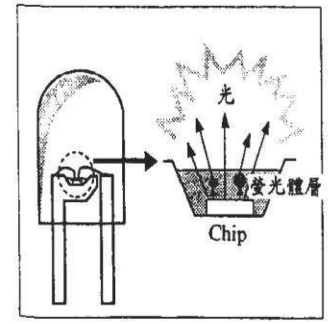
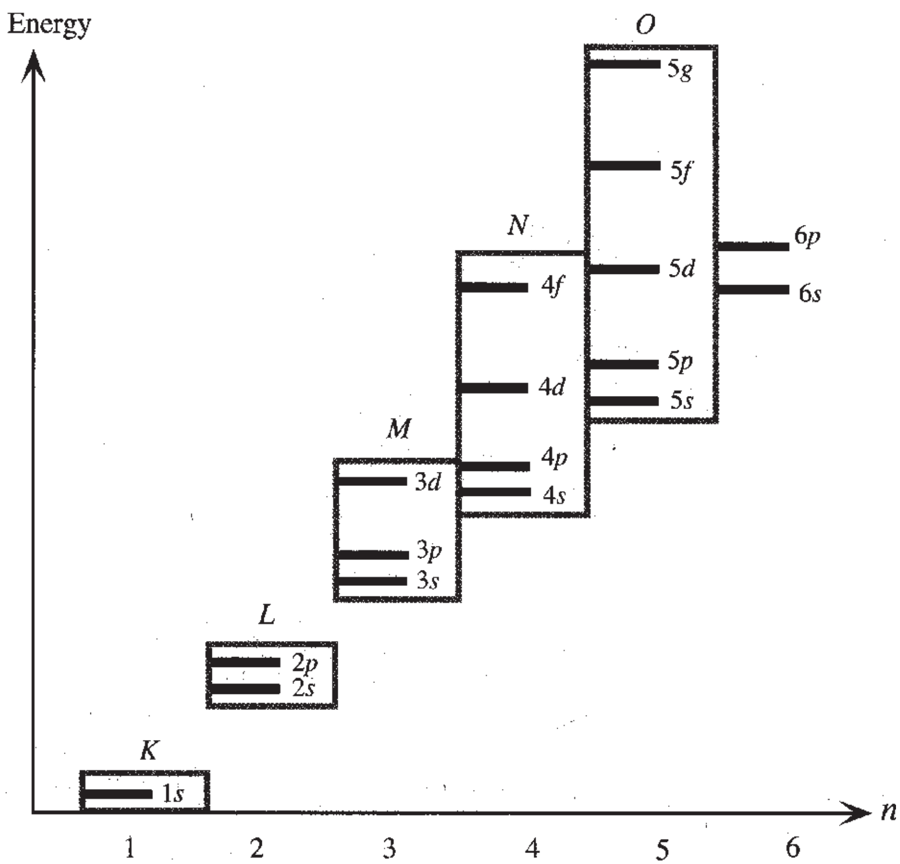


量子點發光介紹

Energy level scheme for atoms



⊙ 多電子原子中軌域填入的次序

1s
2s 2p
3s 3p 3d
4s 4p 4d 4f
5s 5p 5d 5f
6s 6p 6d
7s 7p

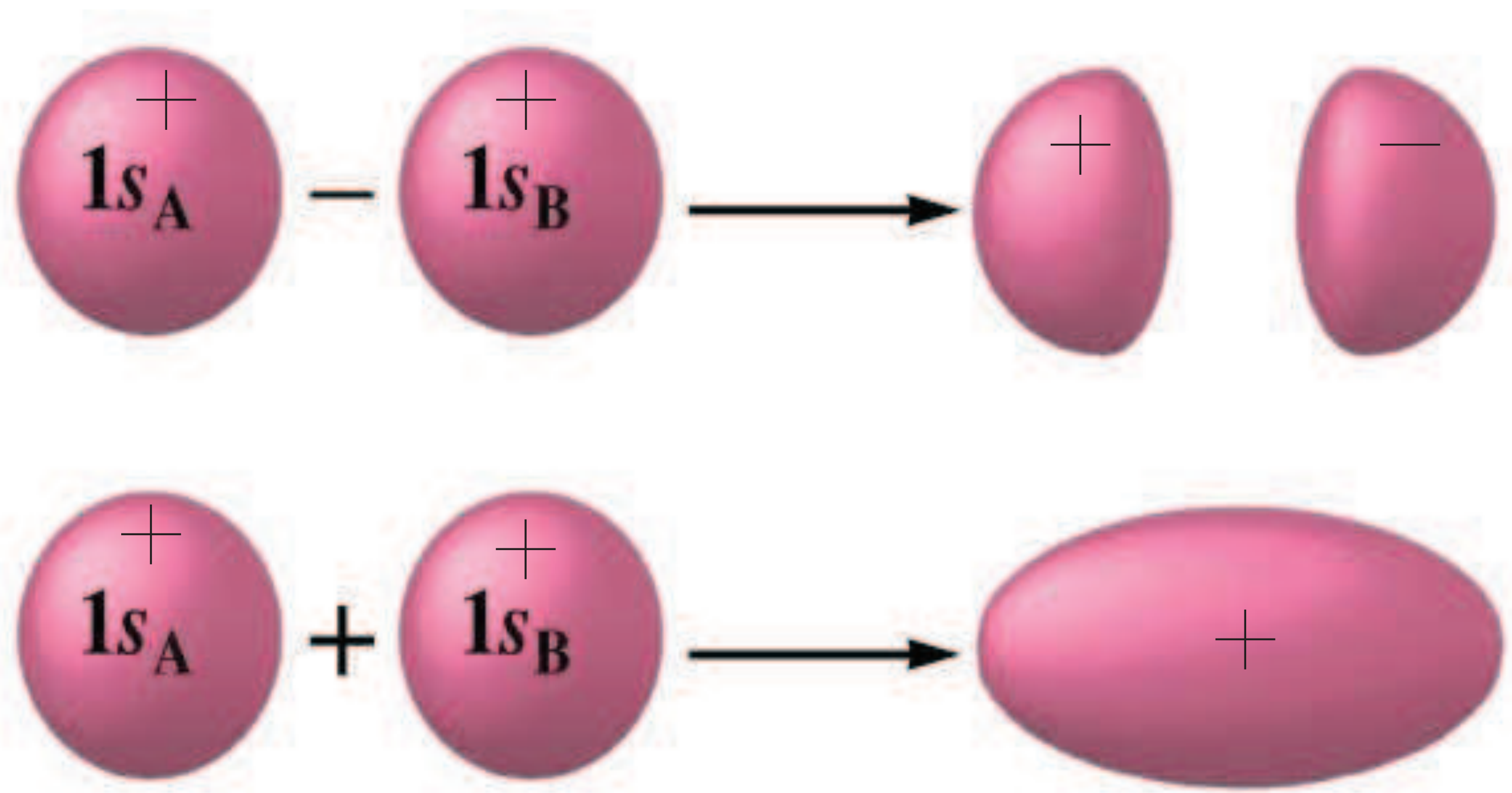
	1s	2s	2p			
$_7N$	↑↓	↑↓	↑	↑	↑	$1s^22s^22p^3$
$_8O$	↑↓	↑↓	↑↓	↑	↑	$1s^22s^22p^4$
$_9F$	↑↓	↑↓	↑↓	↑↓	↑	$1s^22s^22p^5$

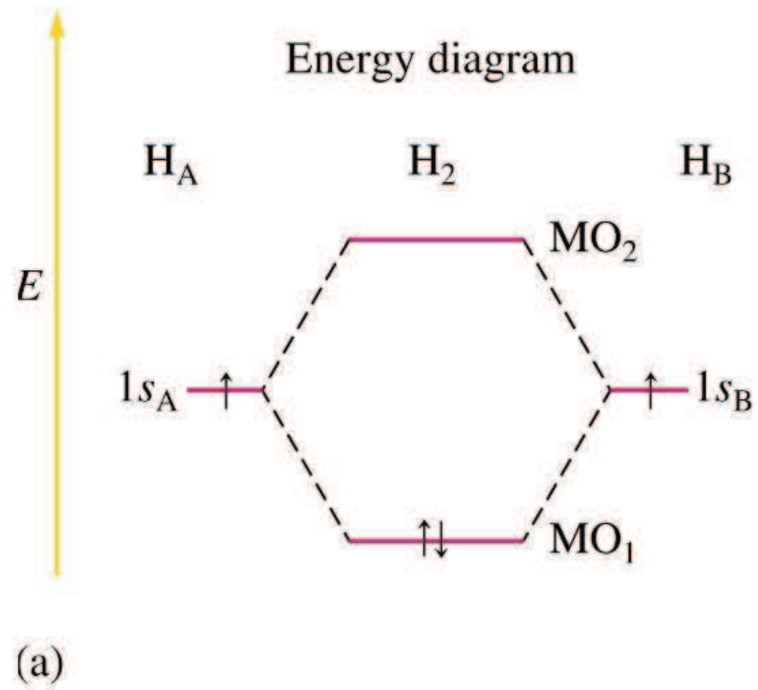
The Molecular Orbital Model (MO)

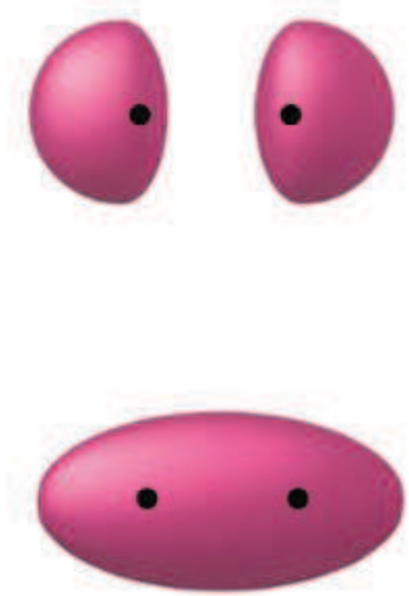
– **Molecular orbitals have many of the same characteristics as atomic orbitals**

– Two of the most important are :
  (1) they can hold two electrons with opposite spins and
  (2) the square of the molecular orbital wave function indicates the electron probability

e.g. The combination of hydrogen 1s atomic orbitals to form molecular orbitals

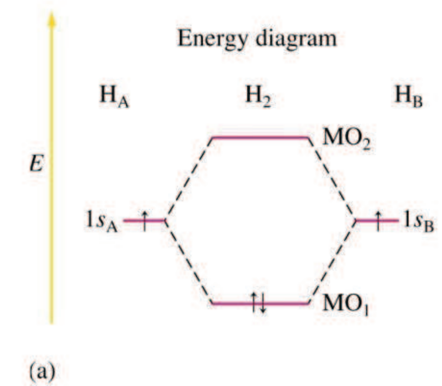






於分子中只有分子軌域可以被電子占據，表示氫原子之1*s*原子軌域不再存在，因為氫分子將有新的軌域生成

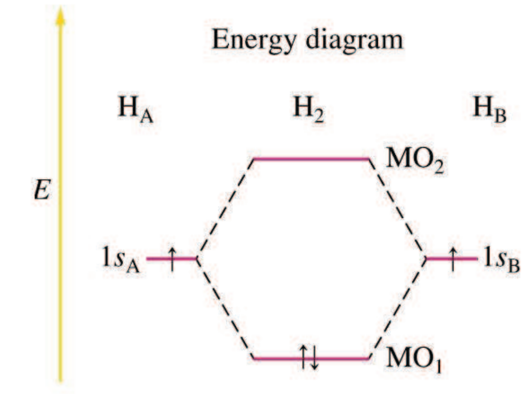
∵兩個分子軌域間的電子恰分布兩原子核的中心線(即核間軸)



- MO_1 之能階比 H 原子之 1*s* orbital 還低，而MO_2則比單一氫原子的 1*s* 軌域高

(a) => 電子填入氫分子之MO_1orbital (較氫原子之能階低)，有利於分子之形成，即有利於 bonding (鍵結) → 電子為兩原子核共享

(b) => 當電子分布在較高MO_2能階時，則稱為 antibonding (反鍵結) → 電子偏向原子各自獨立



(a)

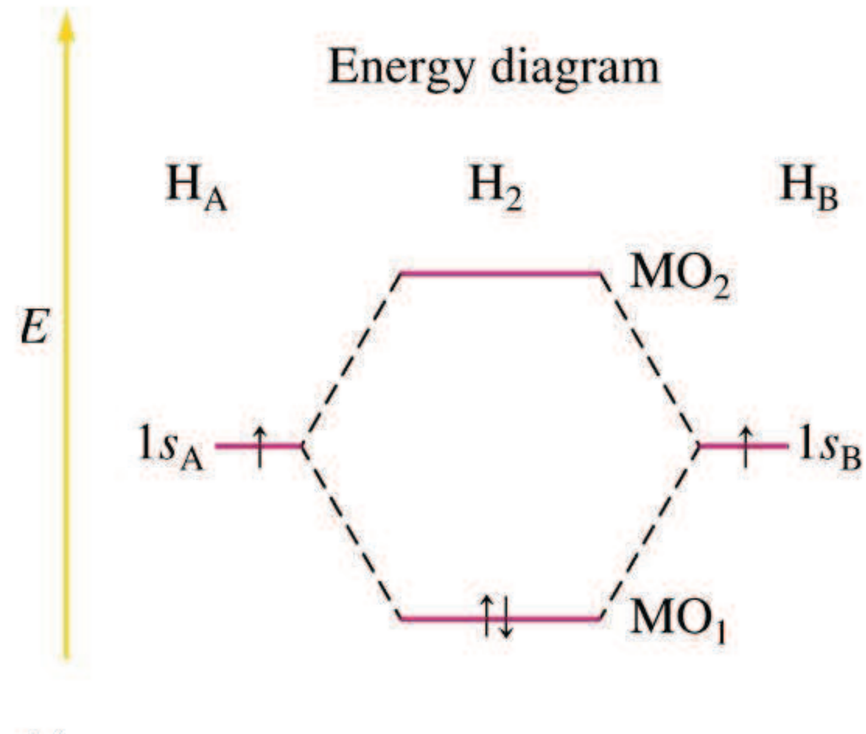
※ Bonding molecular orbital :

Lower in energy than the atomic orbitals of which it is composed. Electrons in this type of orbital favor the molecule; that is , they will favor bonding.

※ Antibonding molecular orbital :

Higher in energy than the atomic orbitals of which it is composed . Electrons in this type of orbital will favor the separated atoms.

A molecular orbital energy – level diagram for the H_2 molecule



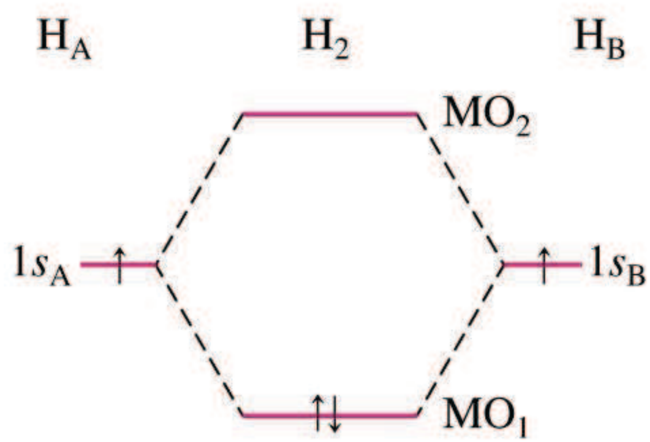
Molecular electron configuration for $H_2 = \sigma_{1s}{}^2$

- **Bond order = (number of bonding electrons — number of antibonding electrons) / 2**

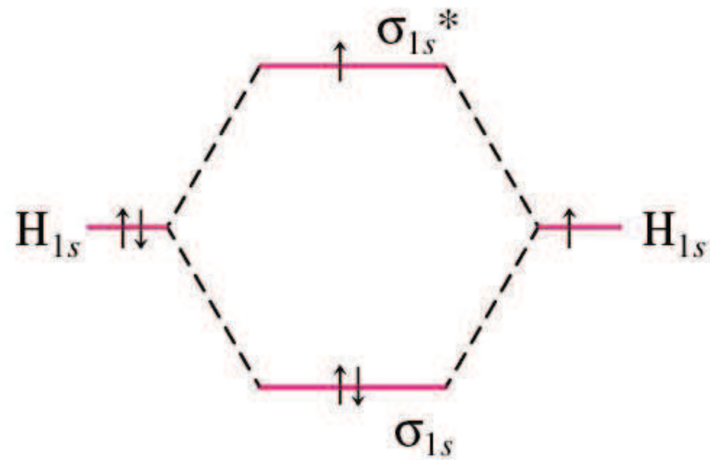
  – Bond order is an indication of bond strength, because it reflects the difference between the number of bonding electrons and the number of antibonding electrons, which in turn reflects the quantity of energy released when the molecule is formed from its atoms.

