清華大學物理系 奈米物理特論 2008/11/13 上課內容 （I）

半導體奈米結構之成長與光電特性

交通大學電子物理系　周武清 教授

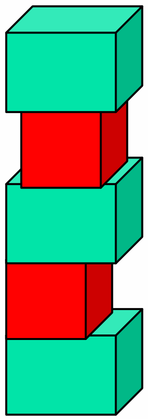
大綱:

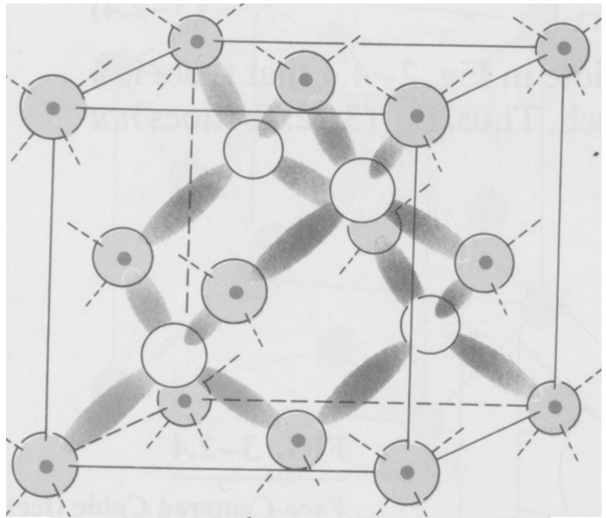
Part I:　半導體奈米結構成長---------
分子束磊晶(MBE, molecular beam epitaxy)
半導體奈米結構形貌研究---AFM

