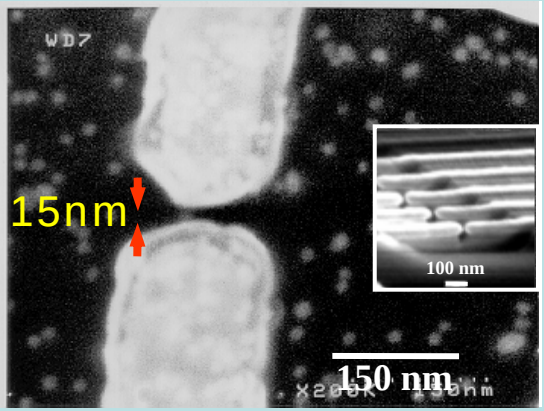
奈米材料及其應用



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台北市南港區11529研究院路二段128號
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無塵室：02 2788 0058 ext: 1128
傳真：　02 2789 2443
網址：　http://www.phys.sinica.edu.tw/~quela

大綱

1.由大表面積造成的效應
2.尺寸限制展現的效應
3.表面電漿子效應
4.光子晶體
5.電子元件
6.再生能源電池

什麼是奈米(nano-meter) = ?

1 米 = 1 m

1 釐米（公分） = 1×10^{-2} m

1 毫米 = 1×10^{-3} m

1 微米 = 1×10^{-6} m

1 奈米 = 1×10^{-9} m

0.1 奈米

人高

指頭

紅血球

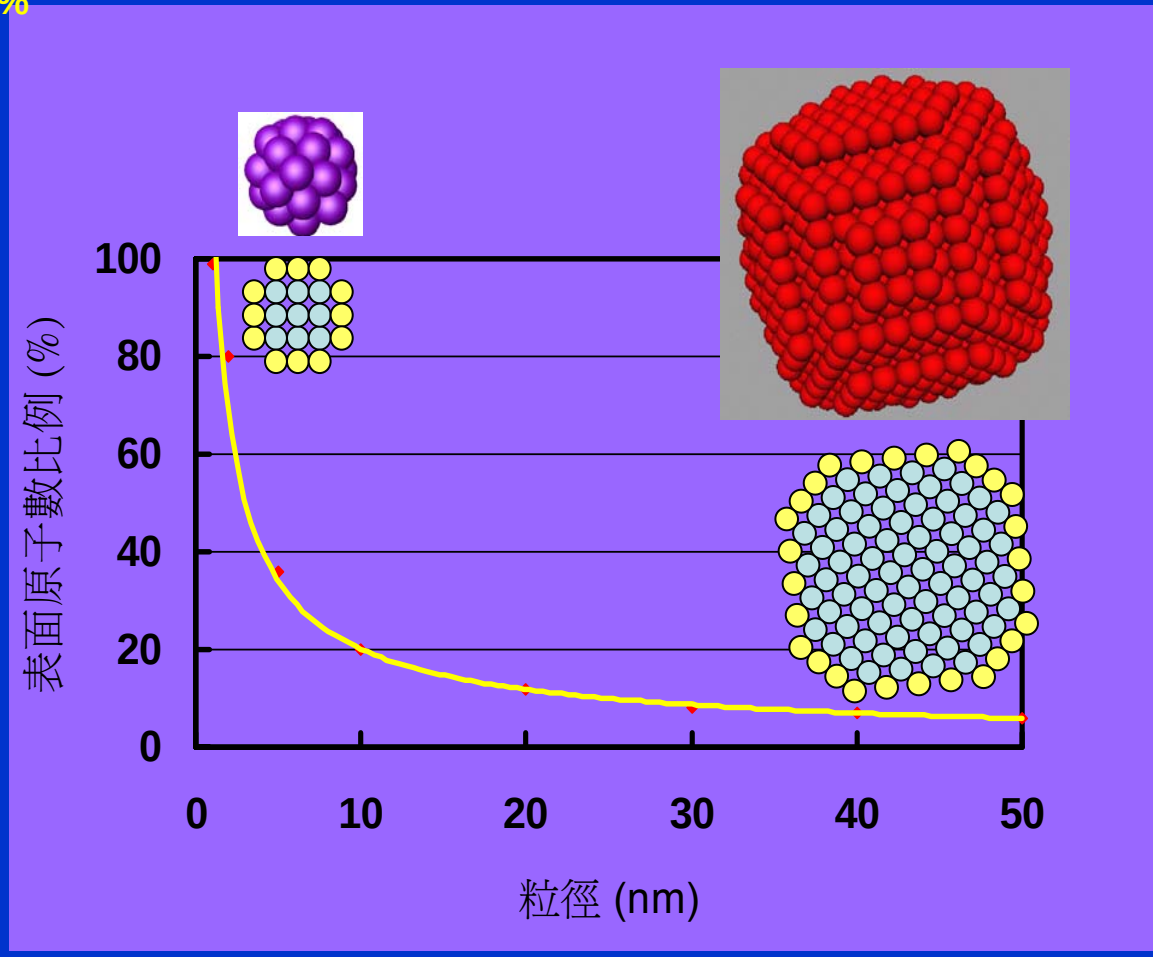
分子及DNA

氫原子

奈米下之物理化學性質是否會改變？

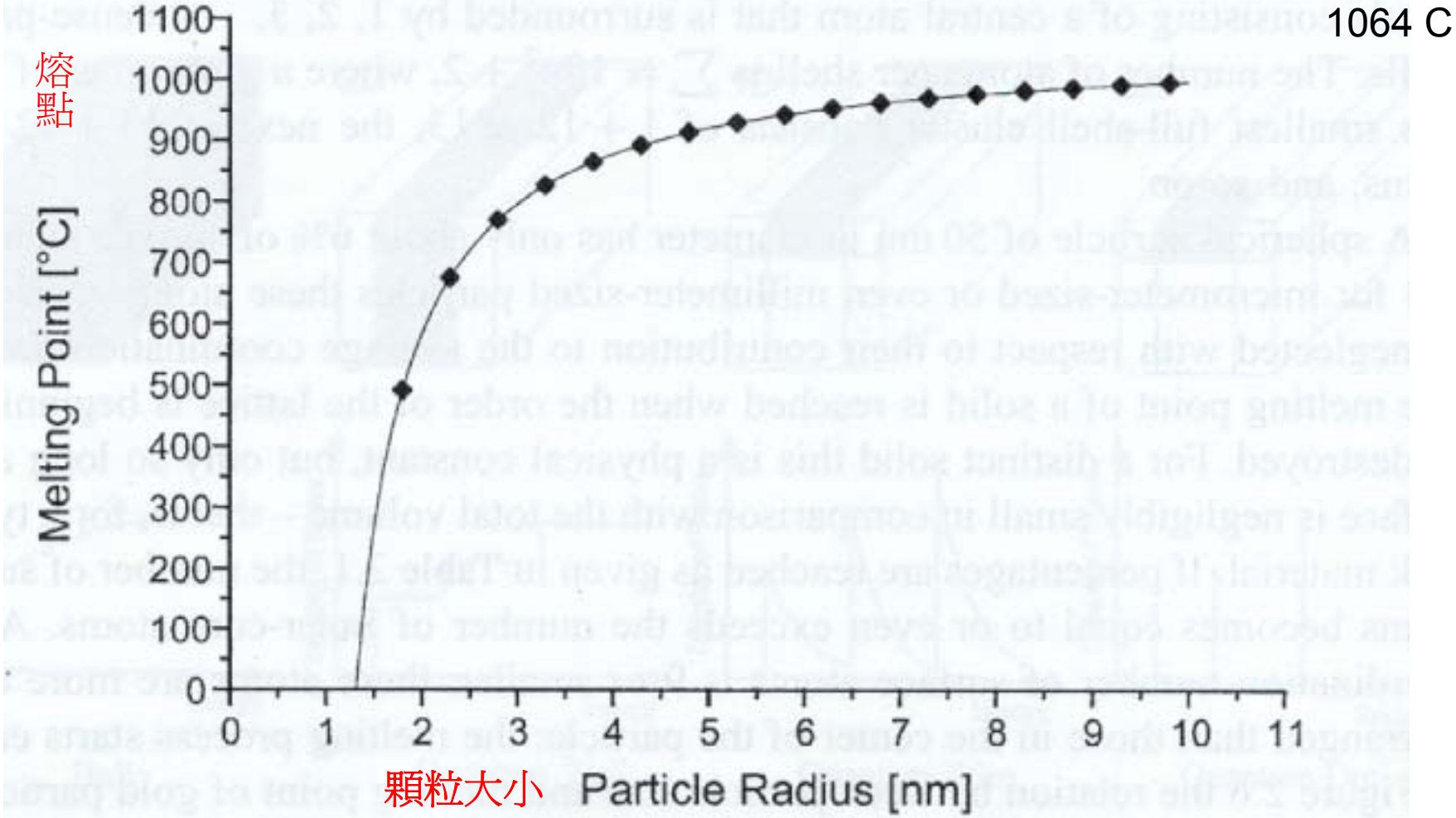
表面/體積　比例增加

clusters	# of atoms	Surface area %
	13	92
	55	76
	147	63
	309	52
	561	45
	1415	35

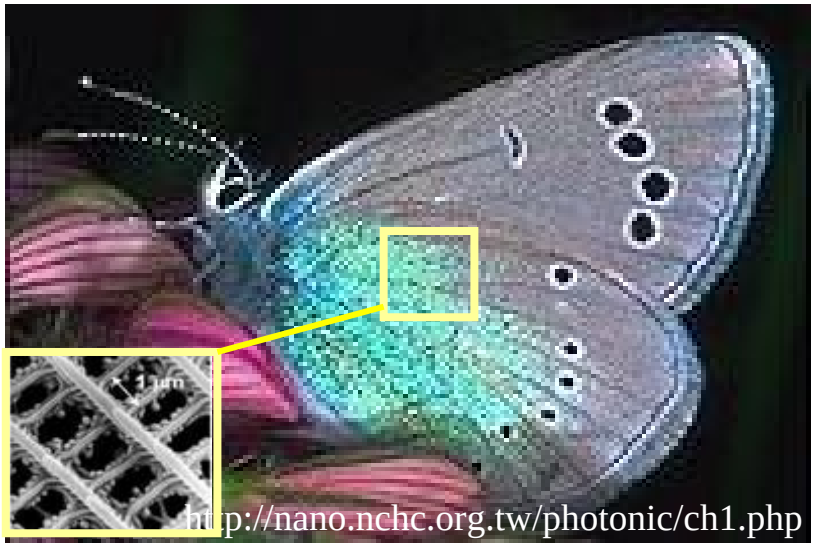


熔點變小

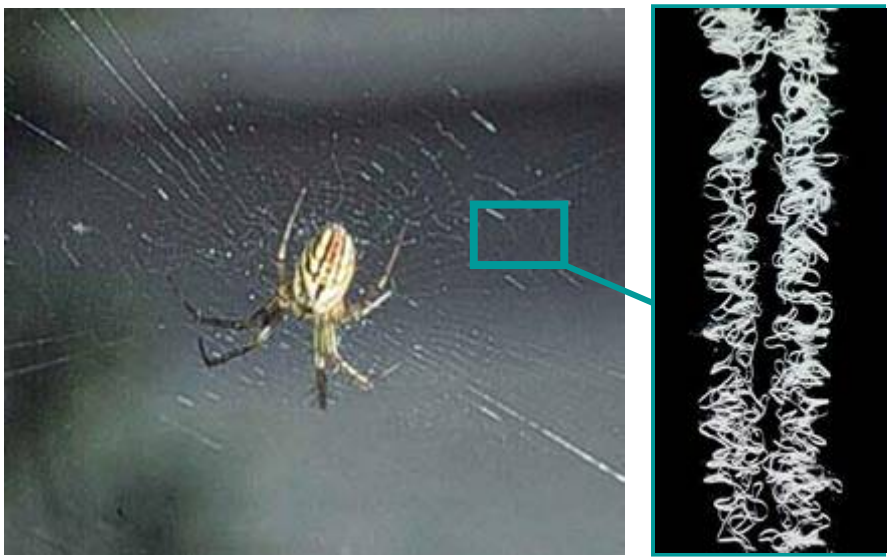
金的熔點與顆粒大小的關係



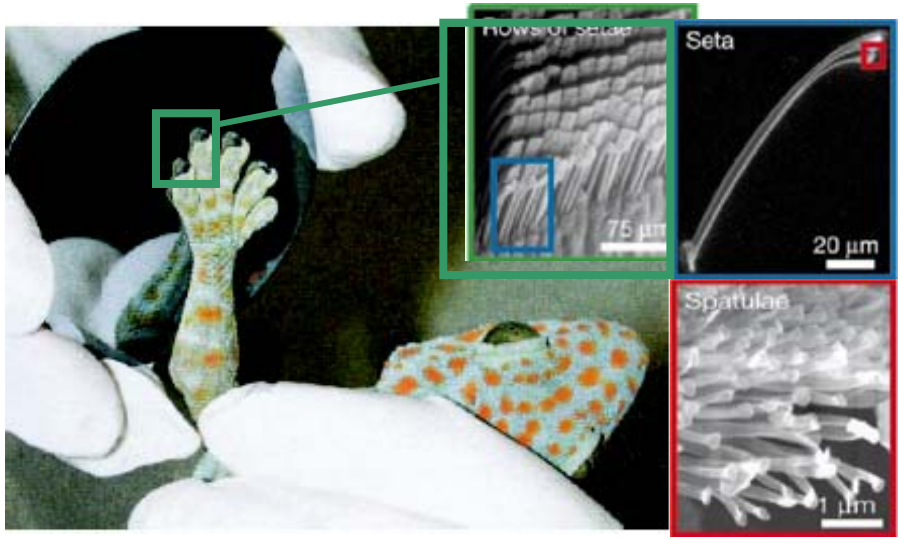
自然界存在的現象

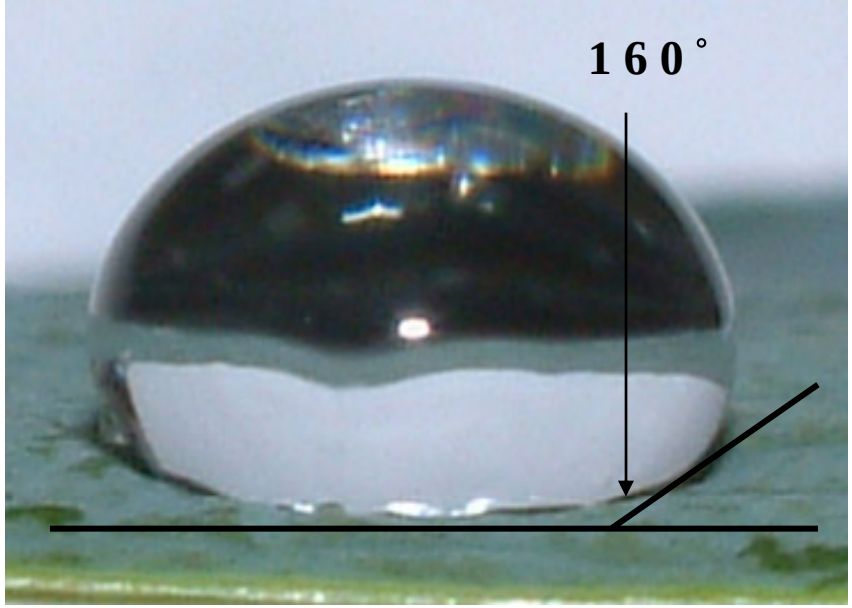


http://nano.nchc.org.tw/photonic/ch1.php

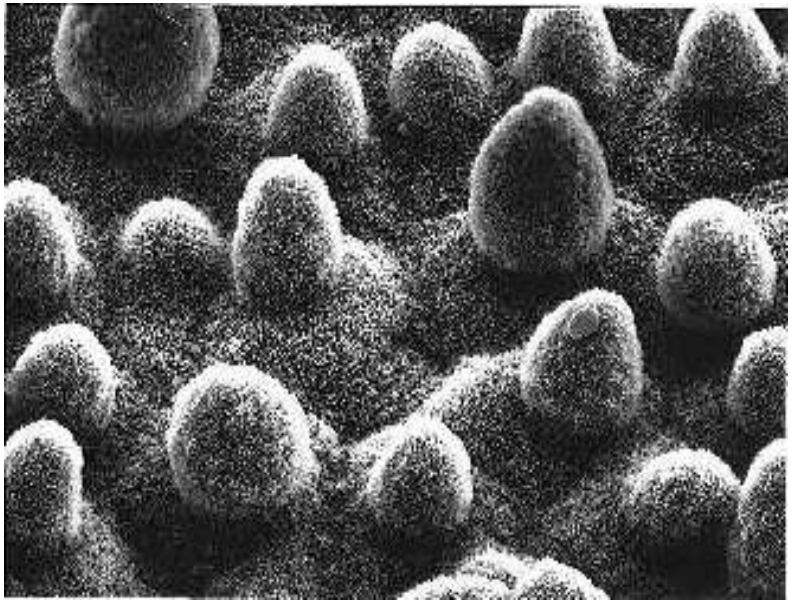


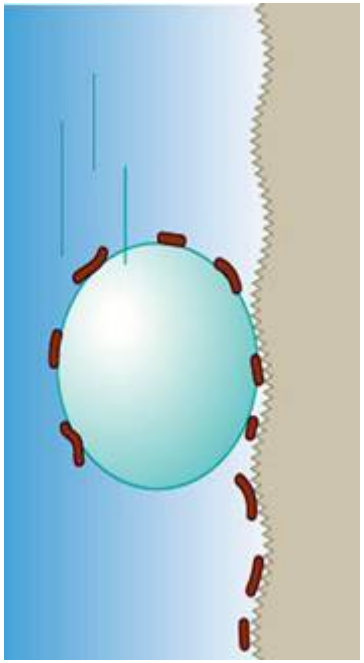
http://www.botanik.uni-bonn.de/system/lotus/en/lotus_effect_html.html