  – Larger bond order → shorter bond length → greater bond strength

e.g. Bond order ==> H_2 , H_2^-



H_2^-

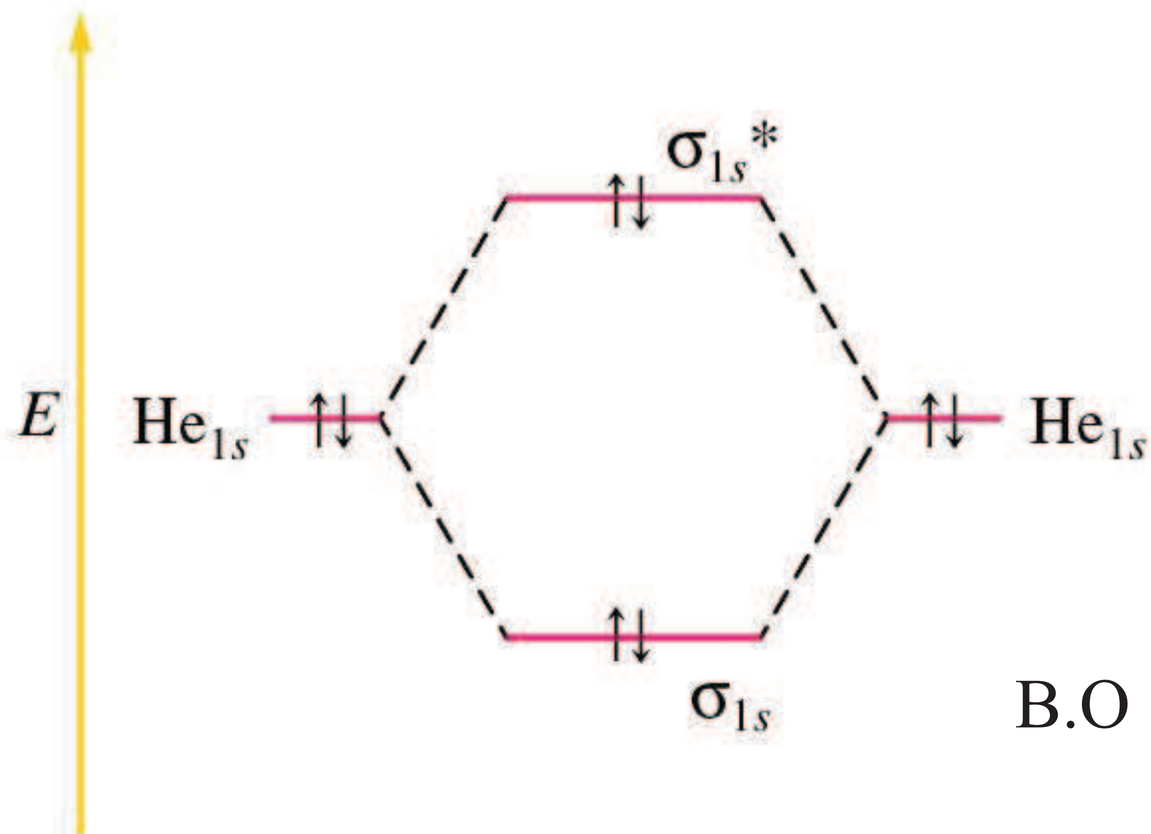


$$B.O. = \frac{2-0}{2} = 1$$

$$B.O = \frac{2-1}{2} = 1/2$$

H_2 較 H_2^- Stable，且前者 bond strength 為後者之2倍

e.g. He_2 是否 stable ?



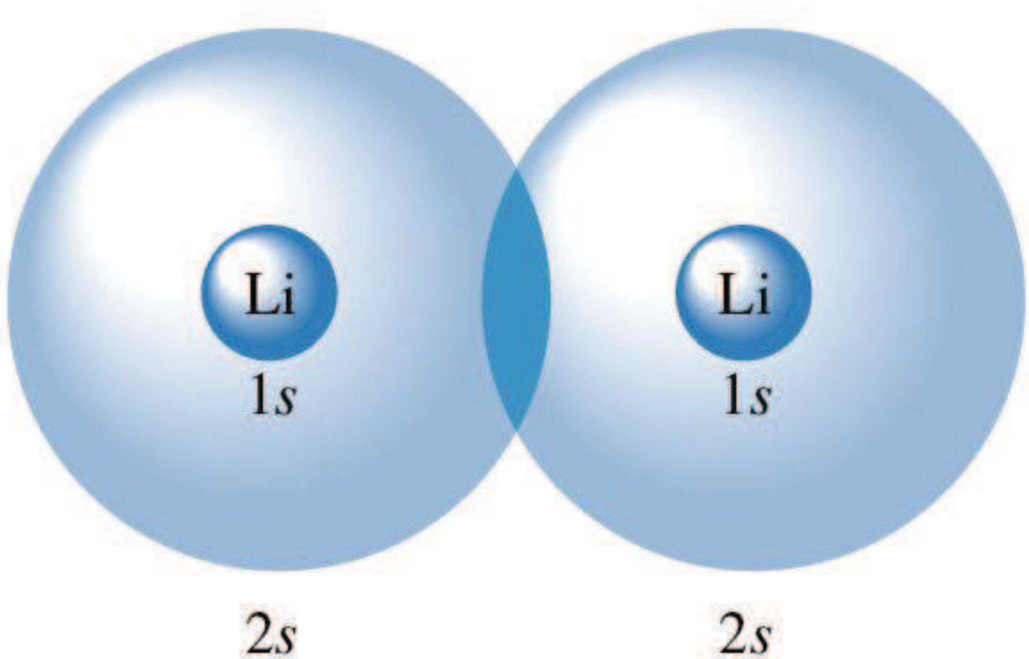
$$B.O = \frac{2-2}{2} = 0$$

$\therefore$ He_2 unstable

14.3 Bonding in Homonuclear Diatomic Molecules

e.g. Li_2

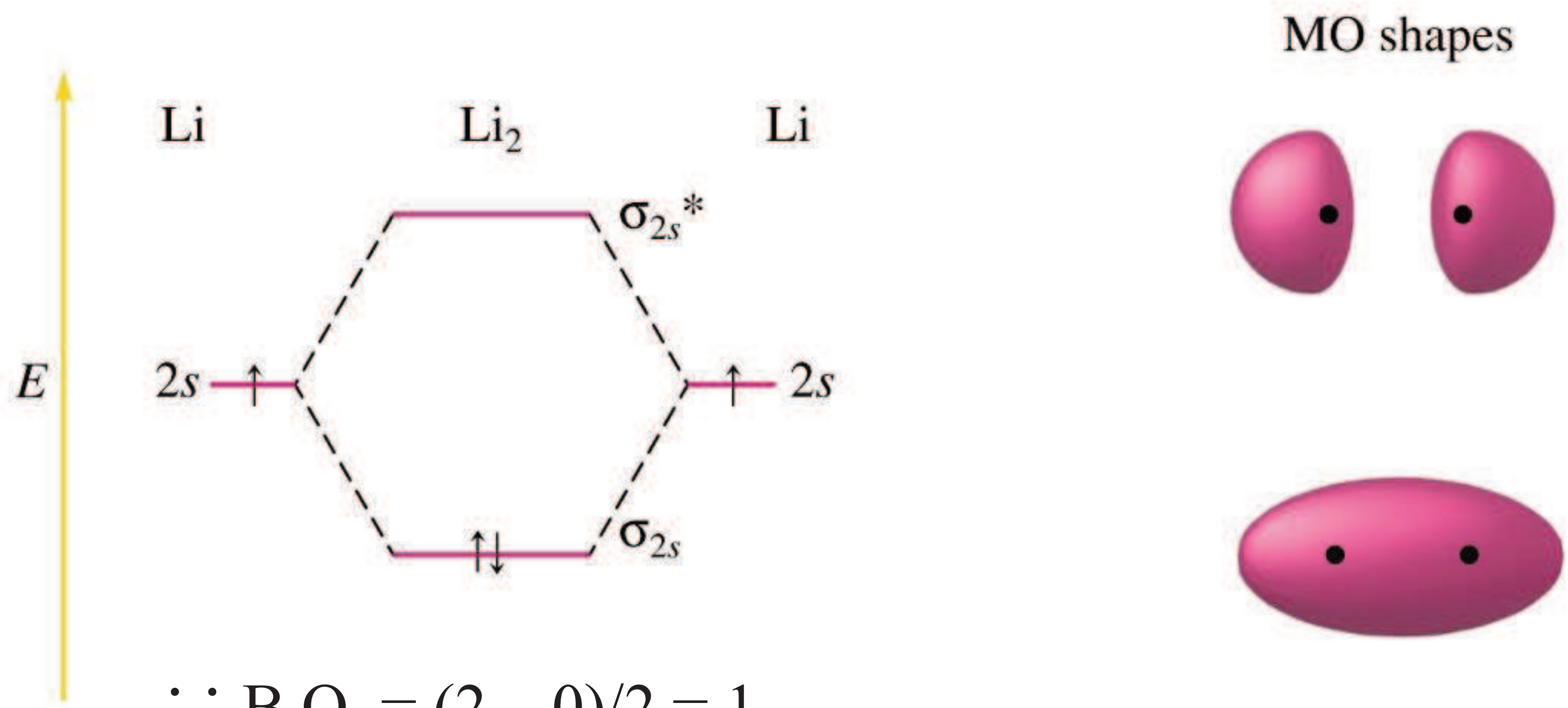
Li electron configuration ： $1s^2\,2s^1$



The relative sizes of the lithium 1*s* and 2*s* atomic orbitals

∵ 1*s* 軌域太小 => 1*s* 軌域並未重疊 => 未參與鍵結

Figure 14.34： Li_2 energy-level diagram

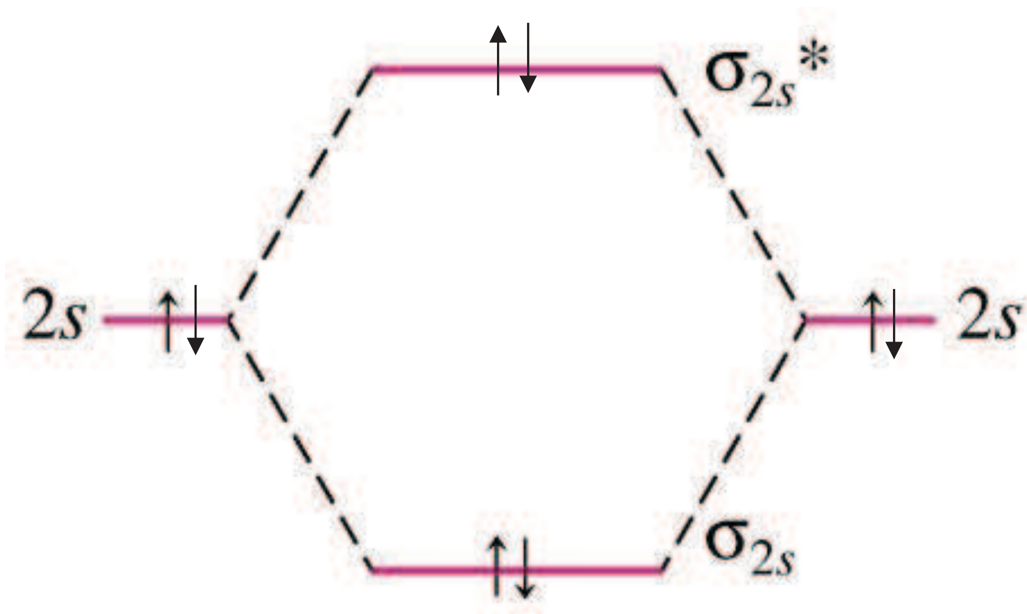


∵ B.O. = (2 – 0)/2 = 1

Li_2 => stable molecules

(但事實上常溫常壓下，許多Li 原子是互相鍵結在一起，而以固體之型式存在)

