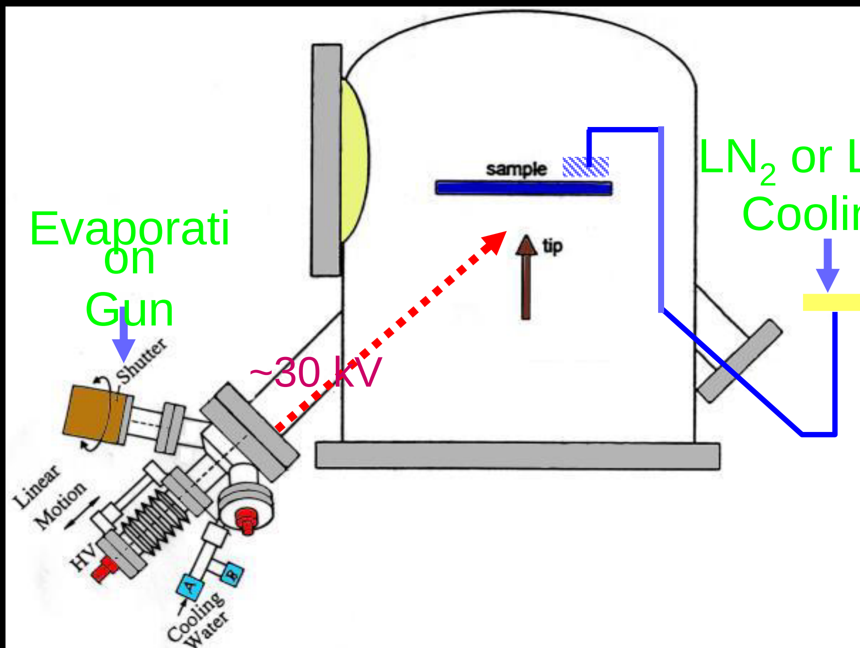
U. Toronto

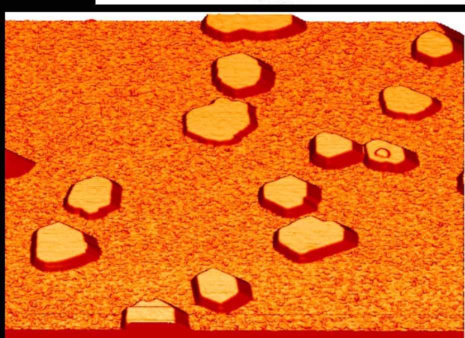
TEM image of a film of 7.0 nm size Fe nanoparticles (coated with surfactant).

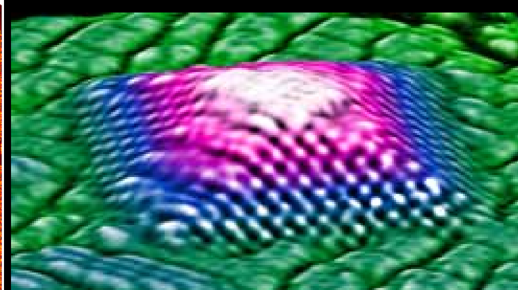
A. Majetich et al., PRB **65**, 224431 (02)

Case-Western U.

Some methods of creating nanostructures



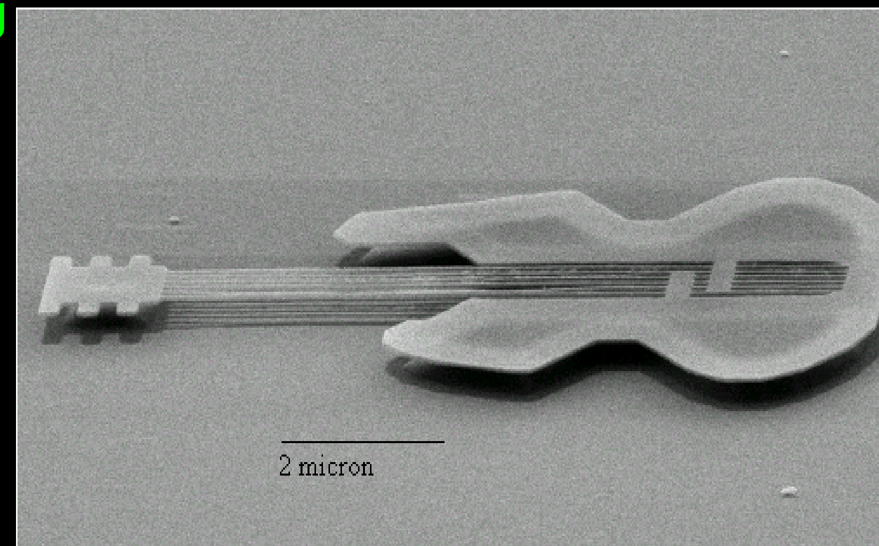




Quantum Islands：Vapor deposition

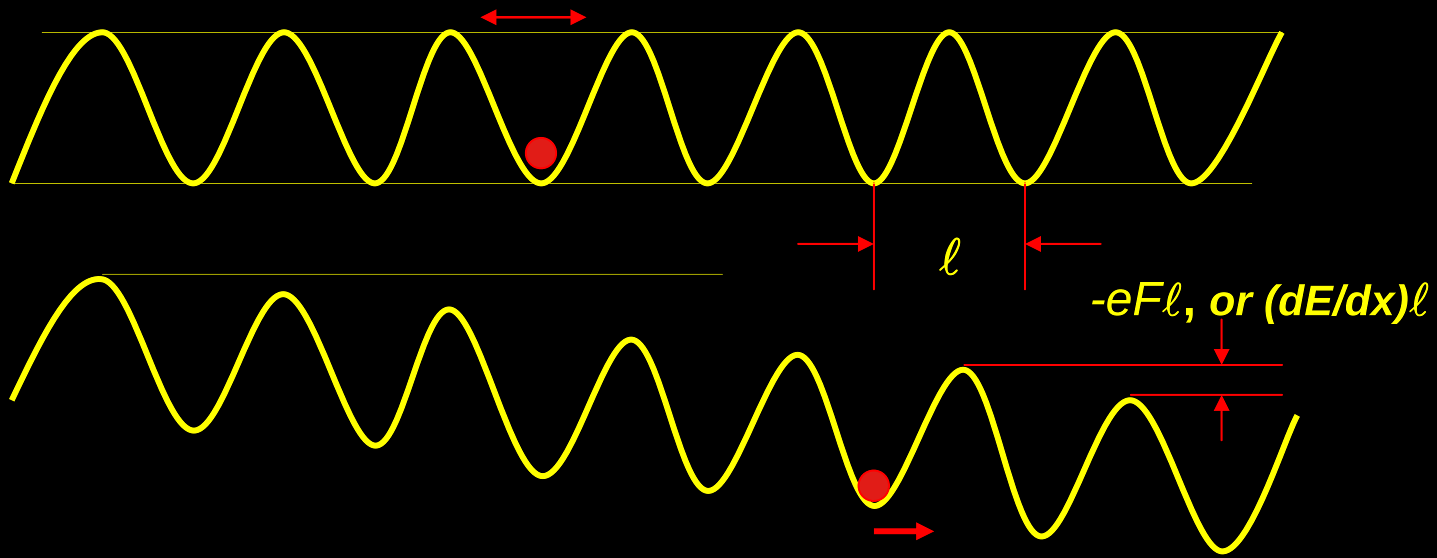
蘇維彬、張嘉升等人 ‘00

Nano-guitar



World’s smallest guitar: length of 10μm with 6 strings of width 50nm。 Need a “nano” idol-robot to play music with this guitar！ Would such robot can ever exist?

Random Walk of an atom

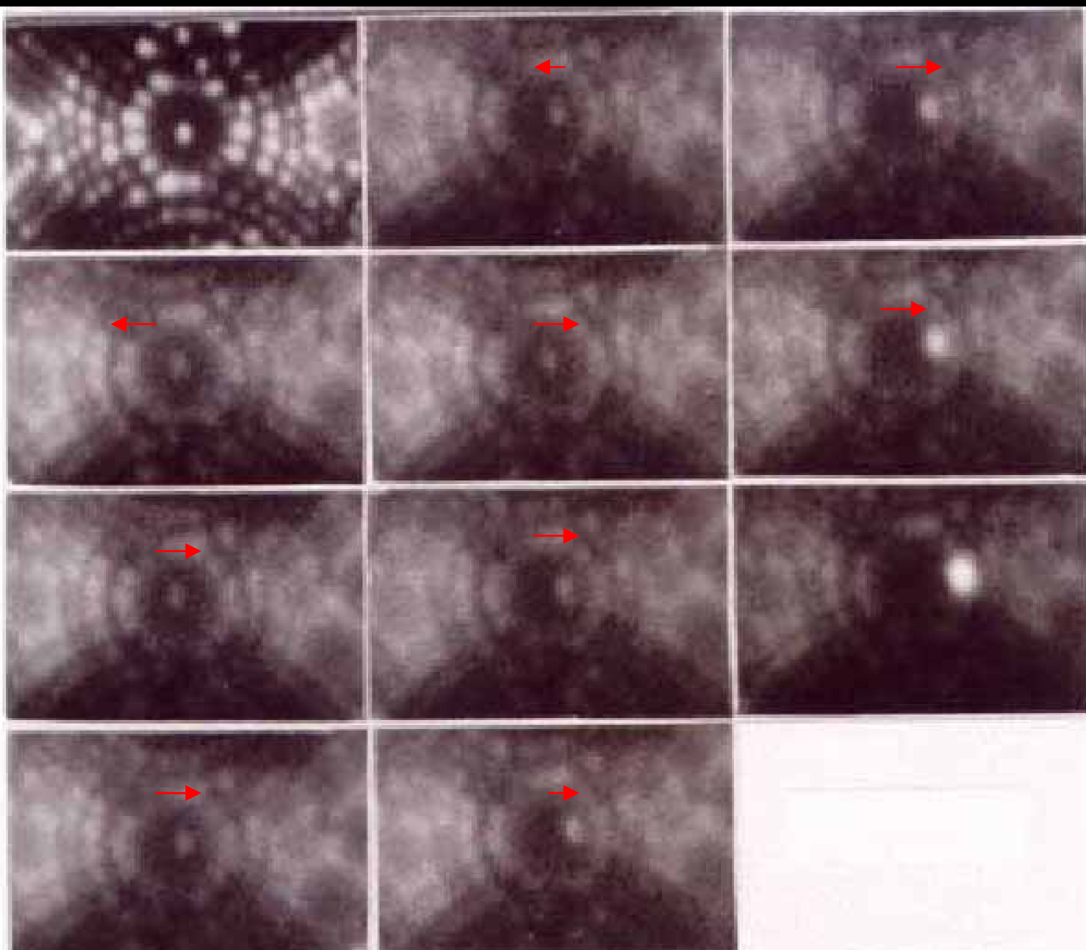


Chemical potential gradient induced directional motion

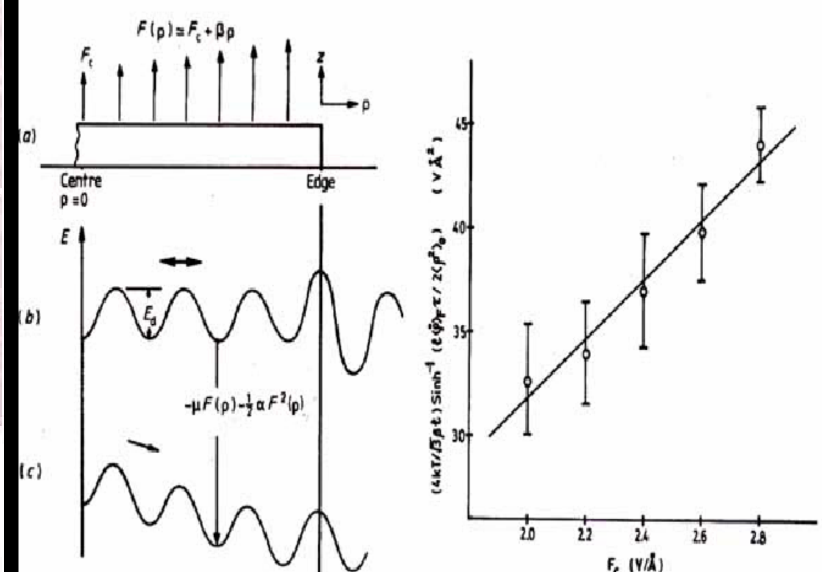
Field gradient, particle density gradient, thermal gradient, atomic interactions, etc. Kinetic Effects

Directional Walk of W Atom on W(112)

Produced by Chemical Potential Gradient (Field Gradient)



$$\mu_0 + \alpha F_c = \frac{2kT}{\beta'} \sinh^{-1}\left(\frac{\ell \langle \rho \rangle_F}{2\langle \rho^2 \rangle_0} \right)$$

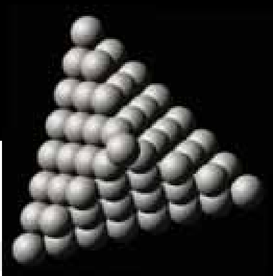


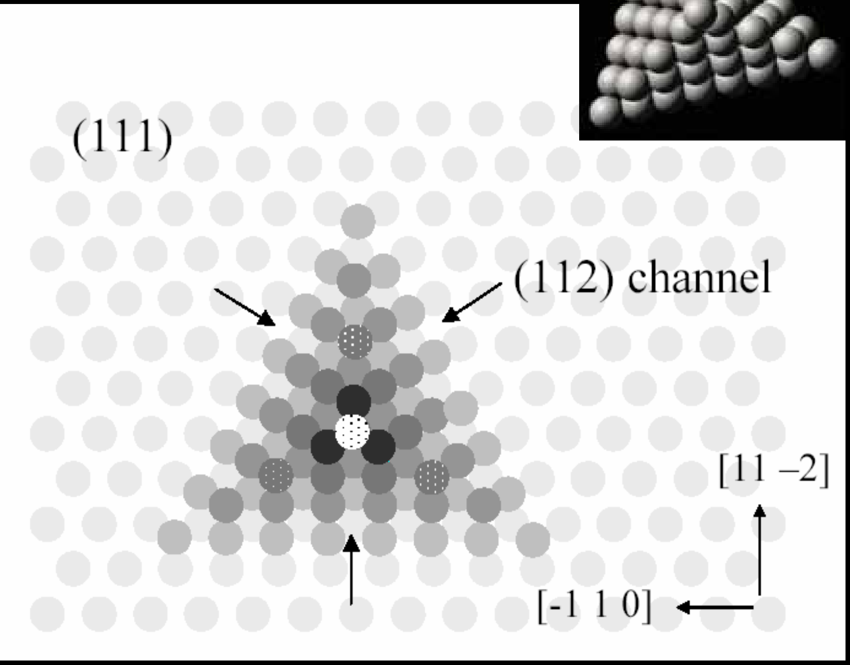
Tsong, Walko, Kellogg, Wang '72, '75 '82