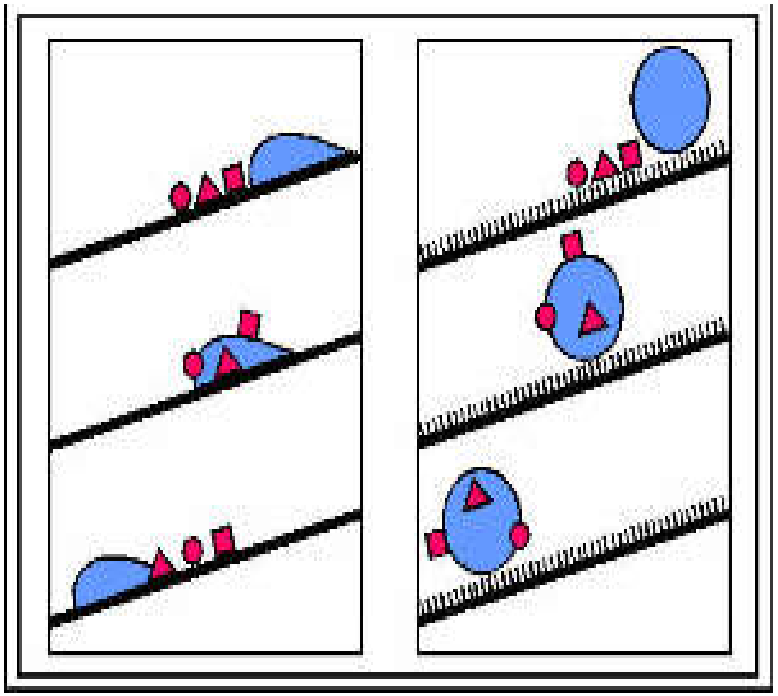


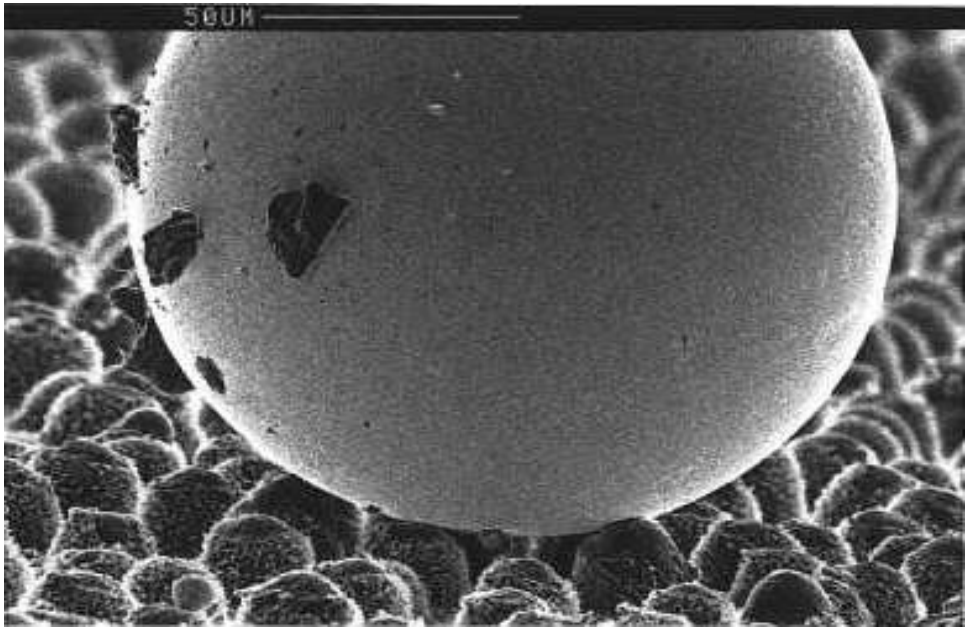


蓮花效應

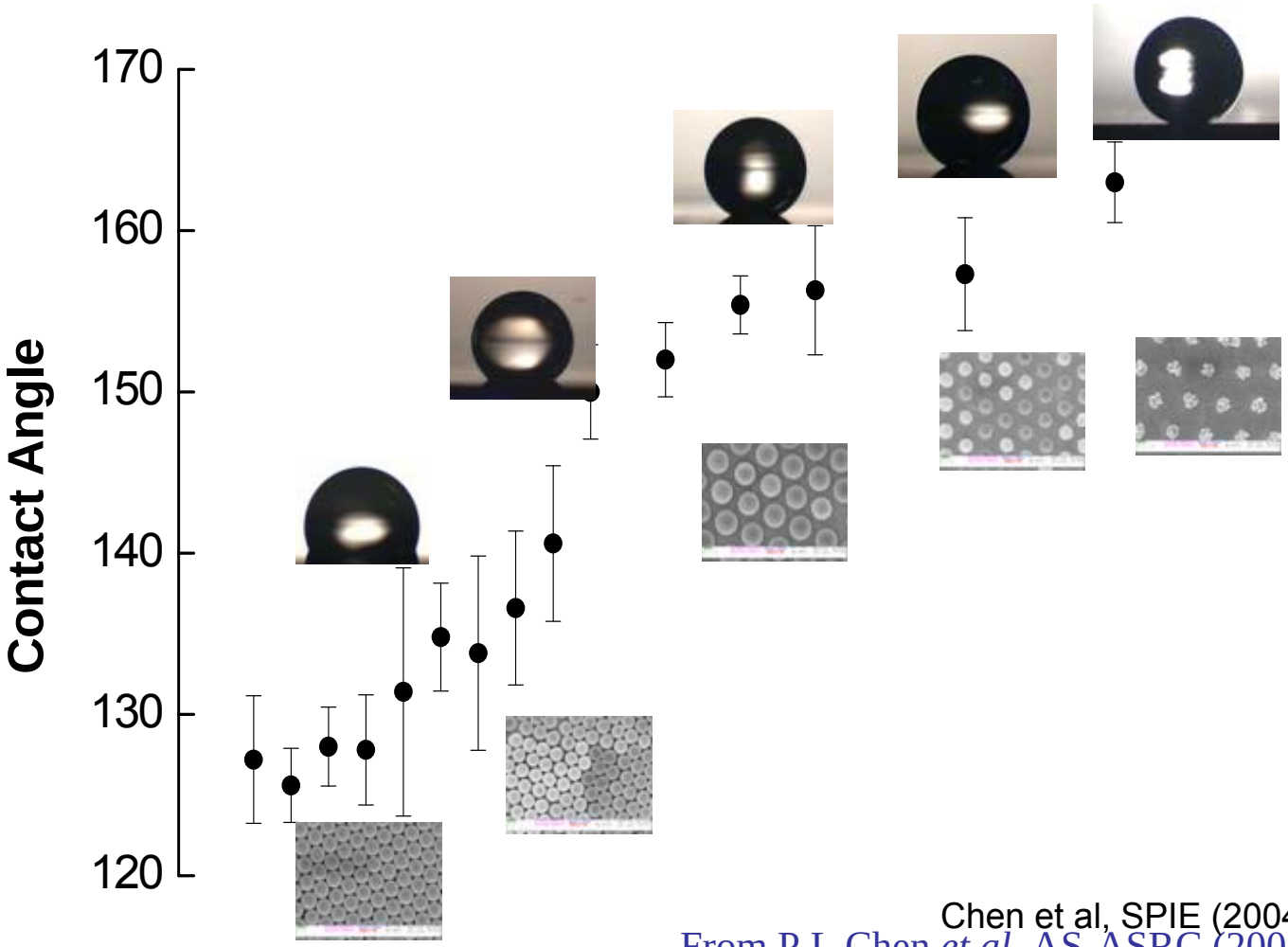


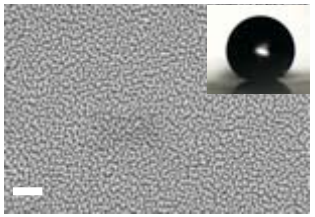




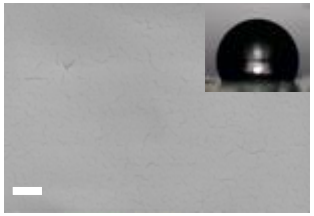

50UM

人造表面粗糙度與水滴接觸角度的關係





Contact Angle 169°



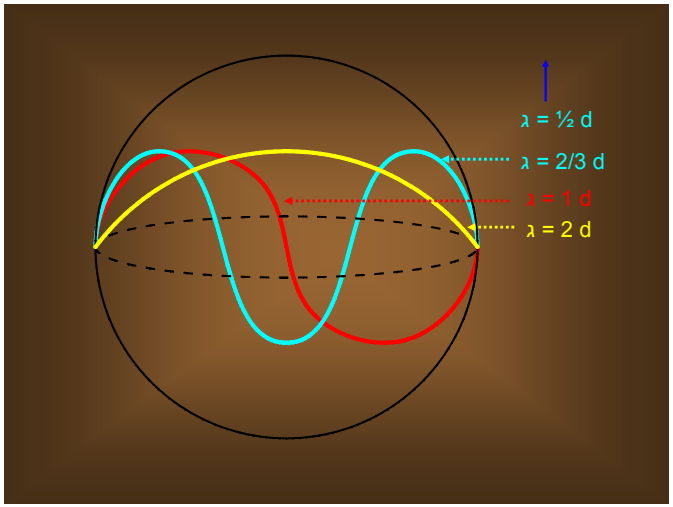
Contact Angle 120°

Chen et al, SPIE (2004)

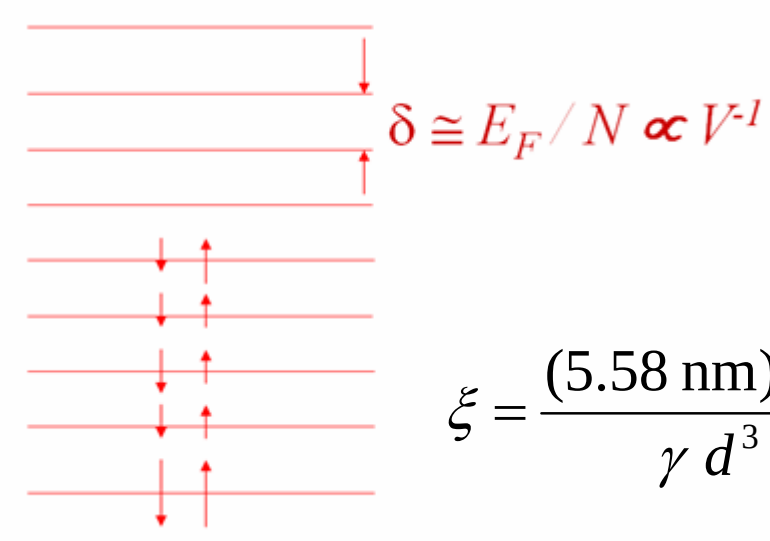
From P.L.Chen *et al*, AS-ASRC (2003)