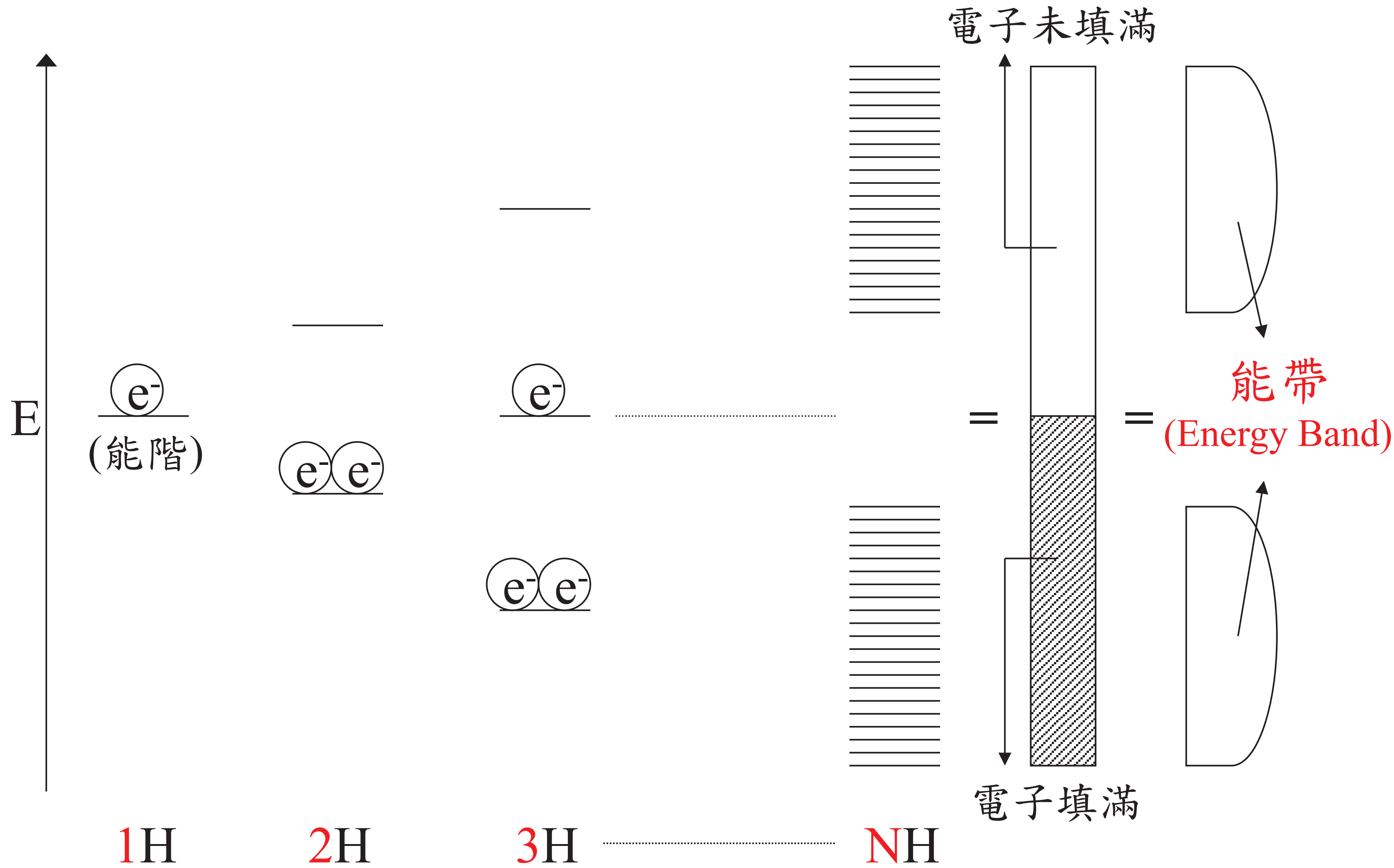
e.g. Be_2（4 個價電子）



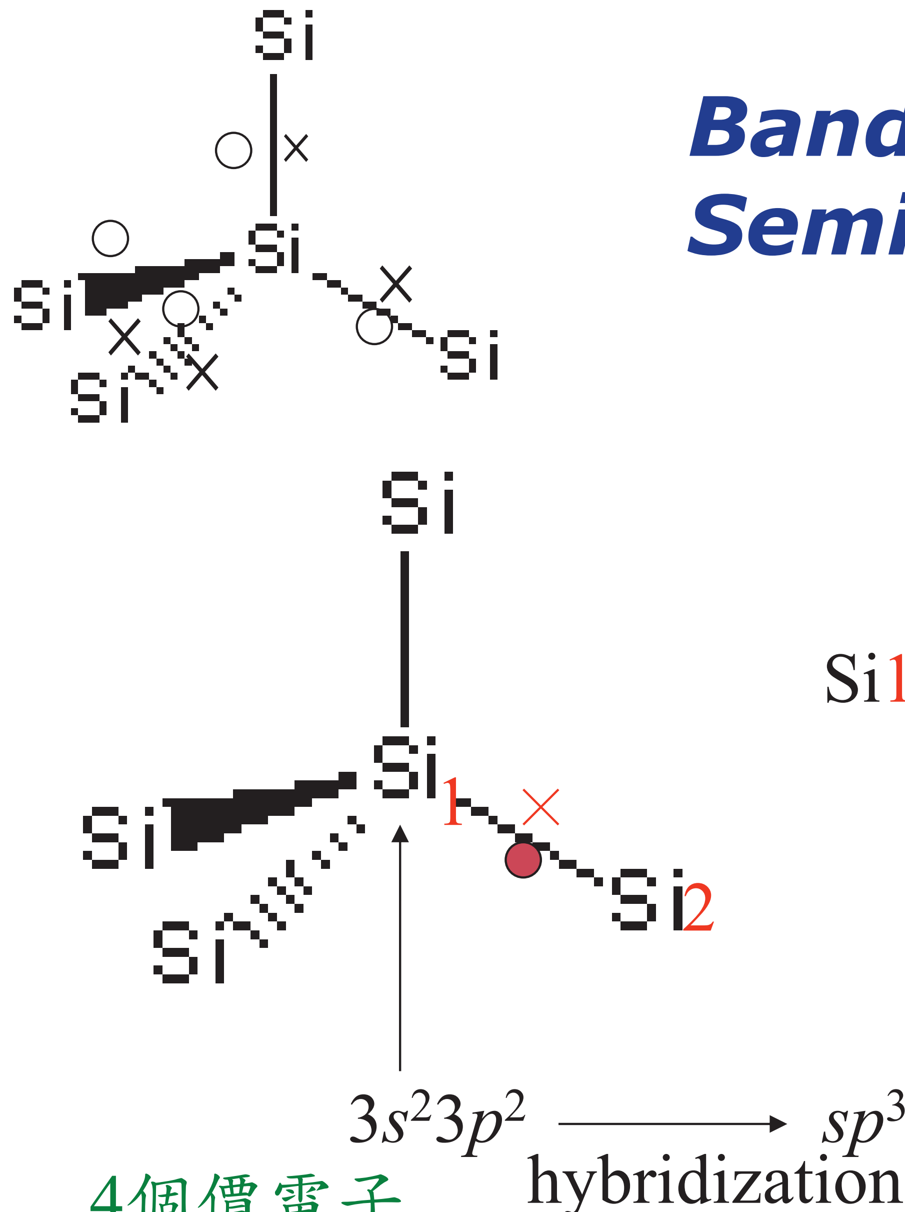
$$\text{B.O.} = (2 - 2)/2 = 0$$

$\therefore Be_2$ unstable

物體如何導電—Band Theory



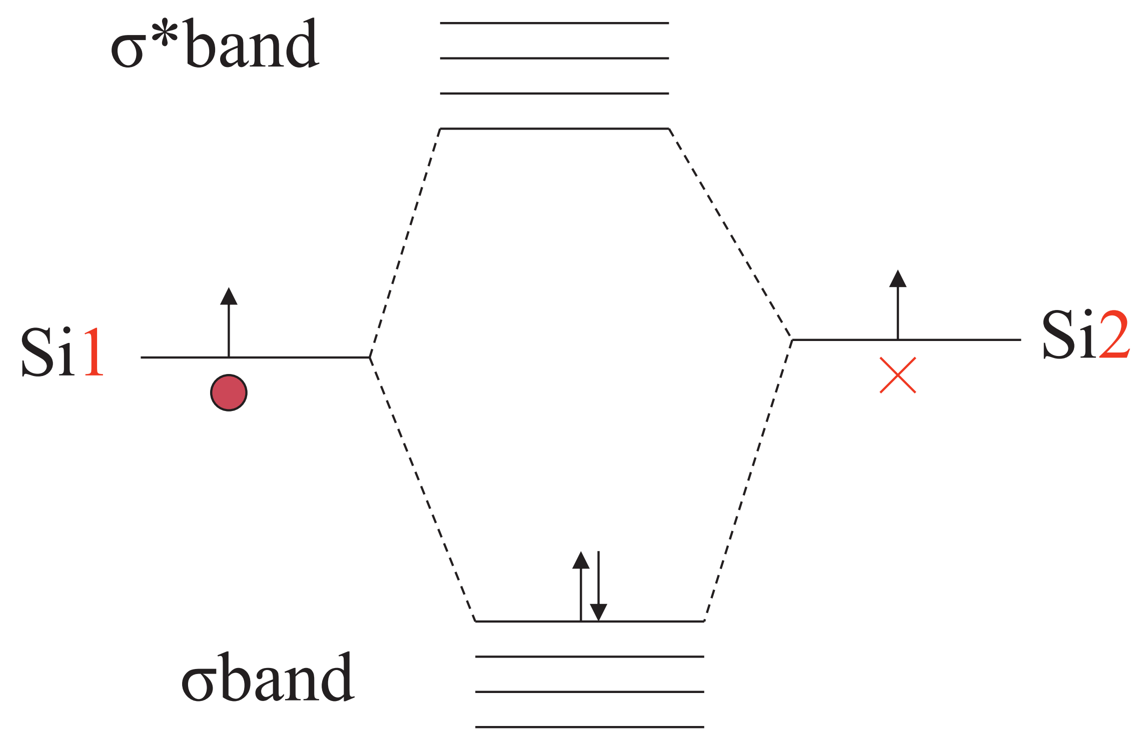
Intrinsic semiconductors



4個價電子

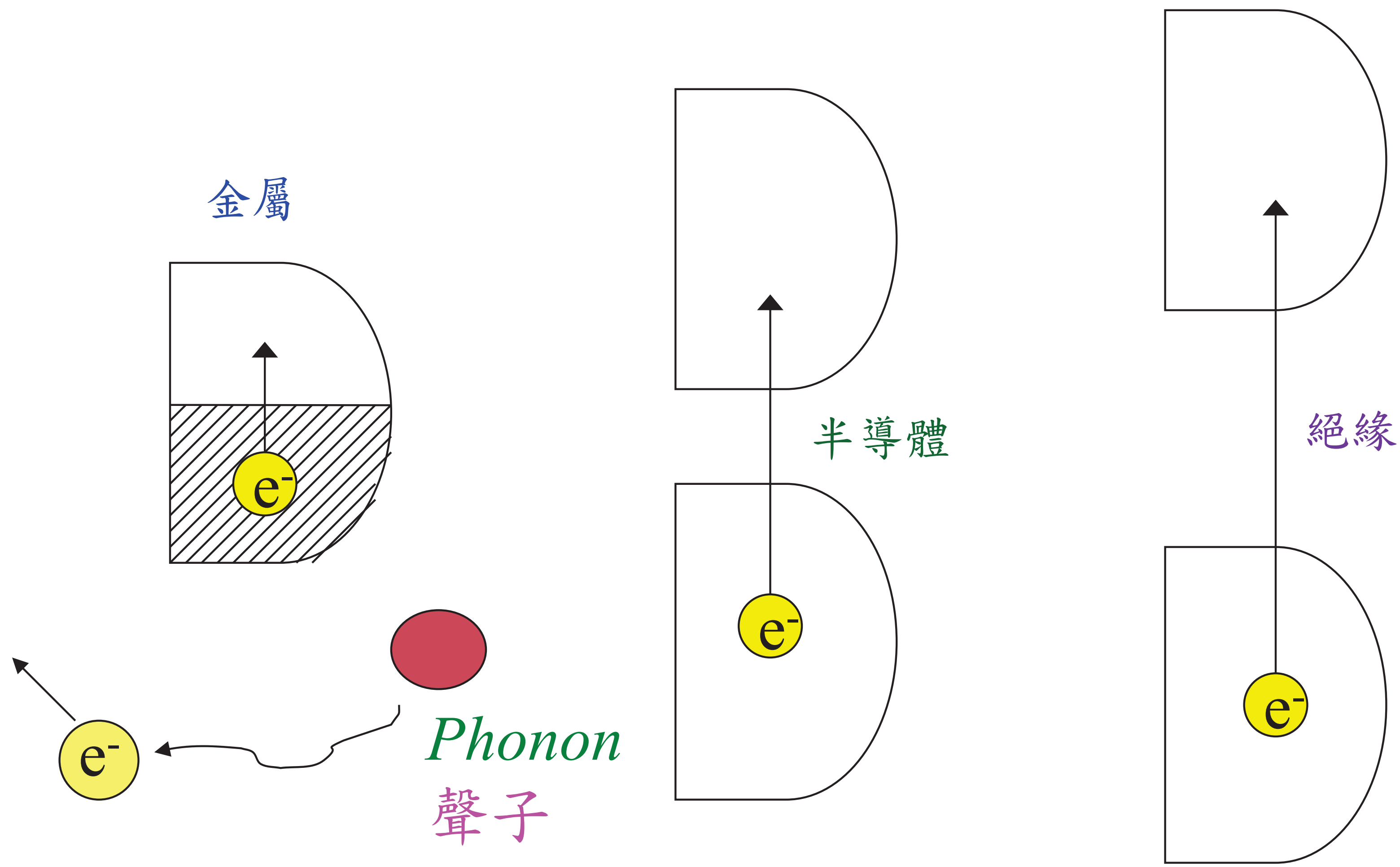
Band structure of Semiconductor (Si)

Empty band→conduction band



Valence band →full

金屬、半導體、絕緣體的導電模式



金屬	半導體	絕緣體
不需給予能量	需給予能量0.5~3 eV	需給予能量≧6 eV
(無能階差)	(能階差0.5~3 eV)	(能階差≧6 eV)
導電性佳	導電性一般或不良	導電性不良或不導電

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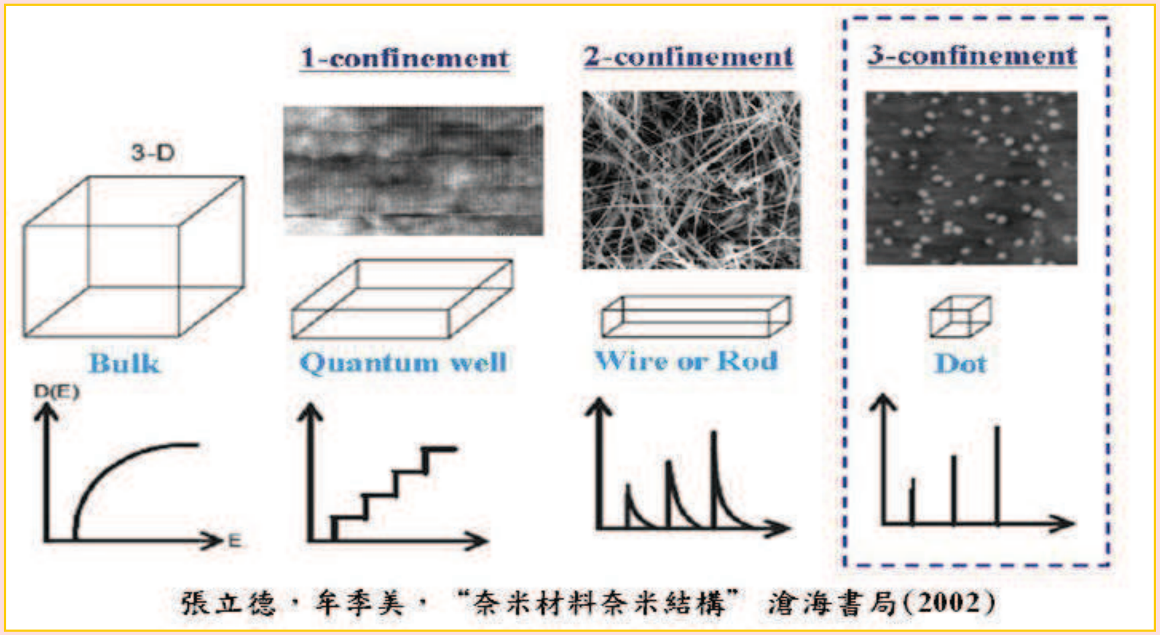
Materials Chemistry Laboratory
Department of Chemistry
National Taiwan University

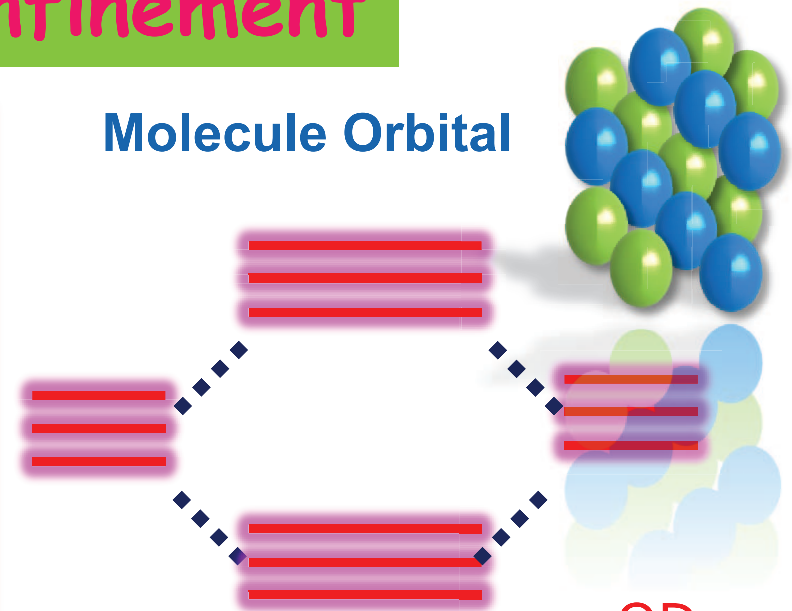
Quantum Confinement

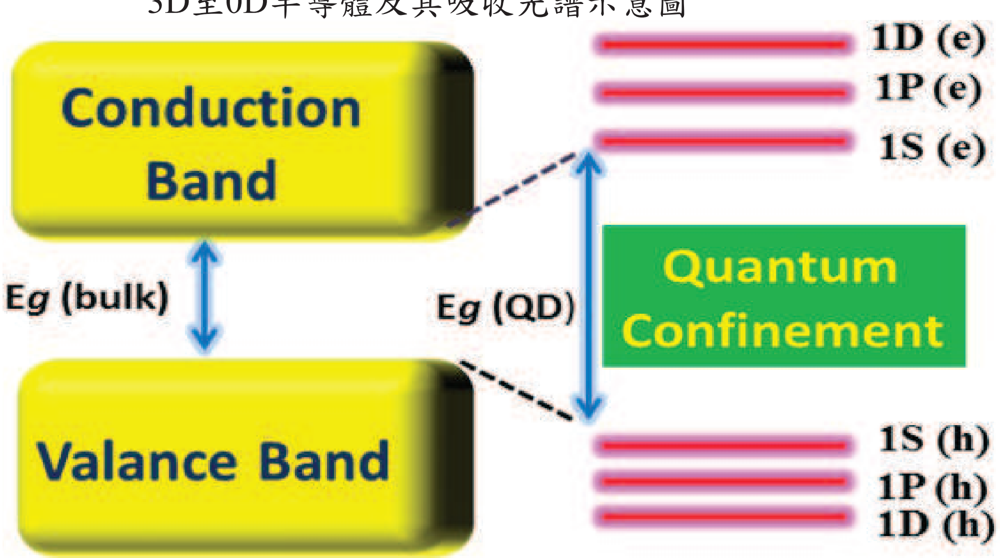


張立德，牟季美，“奈米材料奈米結構” 滄海書局(2002)