Part II:　半導體奈米結構光電特性---Photoluminescence

Part III: 半磁性半導體奈米結構之自旋磁光特性

Hetero-structure epitaxy 異質結構磊晶



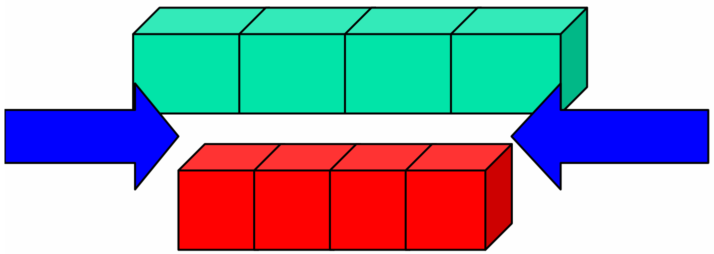


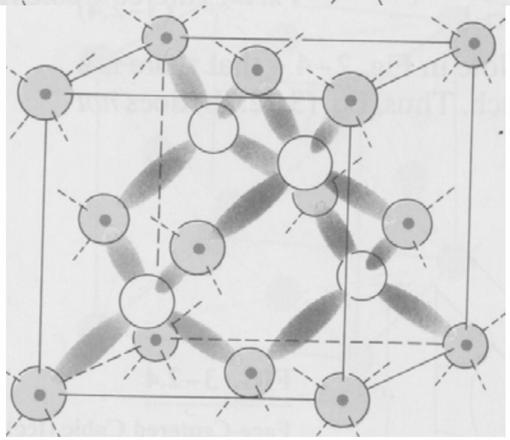
Zn

Te

Eg=2.4 V

Compressive strain 壓縮應變





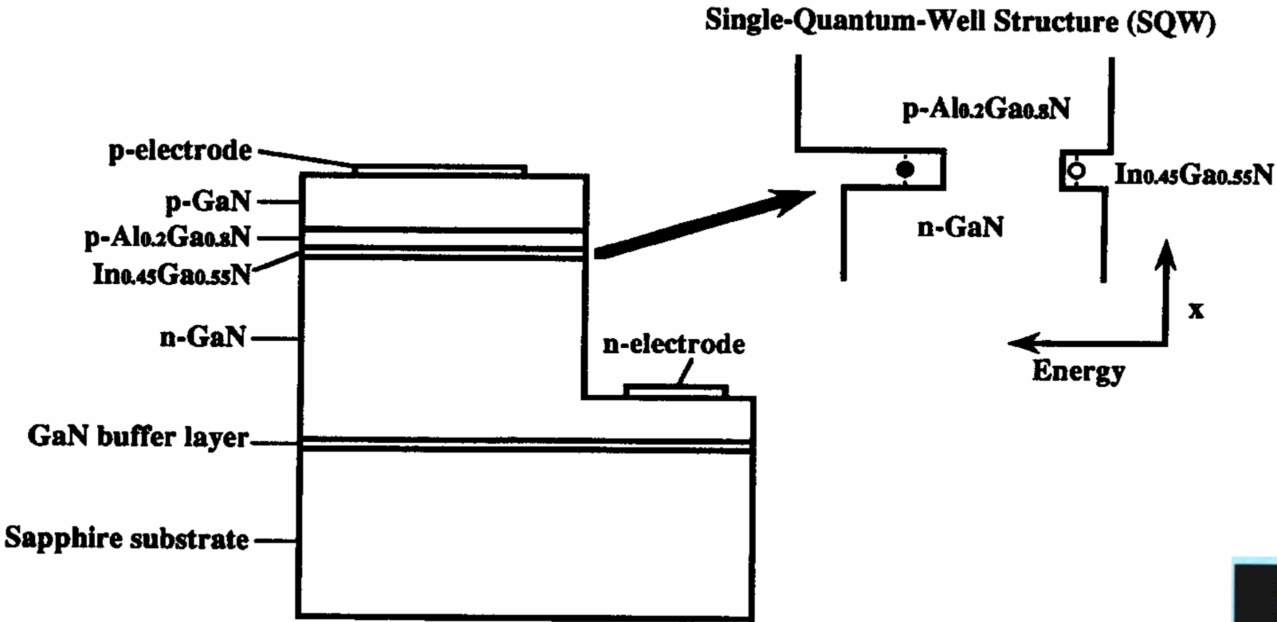
Zn

Se

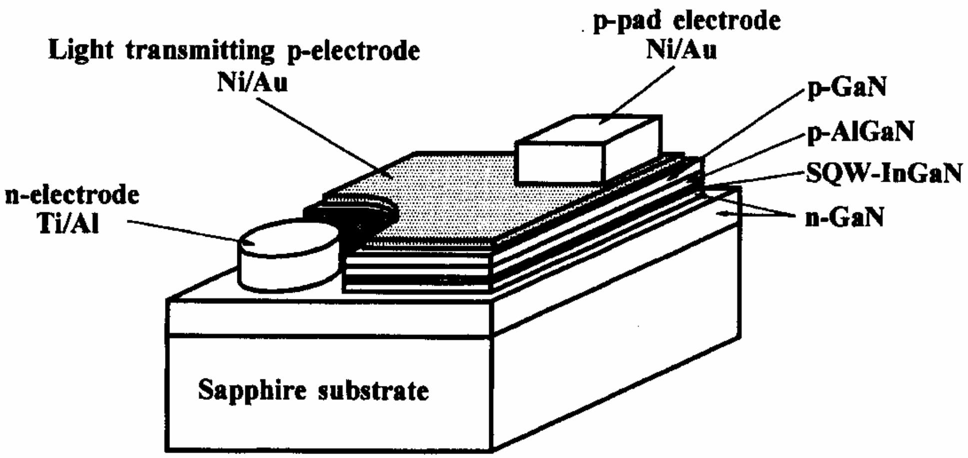
Eg=2.8 V

原子排列與堆疊 魔術師:操控晶格常數 能隙等

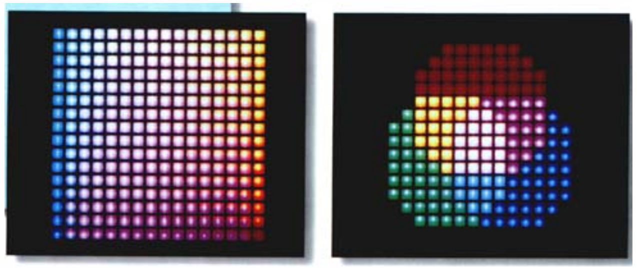
InGaN green SQW LEDs

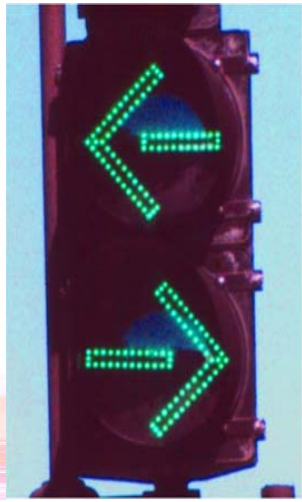


The structure of a green SQW LED



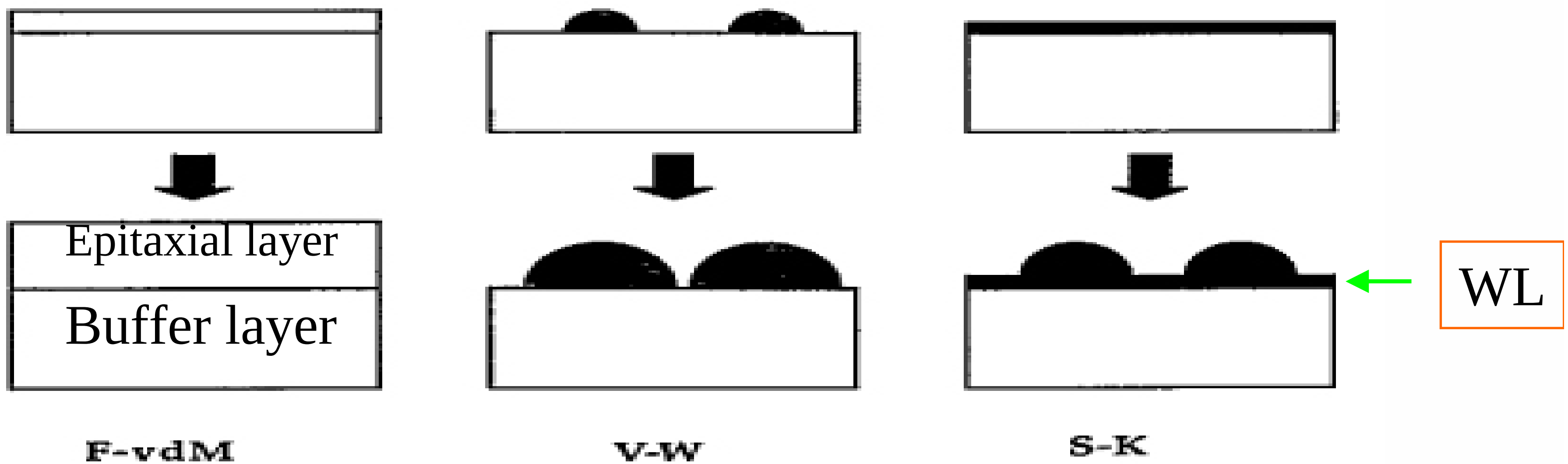
Schematic drawing of the SQW LED





Self-assembled nanostructures, Self-organized quantum dots (QDs)

自聚性量子點



Frank-van der Merwe 二維長晶模式

Volmer-Weber (VW) 三維長晶模式

Stranski-Krastanow (SK)從二維到三維長晶模式**(wetting layer, WL)**

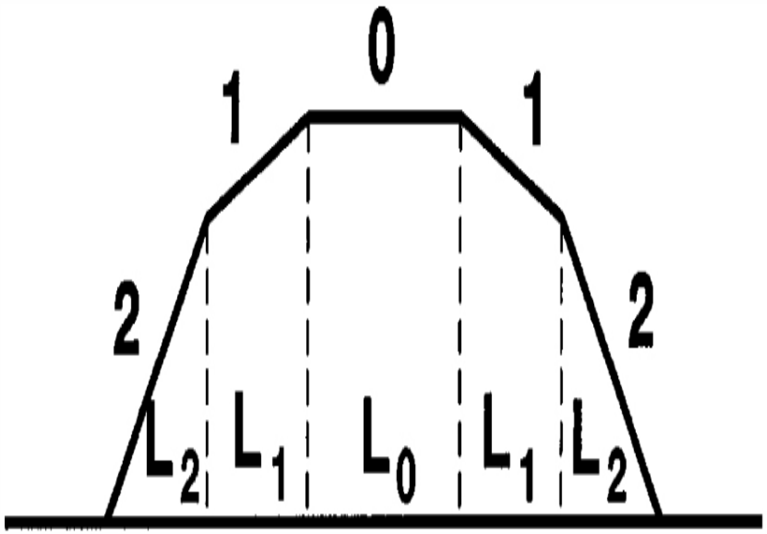
$$u(H, n_1, n_2, \varepsilon) = E_{ml}(n_1) + n_2 E_{isl} + (H - n_1 - n_2) E_{rip}$$

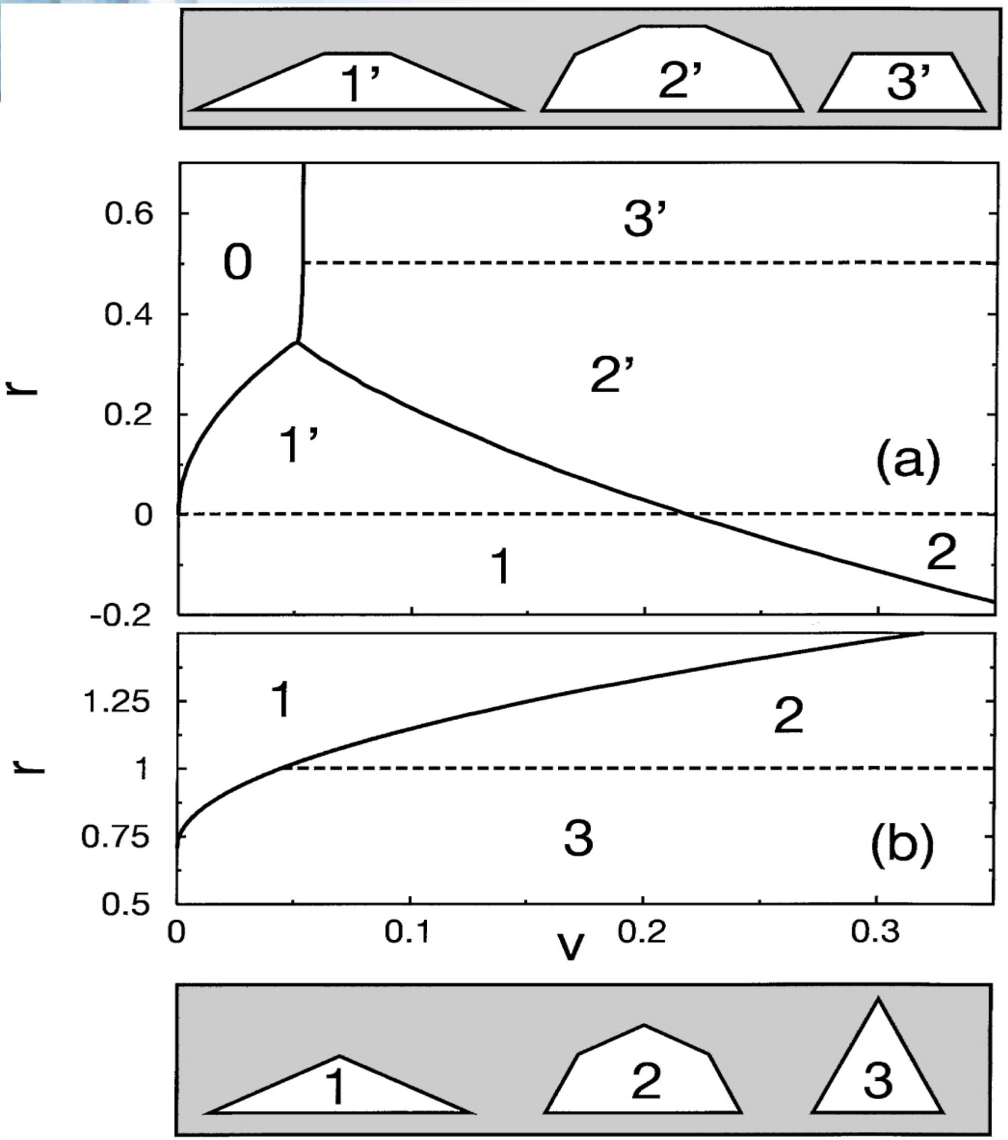
$$E_{ml}(n_1) = \int dn\{G + \Delta[\Theta(1-n) + \Theta(n-1)\, e^{-(n-1)/a}]\} \qquad G = C\varepsilon^2 - \Phi_{AA}$$

$$E_{isl} = gC\varepsilon^2 - \Phi_{AA} + E_0[-(2/x^2)\ln e^{1/2}x + \alpha/x + \beta(n_2)/x^{3/2}]$$