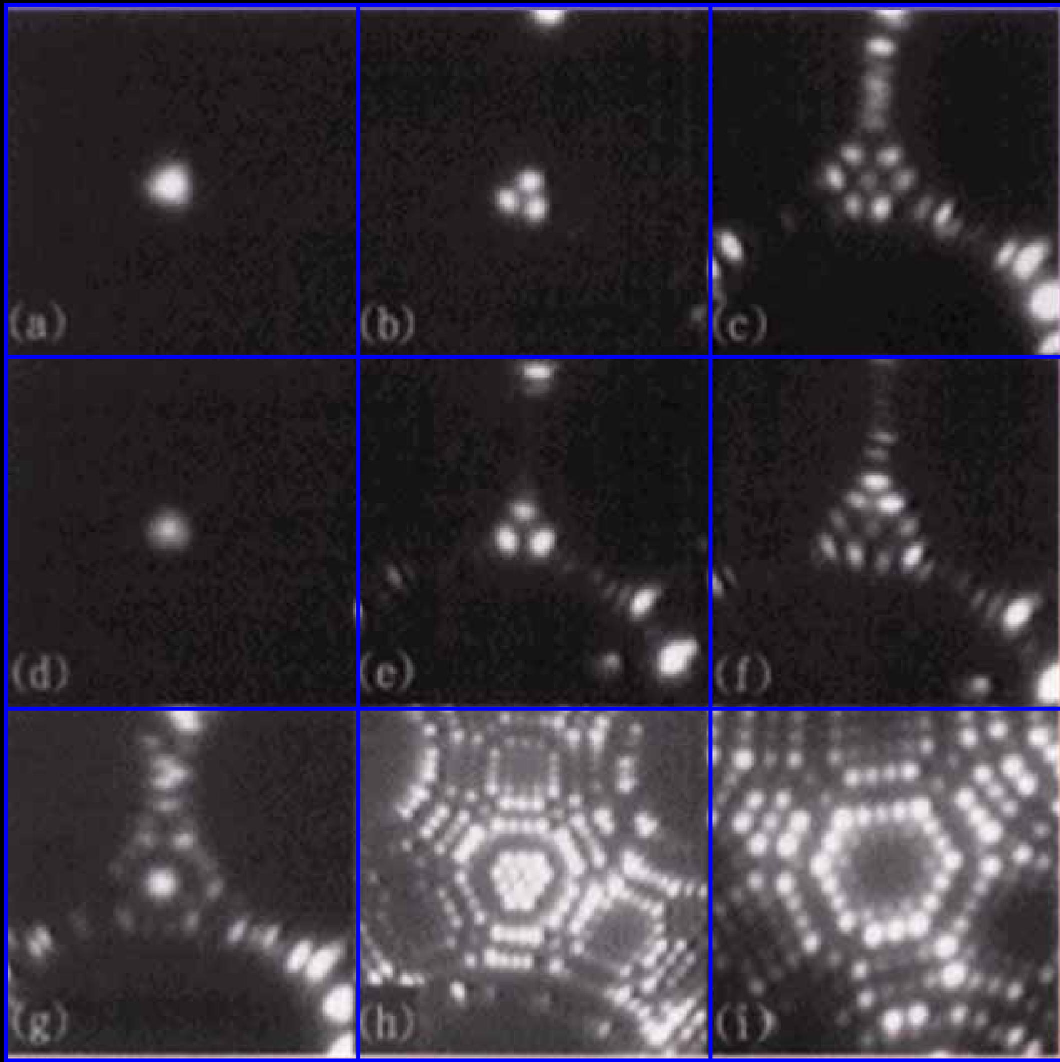
World's smallest pyramid： ~1.4 nm in height

1) STM probing
2) Coherent electron beam
3) Point ion source

W(111)







T-Y Fu *et al.*
PRB (2001).

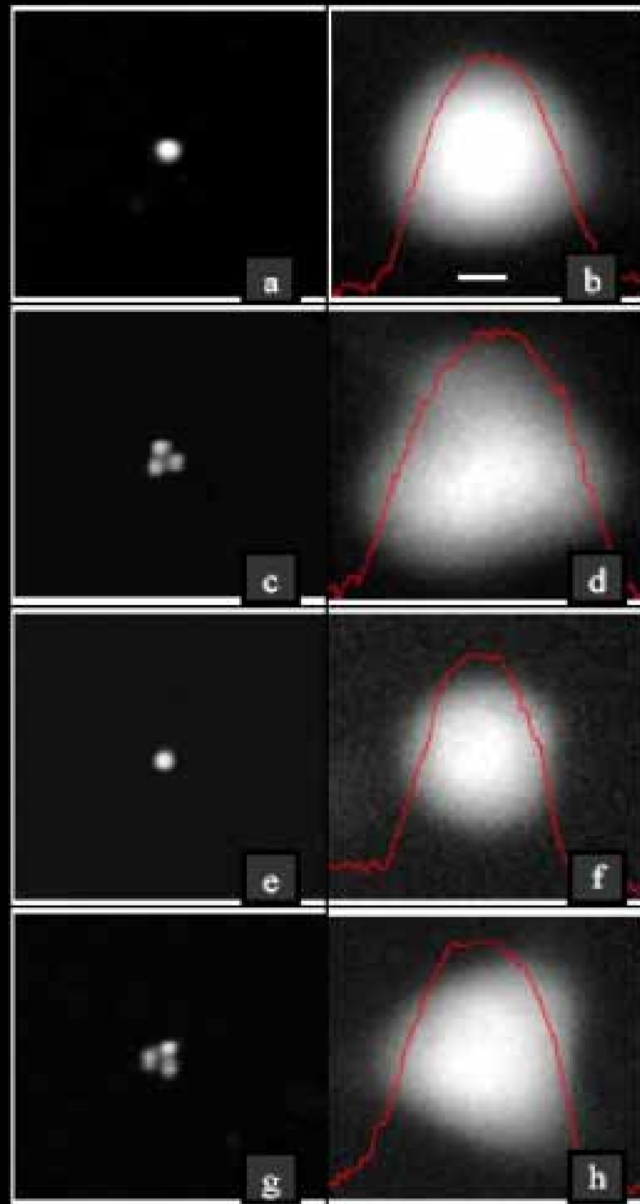
Atom perfect & chemically inert Pd-covered W(111)-base pyramid. Thermally stable up to ~1000 K, h ~ 1.4 nm

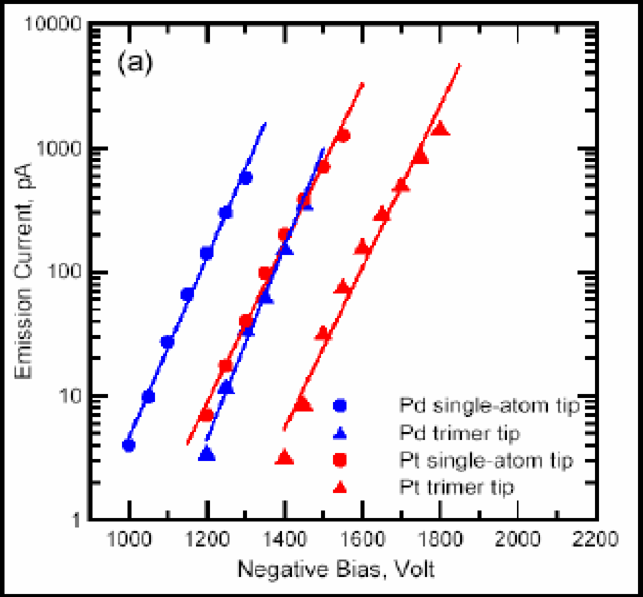
Tsong, IP AS

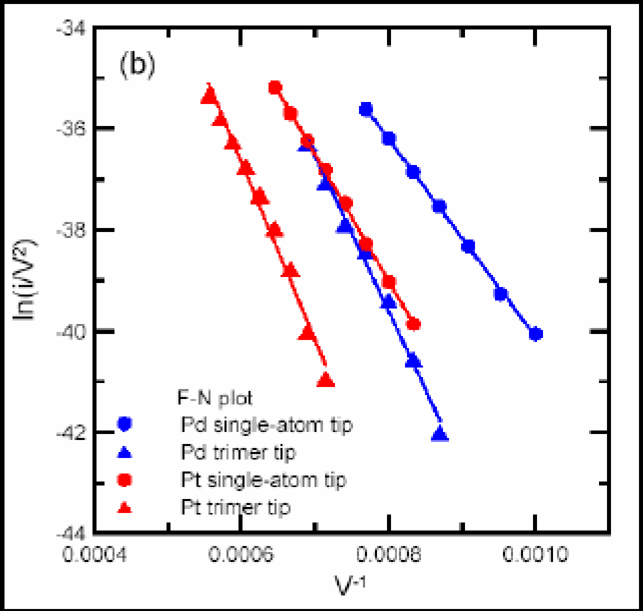
FIM images FEM images

Pd on W(111)

Pt on W(111)







Field emission: extension angle ~ 6 ° Kuo et al. 04

鄭天佐 IP AS

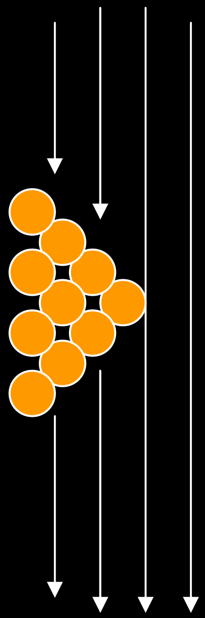
Pyramid of Egypt，～140 m

Ratio： H = 10^{11} V = 10^{33}

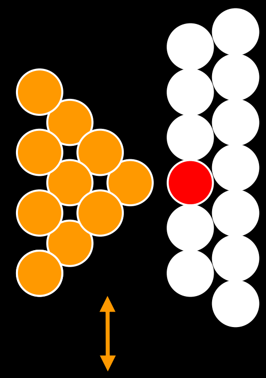
Pyramid of I. M. Pei，～14 m

Ratio： H = 10^{10} V = 10^{30}

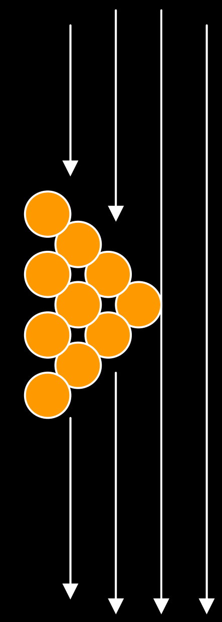
Procedure for Single Atom Chemical Analysis of a Surface by a Density of States Measurement



1) Create a single atom sharp tip, and characterize it by TEM

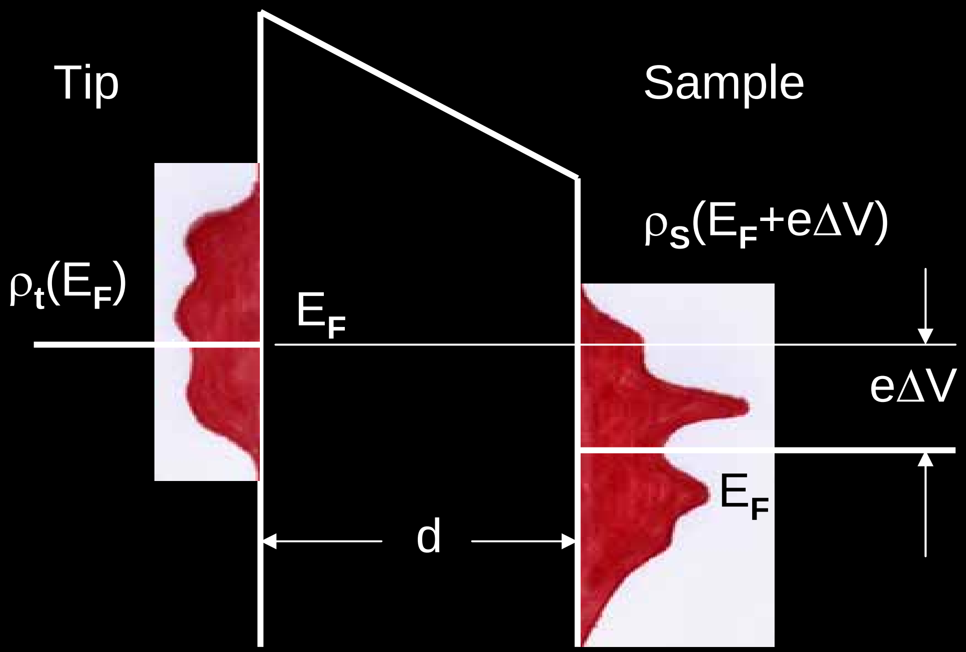


2) Use the tip to scan the sample, take dI/dV vs. V from a pre-selected atom



3) Use TEM to make sure the tip is still atom perfect after the scan

Schematic Diagram Showing Single Atom Chemical Analysis in STM using a Thermally Stable Single Atom Tip of Known Apex Atom



Even if they are not, detailed structure of ρ_S may still help identify the chemical species of the surface atom.