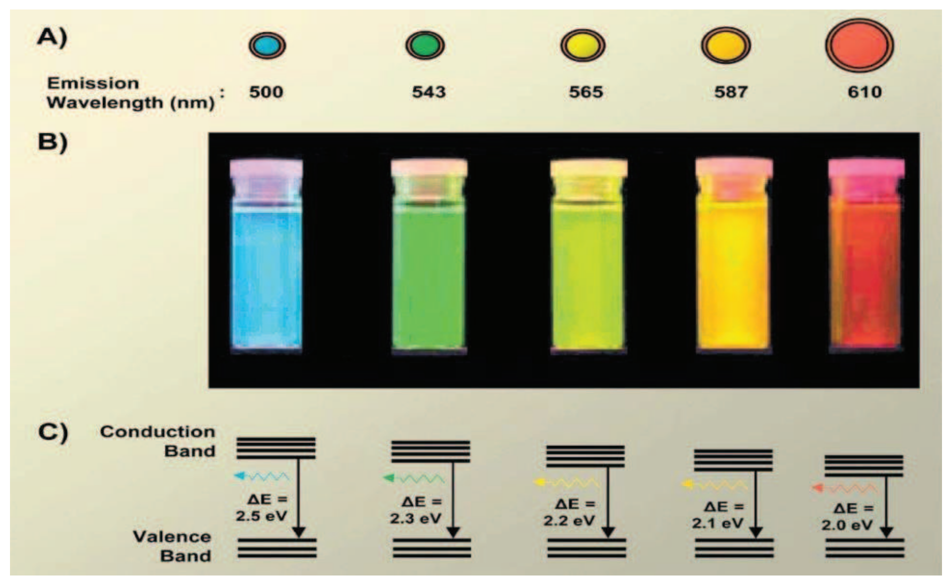
3D至0D半導體及其吸收光譜示意圖

Molecule Orbital

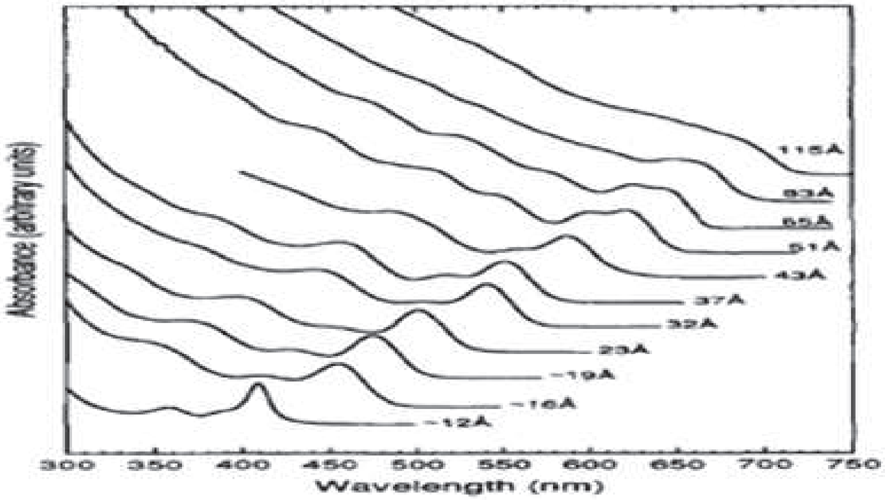




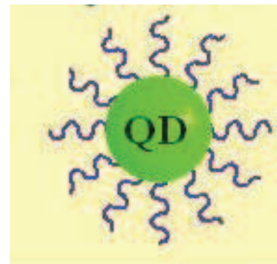
塊狀半導體與量子點能帶間隙比較



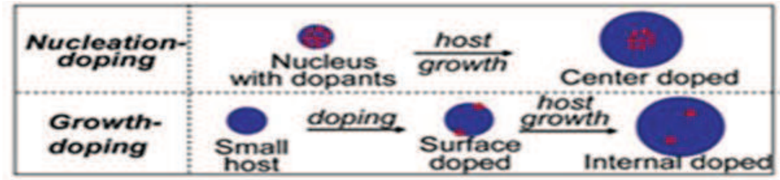
硒化鎘CdSe QDs

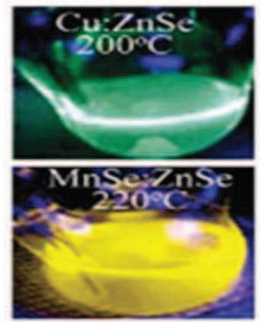


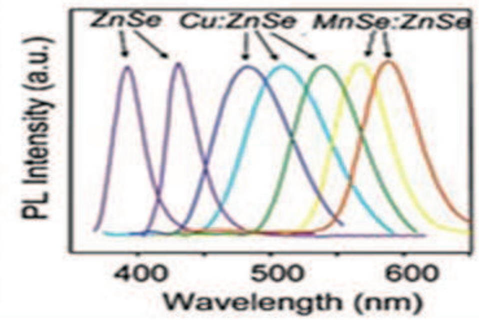
Murray *et al. J. Am. Chem. Soc.* 1993, *115*, 8706



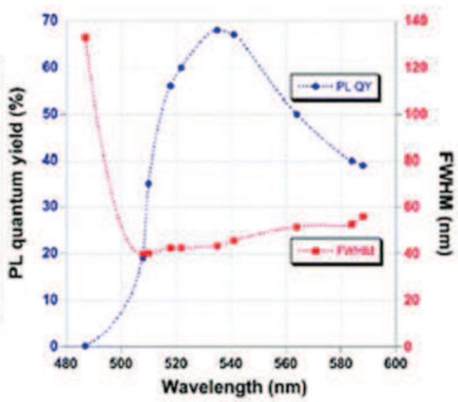
硒化鋅ZnSe QDs



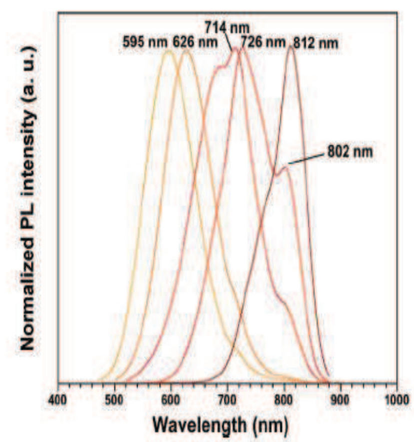




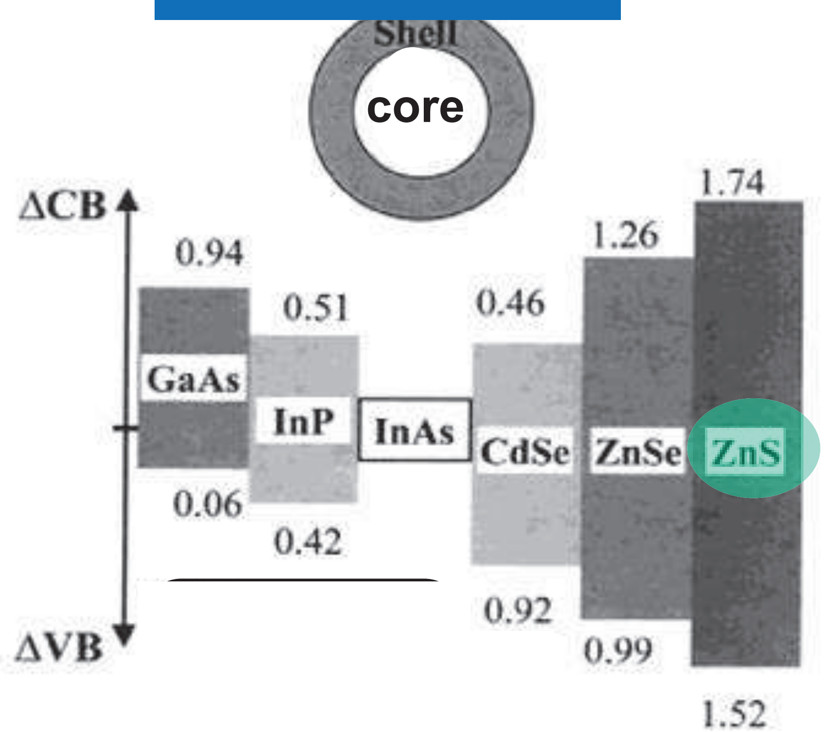
磷化銦 InP QDs

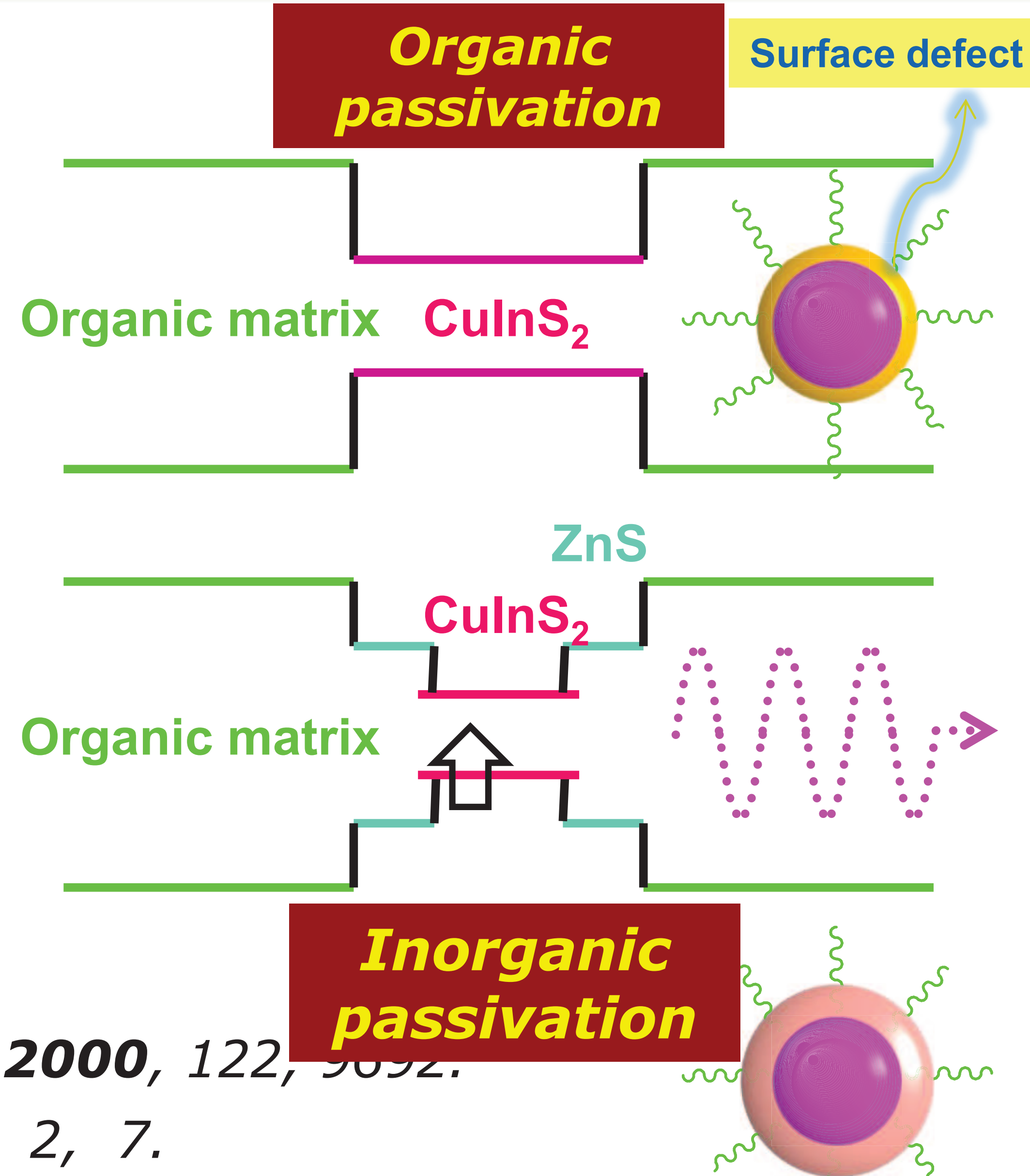


三元結構量子點（Ternary structured $CuInS_2/ZnS$



Surface modification





Band gap
Lattice parameter

- *Cao, et al J. Am. Chem. Soc.* ***2000****, 122, 9692.*
- Reiss, et al *Nano Lett.*, ***2002***, *2, 7.*

Company	Nation	website
nanosys	U.S.A **(LG)**	http://www.nanosysinc.com/
evident TECHNOLOGIES	U.S.A **(Samsung)**	http://www.evidenttech.com/
QD VISION	U.S.A **(Sony)**	http://www.qdvision.com/
NANOCO GROUP PLC	U.K	http://www.nanocotechnologies.com/

nanosys™

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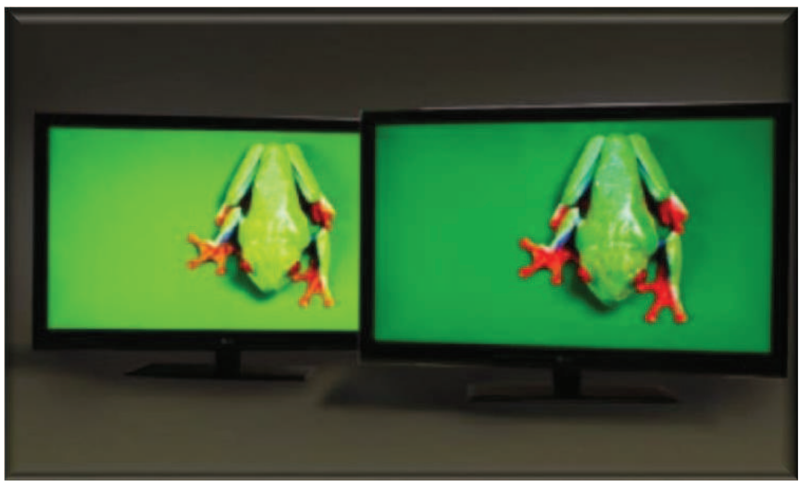
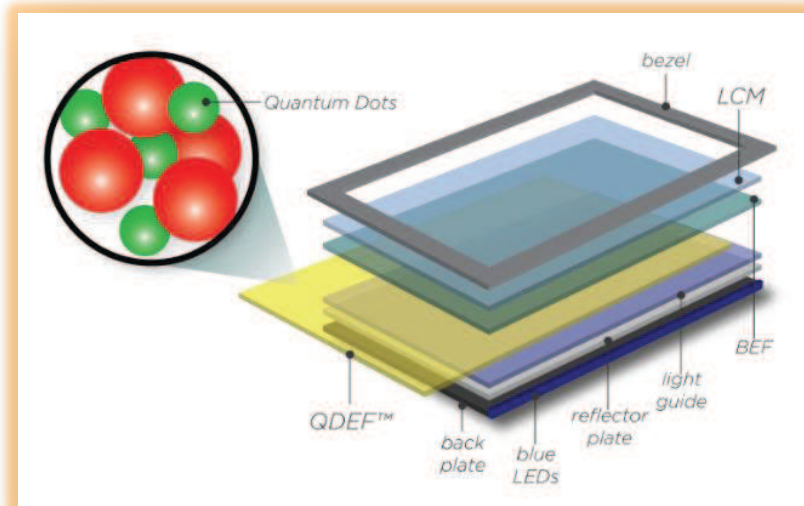
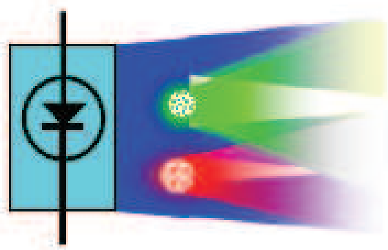




