



新型二维强关联材料与微纳器件的研究

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LED

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GaN

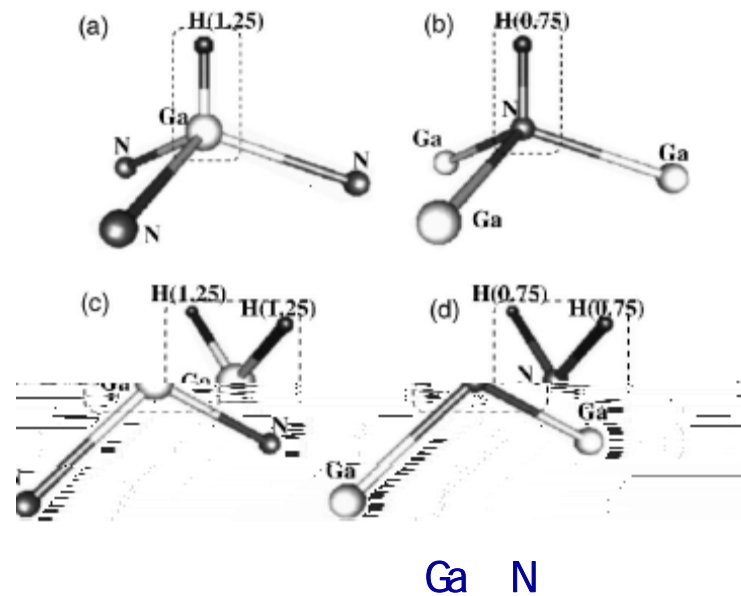
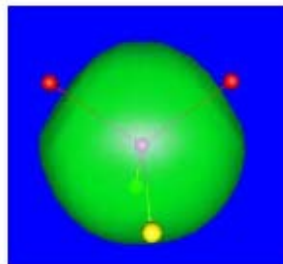
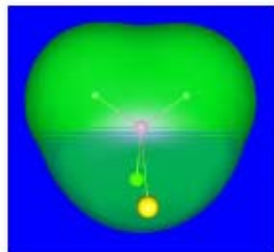
LED