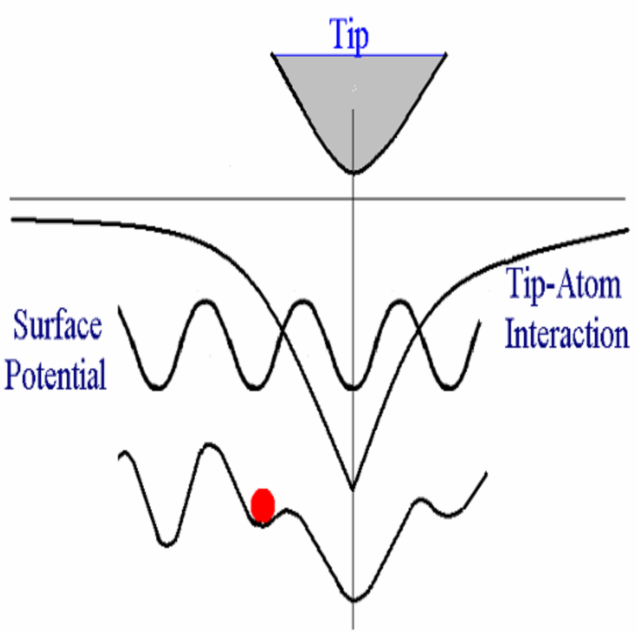
$$I \propto \int_0^{eV} \rho_t(E_F - \varepsilon)\rho_S(E_F - eV + \varepsilon)T(d, eV)d\varepsilon$$

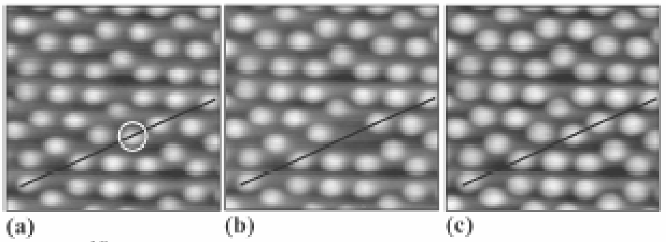
If ρ_t and $T(d,e\Delta V)$ are nearly constant, or ρ_t is a δ-function

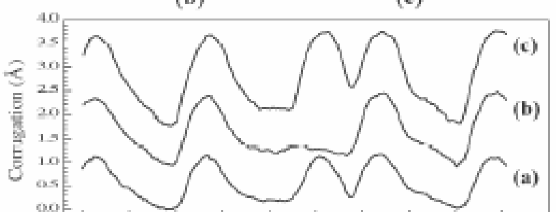
$$\frac{dI}{dV} \propto \rho_S(E_F - eV)$$

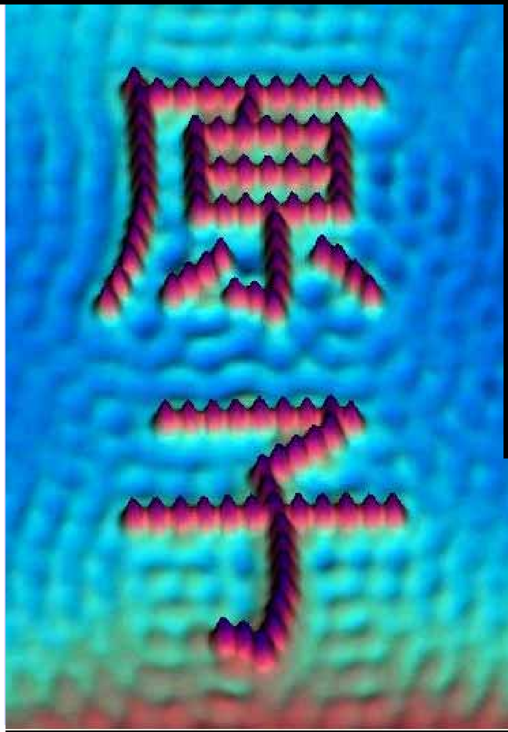
鄭天佐 IP AS

Atomic Manipulation with STM: intrinsic interactions of atoms

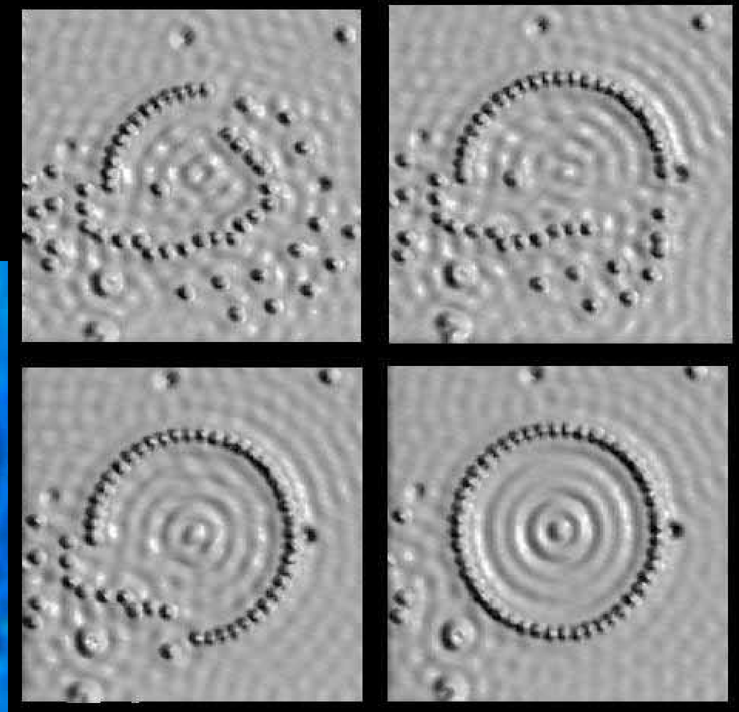


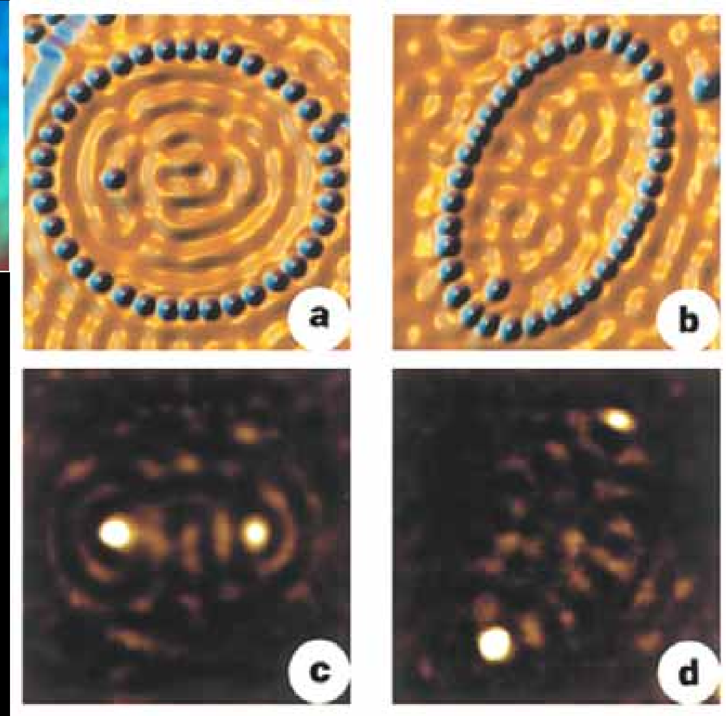






D.M. Eigler et al.
IBM, Amaden





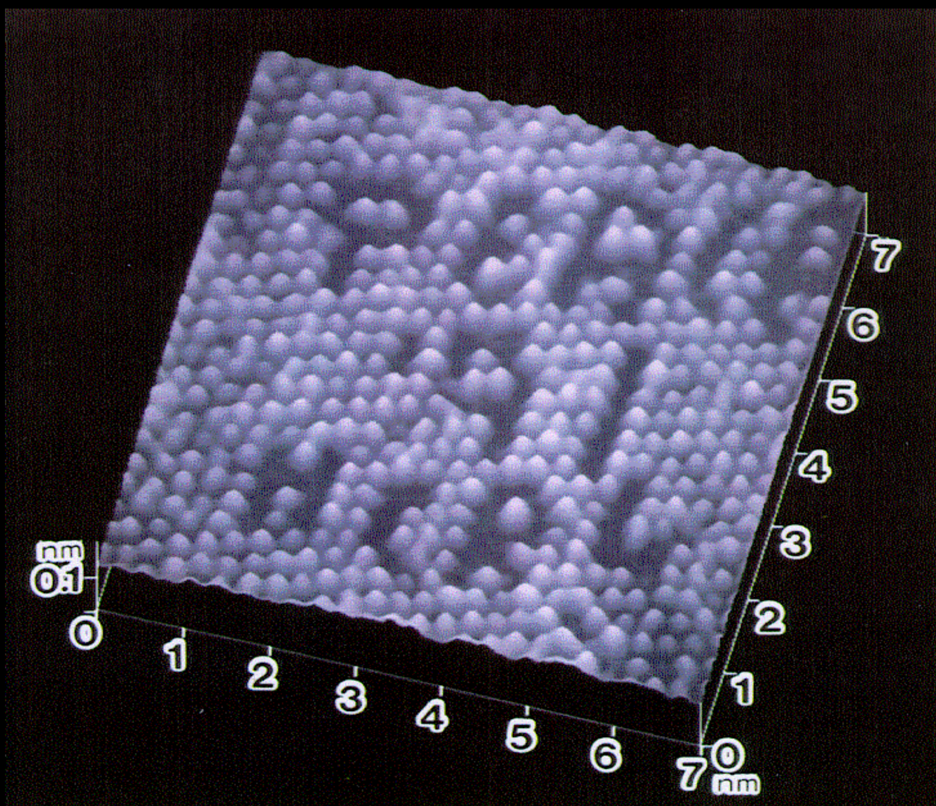
Manipulation with AFM

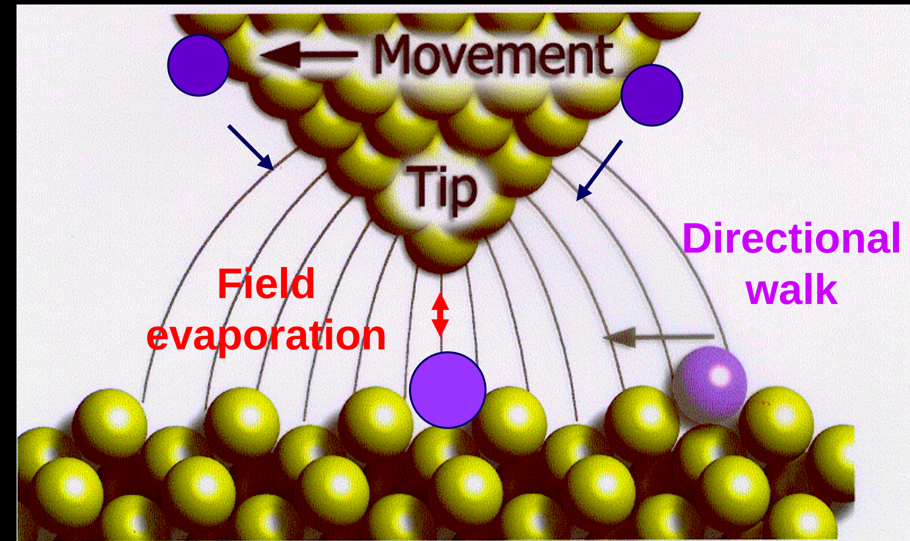
N. Oyabu et al. 大阪大學

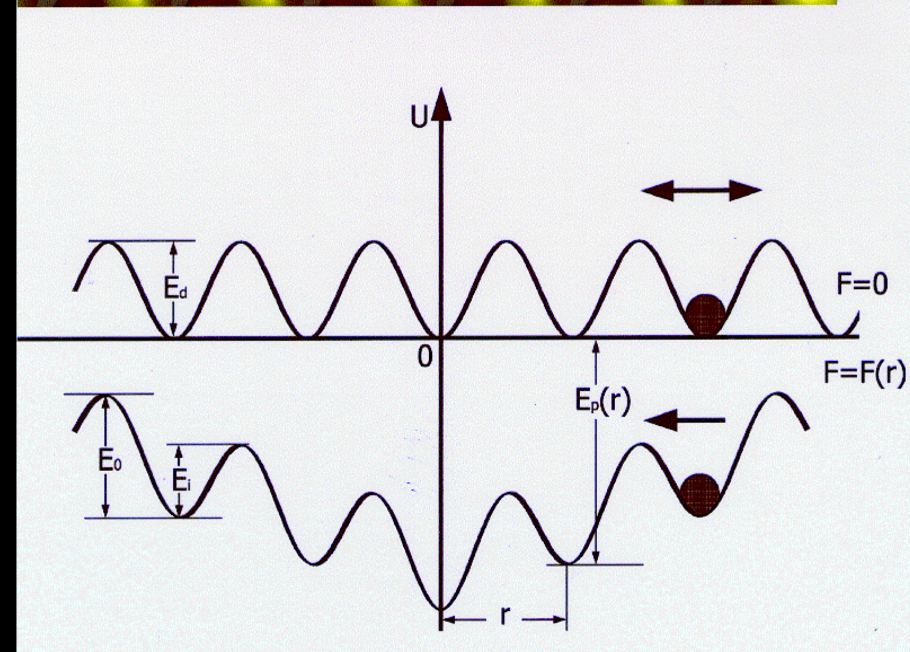
Create atom-vacancy by field evaporation

MoS_2 Surface **Hosoki et al. '91**

Hitachi Co.







$$E_P(r) = -\mu F(r) - \tfrac{1}{2}\alpha F(r)^2$$

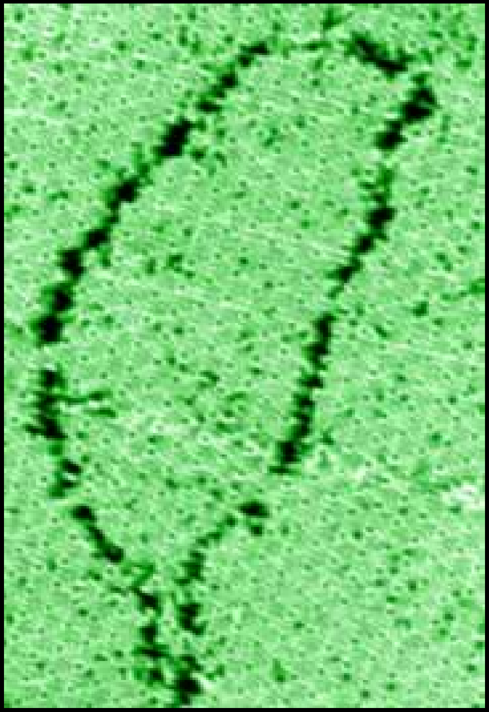
奈米尺寸台灣圖 Surface Modification in Nanoscale

F.G.I.R.W.