Quantum Dot Display

- **Quantum Dot**
  3nm ~ 7nm Nano-crystal + Ligand
  Blue/UV → Absorption
  → RG(B) Conversion → Emission

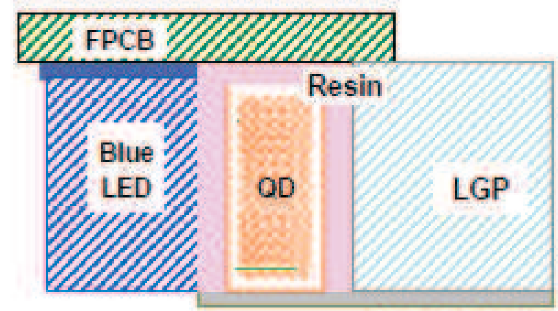


- **Advantage over General Phosphor**
  Customized CCT
  CRI 90+, Wide Gamut

- **Technology**
  QD / Reliability : Nanosys Inc.
  Optical Design/Packaging/Assy/ : LGIT

- **Potential Application**
  Mobile BLU, NB/TV BLU, Illumination,
  Solar Cell, …

- **Mobile BLU Application**



- **Performance / Reliability**

	Gamut (NTSC)	Luminance
Old BLU LCD	70%	500nit
AMOLED	100%	200nit
QD BLU LCD	103%	450nit

* 60℃, 95%, 500hrs Pass, On-going

- **Next Plan for BLU**
  - QD Rail type → Film Type Packaging

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LG Innotek

1. Quantum Dot Display Specifications

Item	2010.1	2010.3	Today's Demo June, 2010	Target (July. 2010)
Display	LCD	LCD	LCD	LCD
Light Source	Blue LED 210mcd @ 20mA		Blue LED 190mcd @ 20mA	Blue LED 210mcd@ 20mA
Panel	3.2" WVGA NTSC 70% with YAG BLU, LCD Transmittance 3.5%			
LGP/LCM Thickness	0.7t / 2.1t	0.45t Wedge / 1.85t		
Brightness Uniformity	79%	50%	79%	80%
Color	(0.30, 0.34)	(0.32, 0.34)	(0.308, 0.332)	(0.310 ±0.02, 0.327±0.02)
Color Uniformity	+/- 0.02	< +/- 0.02	< +/- 0.007	< +/- 0.005
Brightness	400 nits	300 nits	400 nits ↑	500 nits
Color gamut	103%	103%	103%	100% ↑

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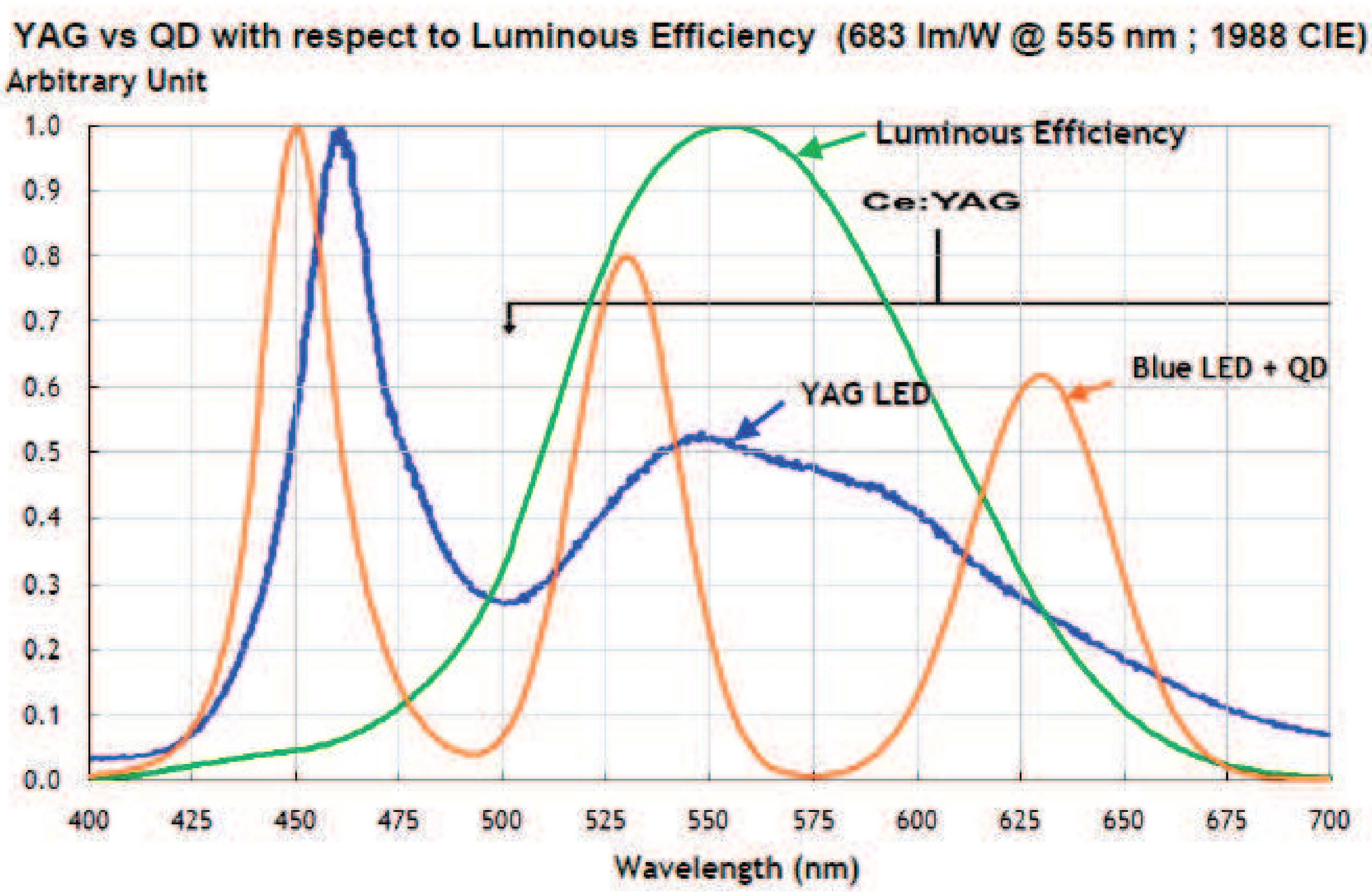
LG Innotek

4. Luminous Efficiency Comparison

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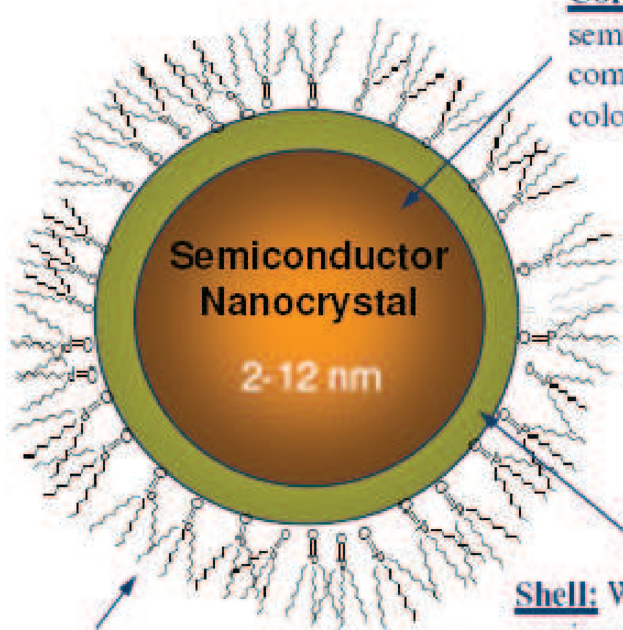
QD Structure and Emissive Properties

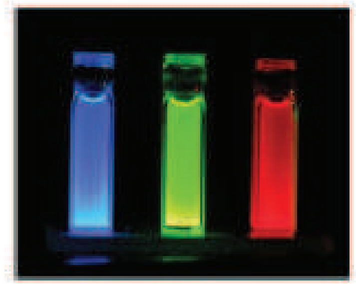
Three parts of QDs are engineered to optimize performance

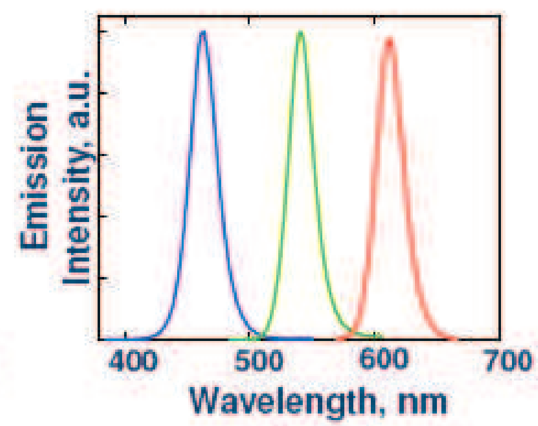


Core: Binary or ternary semiconductor; size and composition determines color

Shell: Wider bandgap semiconductor; enhances efficiency and stability

Caps or Ligands: Typically aliphatic organics; passivates & functionalizes surface





QD VISION

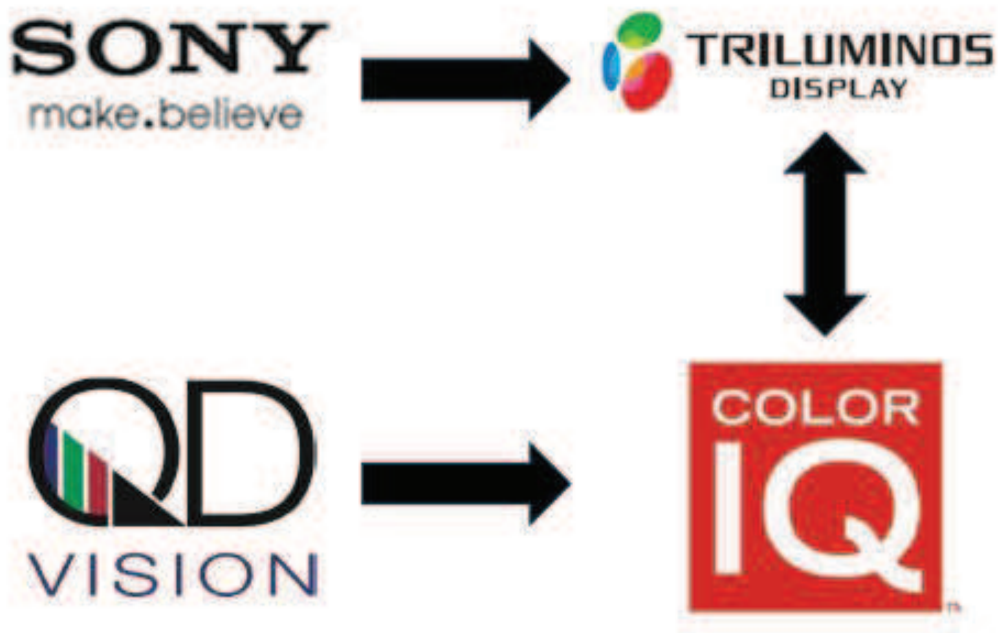
PGS – March 2013

QD Vision's Global Footprint

PGS – March 2013

VISION

Color IQ Optics Enable Triluminos Displays



9 PGS – March 2013

CES 2013: Sony TV Launch of Color IQ Optics

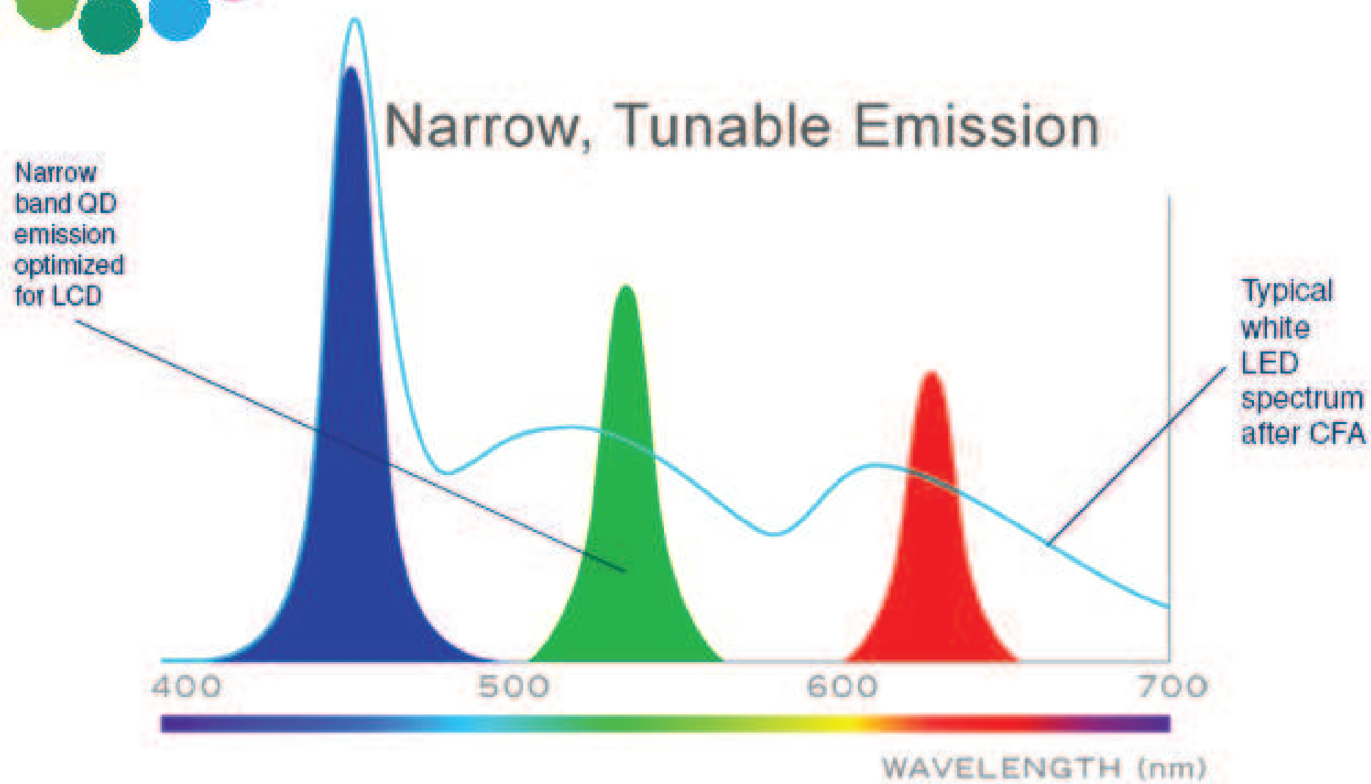
- Three models announced
  - Include both HD and 4K
- All for 2013 release
- QD is Enabling feature of Triluminos Displays
- 100% NTSC-1953 color gamut
- TechRadar Best-in-Show Award

"By integrating QD Vision's Color IQ™ optical component with Sony's unique display technologies, these televisions achieve significantly wider color gamut and provide a far more natural and vivid viewing experience with a heightened sense of depth."