聲子能階與電子能階

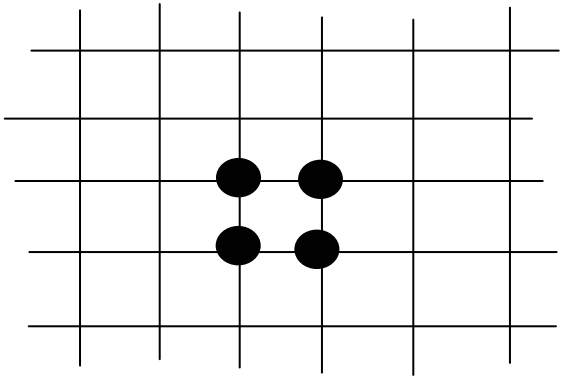
聲子



電子



$$\xi = \frac{(5.58\ \mathrm{nm})^3 v_m}{\gamma\, d^3}$$



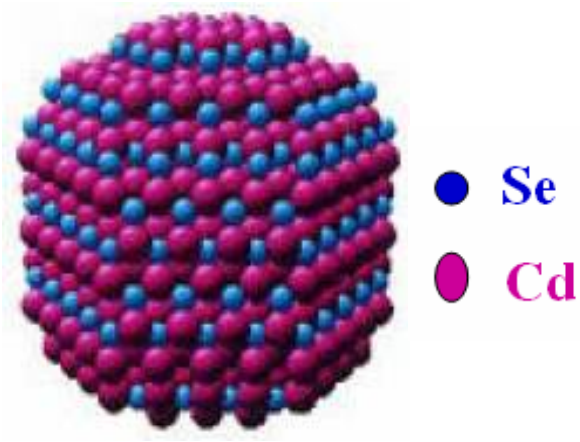
ξ= 0.04-0.12 K d=26 nm

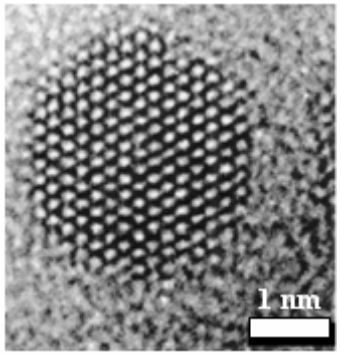
ξ=0.2-0.6 and d = 22

ξ=2.5-7.6 K d = 3.1 nm

CdSe 奈米微粒之螢光顏色與粒徑之關係

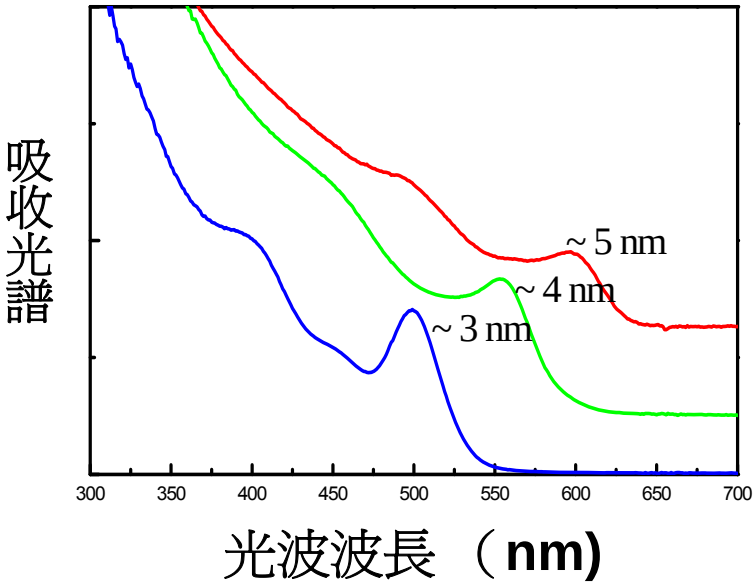
CdSe Structure

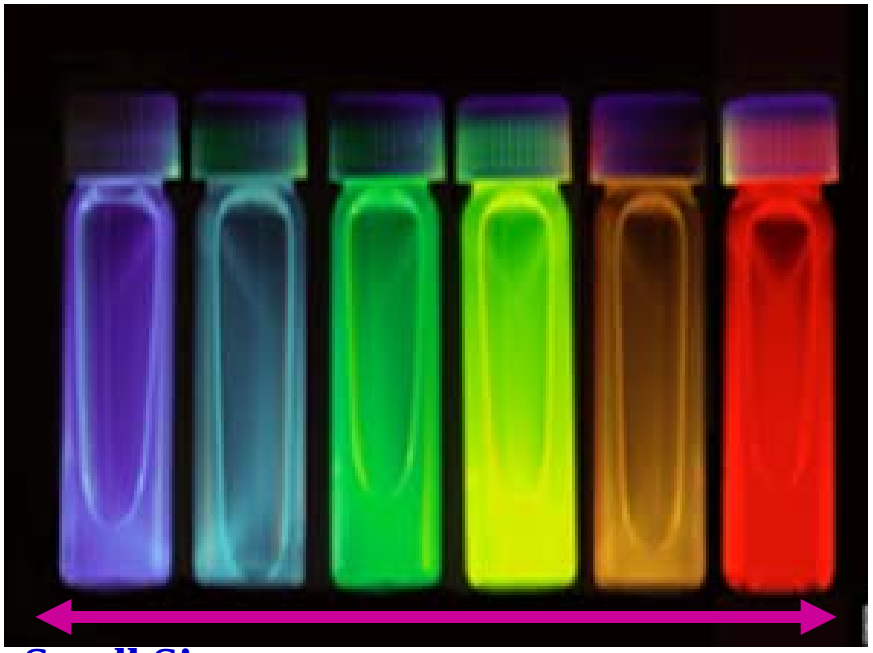




2 nm CdSe電子顯微鏡圖

CdSe之吸收光譜

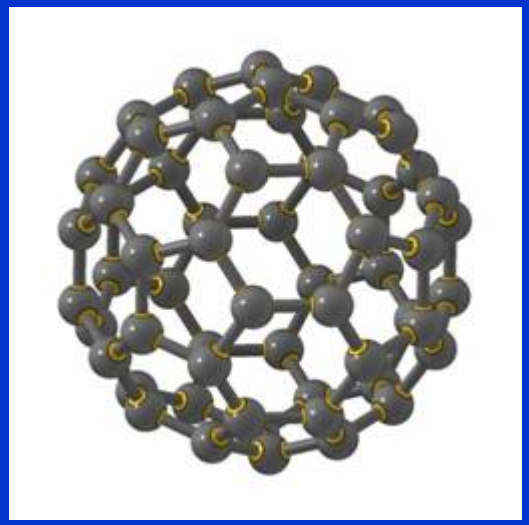




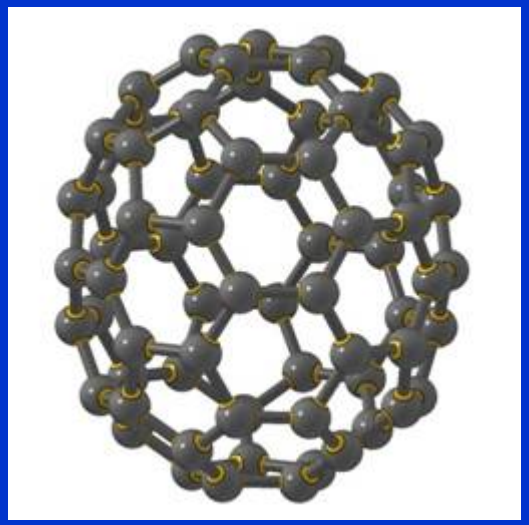
Small Size

Large size

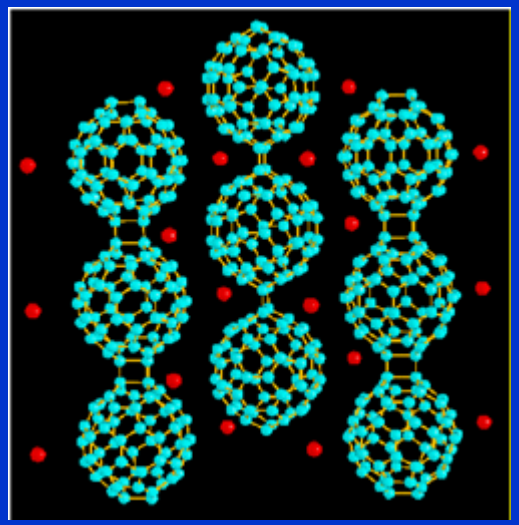
Fullerenes



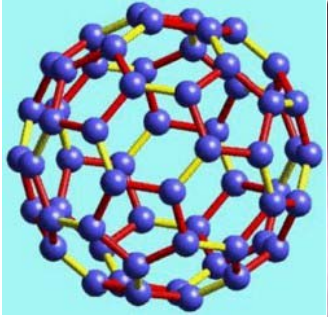
C_{60}

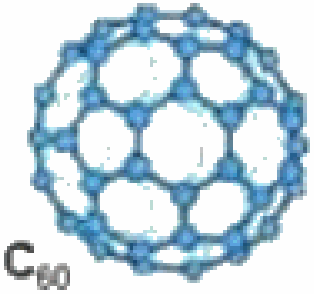


C_{70}

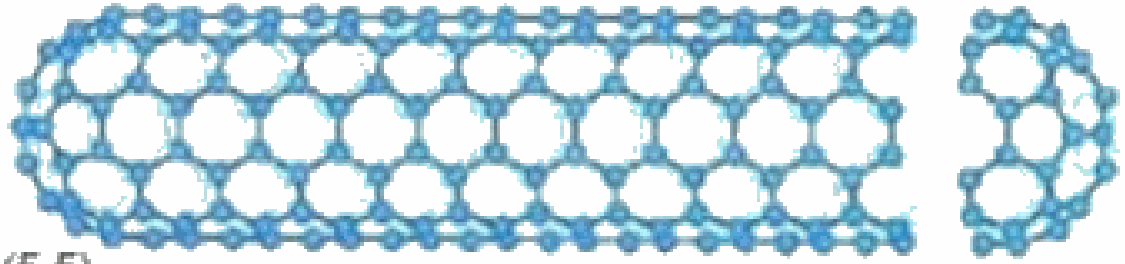


RbC_{60}

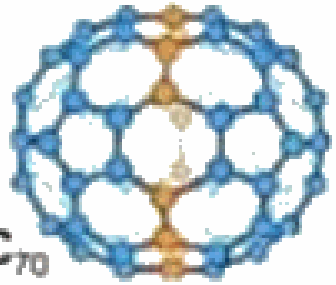




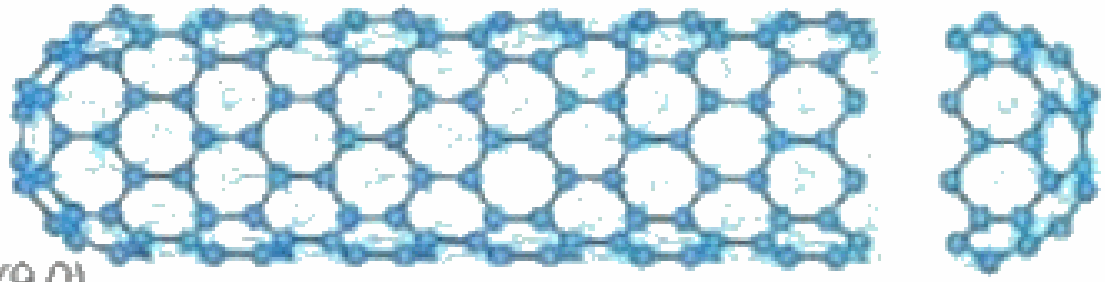
C_{60}



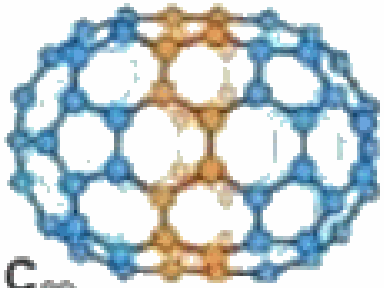
$(m,n)=(5,5)$



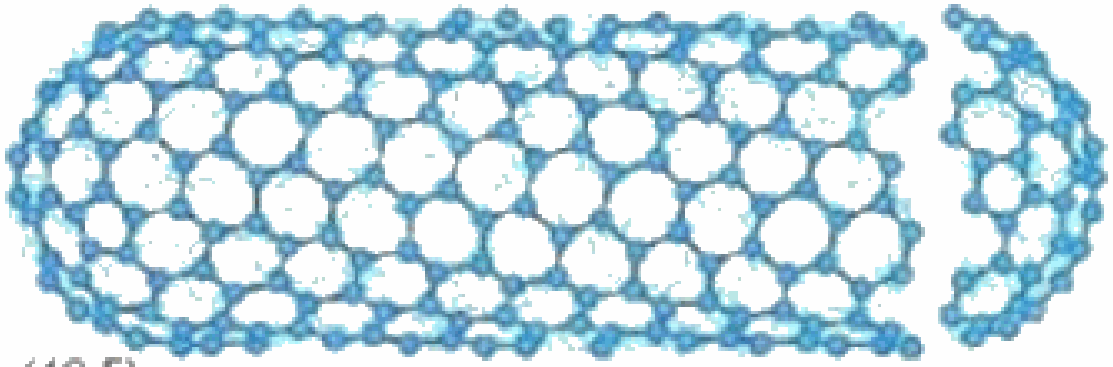
C_{70}



$(m,n)=(9,0)$

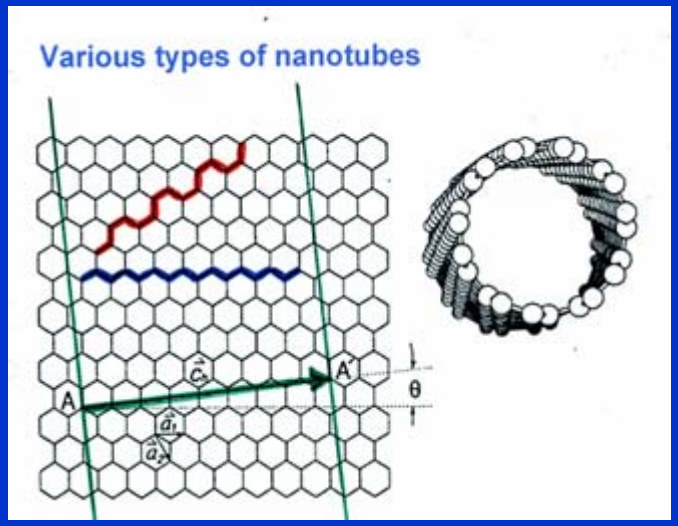


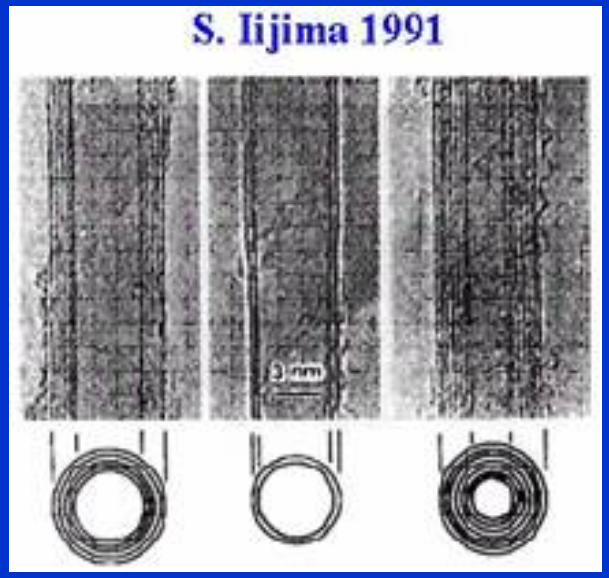
C_{80}

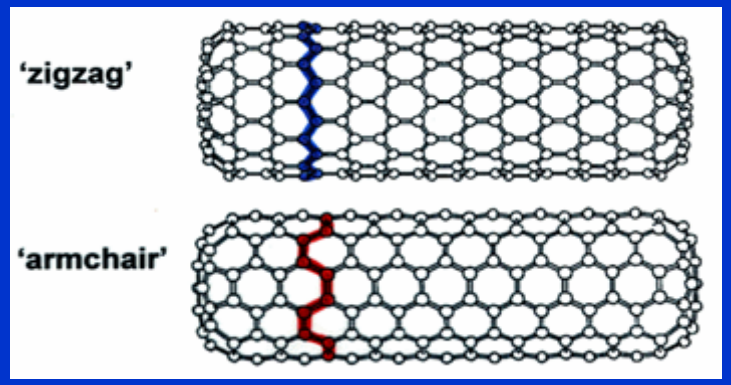


$(m,n)=(10,5)$

奈米碳管


Various types of nanotubes
A
A'
θ

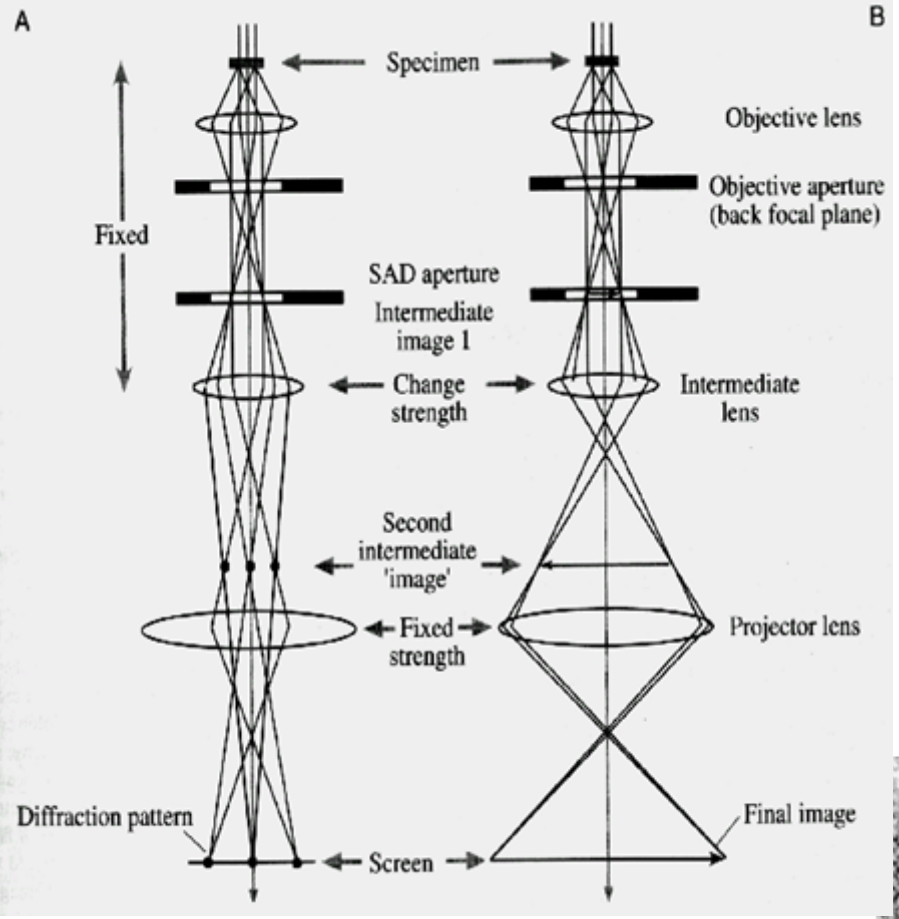

S. Iijima 1991

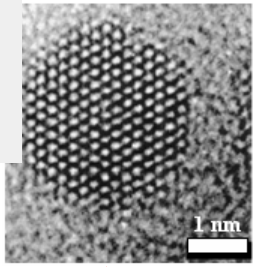

'zigzag'
'armchair'