$$E_{rip} = E_{isl}(x \to \infty) = gC\varepsilon^2 - \Phi_{AA}$$

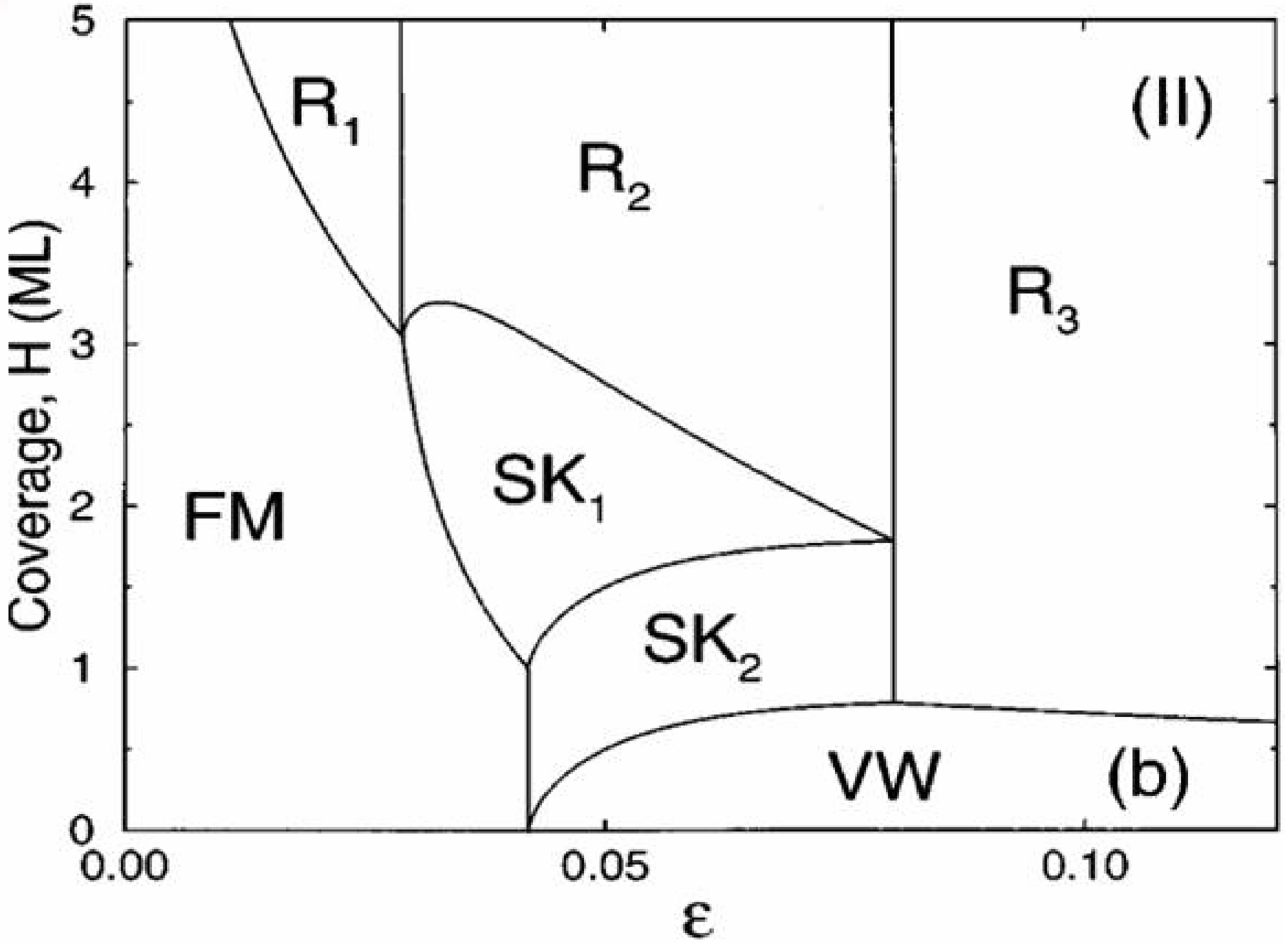
D.J. Eaglesham and M. Cerullo, PRL 64, 1943 (1990)





Key: strained islands **change shape during growth**, **phase diagram**, **surface energy controls the sequence of island shapes**.

I Daruka et al., PRL 82, 2753 (1999)

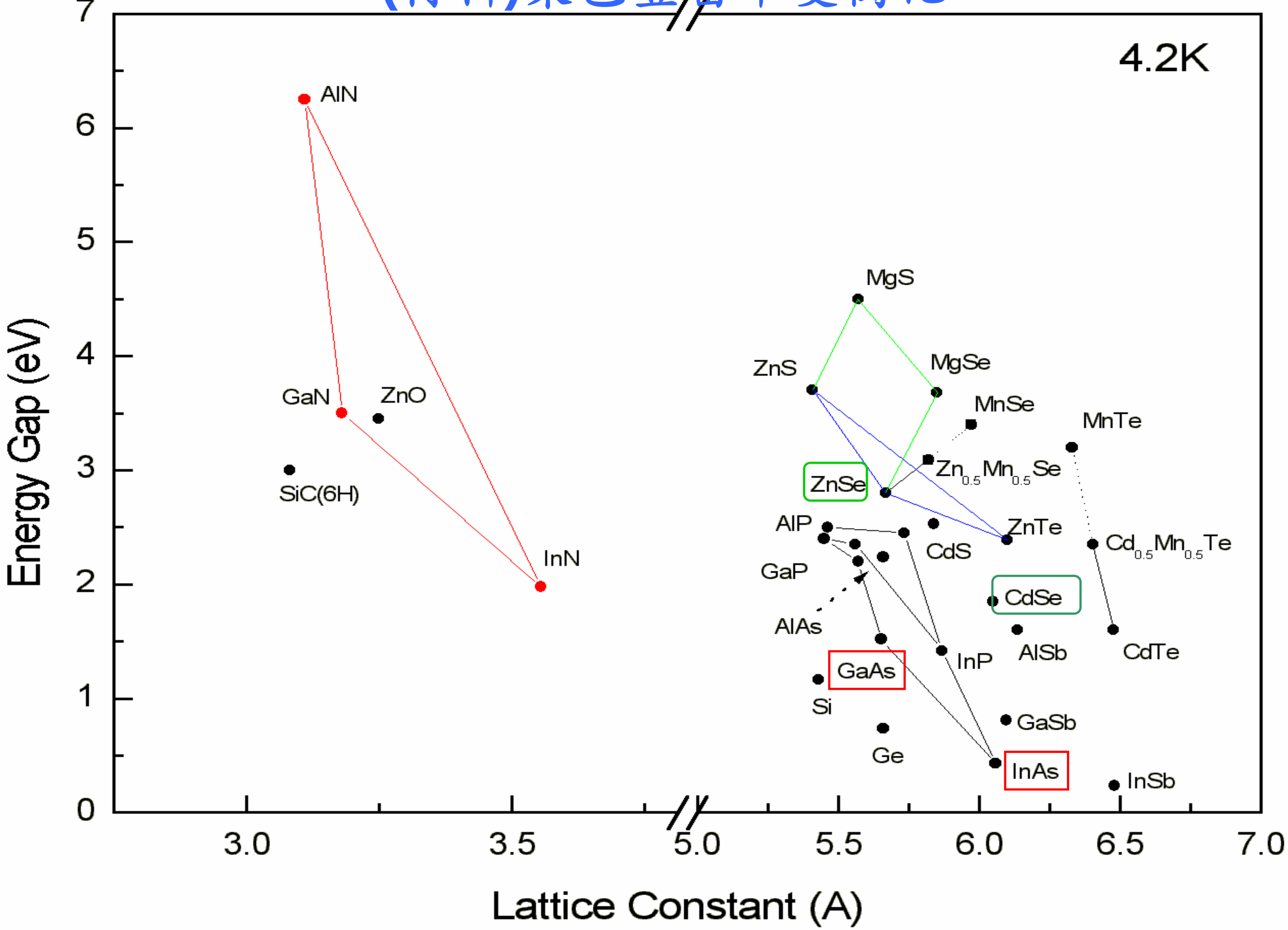


$$u(H, n_1, n_2, \varepsilon) = E_{ml}(n_1) + n_2 E_{isl} + (H - n_1 - n_2) E_{rip}$$

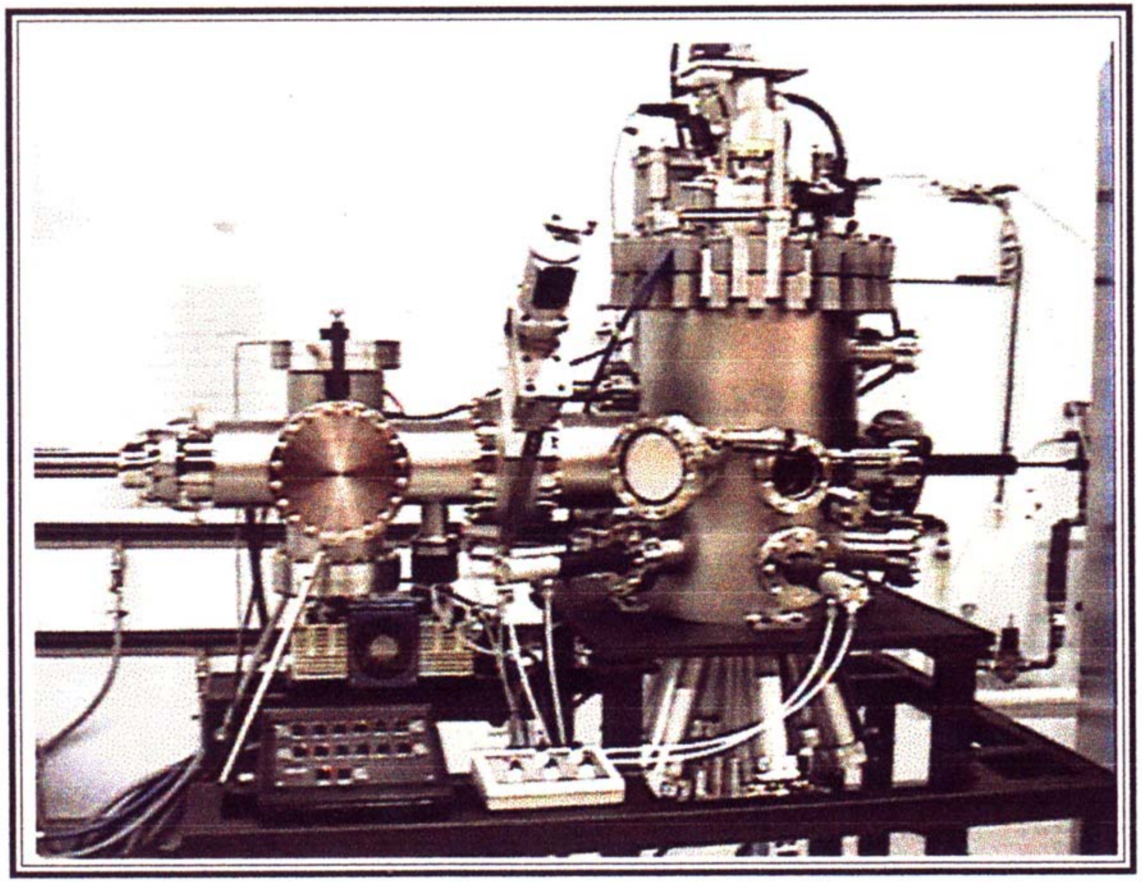
- I. Daruka and A.L. Barabasi, APL 72, 2102 (1998)