Charge Patching Method

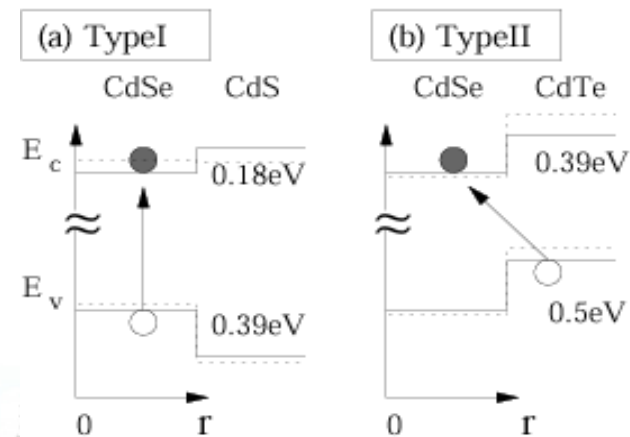
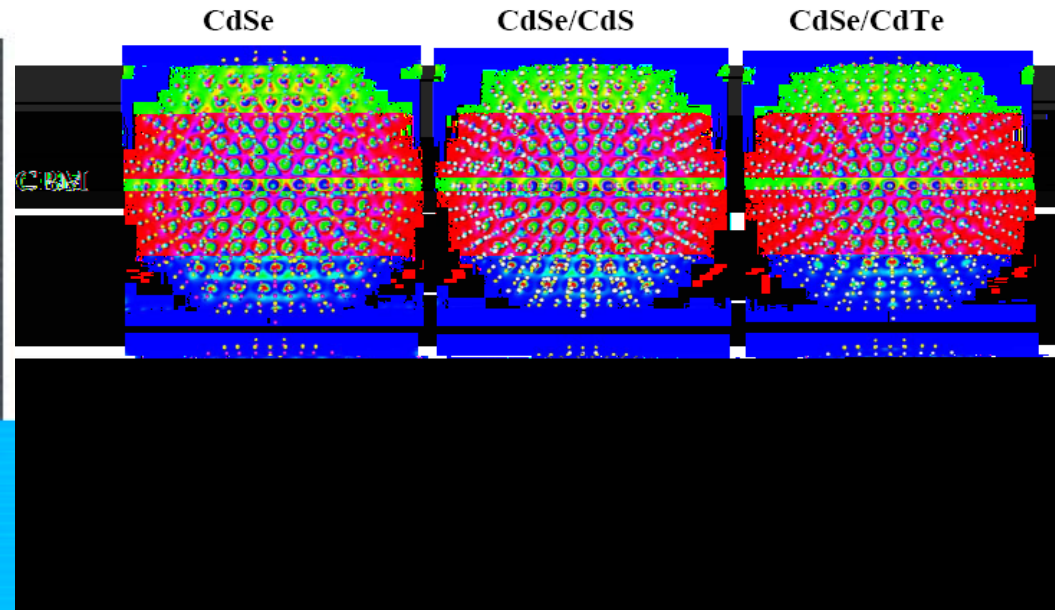
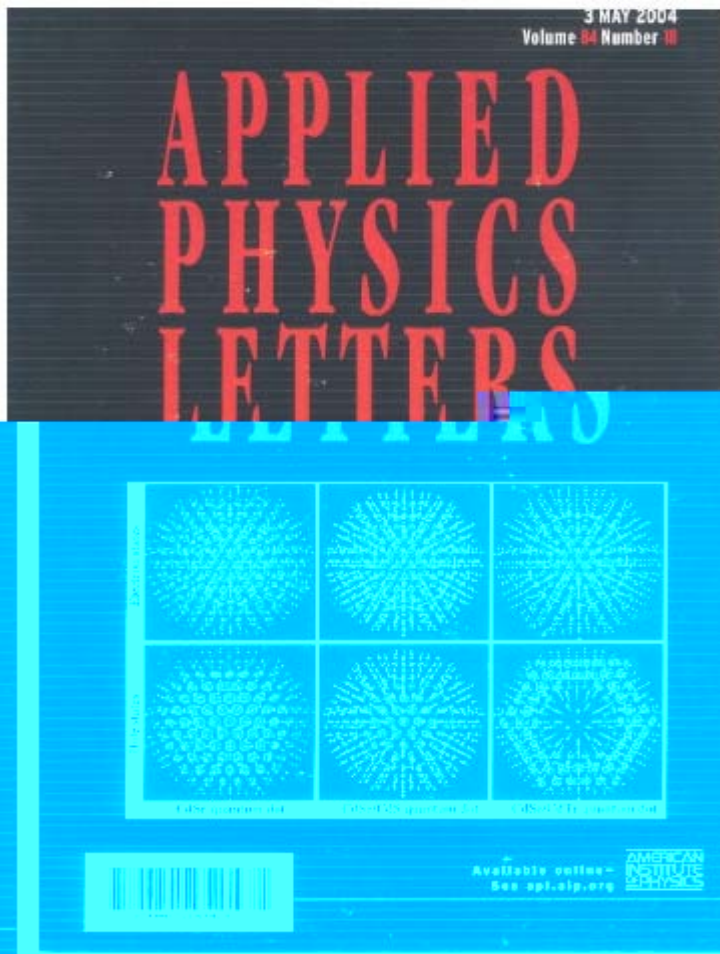
LDA

motif



L.-W.Wang, PRL.88,256402(2002)