T
ϕ
H

如何觀察奈米世界？

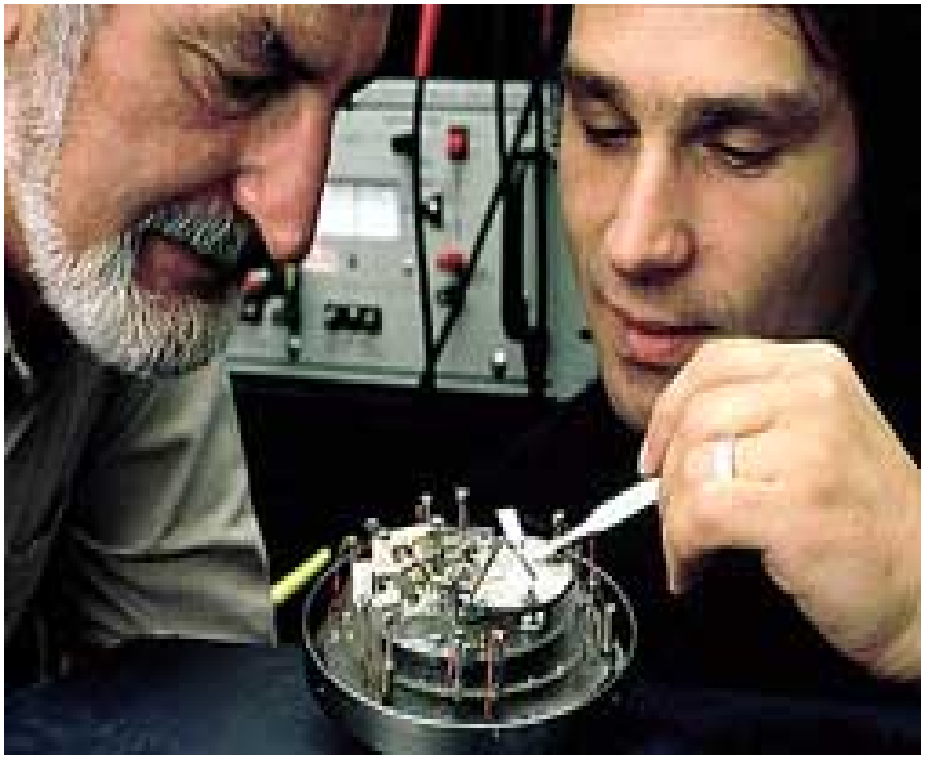
穿透電子顯微術(STEM)



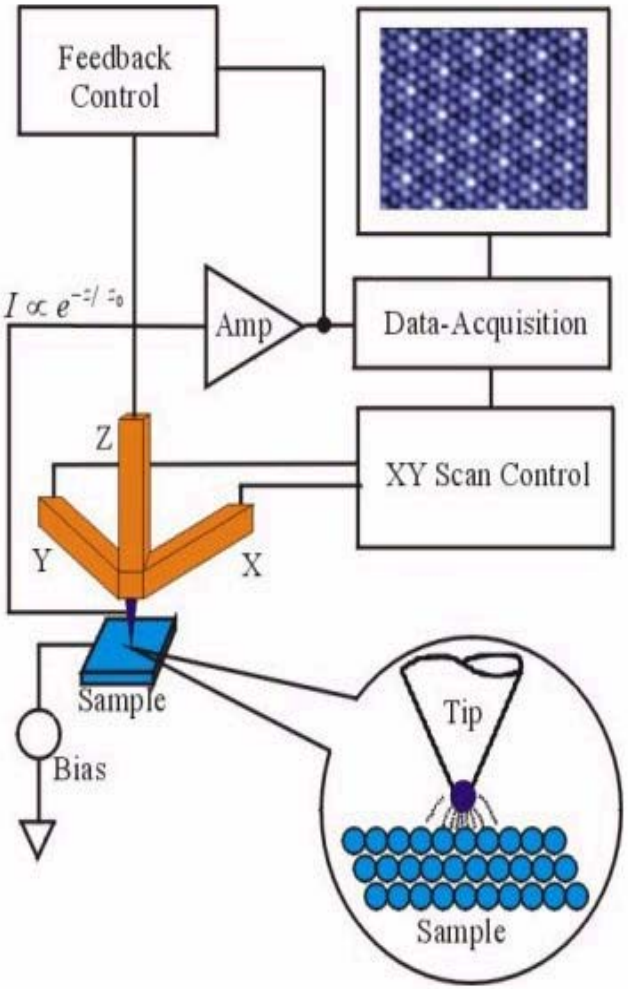


2 nm CdSe電子顯微鏡圖

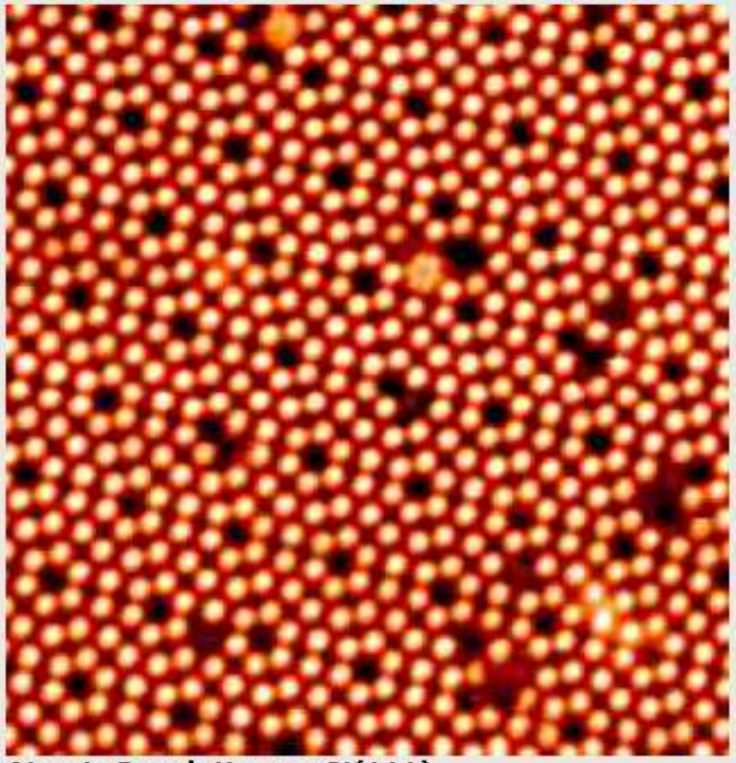
掃描穿隧顯微儀
(Scanning Tunneling Microscopy)



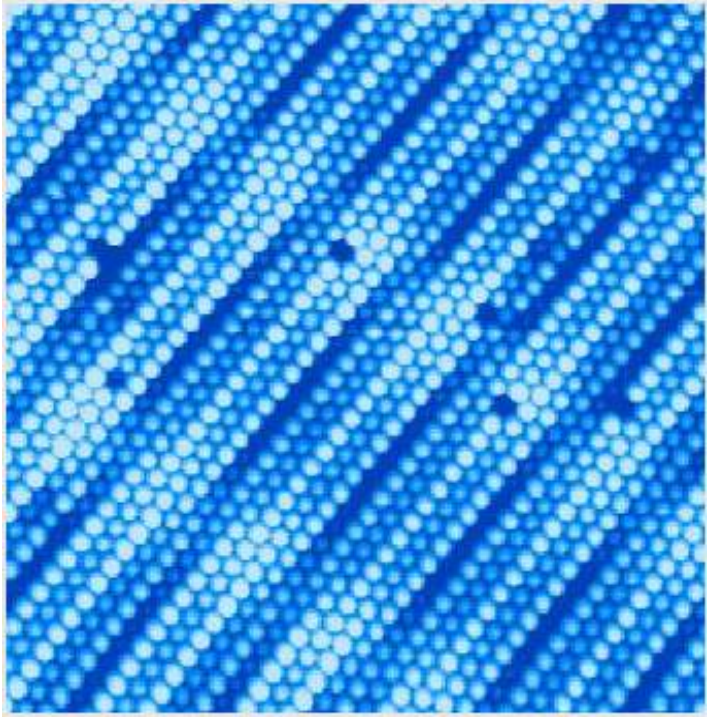
Rohrer and Binnig-1981



原子圖像

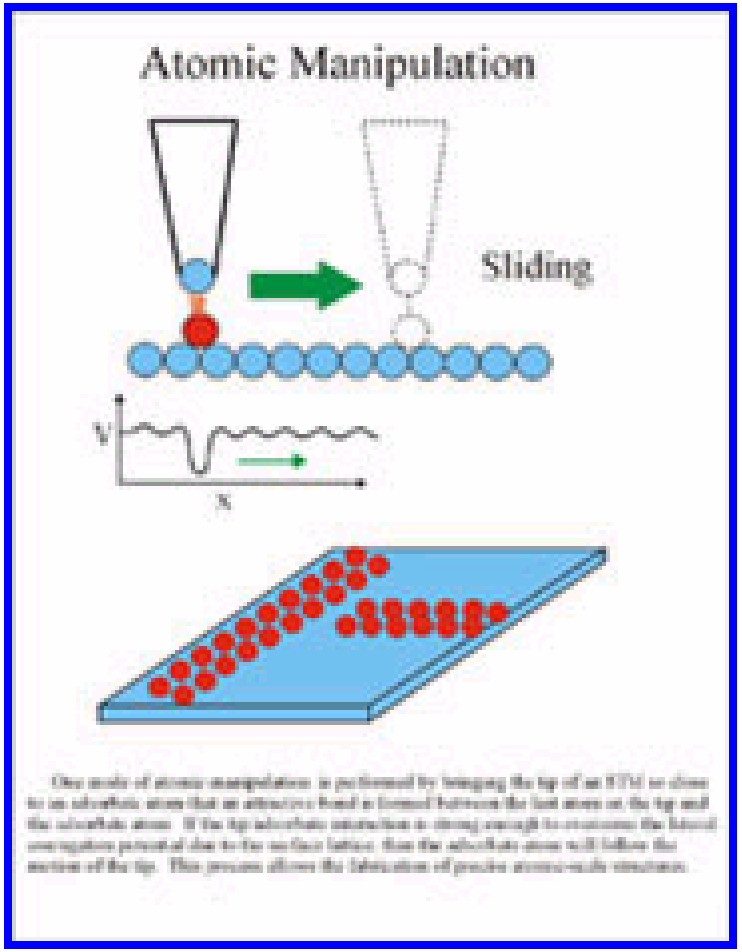


Atomic Resolution on Si(111)
Si(111)7x7; U_{gap} = 1.99 V, It = 2.0 nA, 20 nm x 20 nm



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

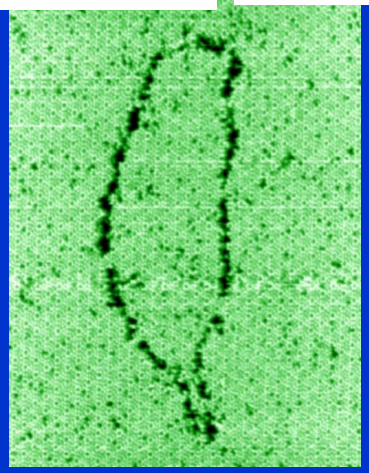
奈米尺度下的操控–平移原子操縱術



D.M. Eigler IBM, Almaden

國內奈米科技發展案例

以場蒸發原子操縱術製作世界上最小之臺灣地圖



100 Å

（中研院鄭天佐博士等提供）

Lycurgus Cup in Roman times

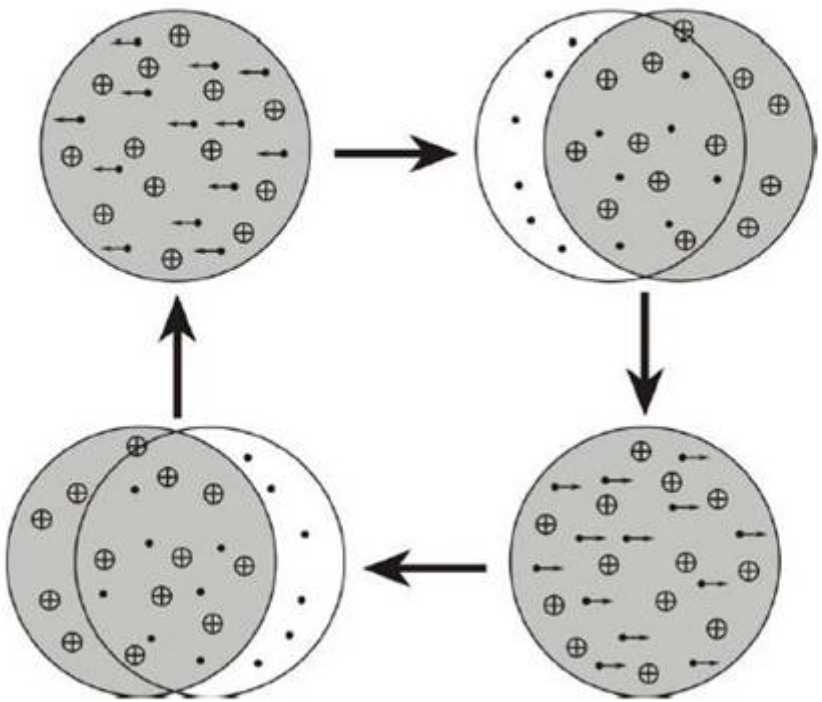
Dr. Juen-Kai Wang

The glass appears green in daylight (reflected light), but red when the light is transmitted from the inside of the vessel.

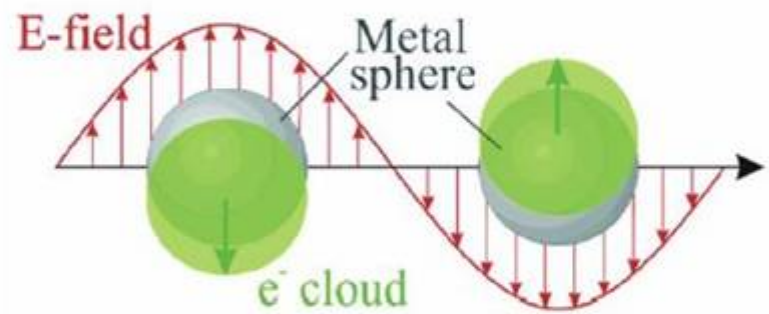
The Lycurgus Cup, Roman (4th century AD), British Museum *(www.thebritishmuseum.ac.uk)*
*F. E. Wagner et al., Nature **407**, 691 (2000).*