Energy Gap vs Lattice Constant

(材料)菜色豐富千變萬化

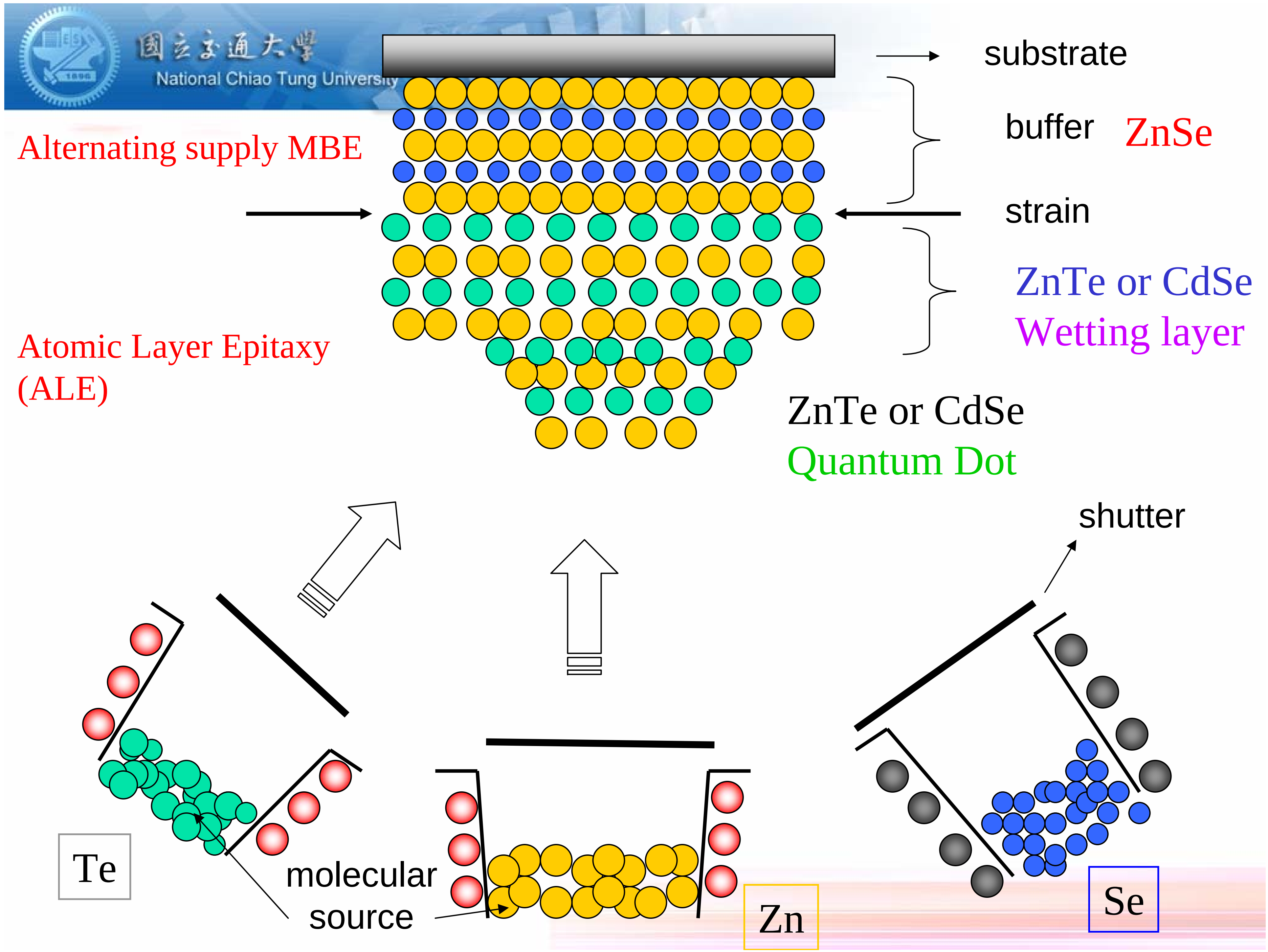


EPI
Model 620
Molecular Beam Epitaxy System



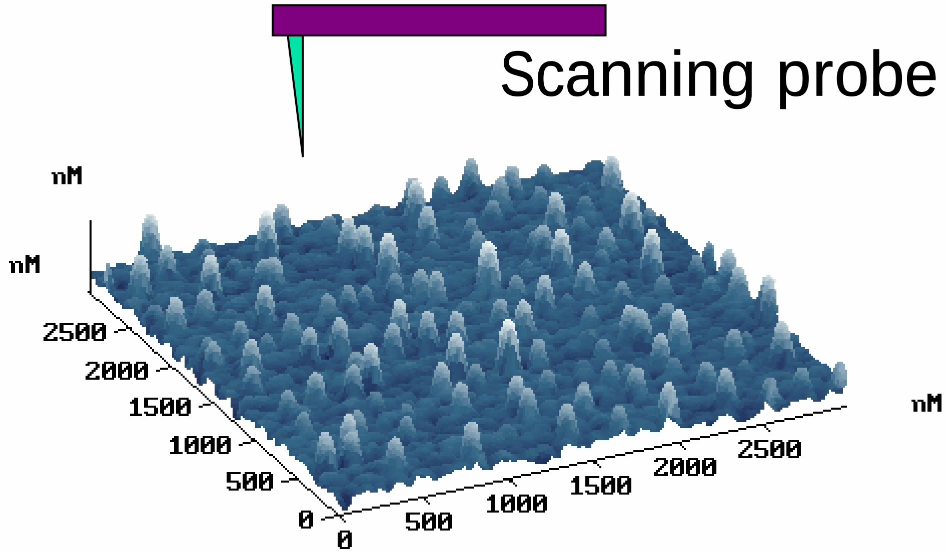
Rev Date: 11/96

超高真空操作程序與重要性、分子束源種類及調控磊晶速率

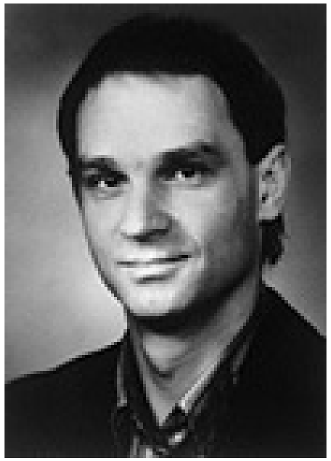

國立交通大學
National Chiao Tung University
Alternating supply MBE
Atomic Layer Epitaxy
(ALE)
substrate
buffer
ZnSe
strain
ZnTe or CdSe
Wetting layer
ZnTe or CdSe
Quantum Dot
shutter
Te
molecular
source
Zn
Se

Atomic force microscopy, AFM

Scanning probe microscopy



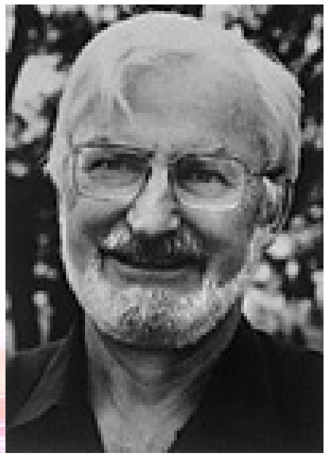
Gerd Binnig



1982IBM蘇黎世研究所的Gerd Binnig和Heinrich Rohrer及其同事研製第一臺達到原子分辨解析度的表面分析儀器，掃描穿隧顯微鏡(Scanning Tunneling Microscope, STM)。1986G. Binnig和同事發明原子力顯微鏡(Atomic Force Microscopy, AFM)。 (Note:scanning, computer control bit)