100 nm

Golden Taiwan

Field Evaporation



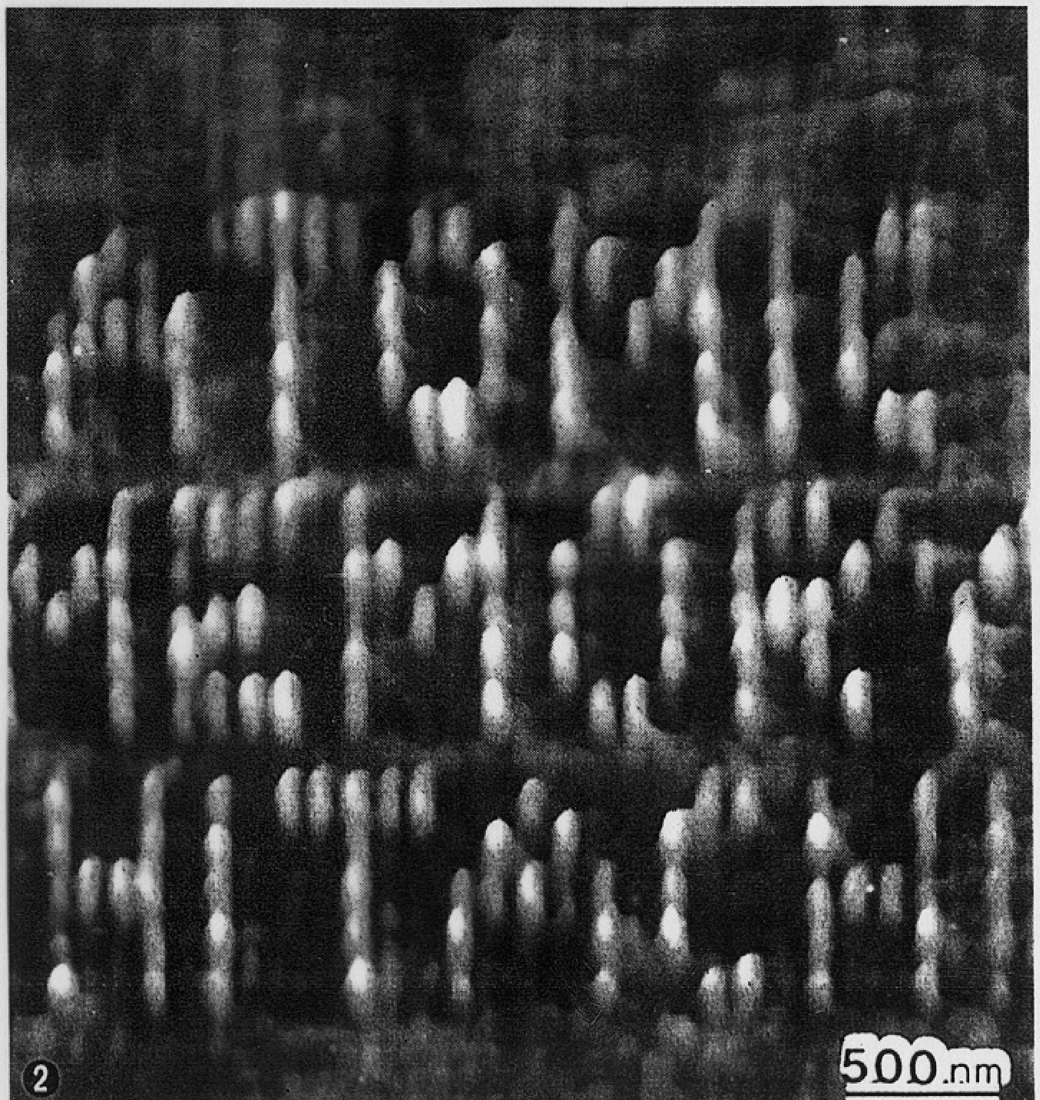
10 nm

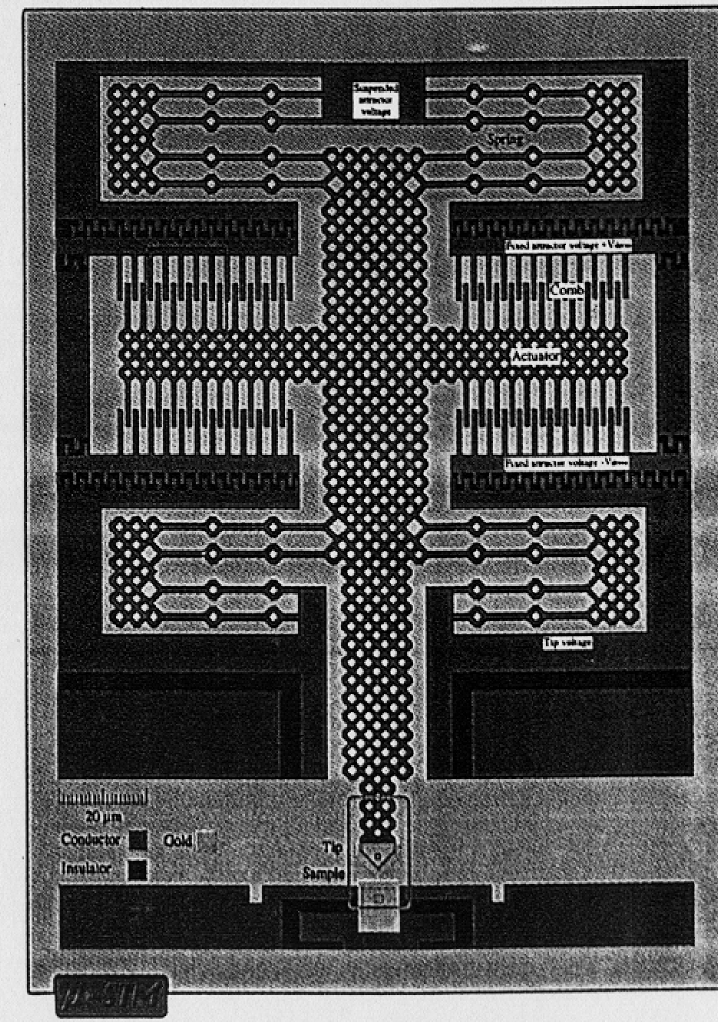
Green Si Island

先有綠色矽島，錢賺多了，才會成為金色寶島？

中研院物理所

STM-MEMS combination system





(a)

~15 nm   Tb/in^2

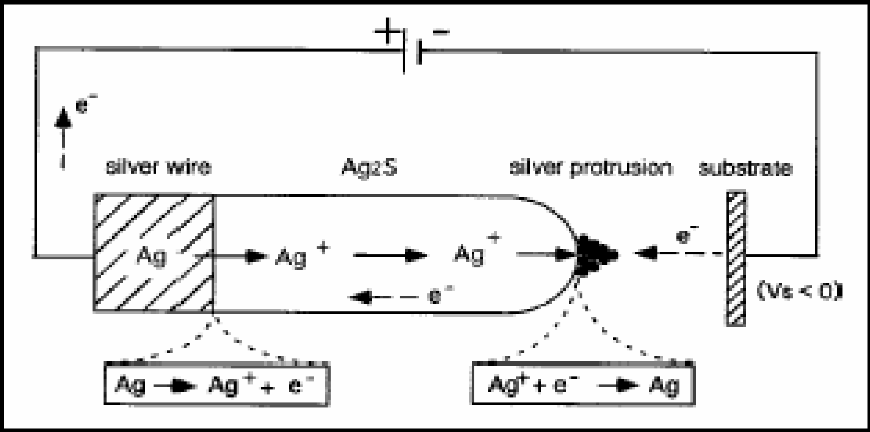
MEMS

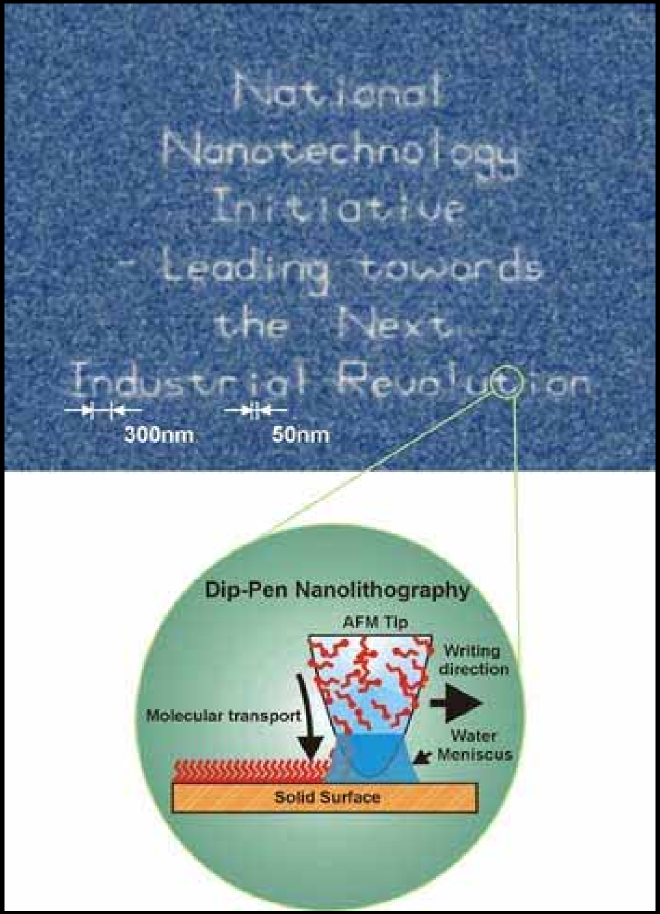
鄭天佐 IP AS

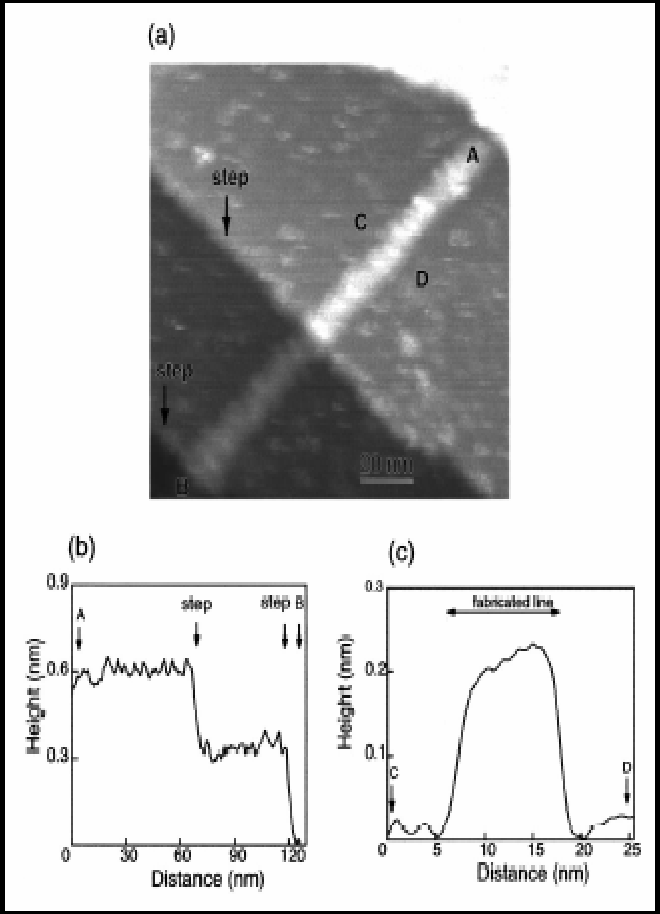
Nano-brush & atom switch

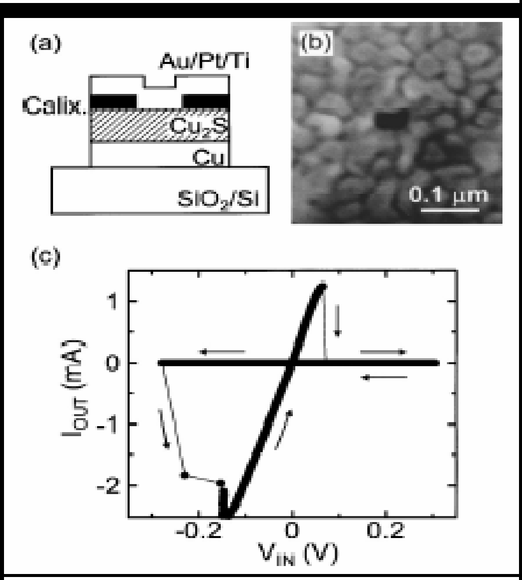
a) 用 Octadecanethiol 當墨水在金表面上寫字. AFM 影像. C.A. Mirkin et al.

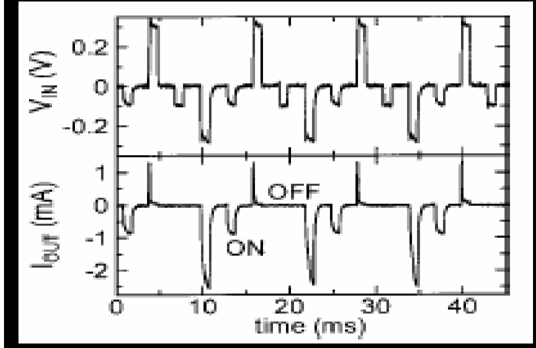
b) Ag 是墨水，Ag_2S 是筆，寫在矽表面上；另它或 Cu_2S 針和薄膜都可用來當原子開關. M. Aono et al.