Electron collective motion in metal clusters

Dr. Juen-Kai Wang



Coherent oscillatory motion



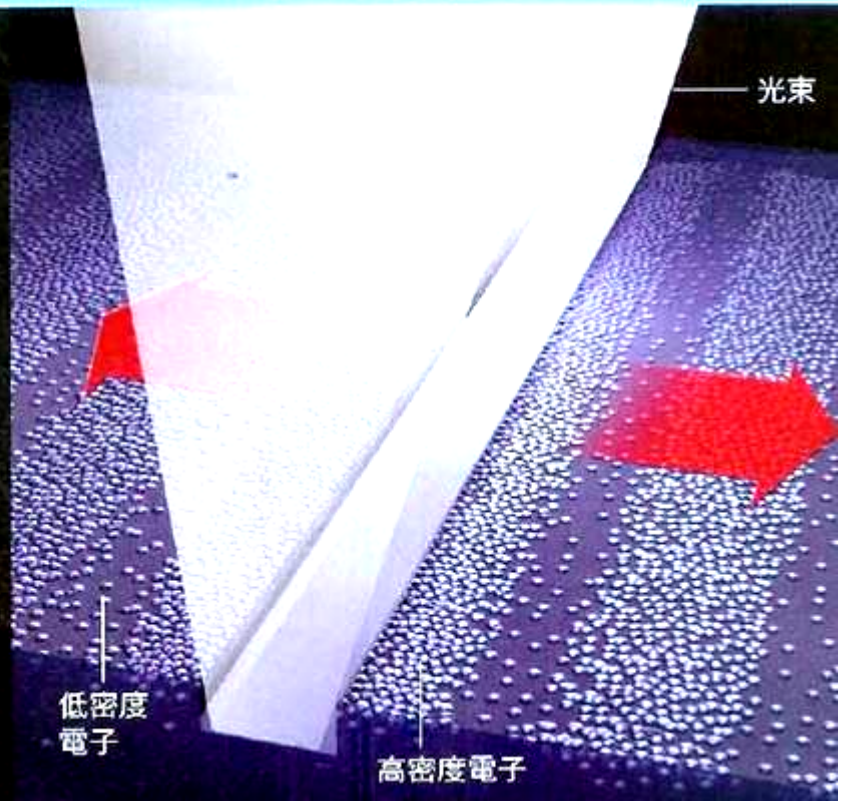
Resonant excitation

把光塞進細小的線路裡

電漿子光學仍是個相當新穎的研究領域，但研究人員已經開發出充份展現這項技術發展前景的原型裝置。

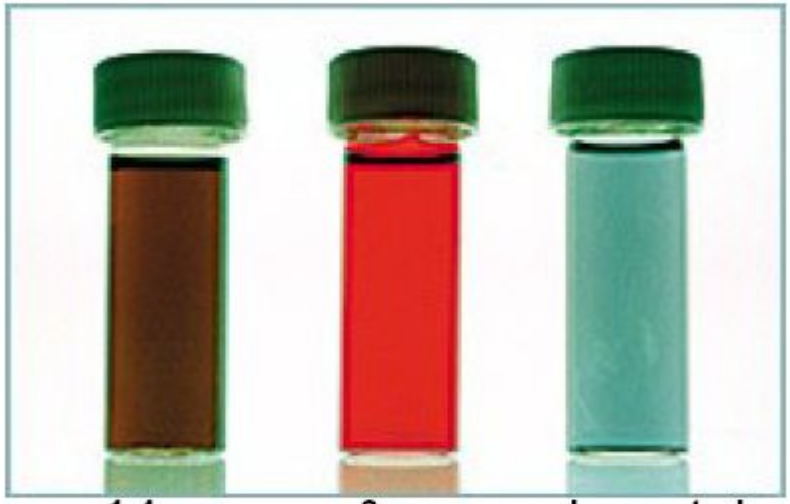
平面波導

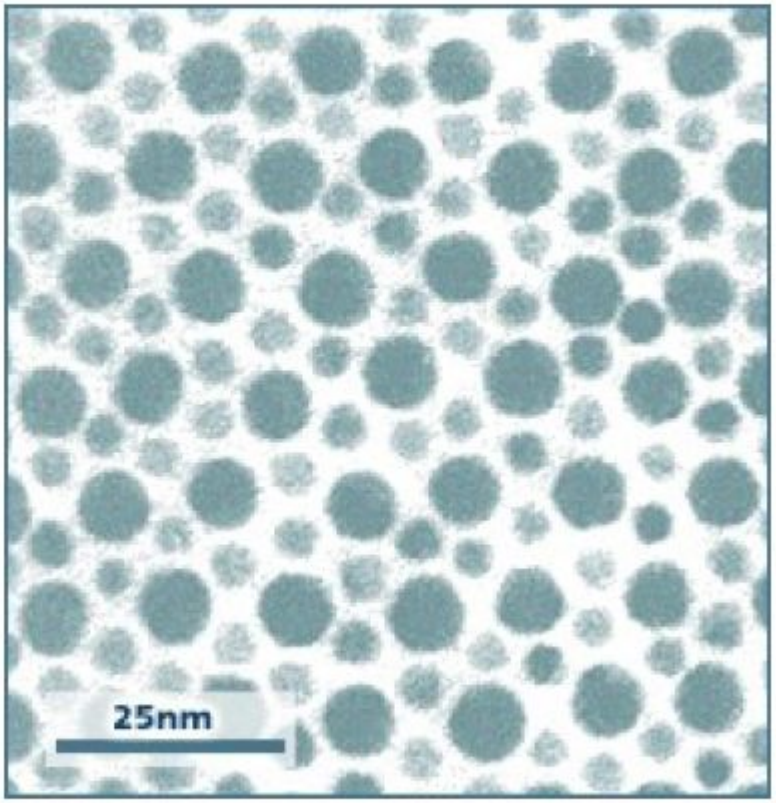
電漿子永遠沿金屬與介電質（例如空氣或玻璃等不導電材料）間的交界面移動。舉例來說，聚焦在金屬直縫上的光所產生的電漿子，會在金屬表面極薄的平面移動（也就是金屬與空氣的交界面）。電漿子可在這個平面波導上行進數公分遠，這已經足以在晶片內傳送訊號，可惜比較大的波會在處理器內部的奈米尺度線路中與其他訊號形成干擾。



Au nanospheres

Dr. Juen-Kai Wang

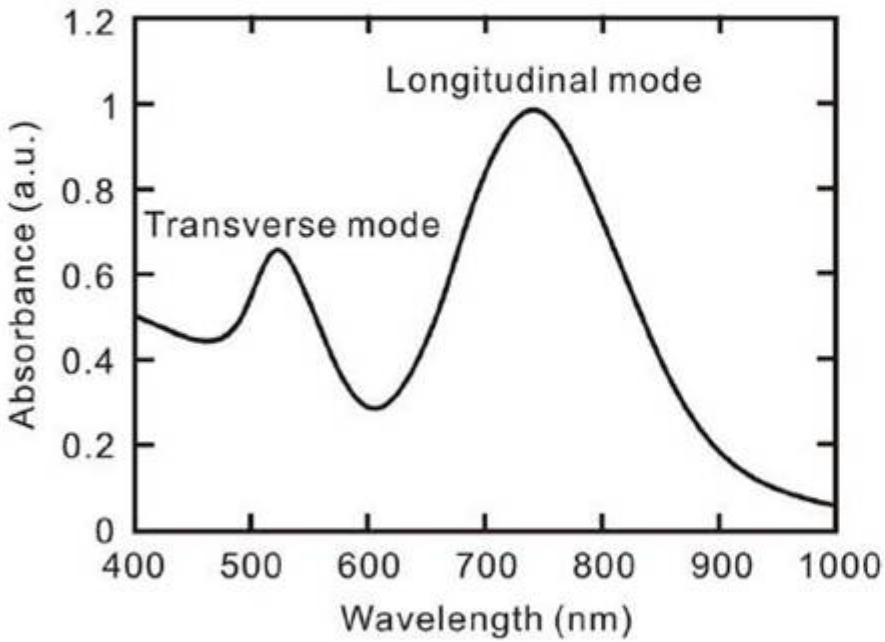


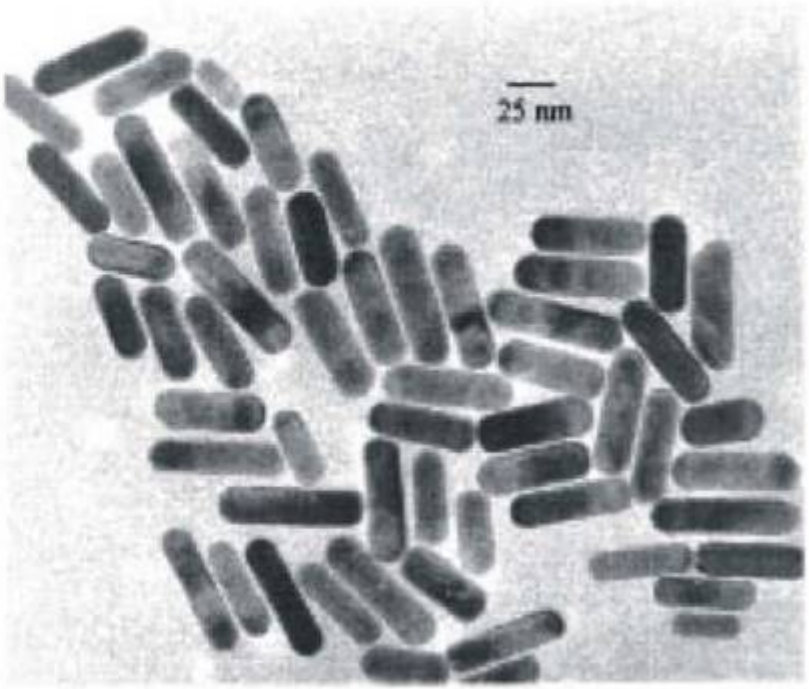


C. J. Kiely, J. Fink, M. Brust, D. Bethell and D. J. Schiffrin, Nature ***444****, 396 (1998)*

Au nanorods

Dr. Juen-Kai Wang

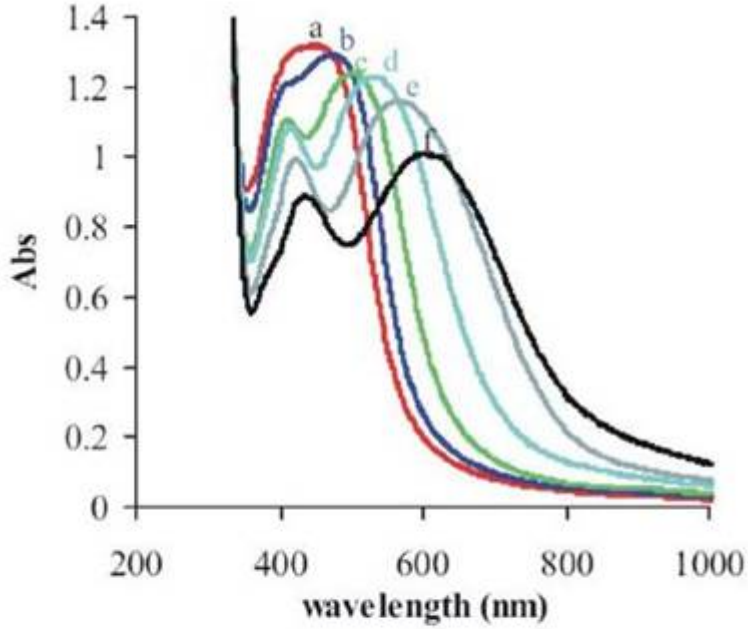




S. Link, M. B. Mohamed and M. A. El-Sayed, J. Phys. Chem. B ***103****, 3073 (1999).*

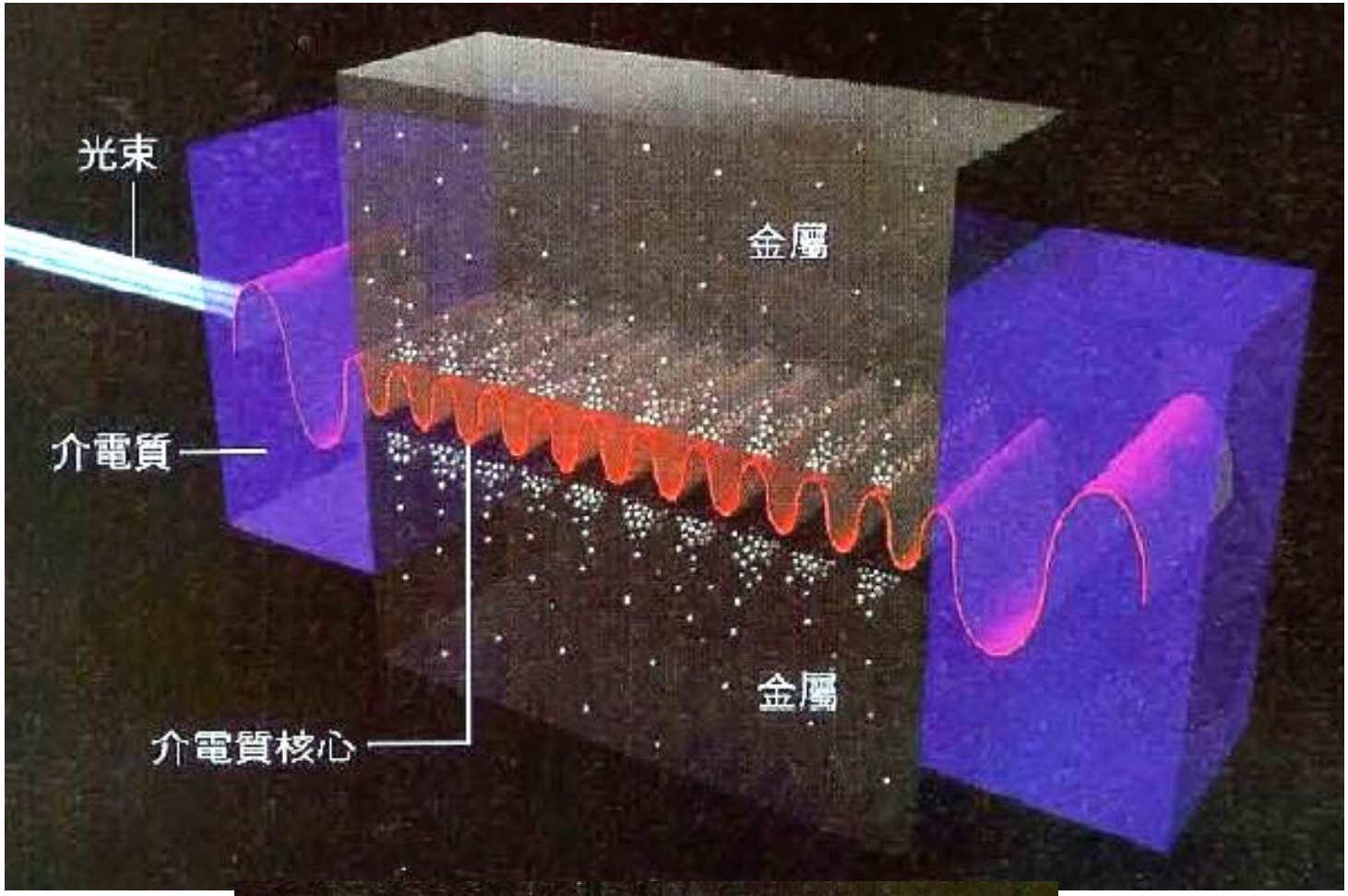
Ag nanorods

Dr. Juen-Kai Wang



increasing aspect ratio (1-10)

C. J. Murphy and N. R. Jana, Adv. Mater. ***14****, 80 (2002)*



電漿子狹縫形波導

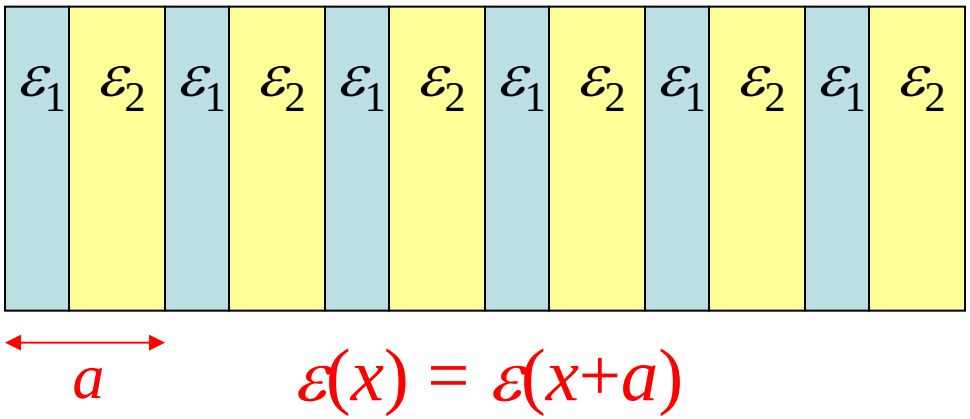
科學家將介電質包覆在金屬中央，製作出尺寸小得多的電漿子線路。電漿子波導可壓縮光學訊號，使它的波長縮小到1/10以下。研究人員已可做出寬度僅50奈米的狹縫形波導，大約與目前最小的電子線路相當。電漿子結構可攜帶的資料量比電子導線高出許多，但訊號傳輸距離無法超過100微米。

Periodic Hermitian Eigenproblems in 1d

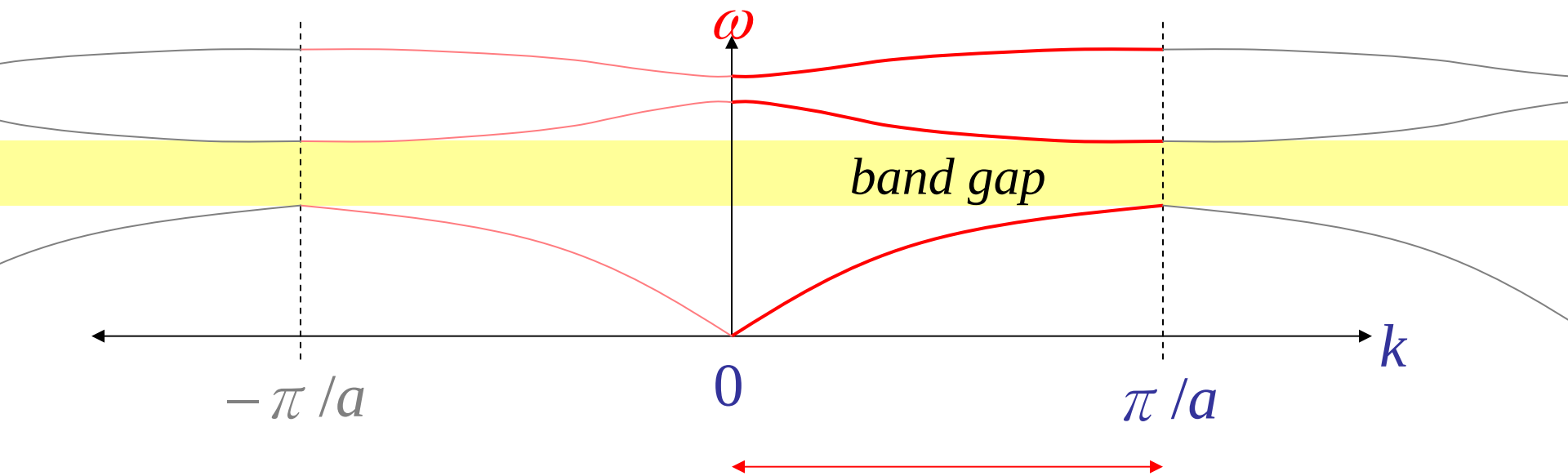
k is periodic:

$k + 2\pi/a$ equivalent to k

"quasi-phase-matching"



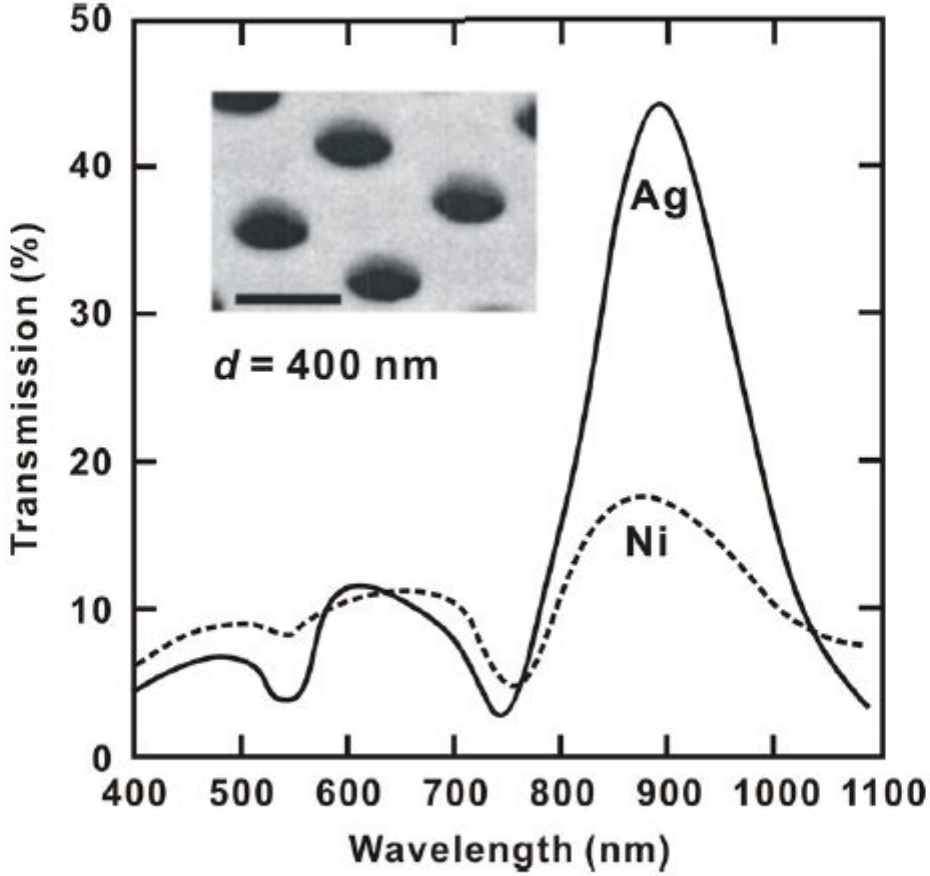
$\varepsilon(x) = \varepsilon(x+a)$



irreducible Brillouin zone

Subwavelength hole array

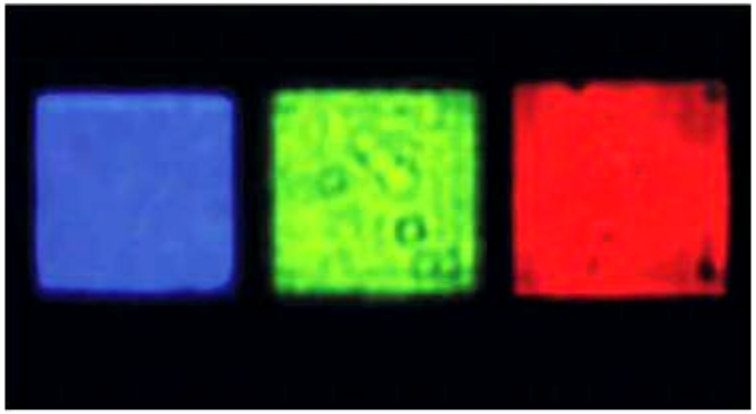
Dr. Juen-Kai Wang

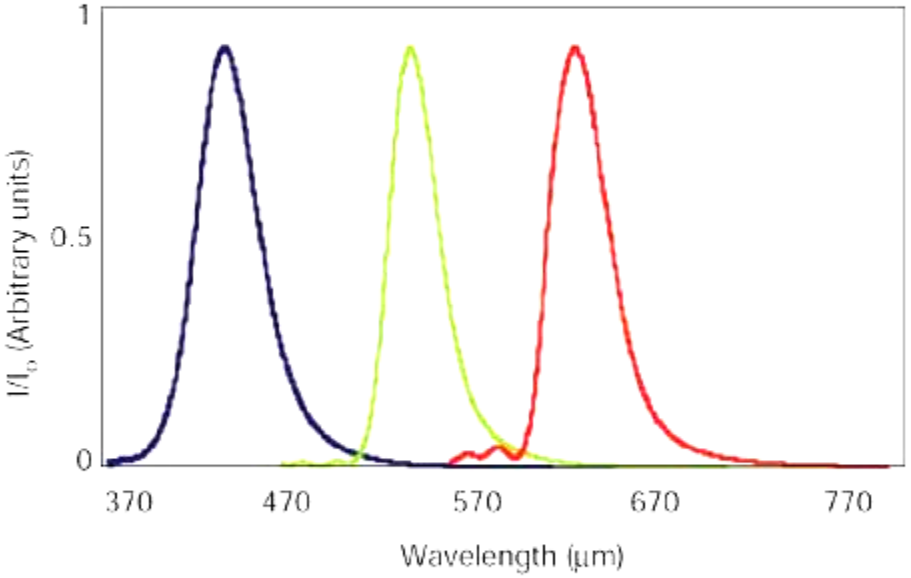


D. E. Grupp et al., Appl. Phys. Lett. ***77****, 1569 (2000)*
L. Martin-Moreno et al., Phys. Rev. Lett. ***86****, 1114 (2001).*

Spectroscopy of nanohole patterns

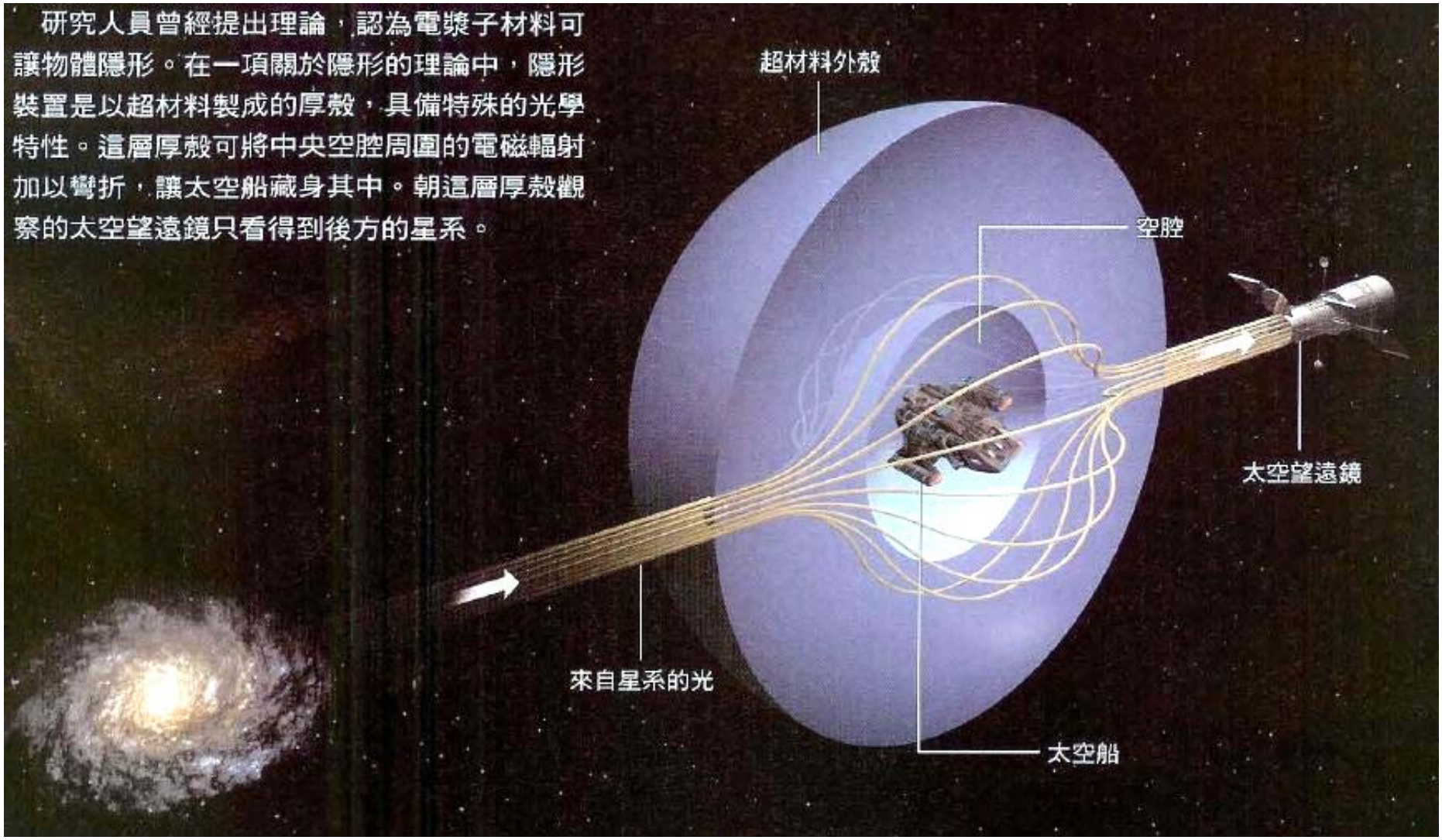
Dr. Juen-Kai Wang



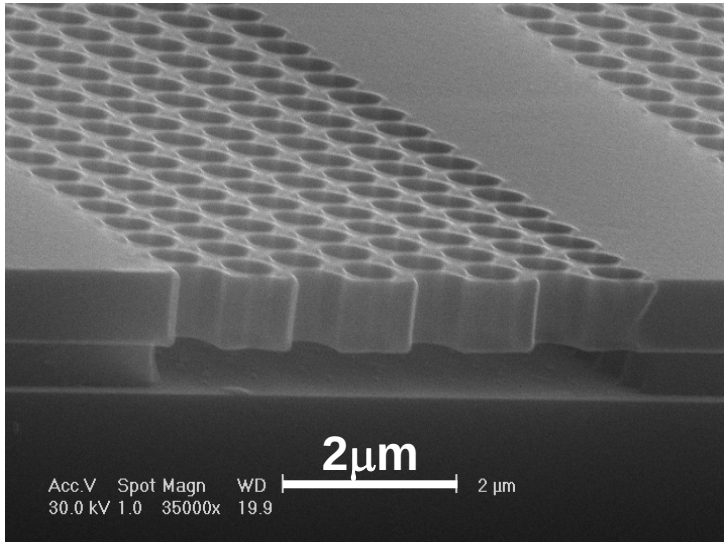


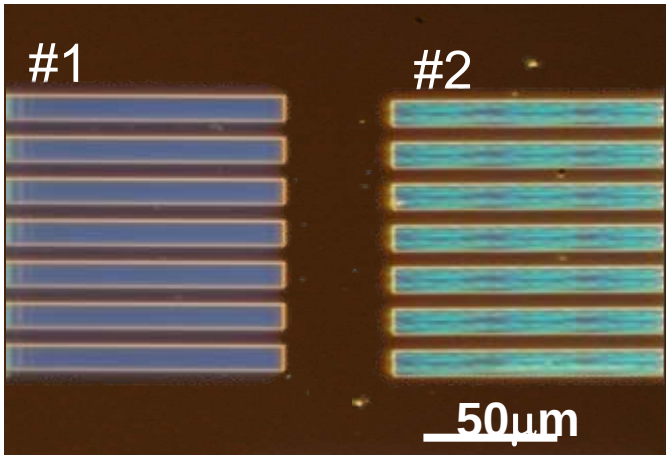
W. L. Barnes, A. Dereux, and T. W. Ebbesen, Nature ***424****, 824 (2003)*

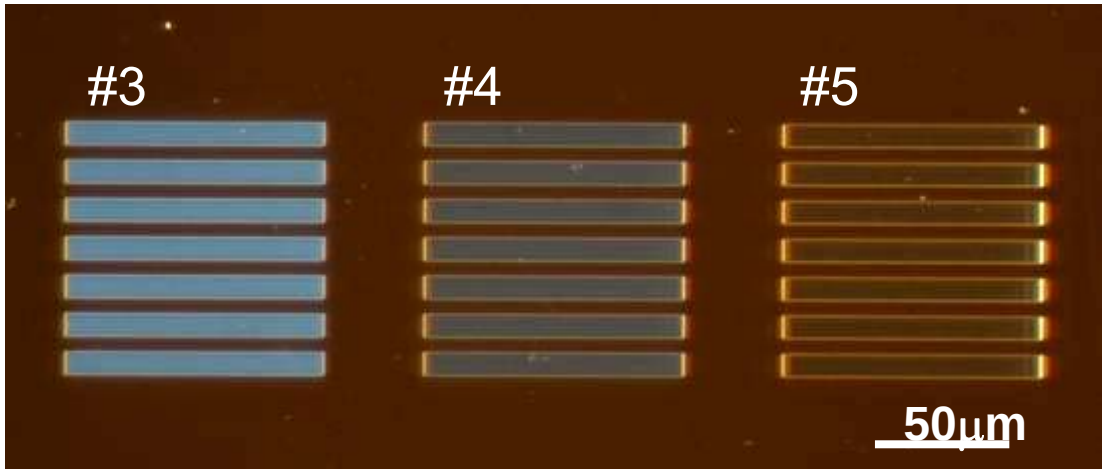
研究人員曾經提出理論，認為電漿子材料可讓物體隱形。在一項關於隱形的理論中，隱形裝置是以超材料製成的厚殼，具備特殊的光學特性。這層厚殼可將中央空腔周圍的電磁輻射加以彎折，讓太空船藏身其中。朝這層厚殼觀察的太空望遠鏡只看得到後方的星系。