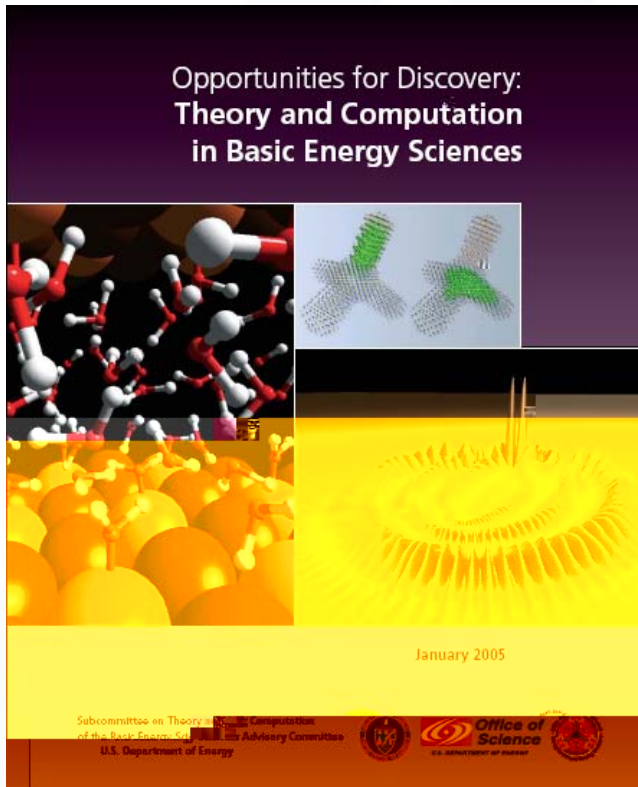
Jingbo Li and L.-W Wang, PRB 72, 125325(2005)