8 PGS – March 2013

QD VISION

Color IQ is Optimal for LCD Systems



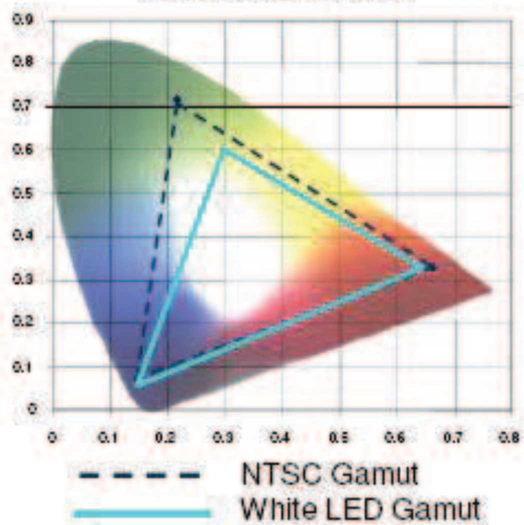
PGS – March 2013

QD VISION

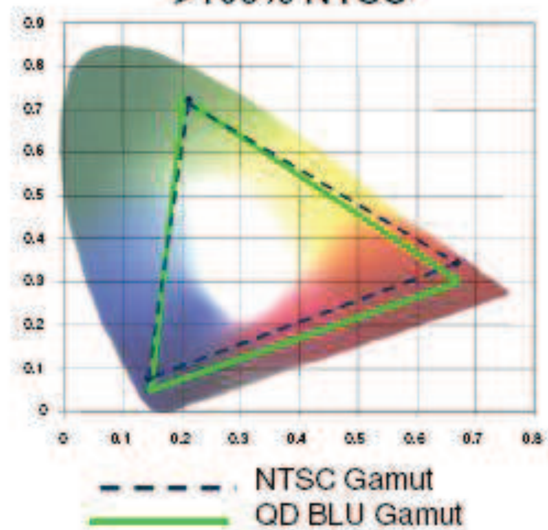
Quantum Dots Widen LCD color gamut

Dramatically improves color vs. white LEDs

White LED BLU
mid-70% NTSC



QD-enhanced BLU
>100% NTSC



Preserves cost basis of LCD,
while delivering color performance of OLED.

12 PGS – March 2013

QD VISION

台灣大學化學系・材料化學實驗室
Materials Chemistry Laboratory
Department of Chemistry
National Taiwan University

Visualizing Wide Color Gamut

Radiant Reds | Gorgeous Greens | Beautiful Blues

But you have to see it to believe it…

13 PGS – March 2013

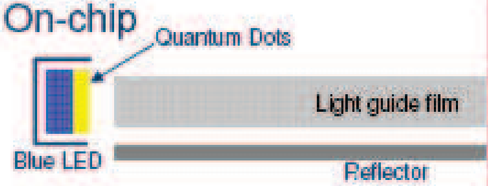
QD VISION

Implementation: QD LCD Geometry Comparison

Order-of-magnitude Analysis of Three Geometries

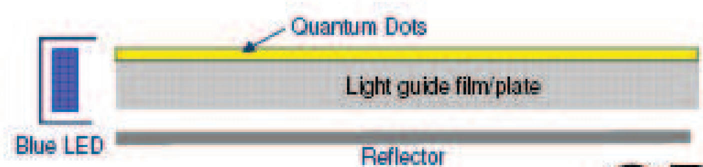
Display Size	Geometry	Area (mm²)	Segment Production Capacity Needs (kg/year)	Order of magnitude Cost/unit	Reliability (normalized to 1x)
4"	On-chip	0.1	1	$0.001	0.01
	On-edge	10	10	$0.10	1
	On-surface	10000	10000	$10	10000
14"	On-chip	10	10	$0.10	0.001
	On-edge	100	100	$1	0.1
	On-surface	100000	10000	$1,000	1000
42"	On-chip	100	10	$1	0.001
	On-edge	10000	1000	$10	1
	On-surface	1000000	100000	$10,000	10000

On-chip



On-edge

On-Surface



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Coe-Sullivan, *et al.*, JSS **2** (2) R3026-R3030 (2013).

QD VISION

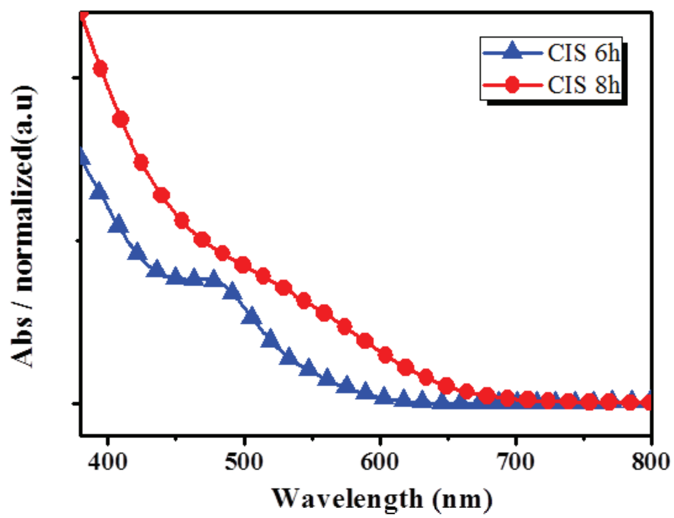
NTU-MCL Development in QDs for LEDs

台灣大學化學系 材料化學實驗室
Materials Chemistry Laboratory
Department of Chemistry
National Taiwan University

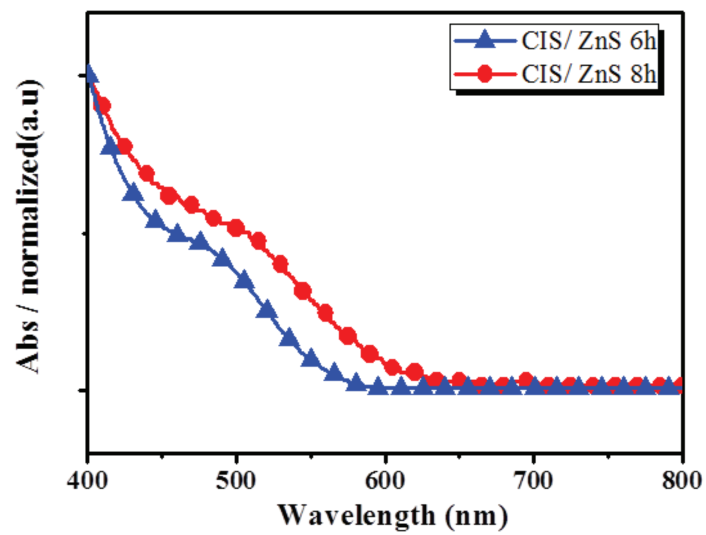
Characterization of $CuInS_2$ & $CuInS_2$/ZnS

Uv-Vis

(a)

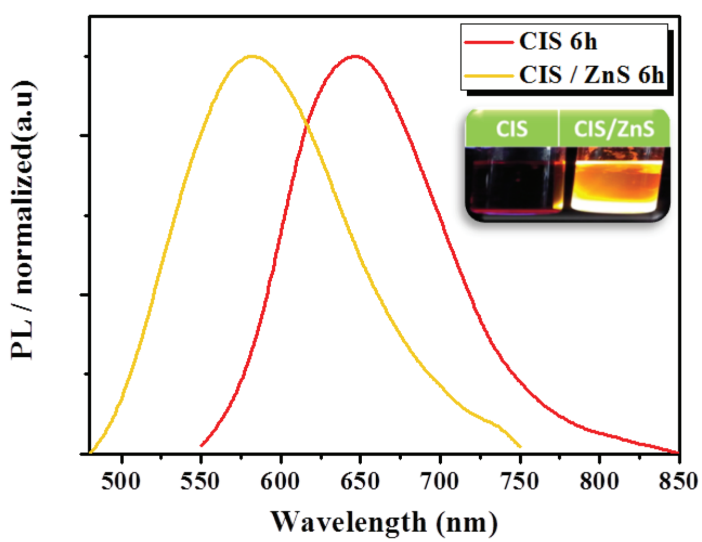


(b)



PL

(a)



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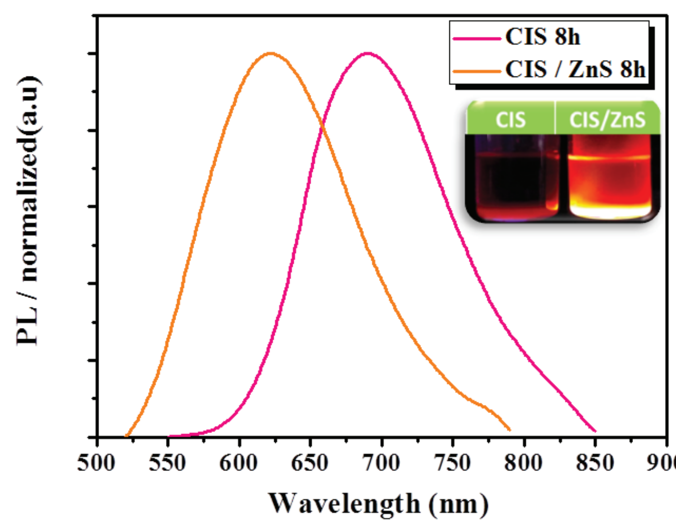
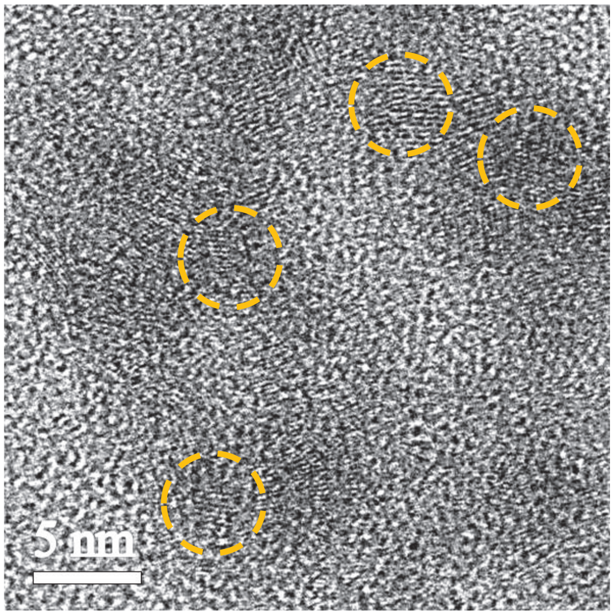
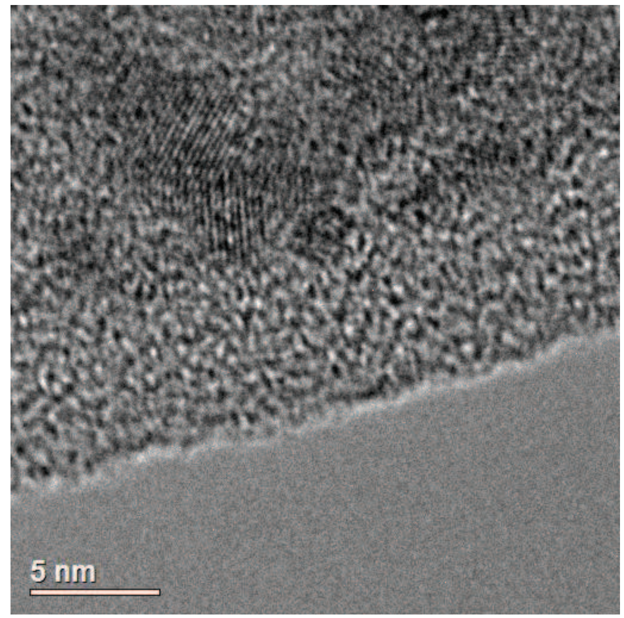
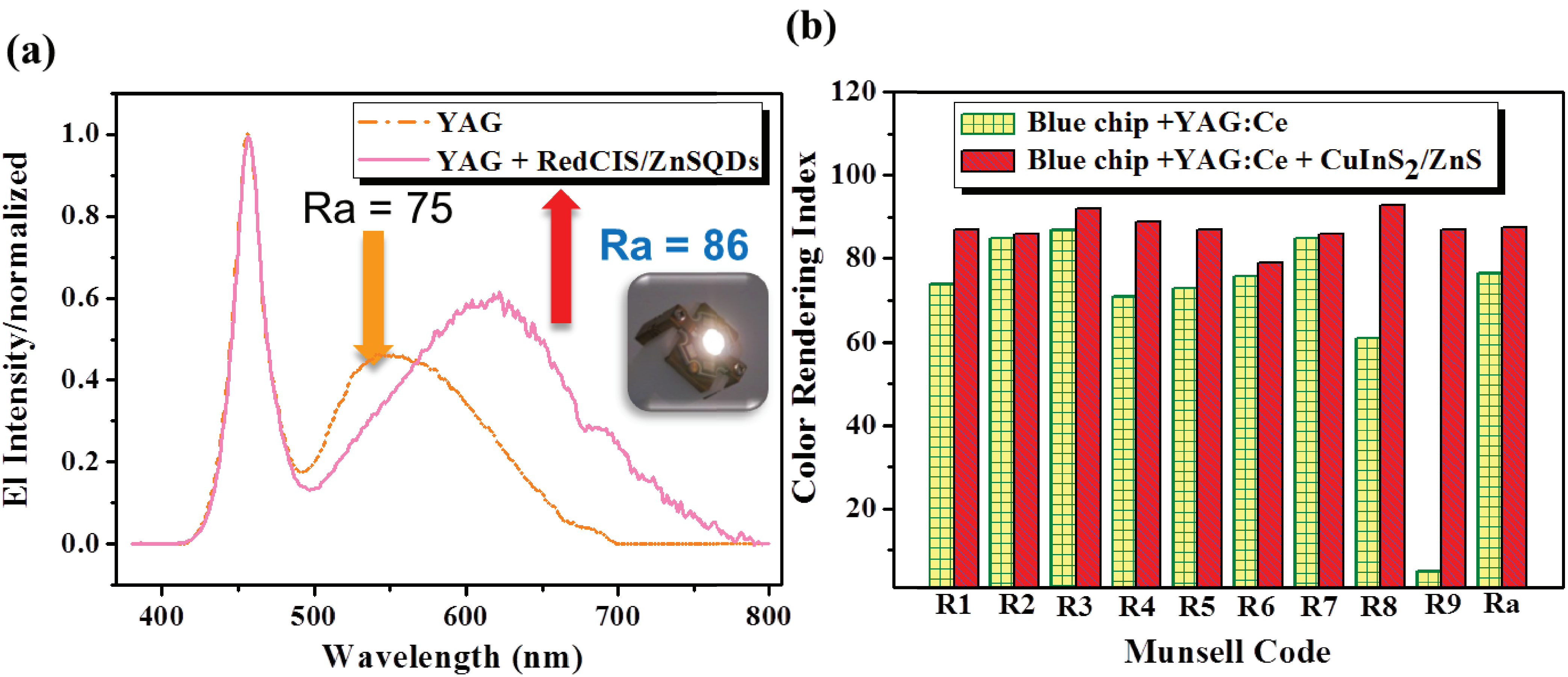