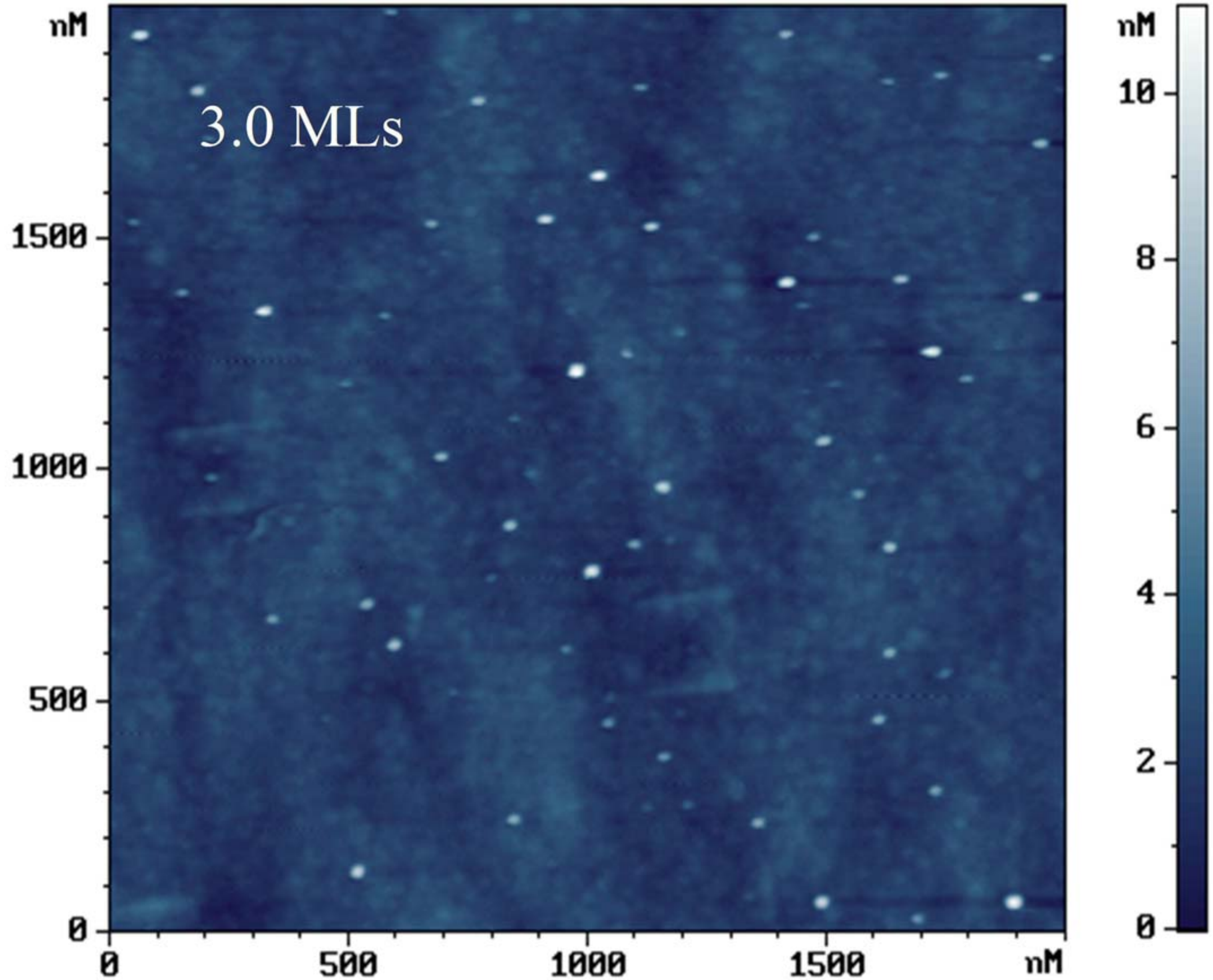
Scanning probe microscopy (SPM), SNOM

Heinrich Rohrer



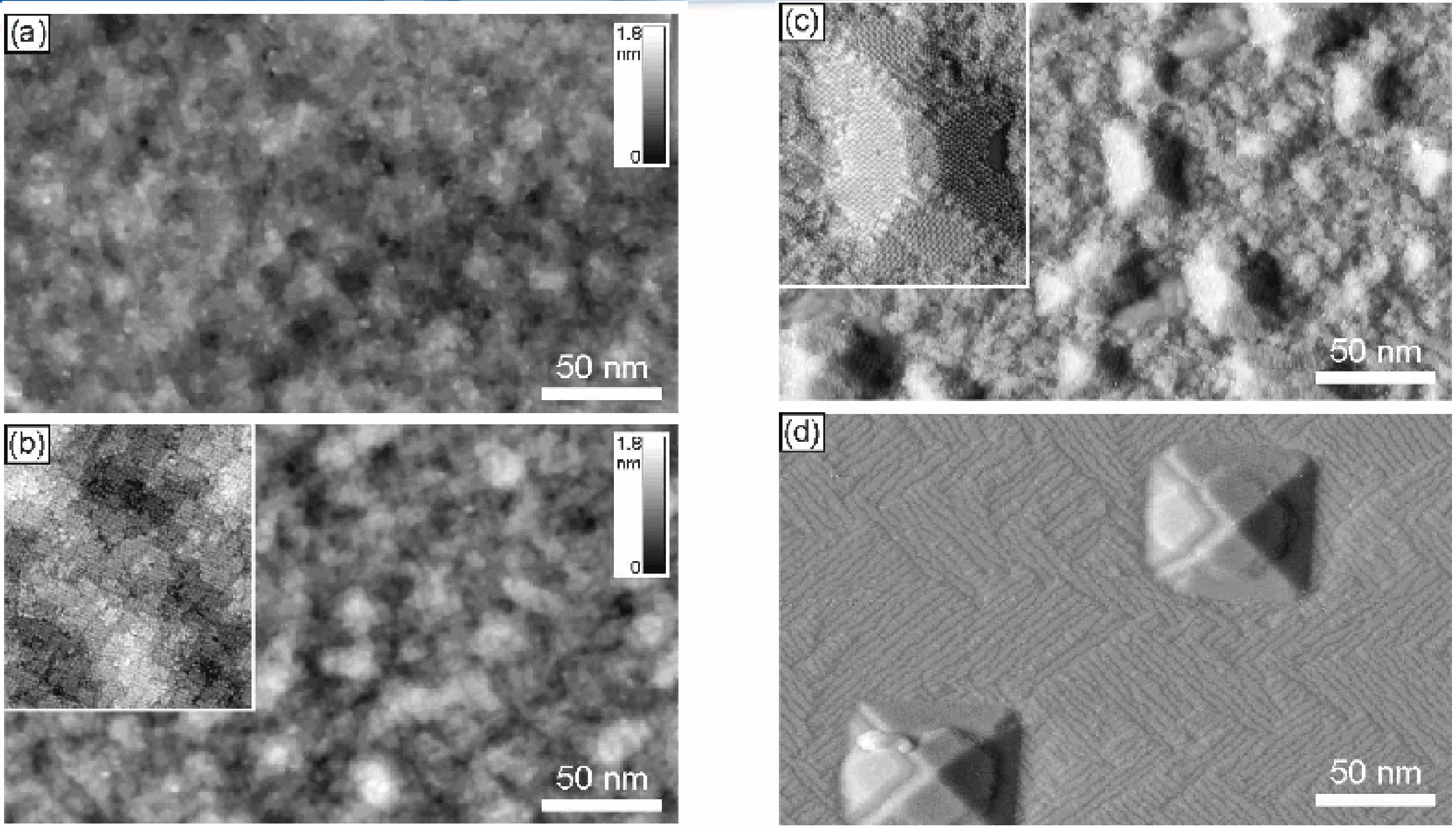
The Nobel Prize in Physics 1986

"for their design of the scanning tunneling microscope"