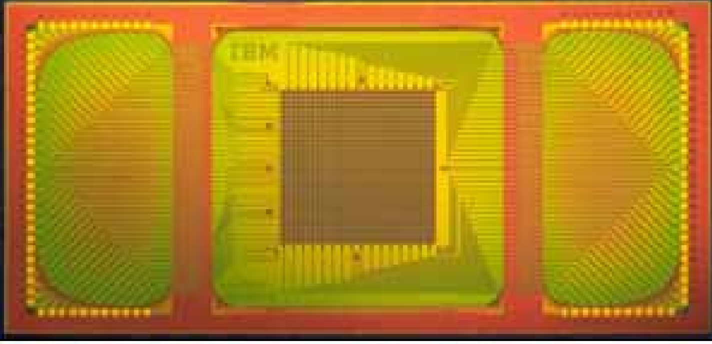


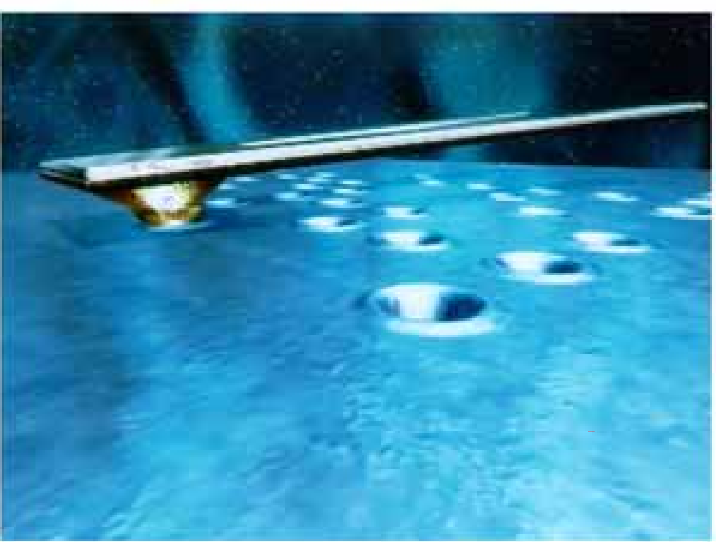


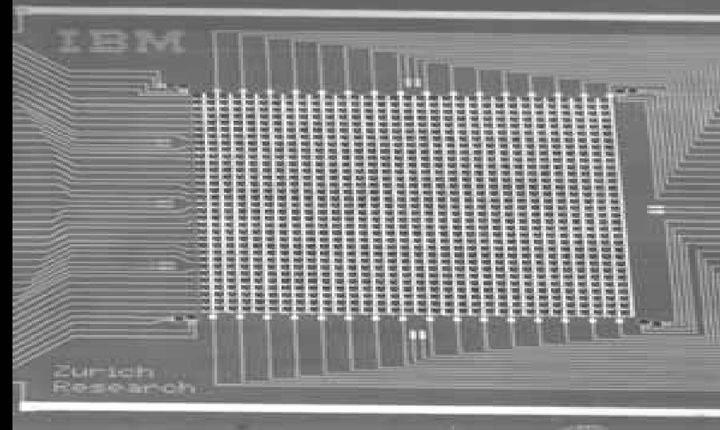


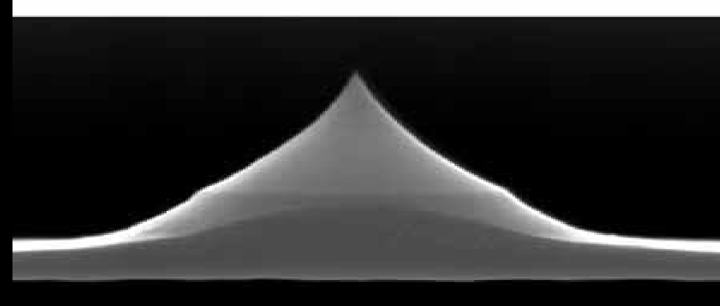


鄭天佐 IP AS







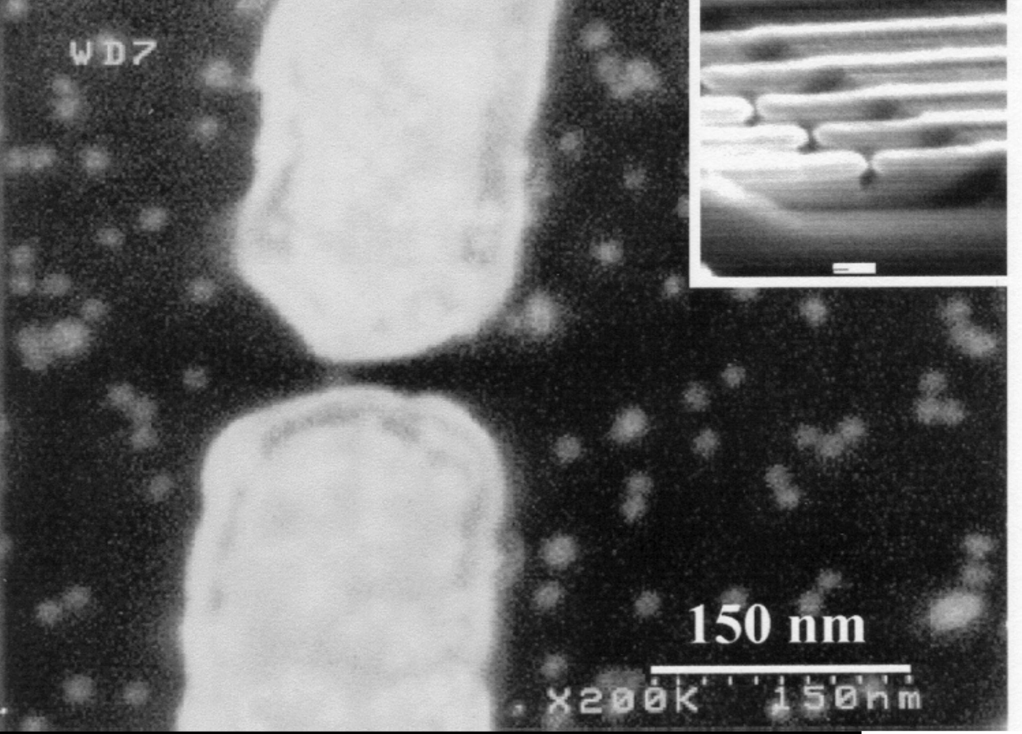


IBM Millipede 千足兆位元記憶體 2002

0: 無洞

1: 有洞

store 25 DVD in a stamp size memory chip



Gold Nano Particle

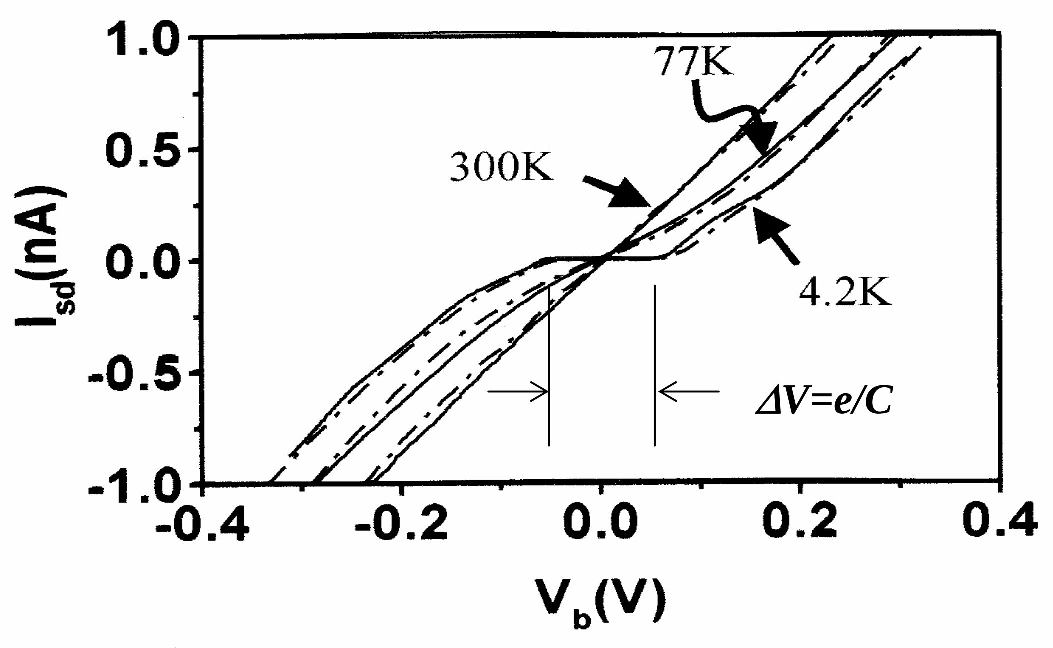
Coulomb Blockade

Single Electron Electronics

$V = q/C = ne/C \geq e/C$

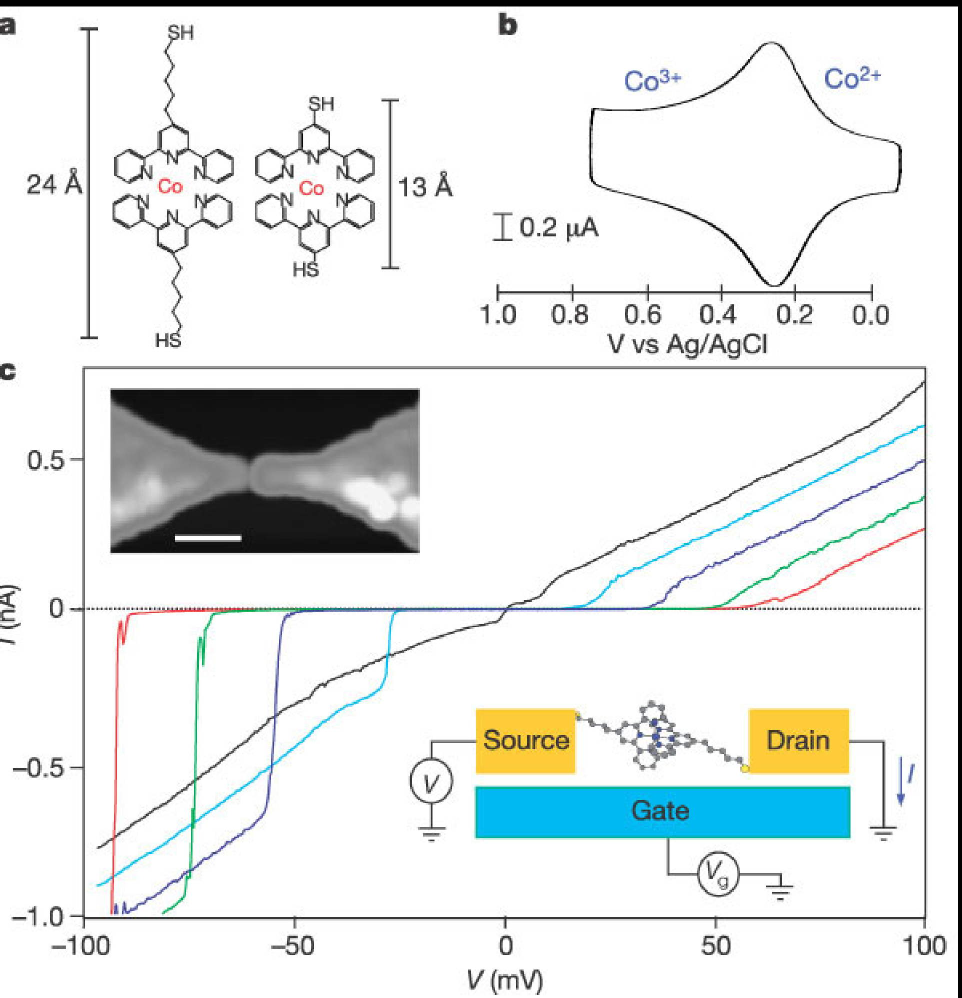
$\Delta n=1, \ \Delta V = e/C$

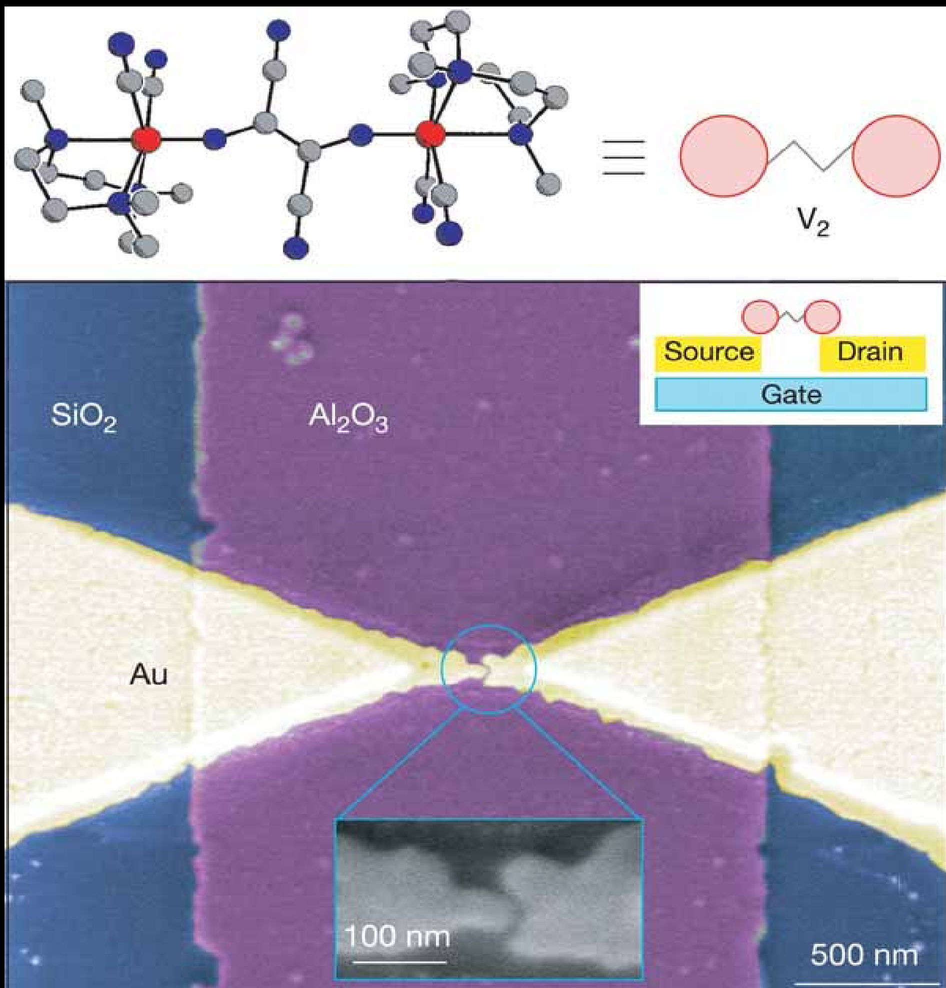
中研院物理所 陳啓東等 (C. D. Chen et al.)