TEM

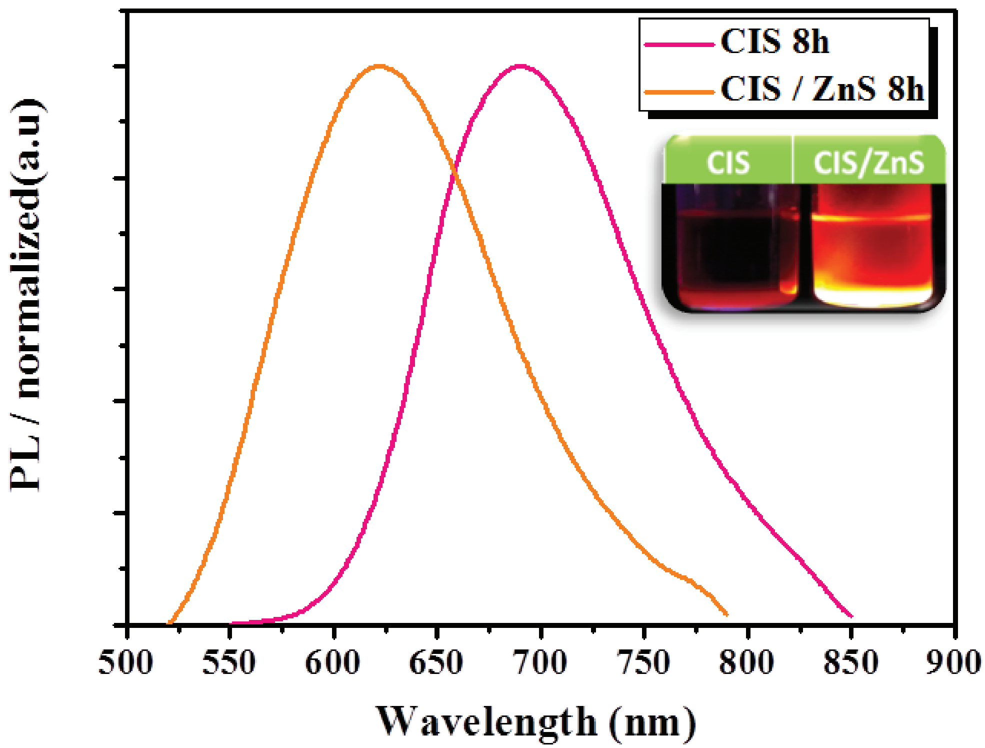




HR-TEM image of $CuInS_2/ZnS$ QDS.
The yellow circles indicates the locations of $CuInS_2/ZnS$ QDs


(a)
El Intensity/normalized
1.0
0.8
0.6
0.4
0.2
0.0
400
500
600
700
800
Wavelength (nm)
YAG
YAG + RedCIS/ZnSQDs
Ra = 75
Ra = 86
(b)
Color Rendering Index
120
100
80
60
40
20
Blue chip +YAG:Ce
Blue chip +YAG:Ce + CuInS2/ZnS
R1
R2
R3
R4
R5
R6
R7
R8
R9
Ra
Munsell Code

HOPAX



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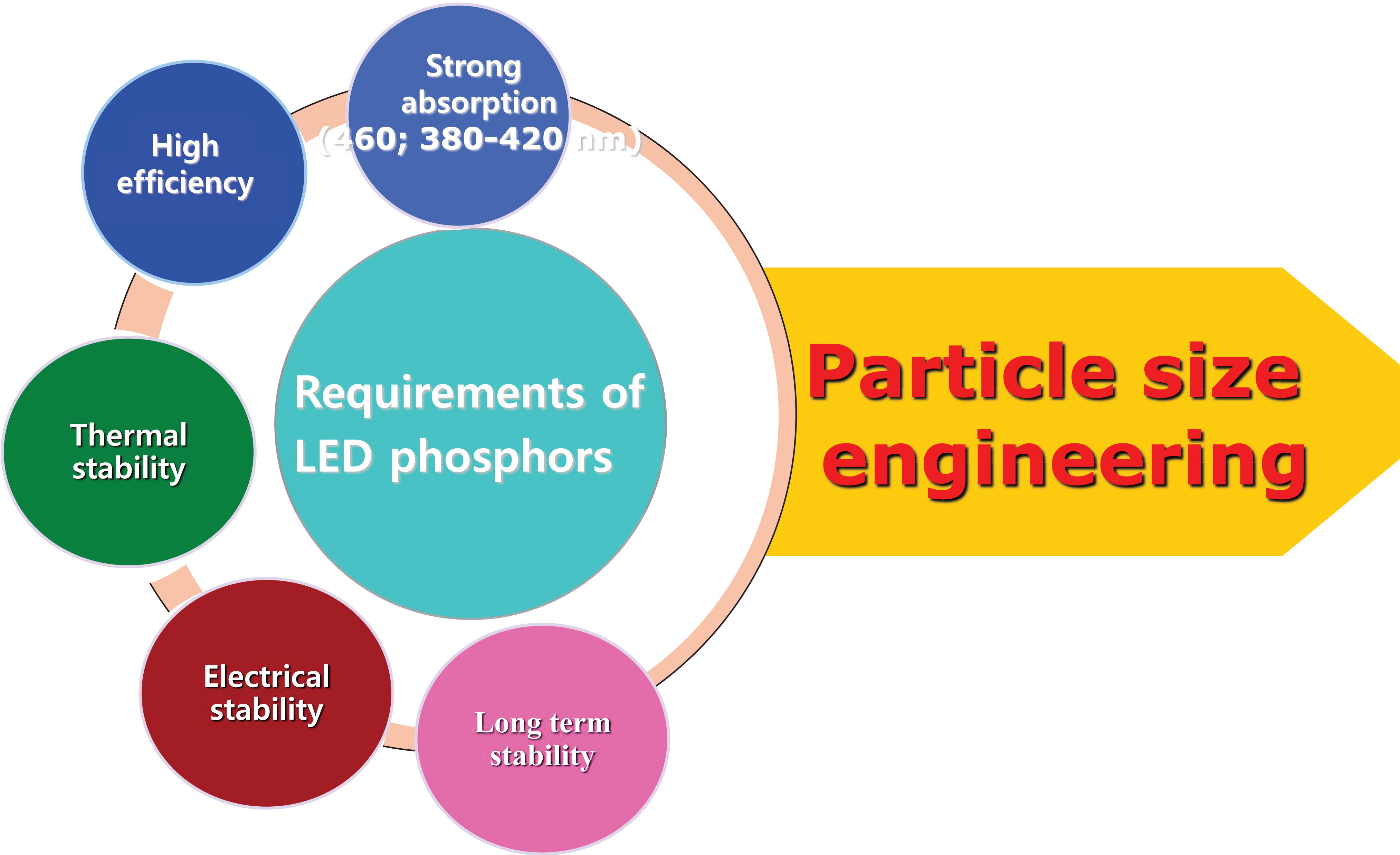
Requirement of LED phosphors



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Ceramic Product Development and Commercialization

Particle Size Effect on the Packaging Performance of YAG:Ce Phosphors in White LEDs

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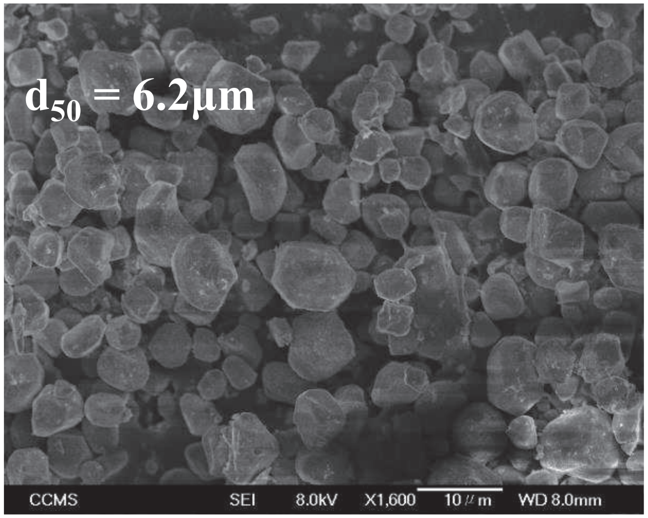
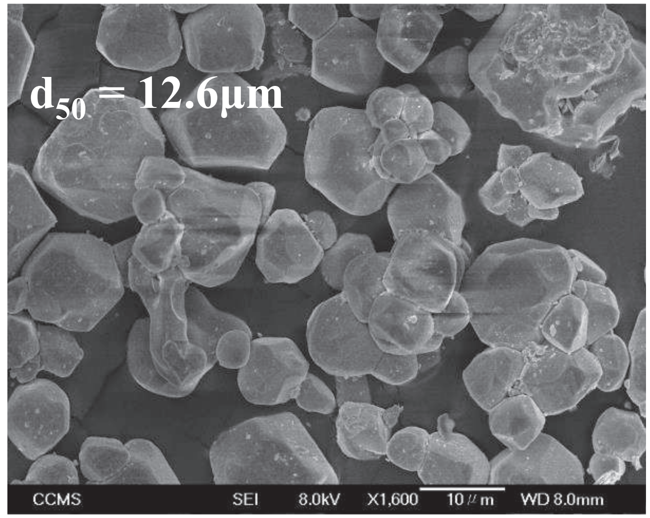
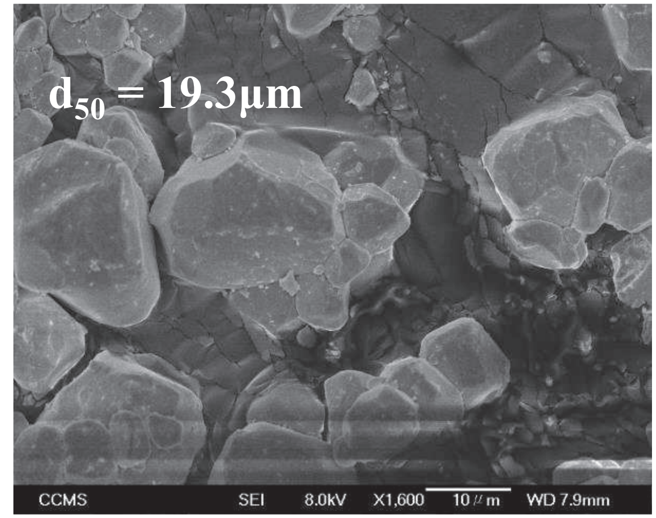
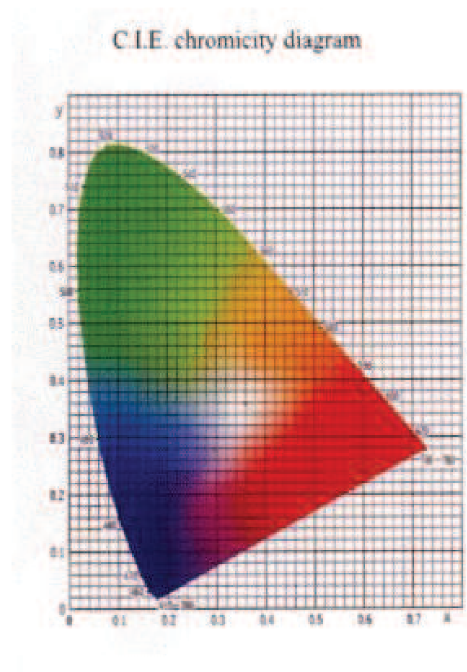






$6\sigma = 0.015 \rightarrow \sigma = 0.0025$

CIE x	CIE y
0.0024	0.0036



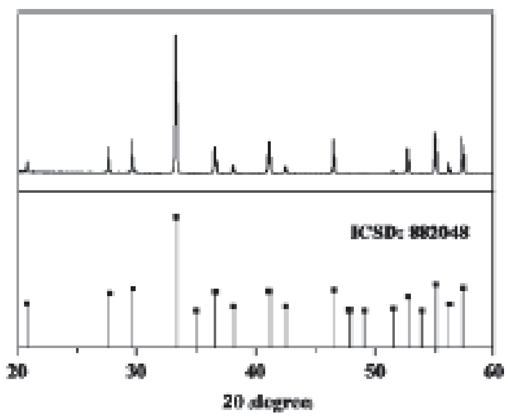
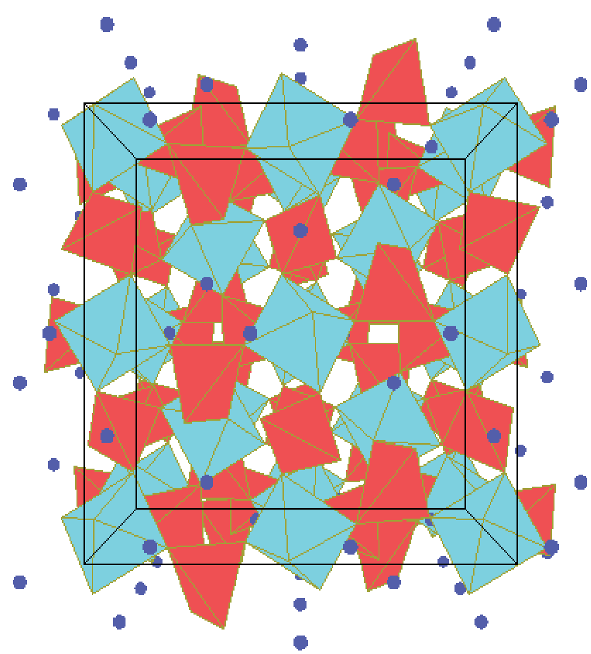


Fig. 1. X-ray diffraction patterns of PS-1 along with the standard pattern of yttrium aluminum garnet phosphor.



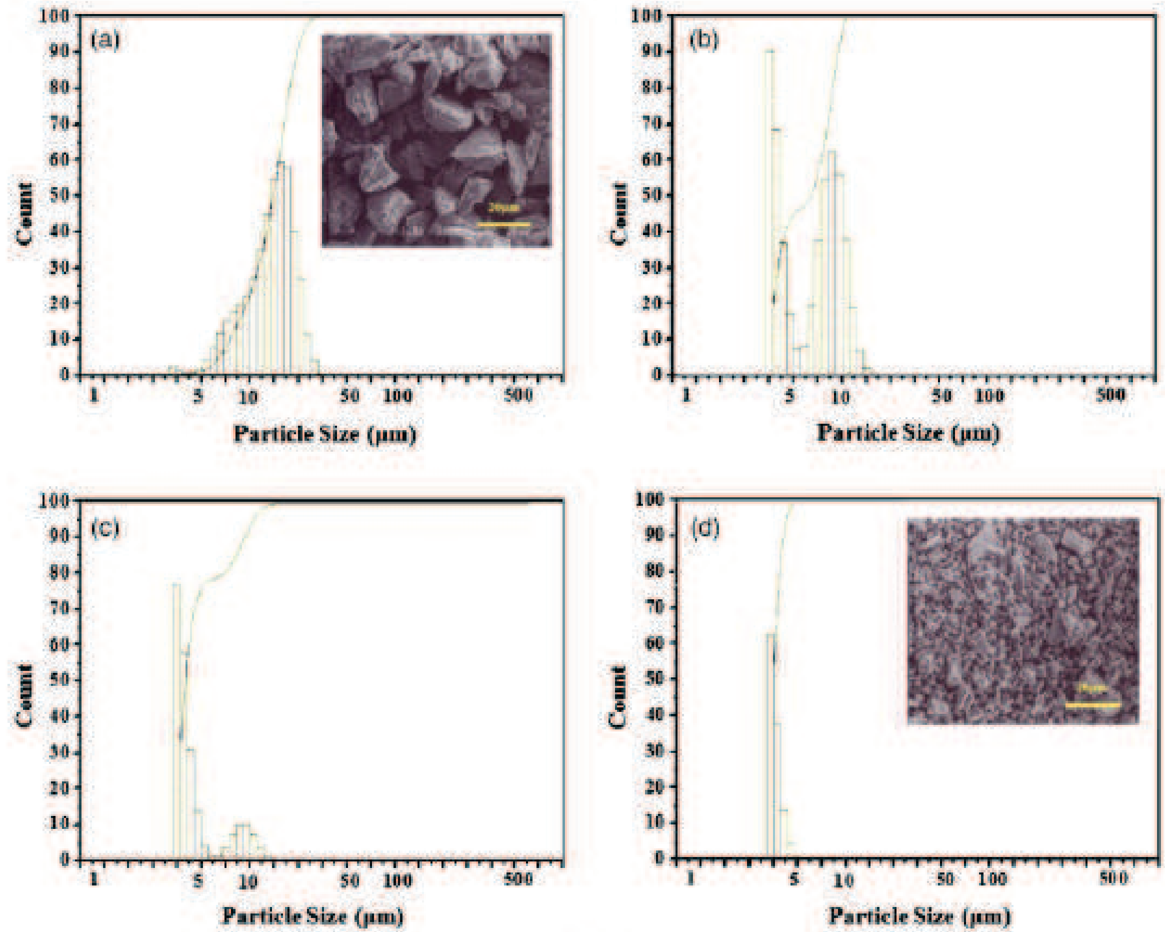


Fig. 2. Particle size distribution of (a) PS-1, (b) PS-2, (c) PS-3, and (d) PS-4 yttrium aluminum garnet (YAG:Ce) phosphors. Inset shows scanning electron microscopic images of (a) PS-1 and (d) PS-4 YAG:Ce phosphors.