碲化鋅量子點之表面高低(明暗)形貌直徑約10-30奈米 AFM

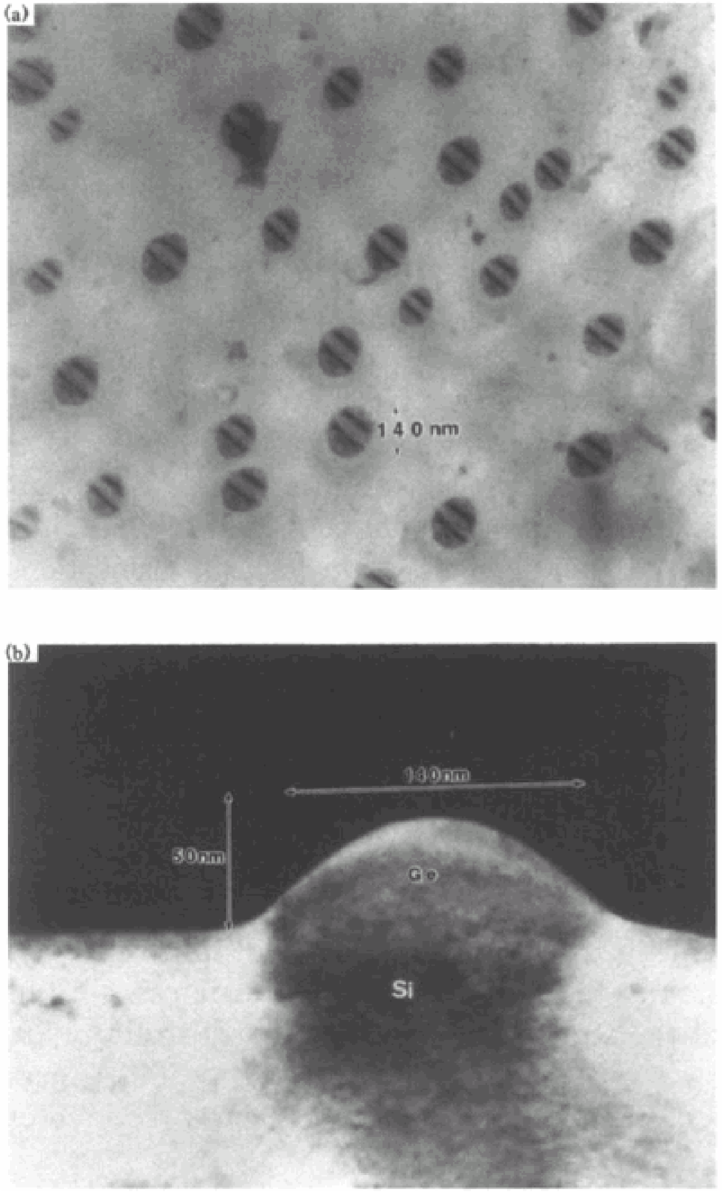
半導體奈米結構之形狀



In situ **scanning tunneling microscopy study of C-induced Ge quantum dot formation on Si(100)**

O. Leifeld et al., APL74, 994 (1999)

Dislocation-Free Stranski-Krastanow Growth of Ge on Si(100)



D. J. Eaglesham and M. Cerullo

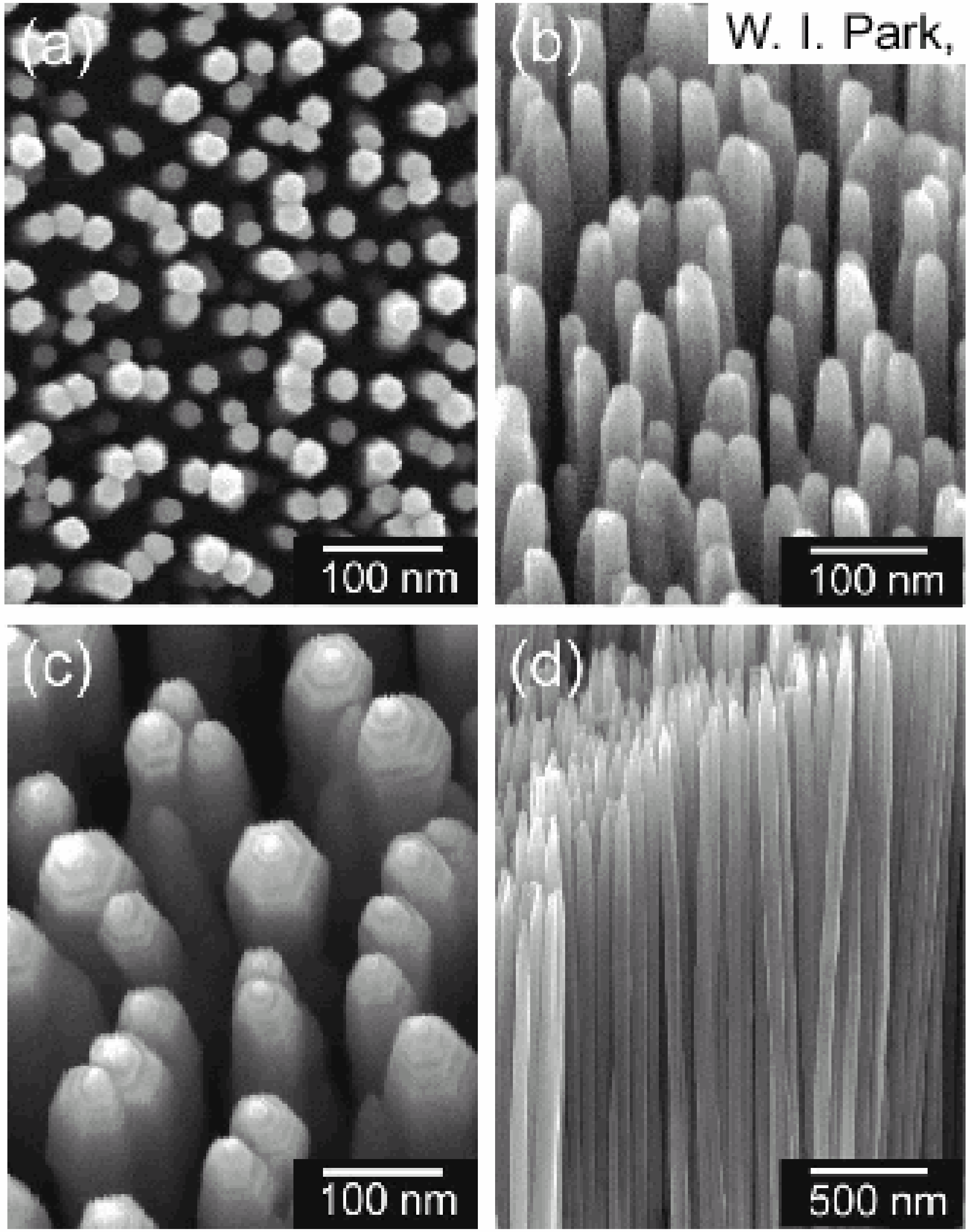
PRL64, 1943 (1990)

dome-shaped

半導體奈米結構之形狀

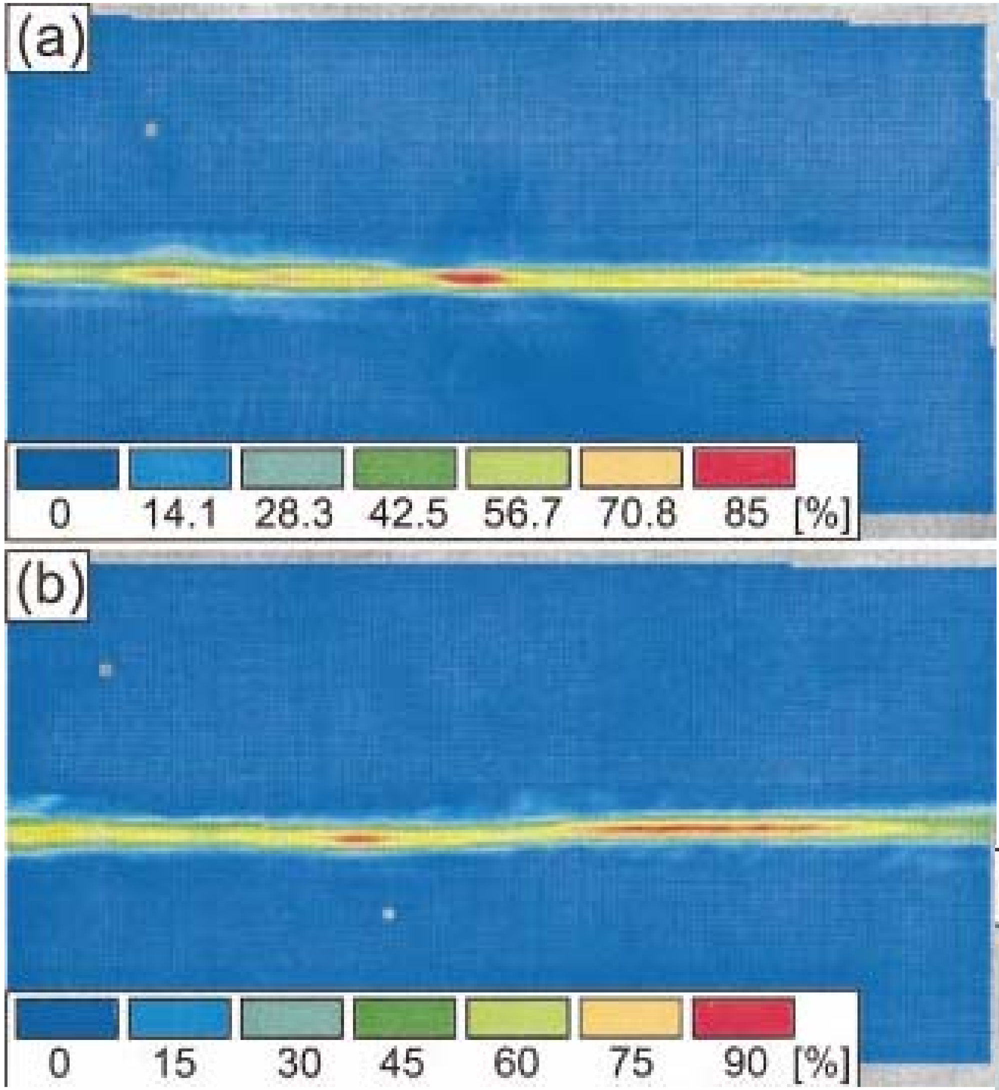
Metalorganic vapor-phase epitaxial growth of vertically well-aligned ZnO nanorods