Organic Molecule Single Electron Electronics

Nature **June 2002, "In the new world of 'nanoelectronics', a transistor whose active component is a single atom has now been demonstrated."**





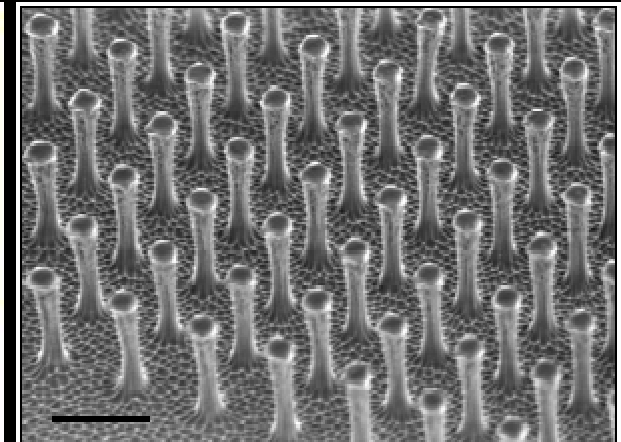
Coulomb blockade & Kondo effect in single-atom transistors PARK et al.

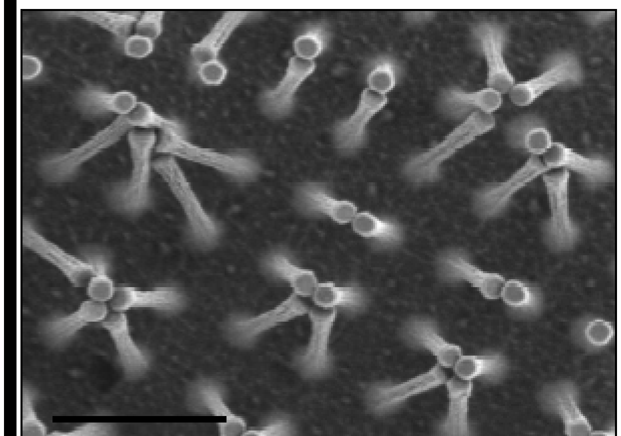
Kondo resonance in a single-molecule transistor LIANG et al.

鄭天佐 IP AS

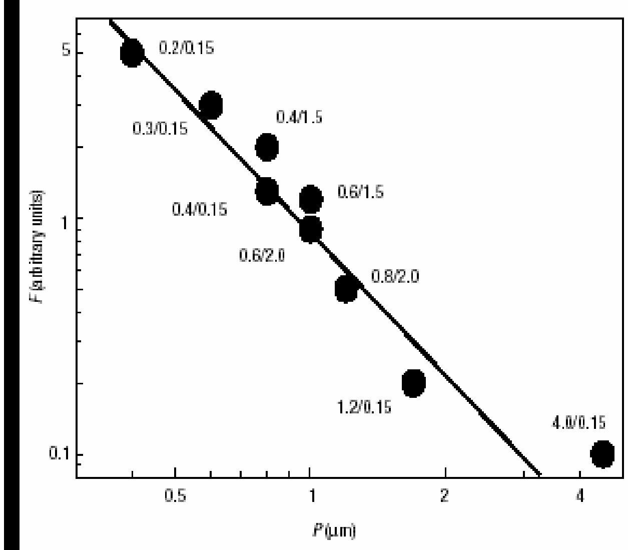
Spider man's kong-fu

蛛蜘人腳掌和手掌練到長出 200 至 500 奈米粗細的毛，其尖端有一層水分子以 van der Waals 沾在固體表面上





Sticky reusable adhesive tapes under development



濕聚合物針頭與矽表面的沾黏力

The perpendicular force *F* required for detaching various samples of polyimide hairs from a silicon surface. The experimental points are marked by *D*/*H*, indicating the hairs' diameters *D* and heights *H*, respectively.The solid curve is the best fit to $F \propto P^{-2}$. S (mm^2)

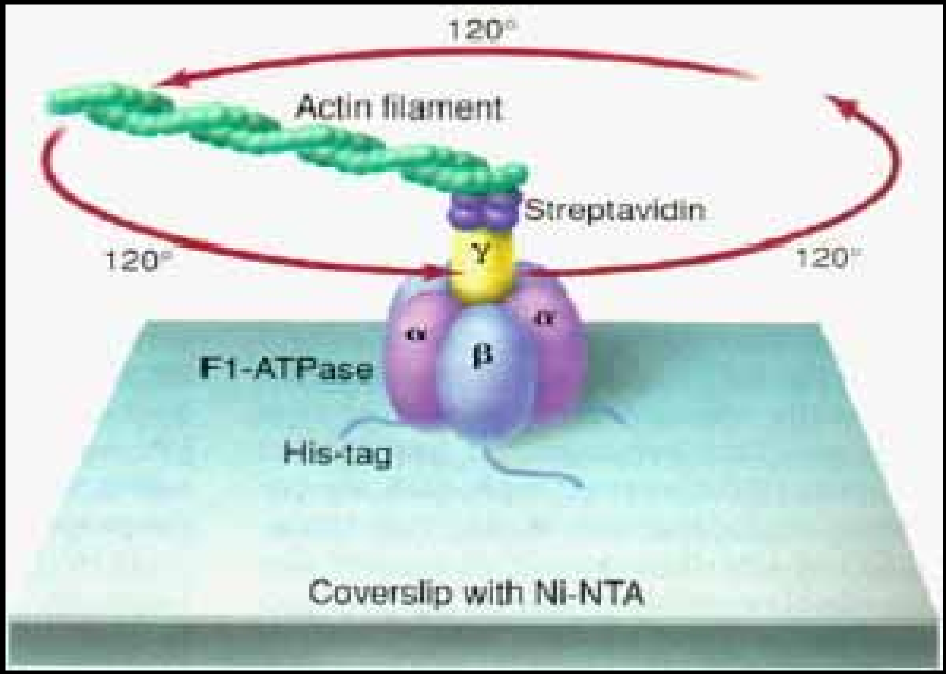
鄭天佐 IP AS

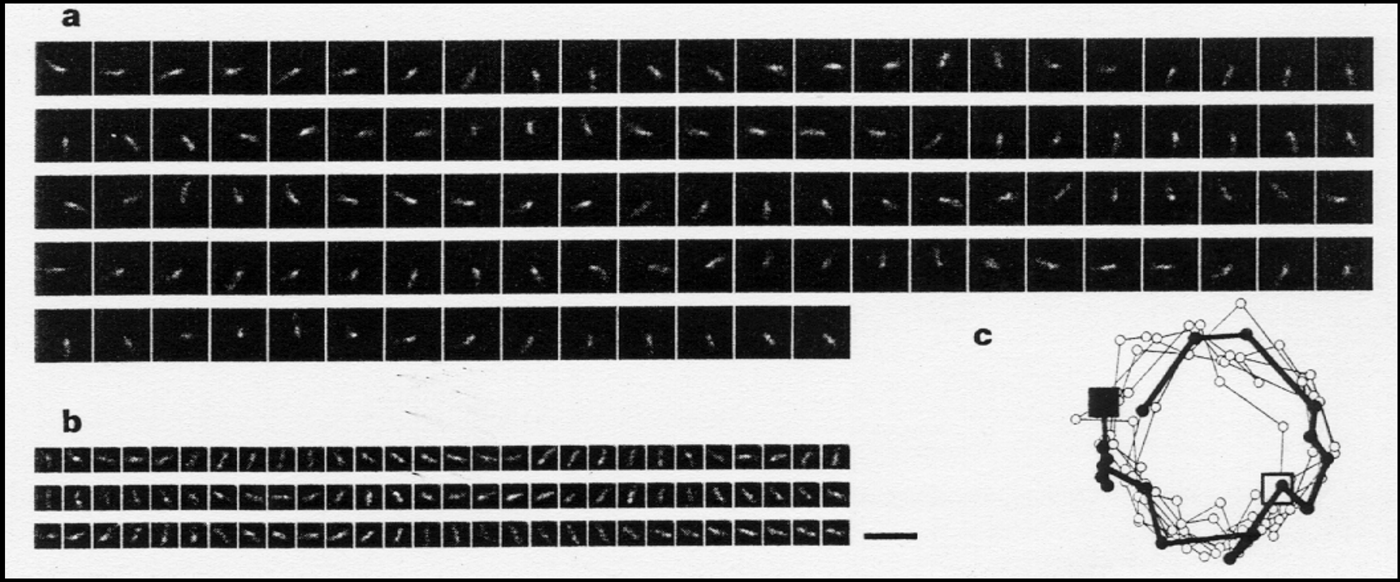
Bio-motor

Seeing rotational motion of F_1-ATPase

Noji, Yasuda, Yoshida & Kinosita

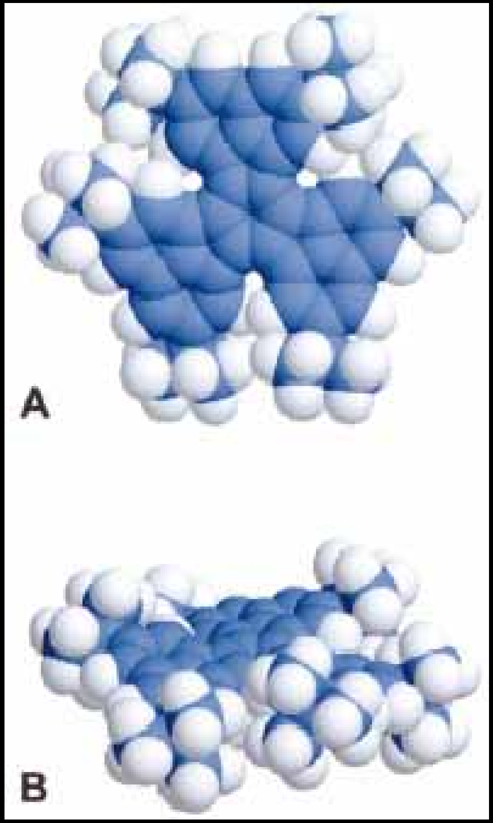
Nature 386, 299 (97)

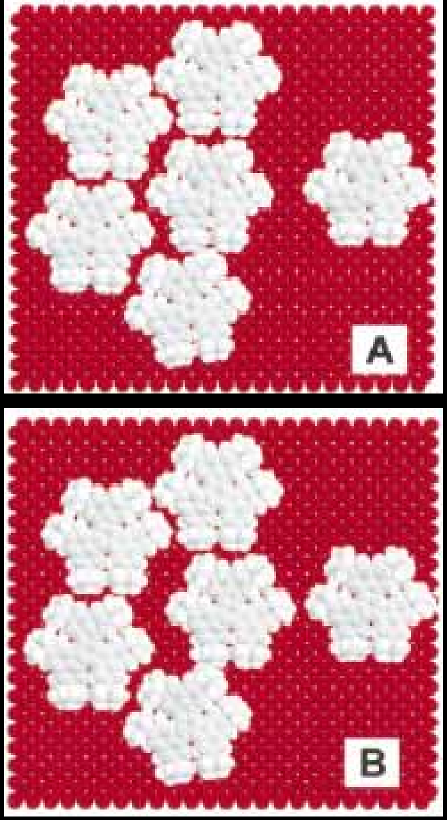


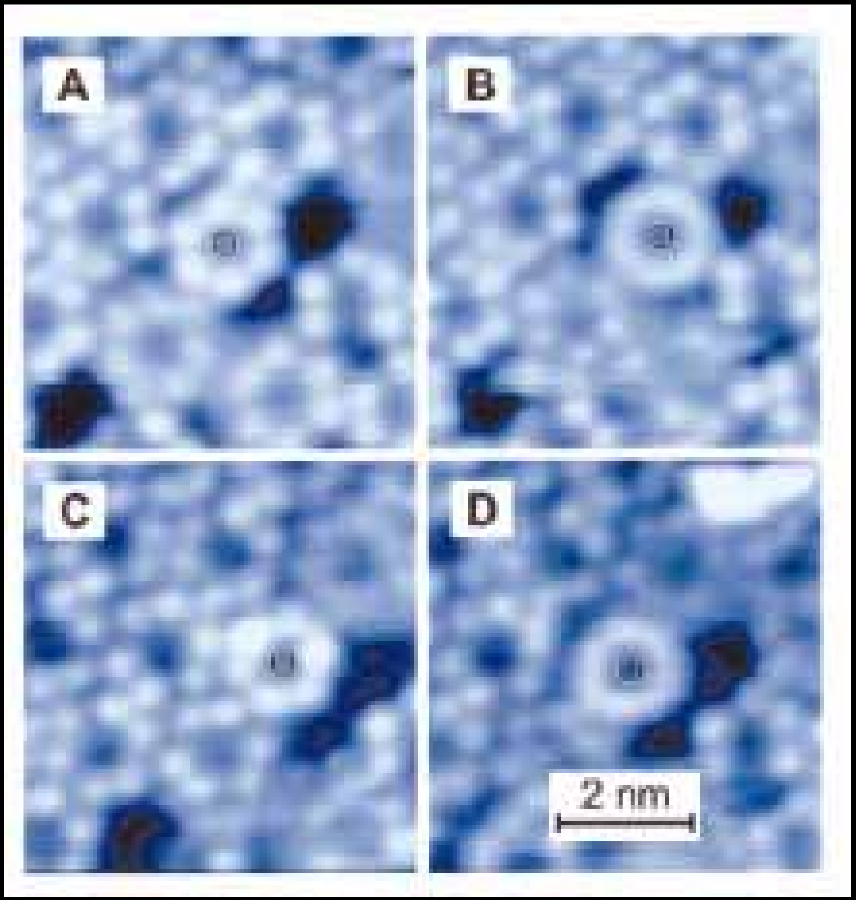


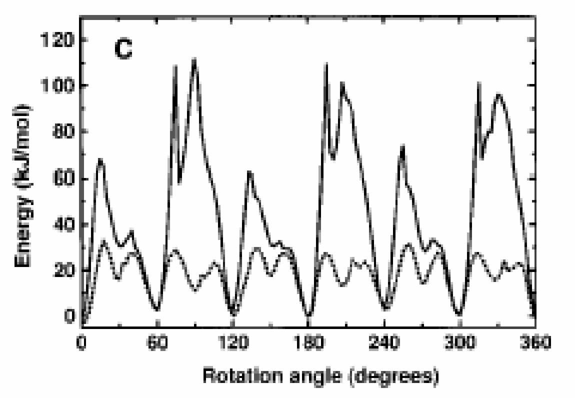
STM images of propeller shaped HB-DC molecules on the Cu (001) surface