Table I. The Particle Sizes Distribution of D10, D50, and D90%. Wt % of Yttrium Aluminum Garnet (YAG:Ce) Mean % of YAG Phosphor in Silicone

No.	Sample	P/N (D10%) (μm)	P/N (D50%) (μm)	P/N (D90%) (μm)	Wt % of YAG:Ce
1	PS-1	8.3	15.6	22.0	5.7
2	PS-2	—	7.2	10.5	4.5
3	PS-3	—	4.1	9.3	4.4
4	PS-4	—	2.2	4.4	3.7

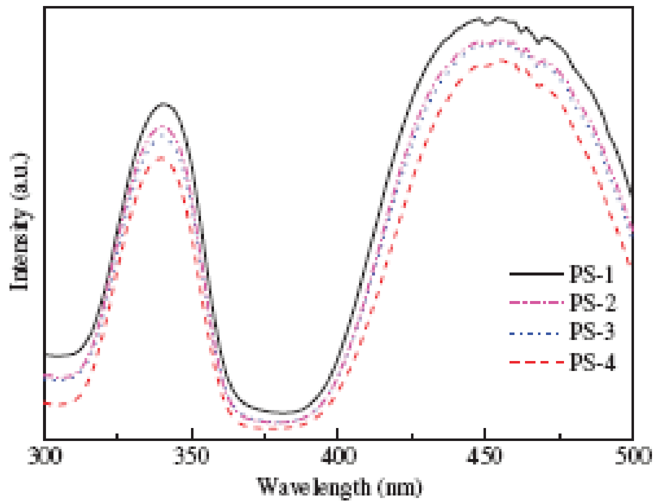


Fig. 3. Photoluminescent excitation spectra of (a) PS-1, (b) PS-2, (c) PS-3, and (d) PS-4 yttrium aluminum garnet phosphors.

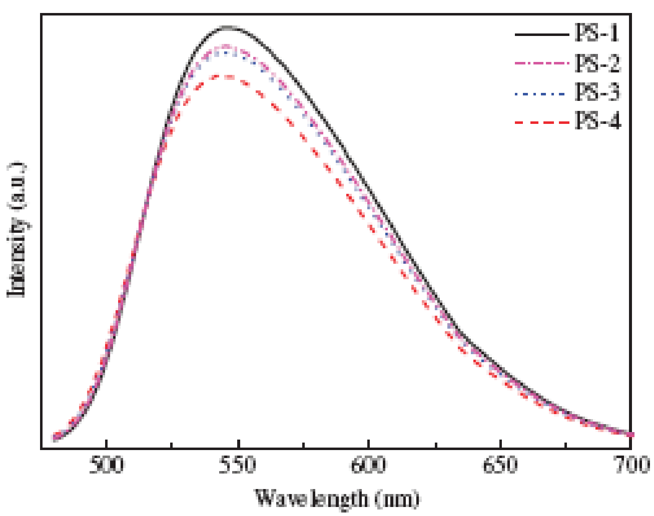


Fig. 4. Photoluminescence spectra of (a) PS-1, (b) PS-2, (c) PS-3, and (d) PS-4 yttrium aluminum garnet phosphors at 460 nm excitation.

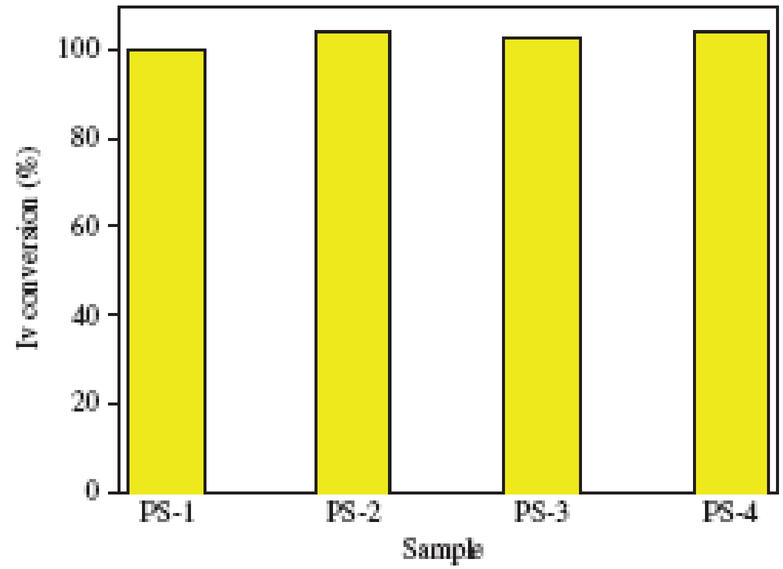
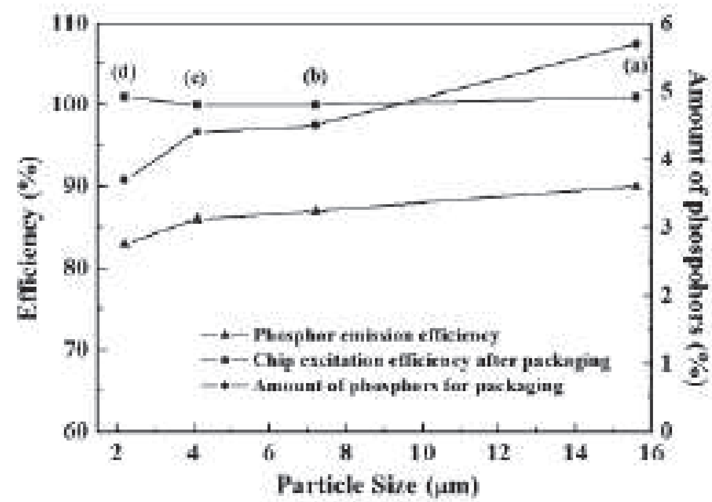


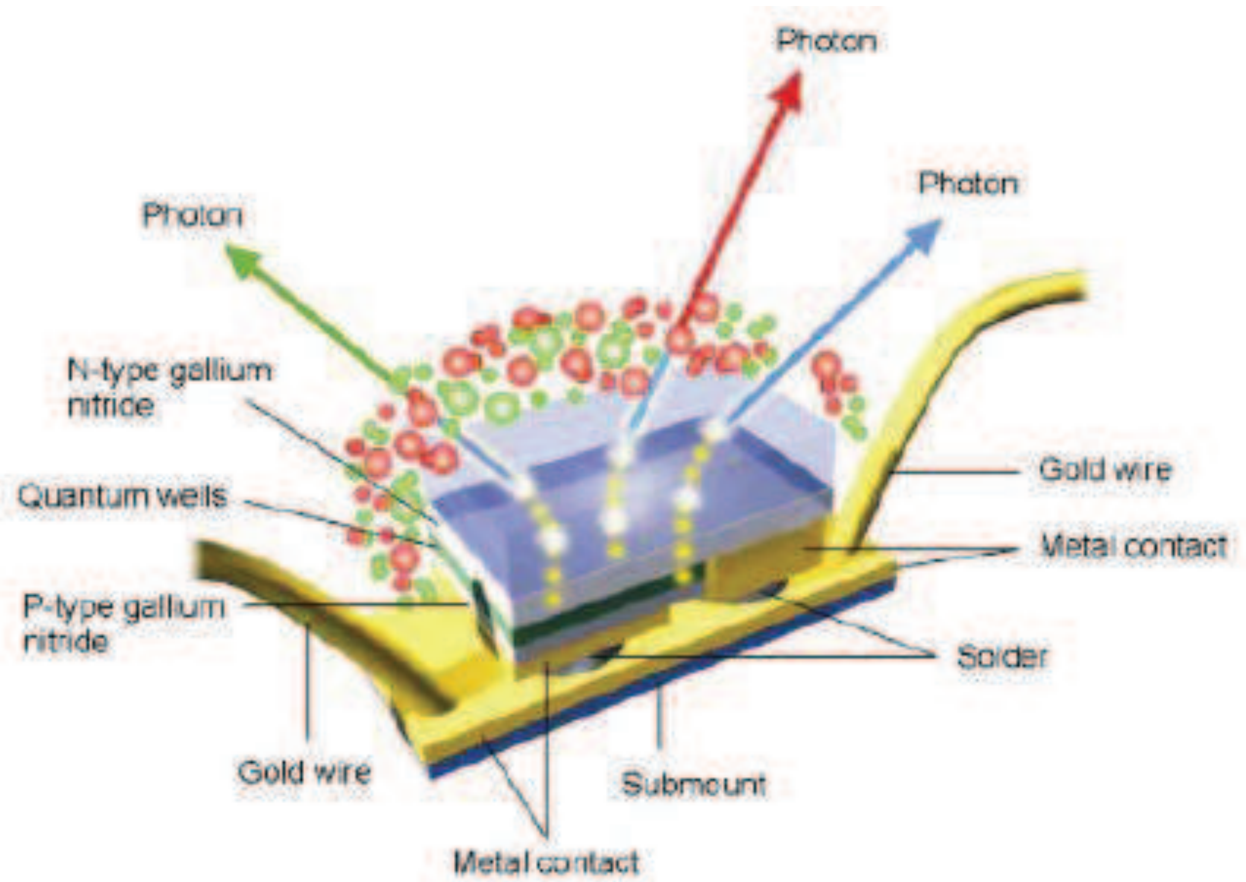
Fig. 5. I_v comparison (%) of white package LEDs of (a) PS-1, (b) PS-2, (c) PS-3, and (d) PS-4 yttrium aluminum garnet phosphors.

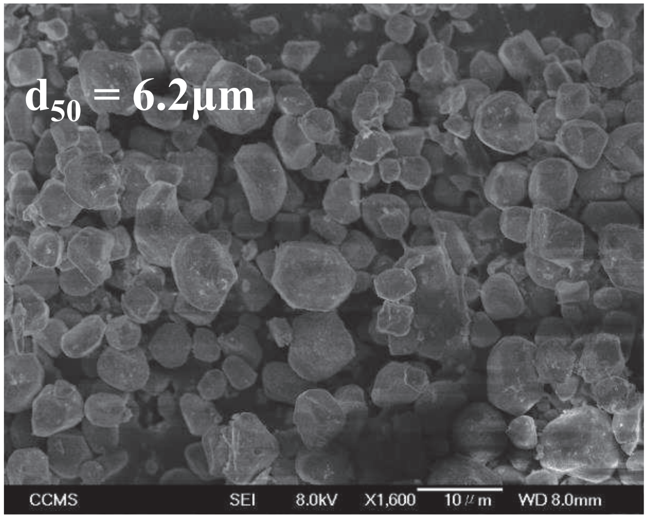


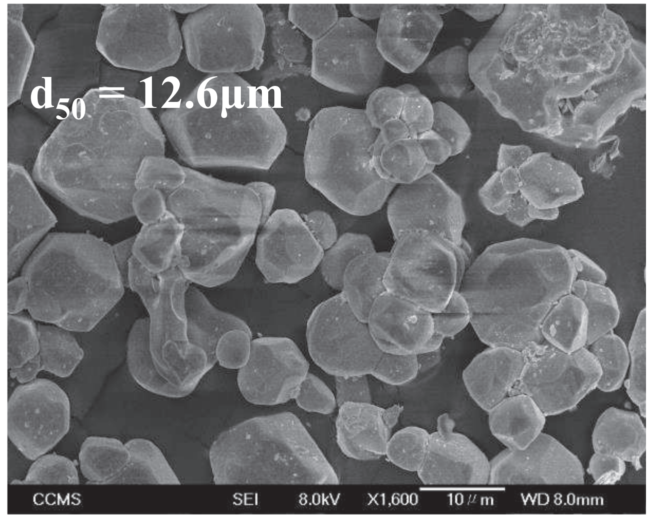
(5.7-3.7)/5.7 = 35%

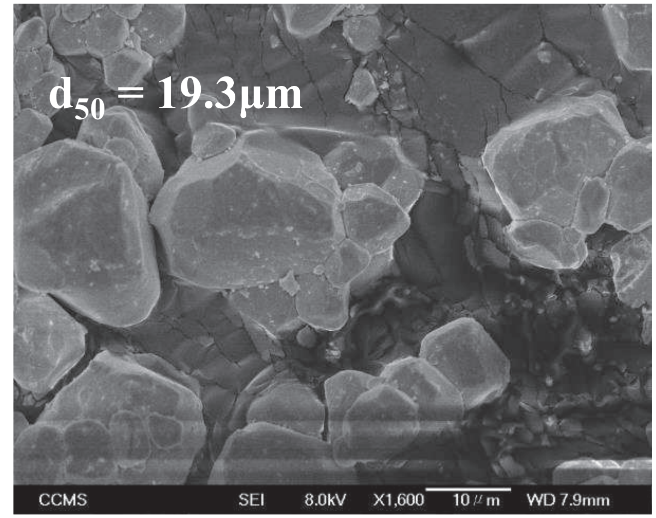
Fig. 6. Plots of phosphor emission, excitation efficiency after packaging and amount of phosphors for packaging (wt %) against the particle sizes of (a) PS-1, (b) PS-2, (c) PS-3, and (d) PS-4 YAG:Ce phosphors.

Particle Engineering



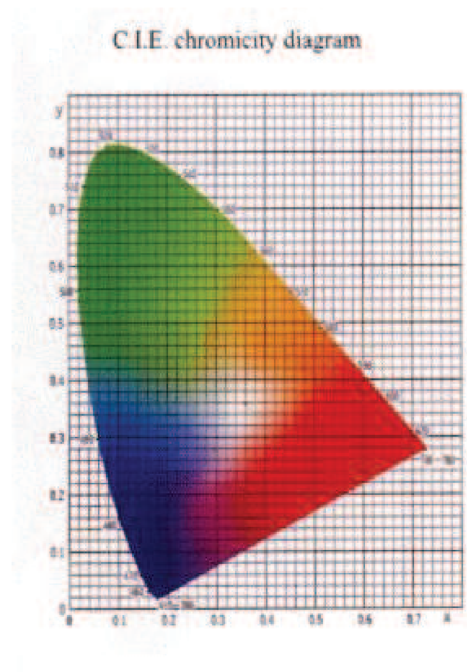






$6\sigma = 0.015 \rightarrow \sigma = 0.0025$

CIE x	CIE y
0.0024	0.0036



תודה
Dankie Gracias
Спасибо شكراً
Merci Takk
Köszönjük Terima kasih
Grazie Dziękujemy Děkojame
Ďakujeme Vielen Dank Paldies
Kiitos Täname teid 谢谢

Thank You

Tak
感謝您 Obrigado Teşekkür Ederiz
감사합니다
Σας Ευχαριστούμ
ขอบคุณ
Bedankt Děkujeme vám
ありがとうございます
Tack