CdSe/CdTe

tetrapod



Electron state

Hole state

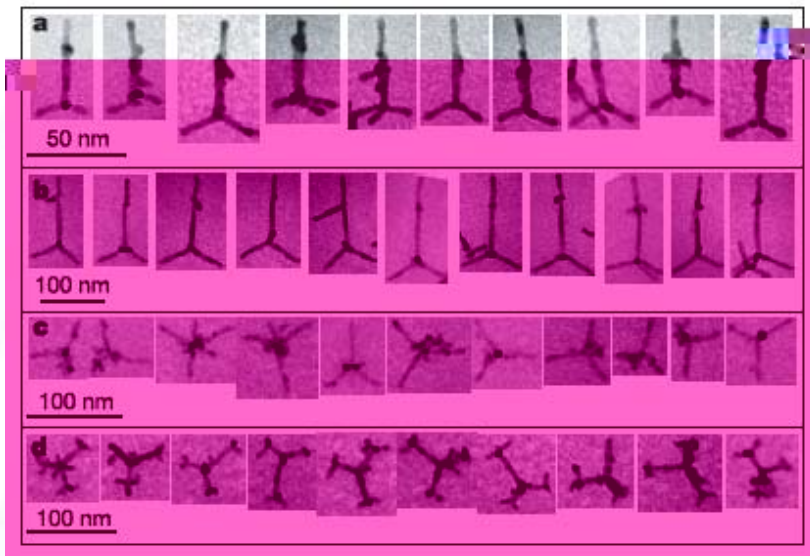
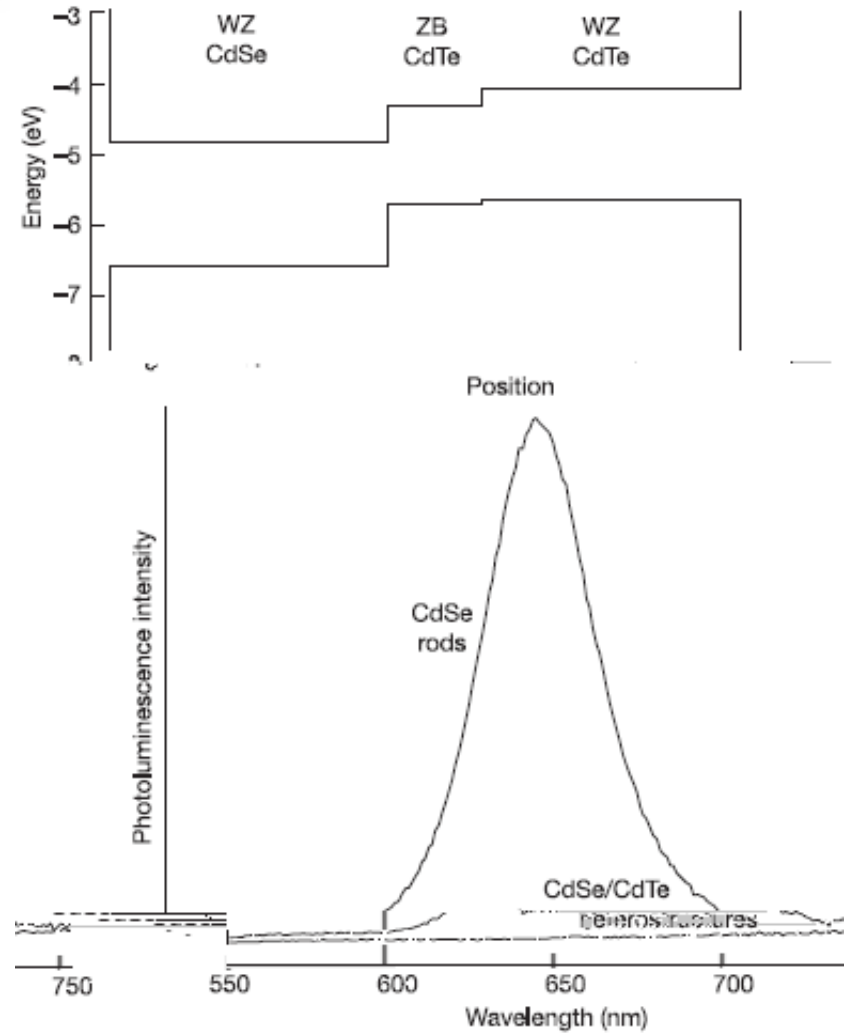
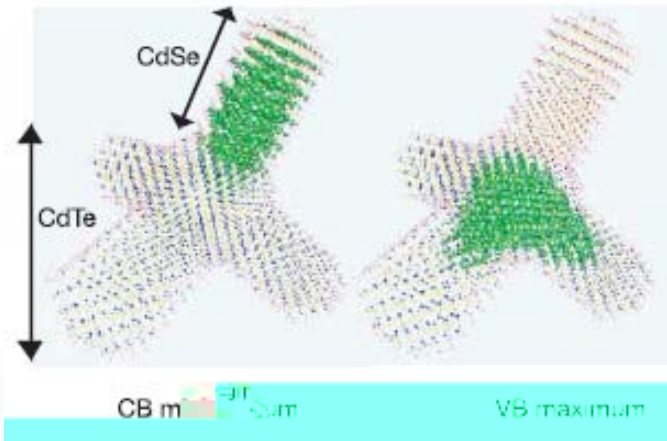
CdSe

CdTe

D. J. Milliron, S. M. Hughes, Yi Cui, L. Manna, **Jingbo Li**, L. W. Wang and A. P. Alivisatos, *Nature* 430, 190 (2004).