Gimzewski et al. Science 281,531 (1998)









理論計算：被卡住和不被卡住位置上旋轉時所需克服之勢壘高度

Man-made nano-machine using bio-motor

康乃爾奈米實驗室 Science (2000)

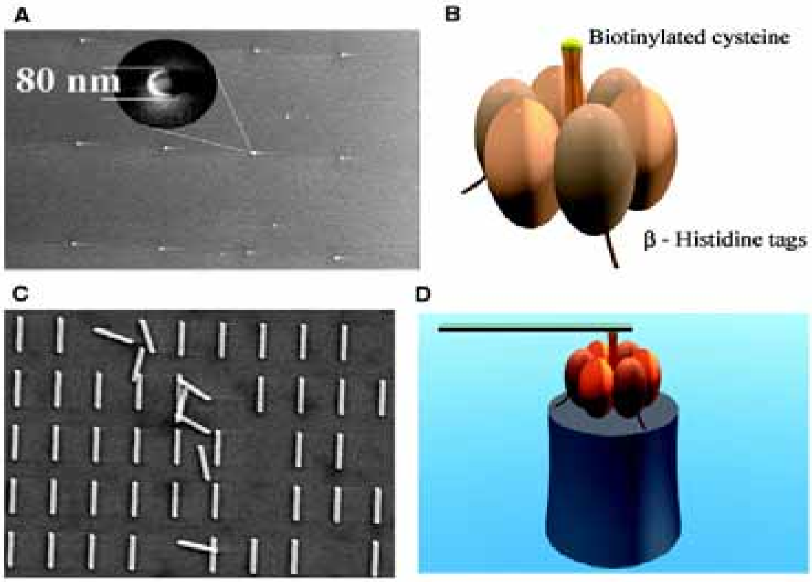


Fig. 1. Schematic diagram of the F_1-ATPase biomolecular motor–powered nanomechanical device. The device consisted of (**A**) a Ni post (height 200 nm, diameter 80 nm), (**B**) the F_1-ATPase biomolecular motor, and (**C**) a nanopropeller (length 750 to 1400 nm, diameter 150 nm). The device (**D**) was assembled using sequential additions of individual components and differential attachment chemistries.

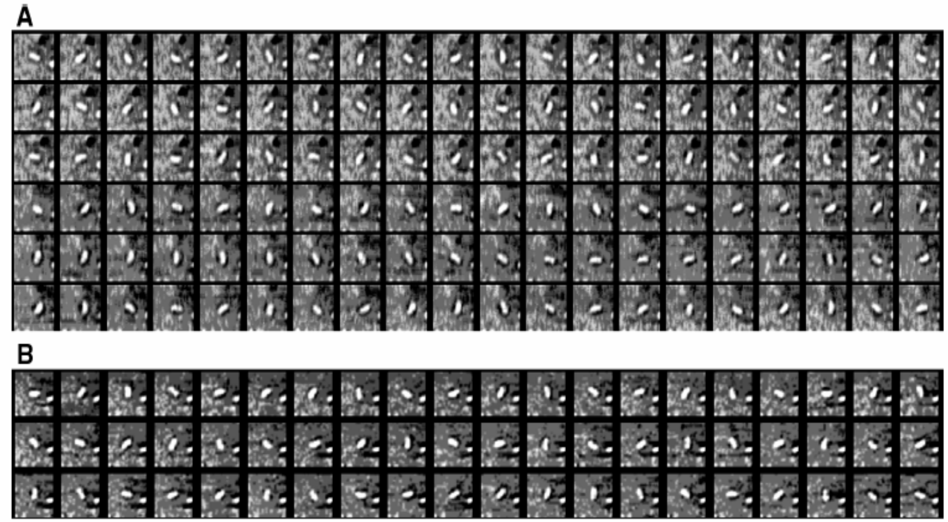
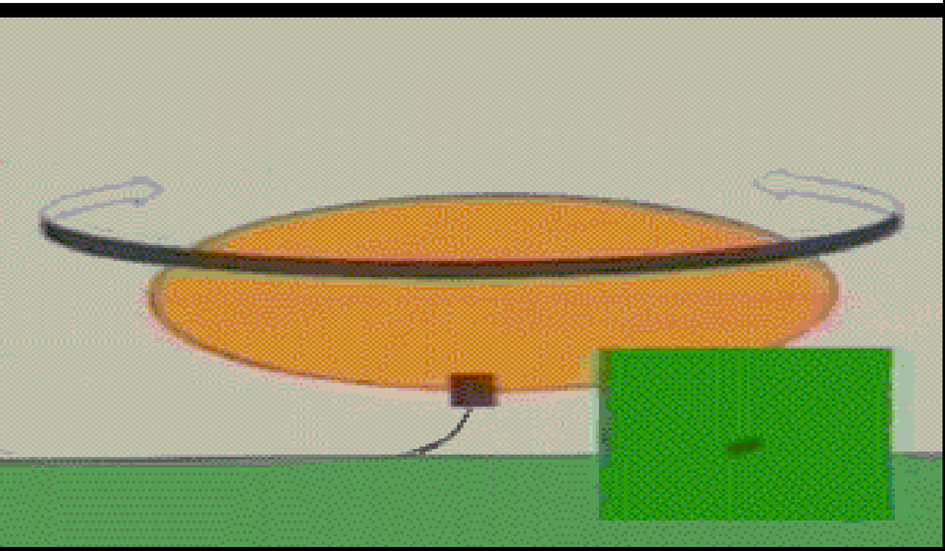


Fig. 2. Image sequence (viewed left to right) of nanopropellers being rotated anticlockwise at 8.3 rps (**A**) and 7.7 rps (**B**) by the F_1-ATPase biomolecular motor. Observations were made using 100× oil immersion or 60× water immersion and were captured with a CCD video camera (frame rate 30 Hz). The rotational velocity ranged from ~0.8 to 8.3 rps, depending on propeller length. Data were recorded for up to 30 min; however, propellers rotated for almost 2.5 hours while ATP was maintained in the flow cell. These sequences can be viewed as movies at the Nanoscale Biological Engineering and Transport Group Web site (http://falcon.aben.cornell.edu/News2.htm).

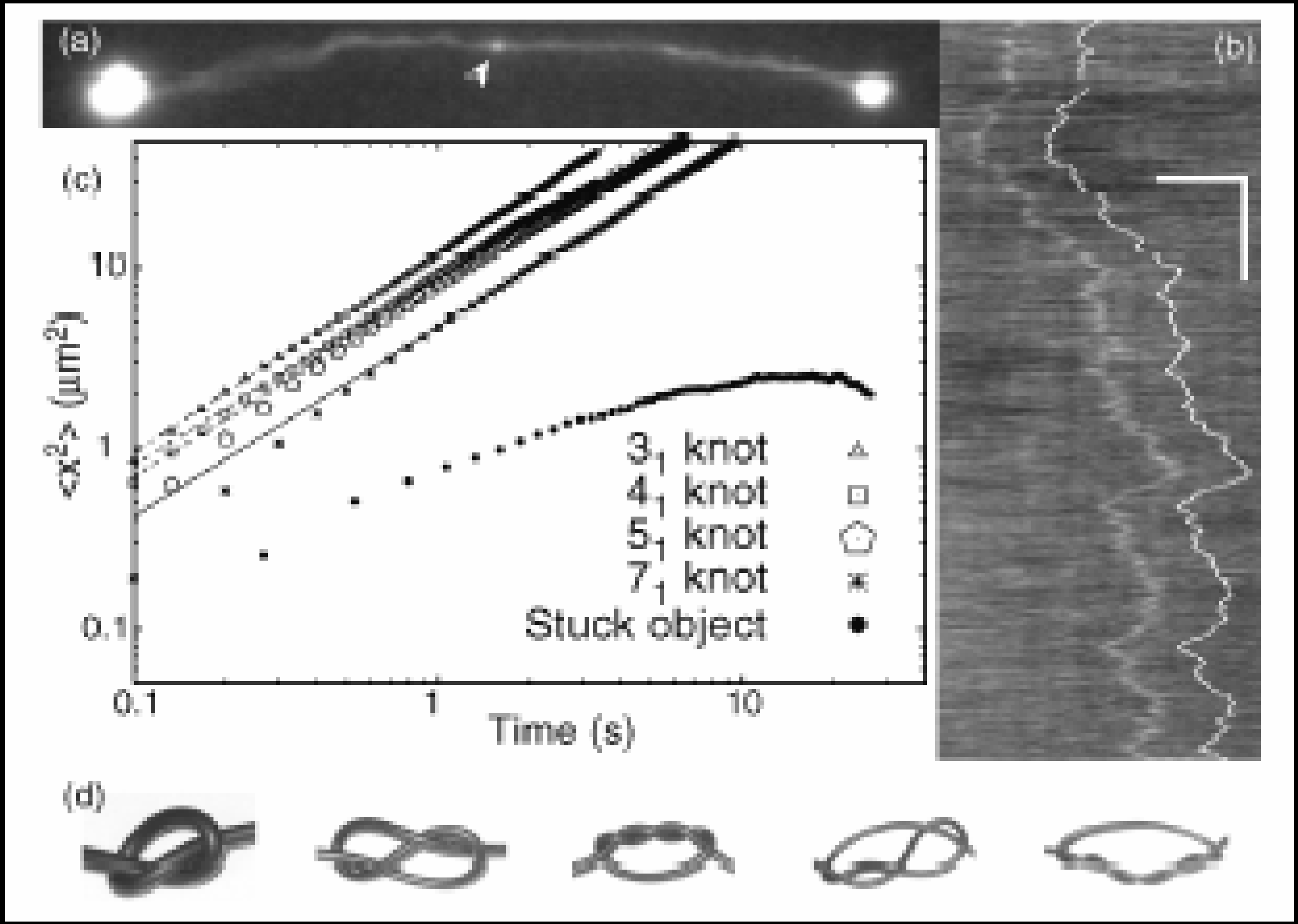


分子馬達轉動實例

From: http://www.npn.jst.go.jp/

Tie a knot in a DNA with optical tweezers, then observe knot diffusion

S R Quake et al., PRL '03



Optical Tweezers: by light-dipole interaction with a dielectric particle. A. Ashkin

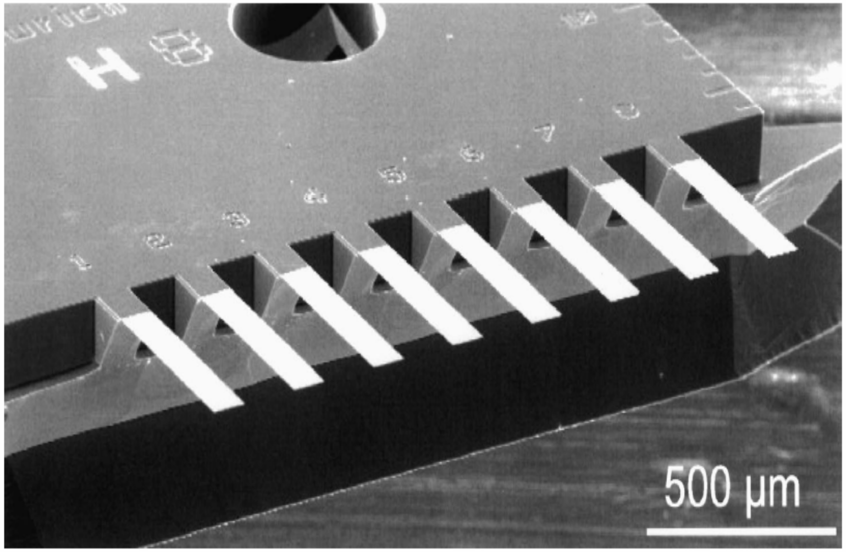
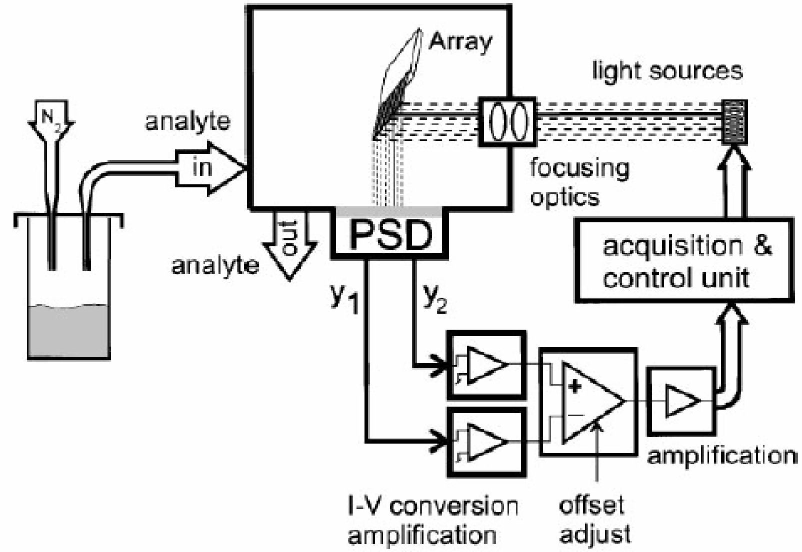


Fig. 1. Scanning electron microscopy image of a microfabricated cantilever sensor array prior to deposition of sensor coatings. The array was produced from silicon by combined dry and wet etching techniques in the Micromechanics department at the IBM Zurich Research Laboratory. Cantilever length: 500 μm, thickness: 1 μm, width: 100 μm. Typical spring constant: 0.02 N m^{-1}.