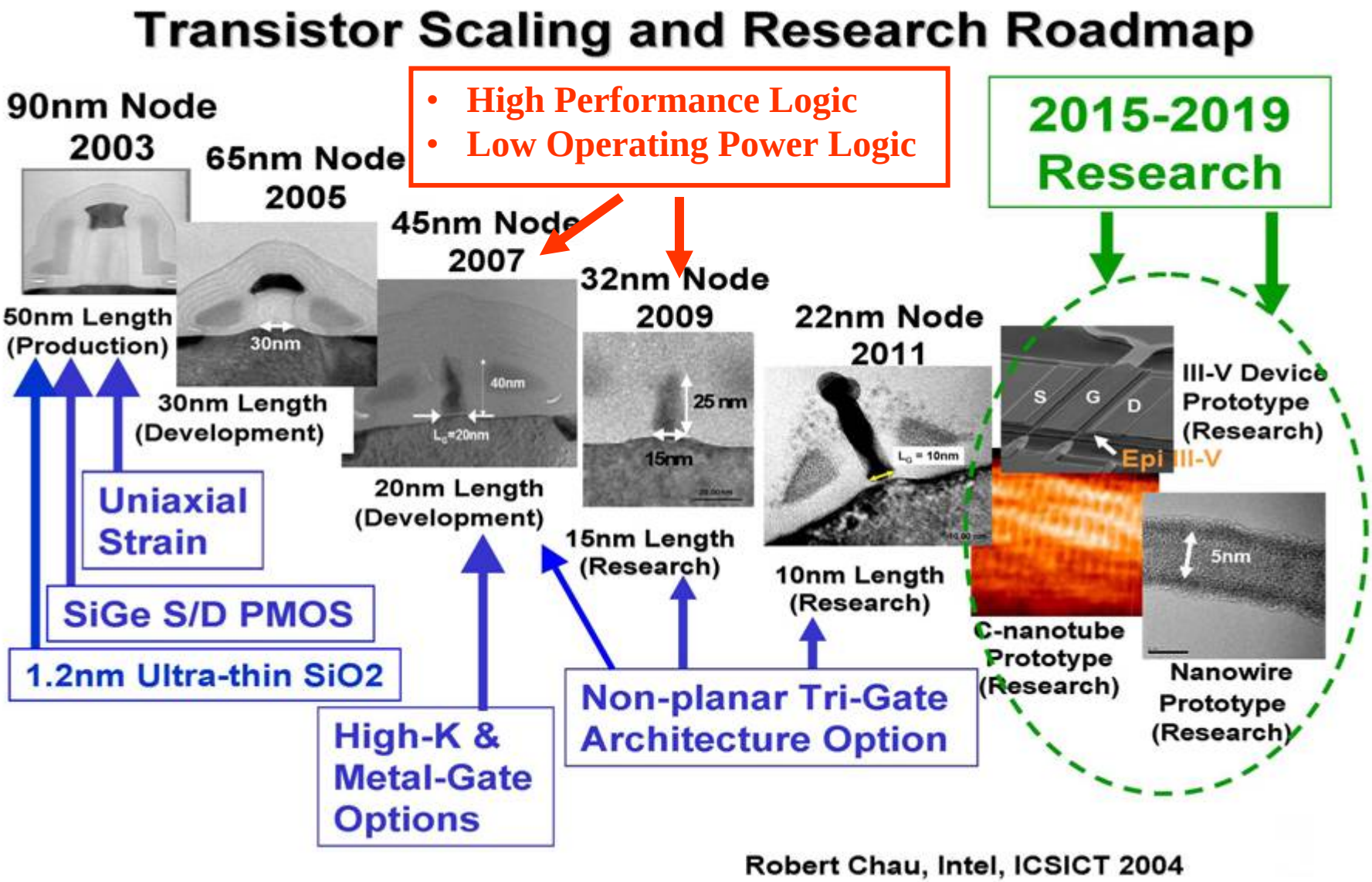
以PMMA/LOR製作的光子晶體



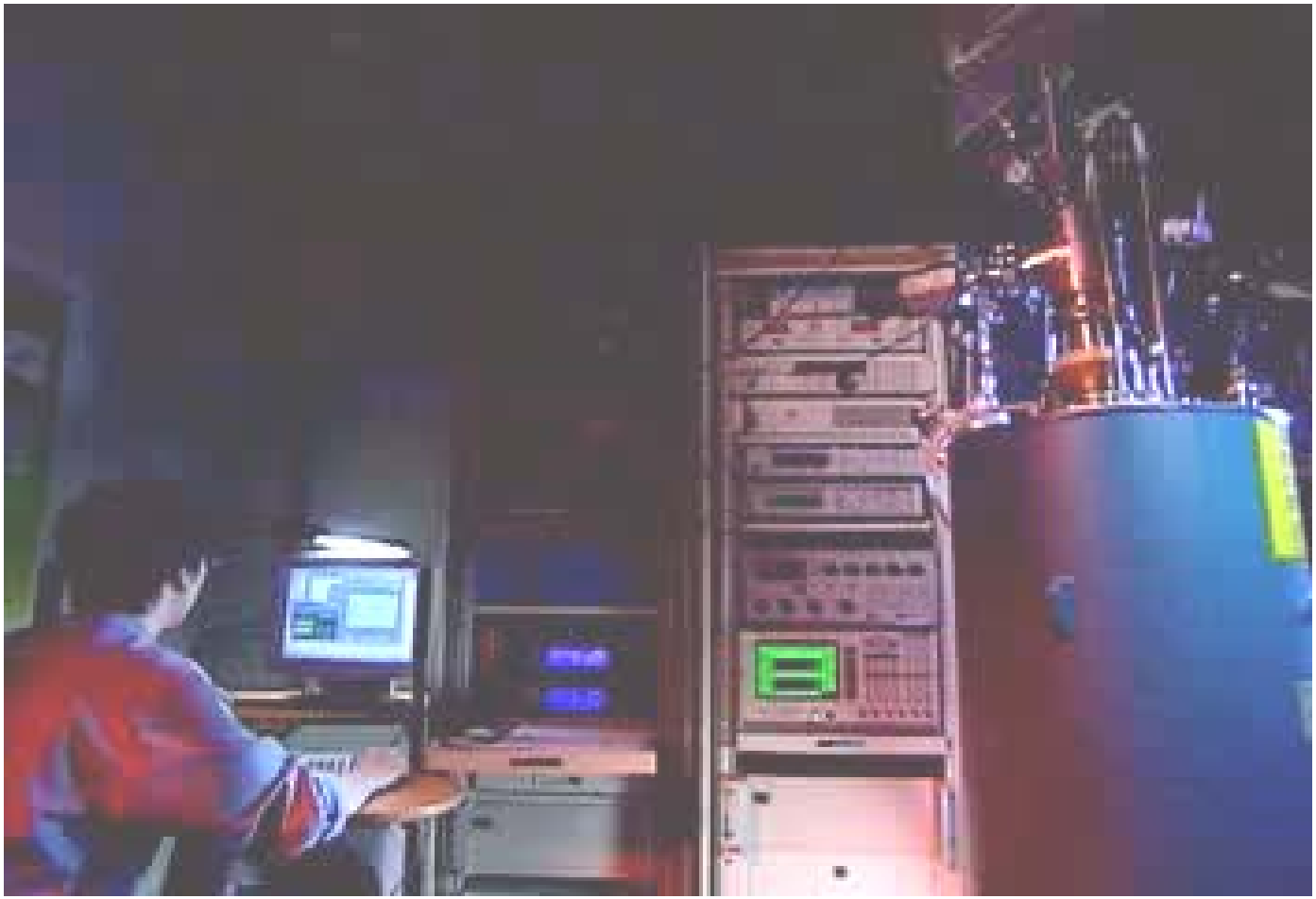




Intel Transistor Scaling and Research Roadmap



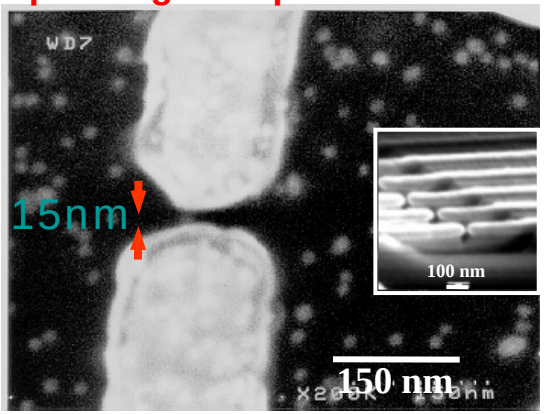
我們的實驗工作



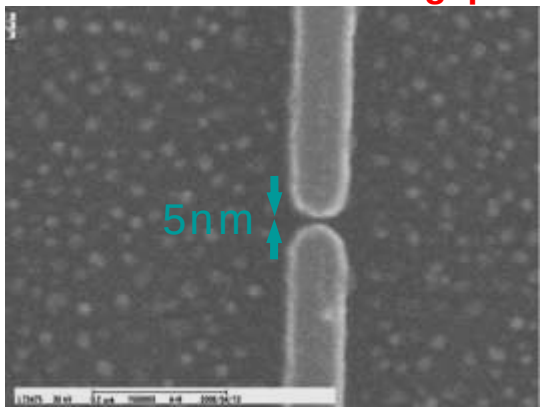
陳啓東—量子電子元件實驗室

Superconducting-Magnetic Electronics

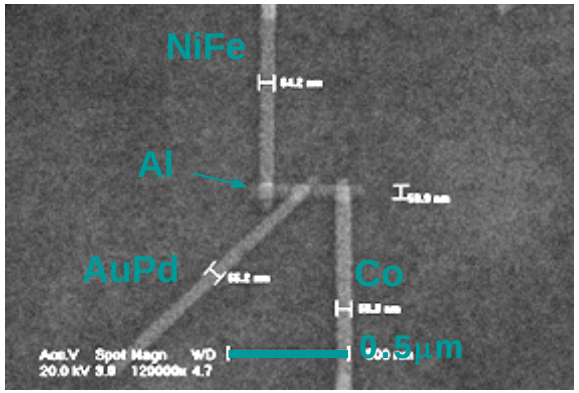
suspending nanoparticle devices



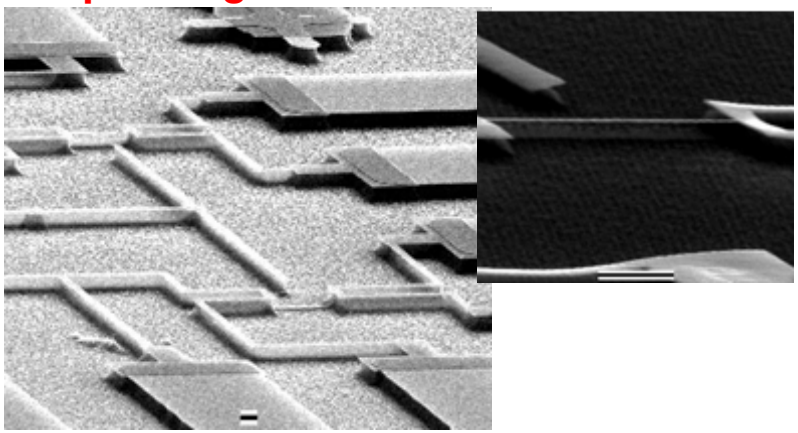
electrodes with a 5nm gap



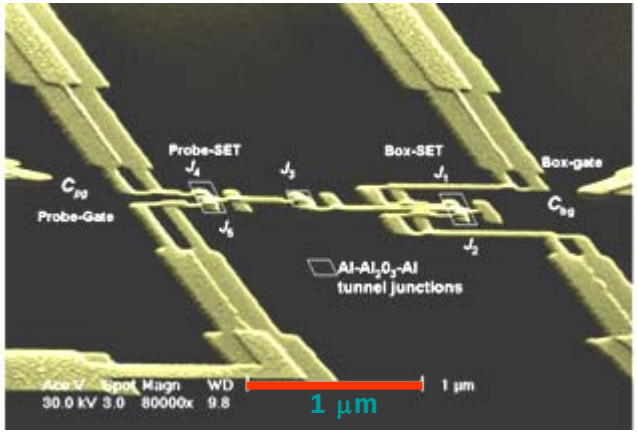
ferromagnetic-superconductor device



Suspending wire devices



Single electron devices

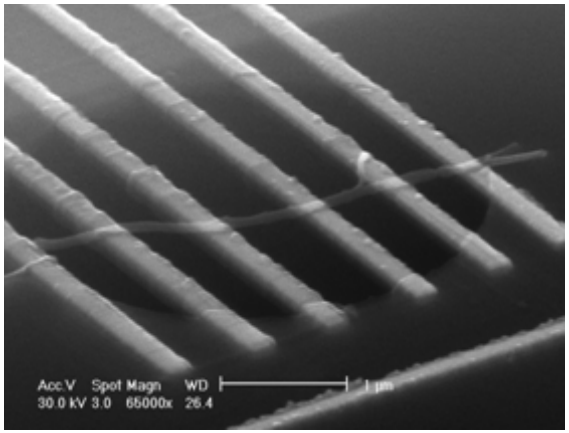


量子電子元件實驗室

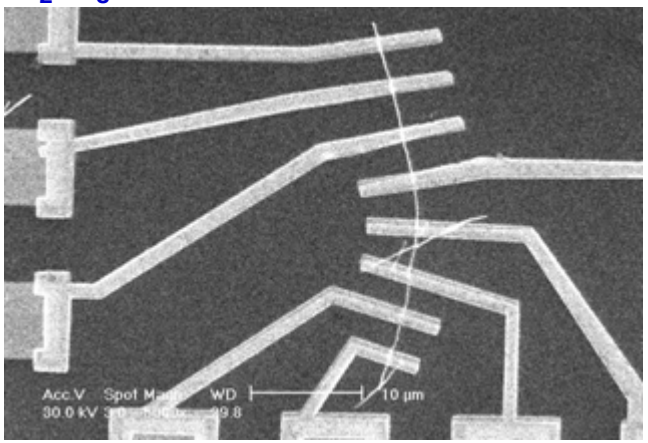
Nanowire electronic devices

Suspended 懸浮喔!