W. I. Park, D. H. Kim, S.-W. Jung, and Gyu-Chul Yi[a)]

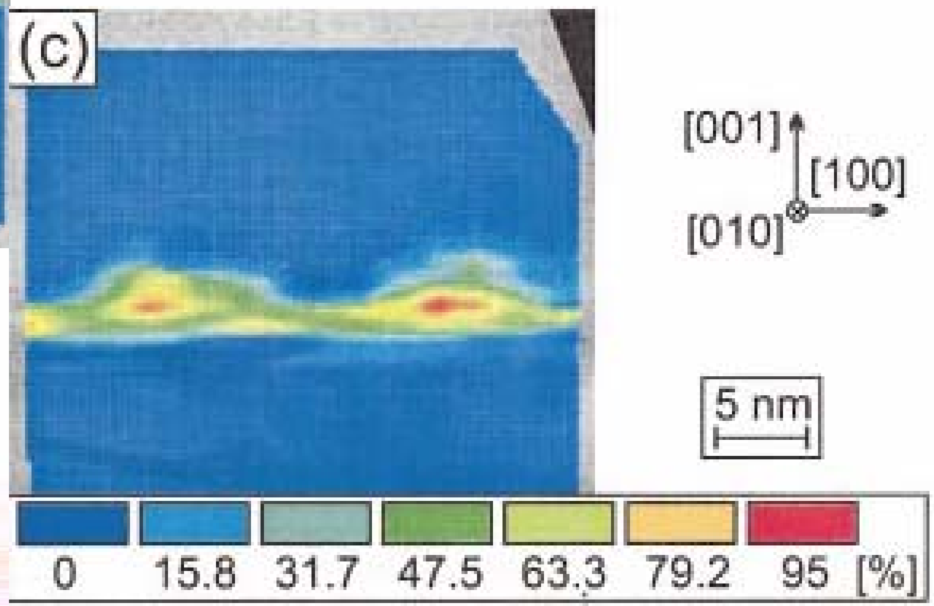


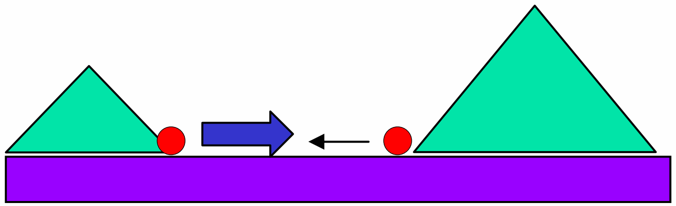
APL80, 4232 (2002)

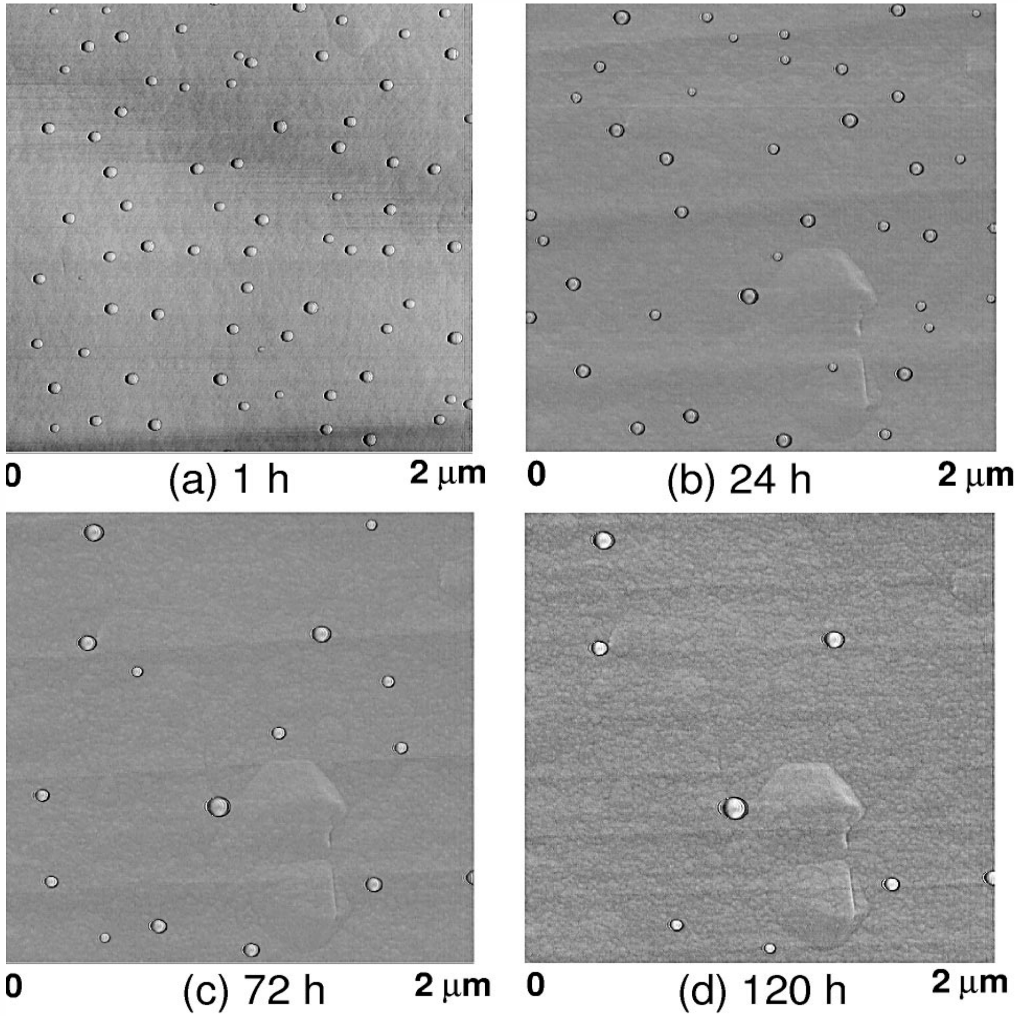
半導體奈米結構之形狀



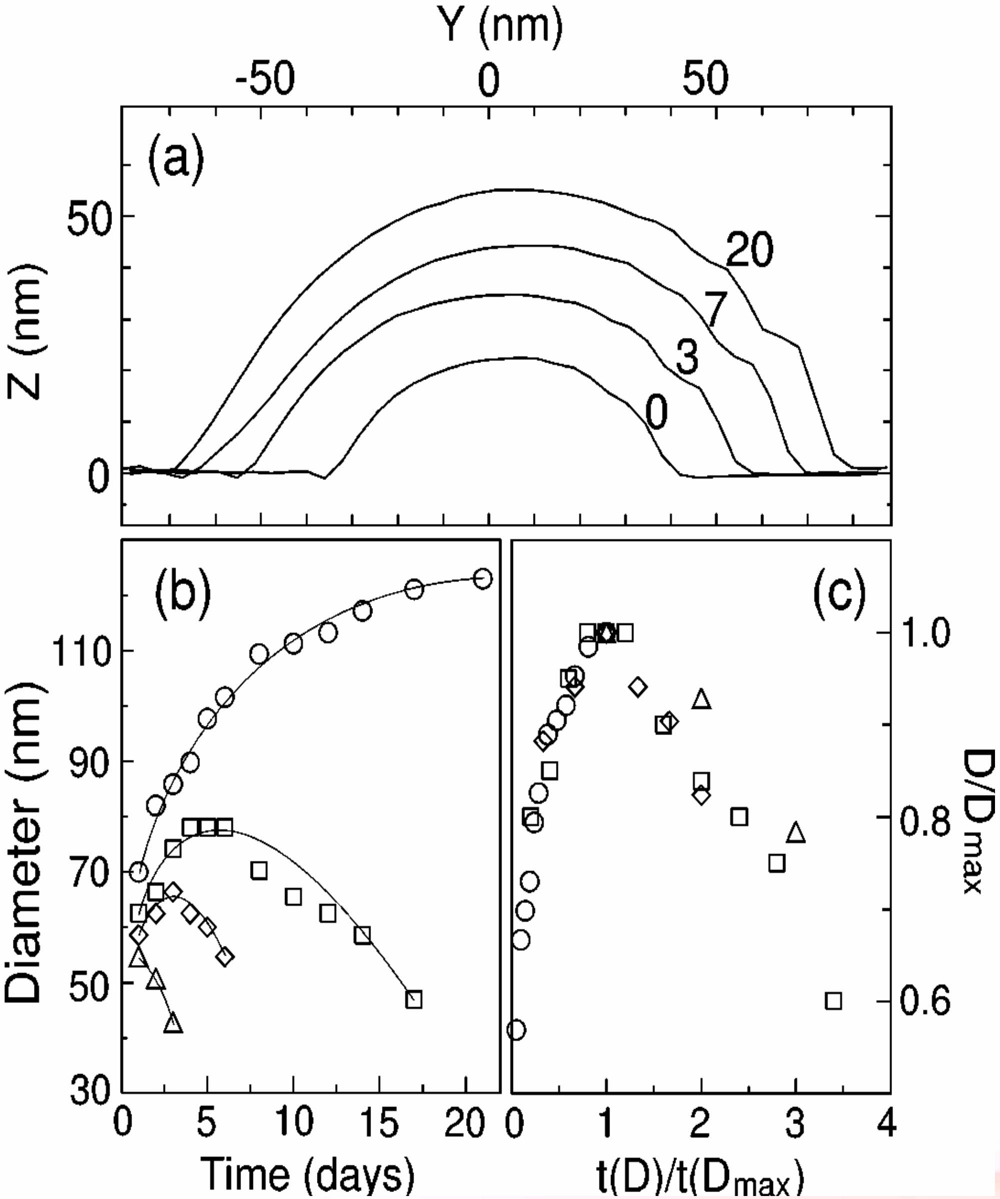
Ref. D. Litvinov et al.
APL 81, 640 (2002)