Chemical sensor using change in resonant frequency

Baller et al.

Ultramicroscopy 82, 1 (2000)

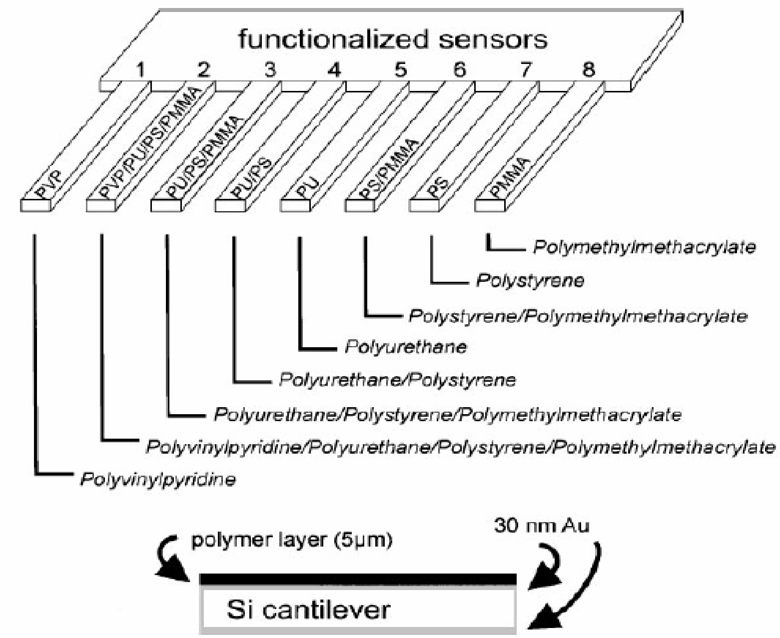
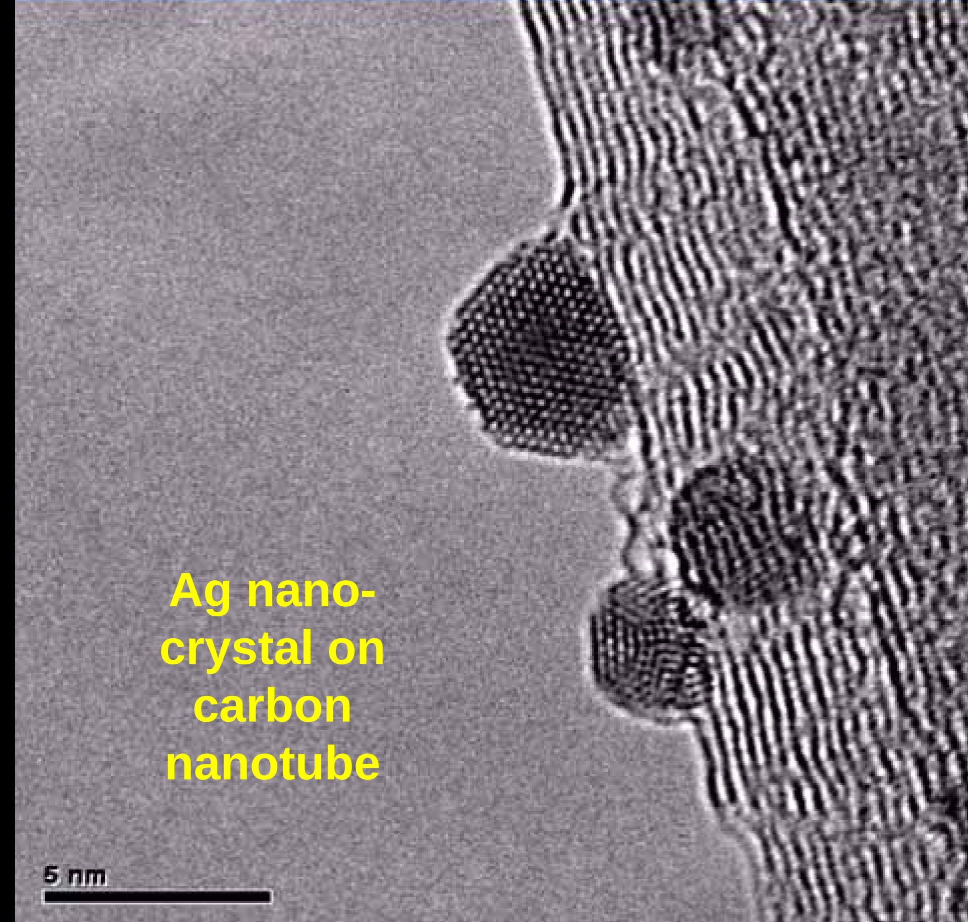
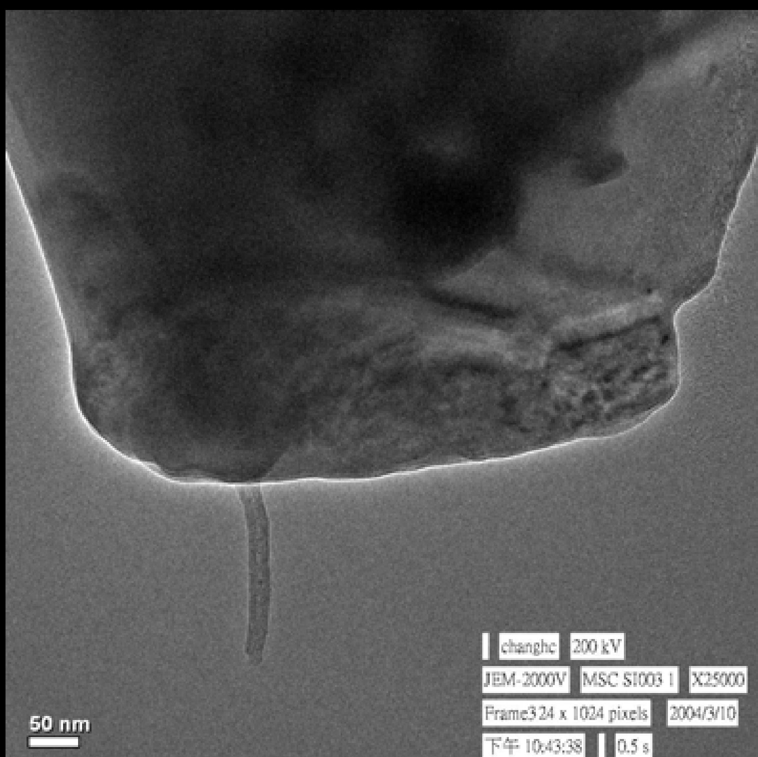


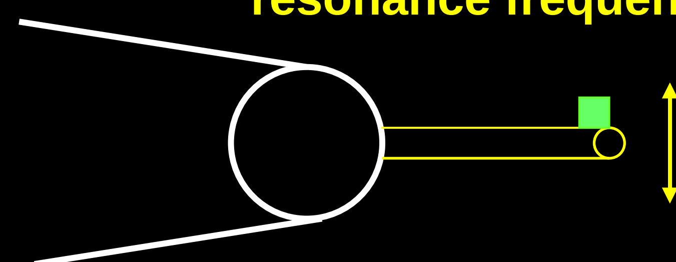
Fig. 3. Schematic view of a cantilever array with polymer coatings used for the eight cantilevers of the sensor array. PVP = polyvinylpyridine, PU = polyurethane, PS = polystyrene, PMMA = polymethylmethacrylate. Schematic cross section of a coated cantilever.

Development of a nano mass sensor using carbon nanotube with a metallic nano-crystal

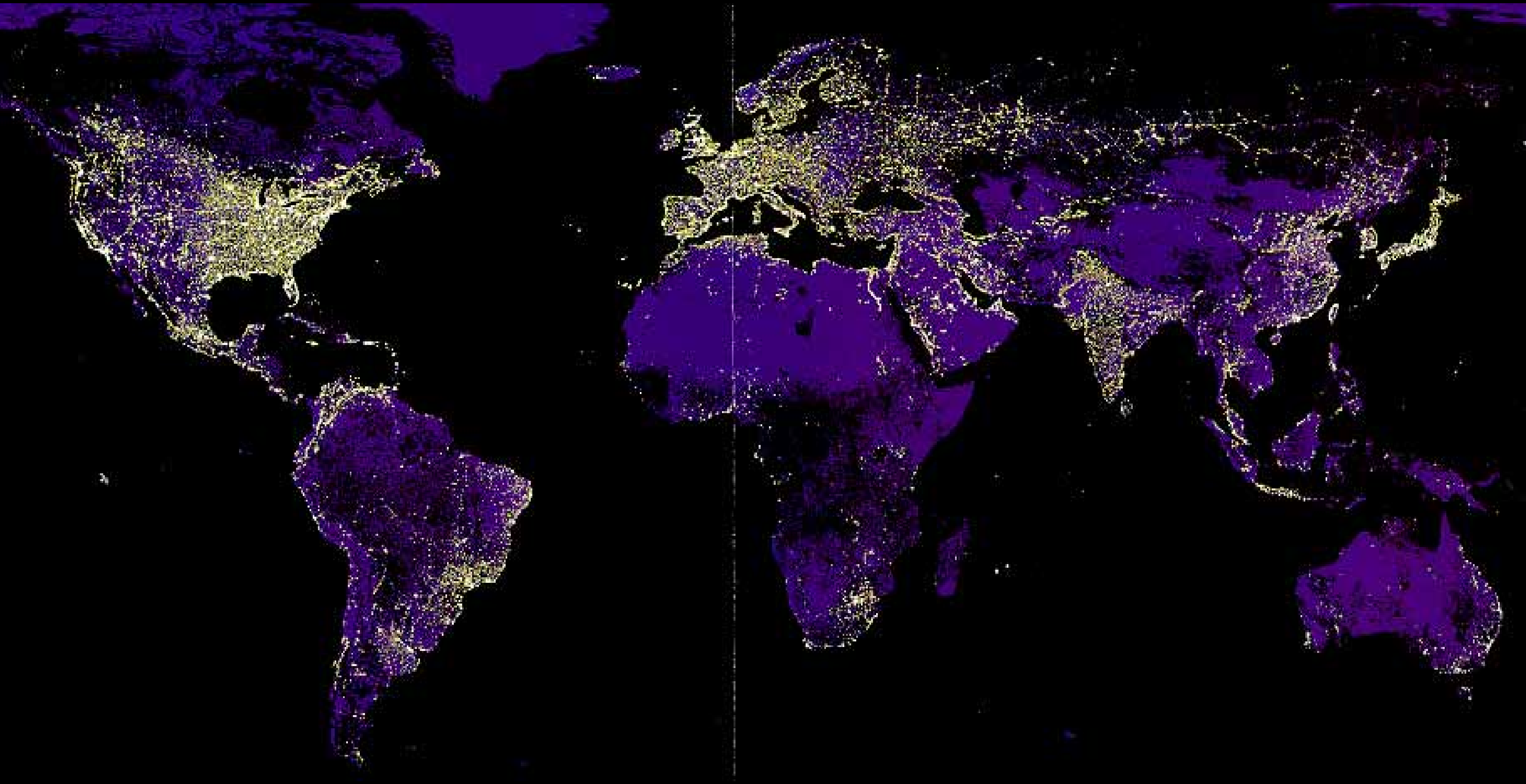




Mass measurement using resonance frequency change



Satellite night view of the earth



Physics Today 4/02

International conflicts often arise from fight for natural resources such as oil

Combine Solar Energy & Nano Technologies

Direct dissociation of water by light into hydrogen and oxygen by semiconductor or oxide catalysts.

Theory: 50% **efficiency** **True？**

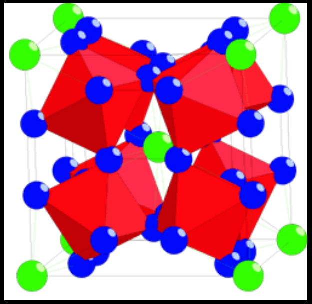
Hydrogen fuel cell & storage technologies

Nanotube? Other compounds?

Solar cells: semiconductor & polymer thin films

How to improve efficiency, cost, environmental concern & life-time

Can we use solar thermal electricity？Materials?



Thallium Filled Antimony Skutterudites

鄭天佐 IP AS

Nanotechnology – small is Beautiful

- Less energy to manufacture & operate
- Use less materials, easy to carry
- Many more functions, more efficient, higher density & sensitivity, etc.
- In electronics, devices are safer
- Less harmful to our environment
- More people can enjoy the fruit of science & technology

- Make sure nano materials are not harmful to our health & environment
- Knowledge expands rapidly. Only continual self-learning can avoid being out of dated.

AS