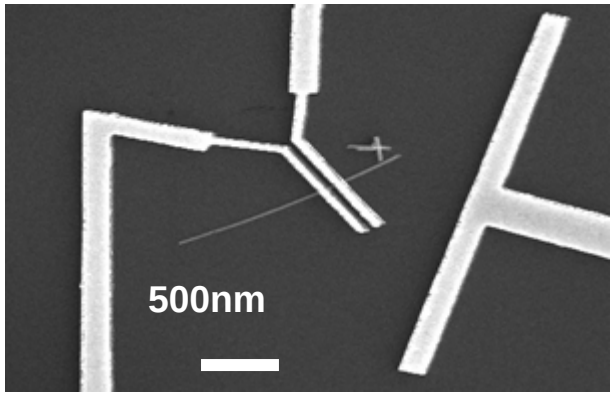
single wall carbon nanotube



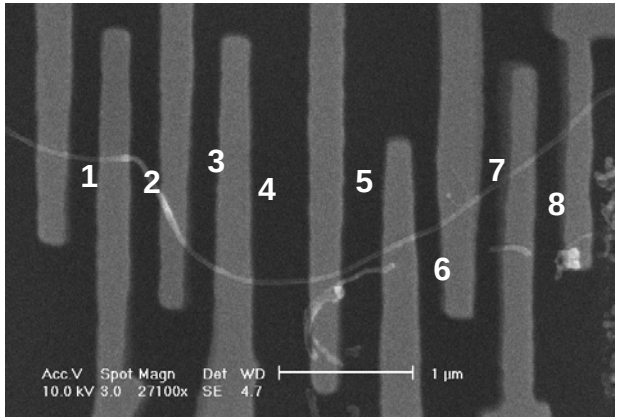
Bi_2Te_3 wire, 中研院物理所 陳洋元教授



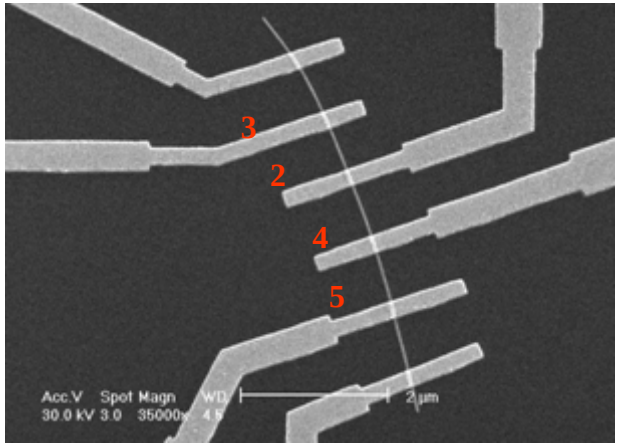
InN wire 台大凝態中心林麗瓊教授



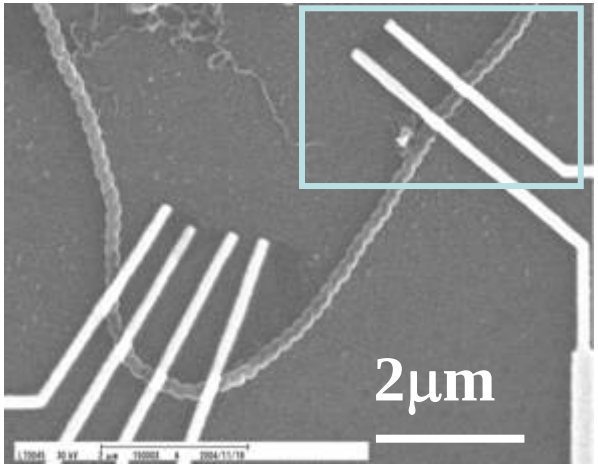
Multiwall carbon nanotube



Ni_3Si_2 wire, 清大材料 陳力俊教授



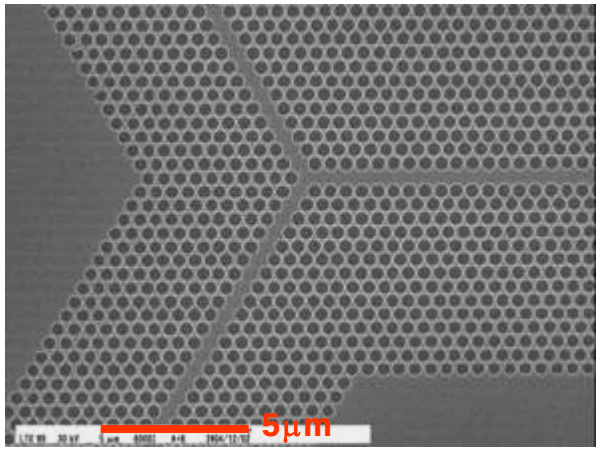
Carbon Helix 原分所陳益聰教授



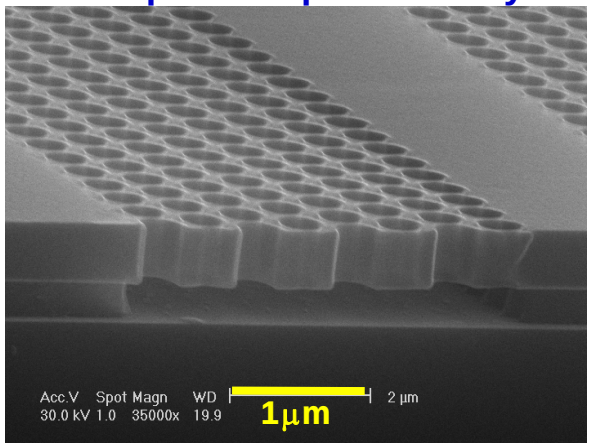
量子電子元件實驗室

Photonic Crystals

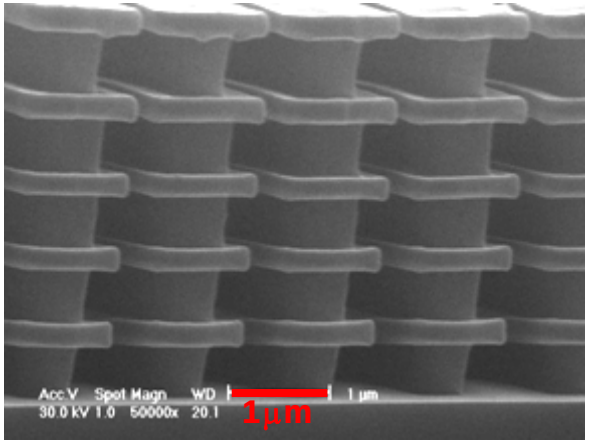
Si-based 2D photonic crystal



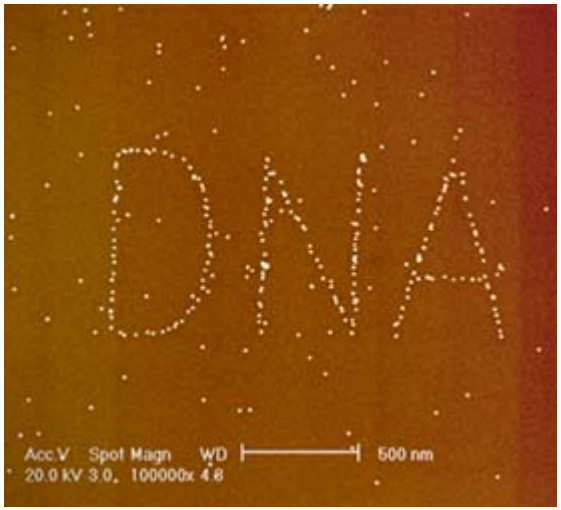
PMMA quasi-2D photonic crystal



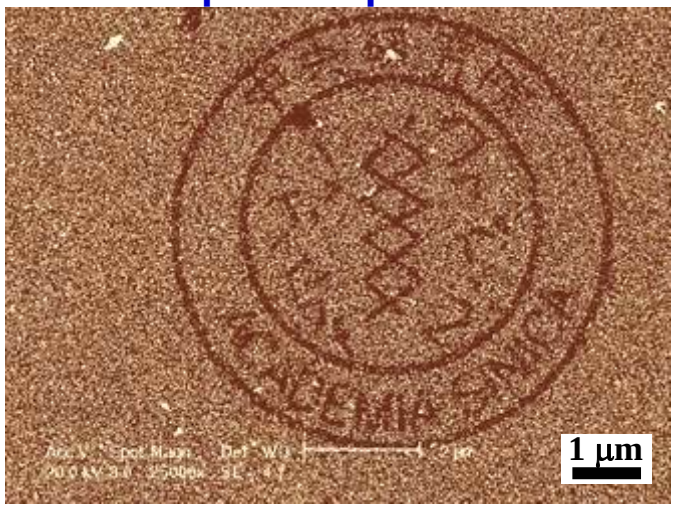
PMMA-LOR lattice structure



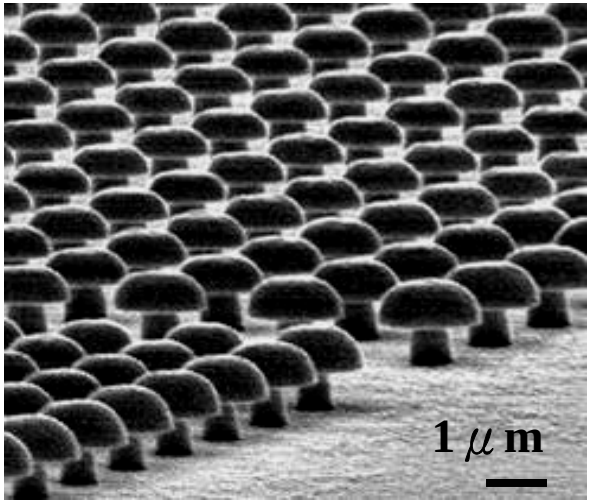
Nano Fabrication technology



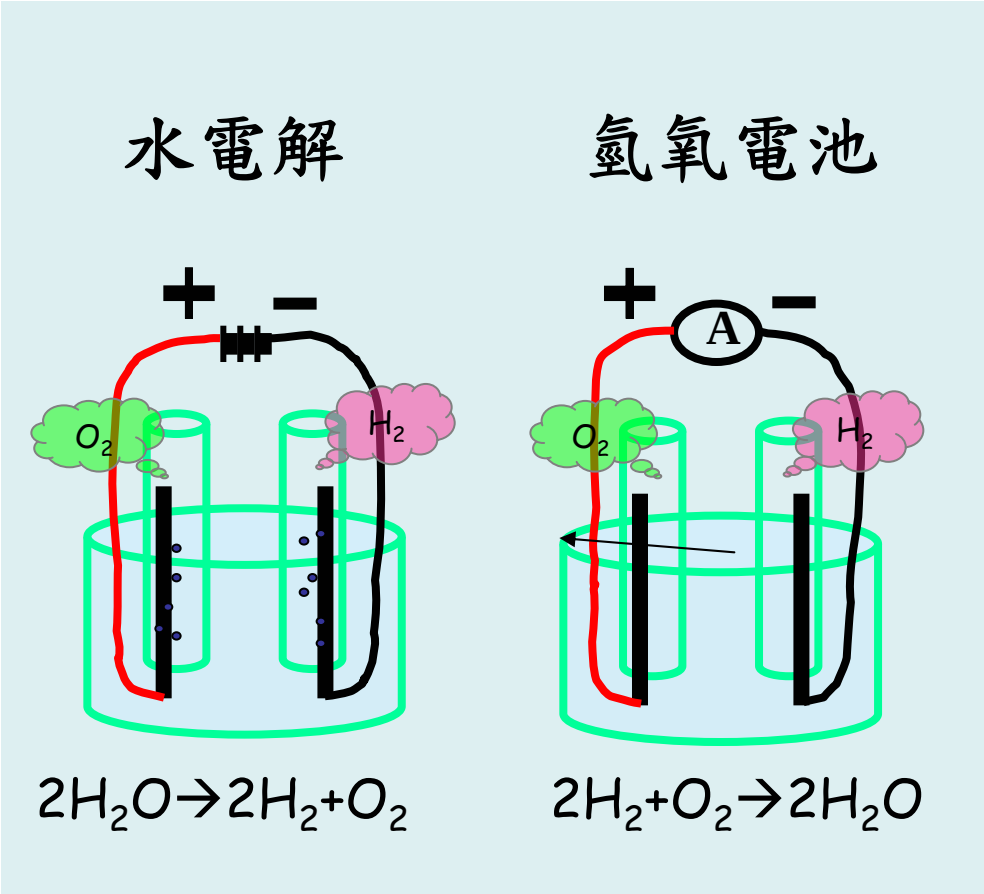
Au-nanoparticle pattern



CdSe 2D-pillars

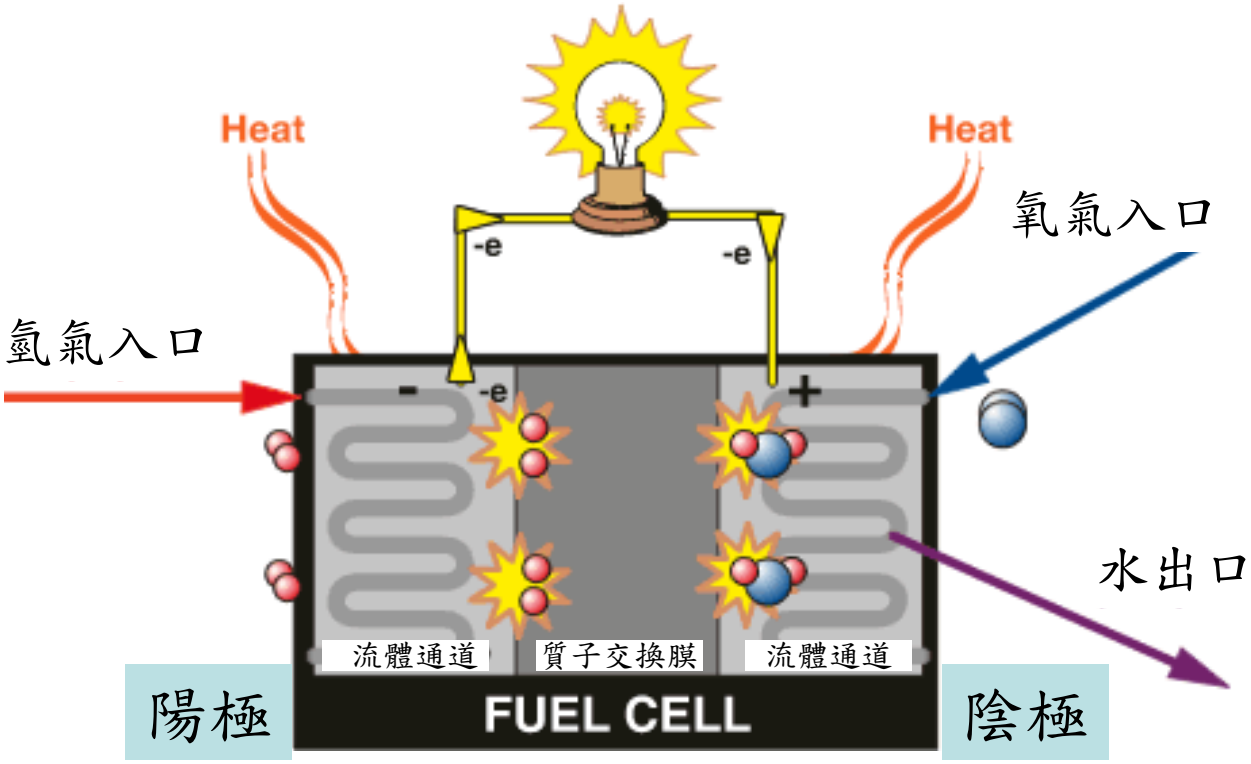


攜帶式能源 --- 電池



小提示: 氫氧電池的概念是由電解水的逆反應而來

電從哪裡來？
燃料電池的電化學原理



陽極

$H_2 \rightarrow 2\,H^+ + 2\,e^-$

陰極

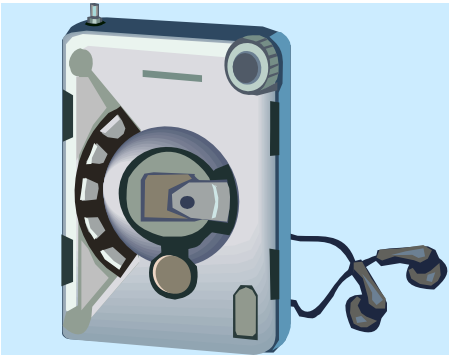
$\frac{1}{2}\,O_2 + 2\,H^+ + 2\,e^- \rightarrow H_2O$

全反應式：$H_2 + \frac{1}{2}\,O_2 \rightarrow H_2O$

直接甲醇燃料電池

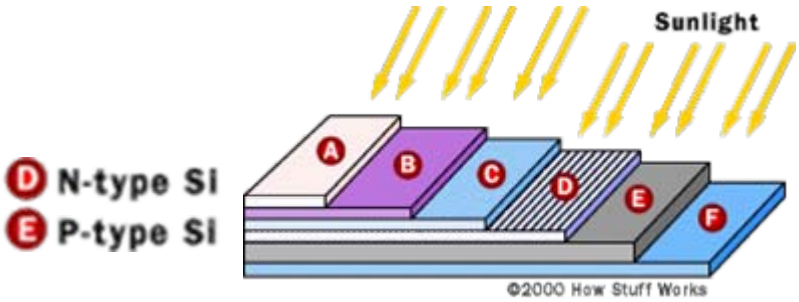
Direct Methanol Fuel Cell (DMFC)

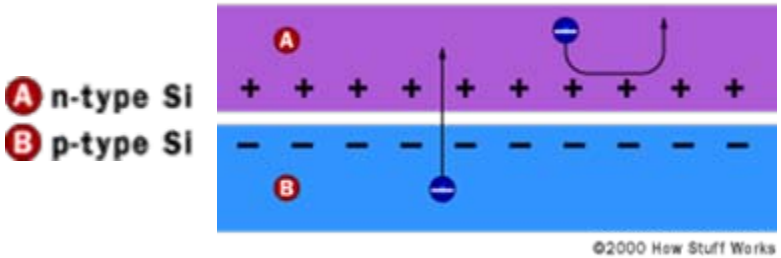
甲醇溶液產生 $6H^+ + 6e^-$



• 熱電材料－另一種太陽能與再生能源電池

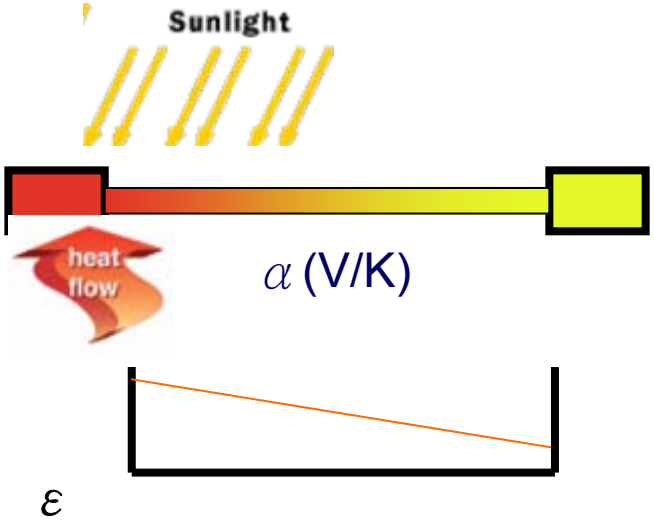
Solar cell





Basic structure of a generic silicon PV ce

Thermoelectric material

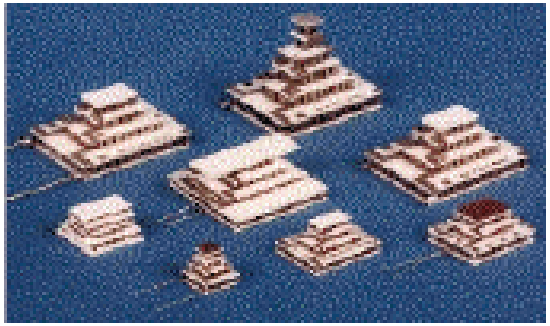


優點：

無 band width of light

Several TE Commercial Applications

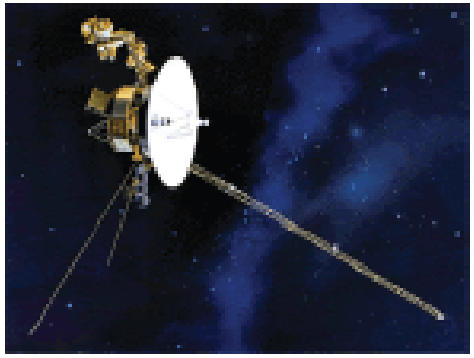
TE Modules (Marlow Indus.)



TE coolers/warmers
Coleman -Igloo

***Seiko* TE Watch**

RTG 's -- Deep Space - NASA



TE Radio Lantern

CCS - Climate Controlled Seat
Lexus & Lincoln etc.

EPSCoR DEPARTMENT of ENERGY

CLEMSON UNIVERSITY