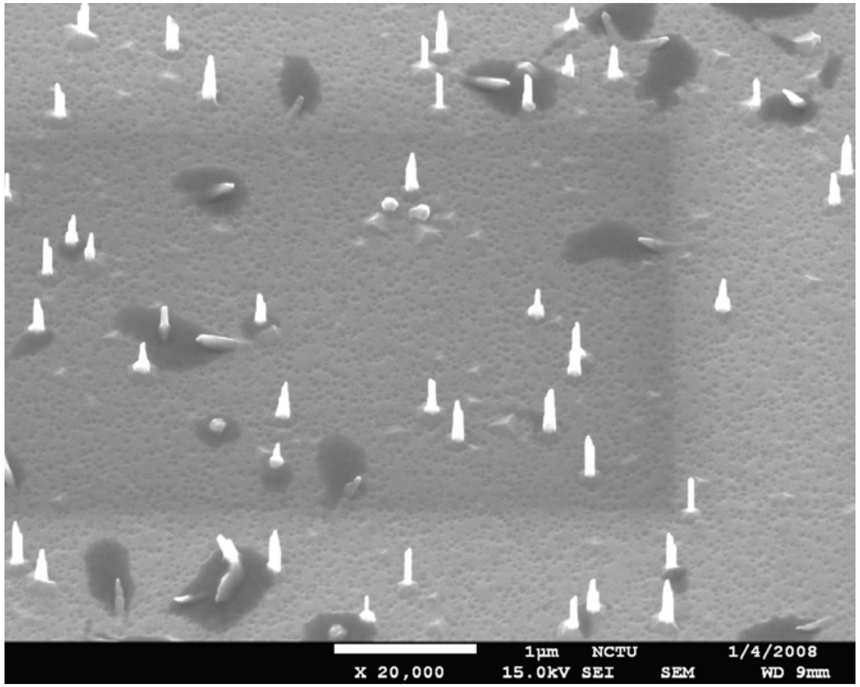


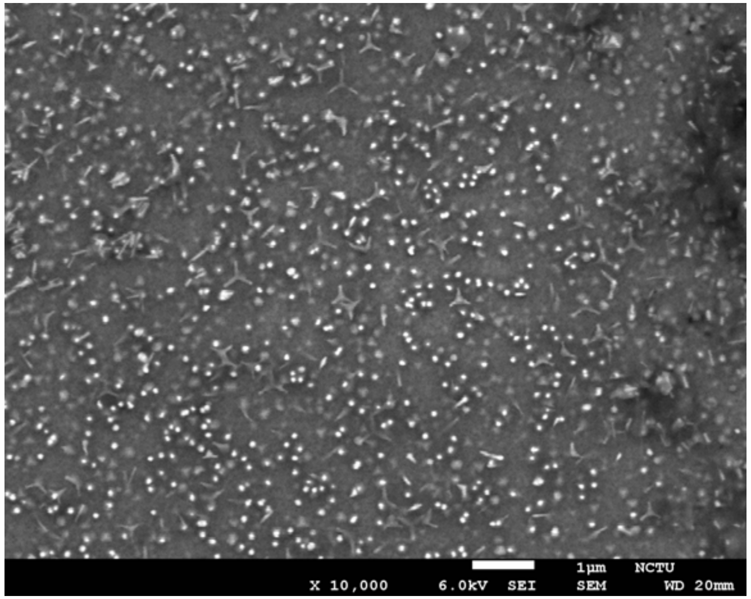


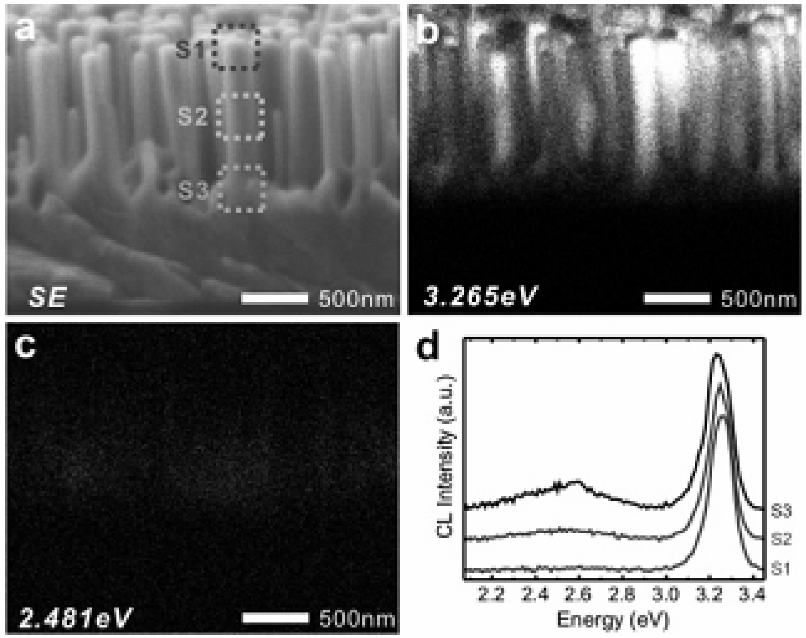
Ref. S.Lee et al., Phys. Rev. Lett. 81, 3479 (1998)

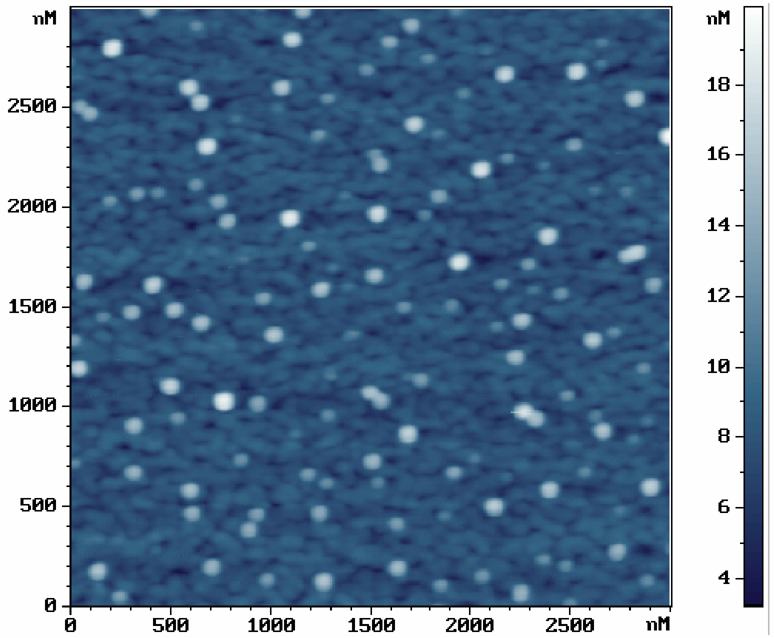

Y (nm)
-50
0
50
(a)
Z (nm)
50
0
20
7
3
0
(b)
Diameter (nm)
110
90
70
50
30
0
5
10
15
20
Time (days)
(c)
1.0
0.8
0.6
D/D_{max}
0
1
2
3
4
$t(D)/t(D_{max})$

ZnO nano-tip


1µm NCTU 1/4/2008
X 20,000 15.0kV SEI SEM WD 9mm


1µm NCTU
X 10,000 6.0kV SEI SEM WD 20mm


a
S1
S2
S3
SE
500nm
b
3.265eV
500nm
c
2.481eV
500nm
d
CL Intensity (a.u.)
Energy (eV)
2.2 2.4 2.6 2.8 3.0 3.2 3.4
S3
S2
S1



CdSe (3.0 MLs)/ZnSe/GaAs

Issue of size distribution