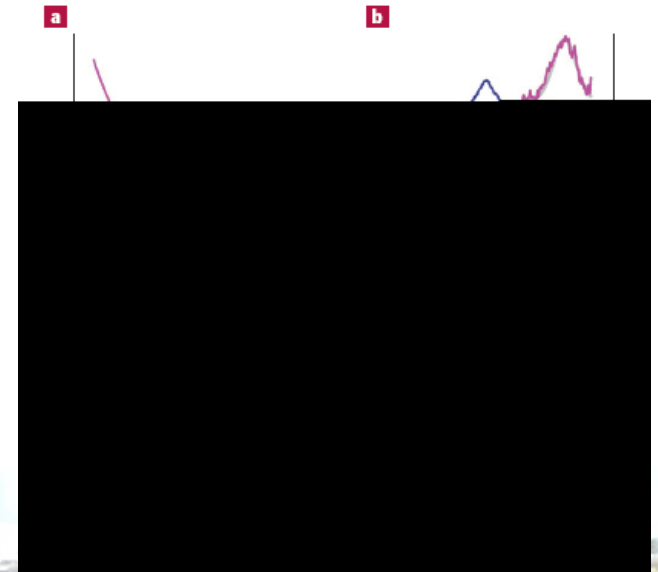
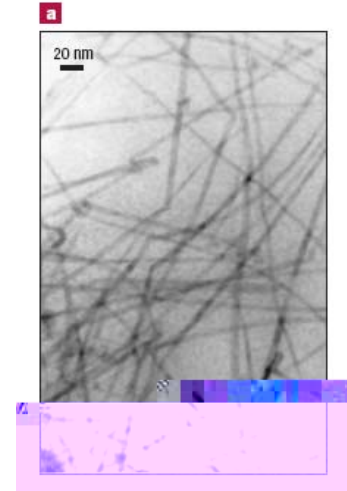
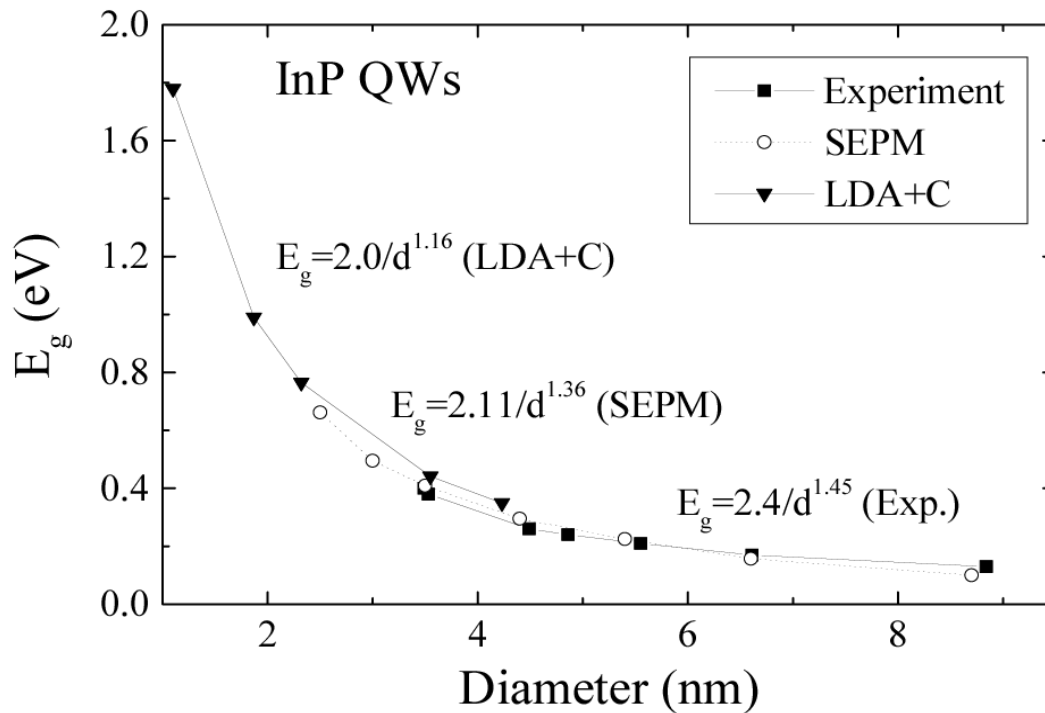
CdSe/CdTe

tetrapod



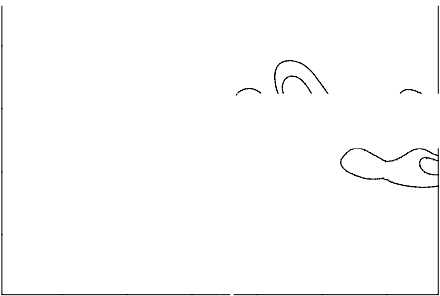
D. J. Milliron, S. M. Hughes, Yi Cui, L. Manna, **Jingbo Li**, L. W. Wang
and A. P. Alivisatos, Nature 430, 190,(2004).

InP

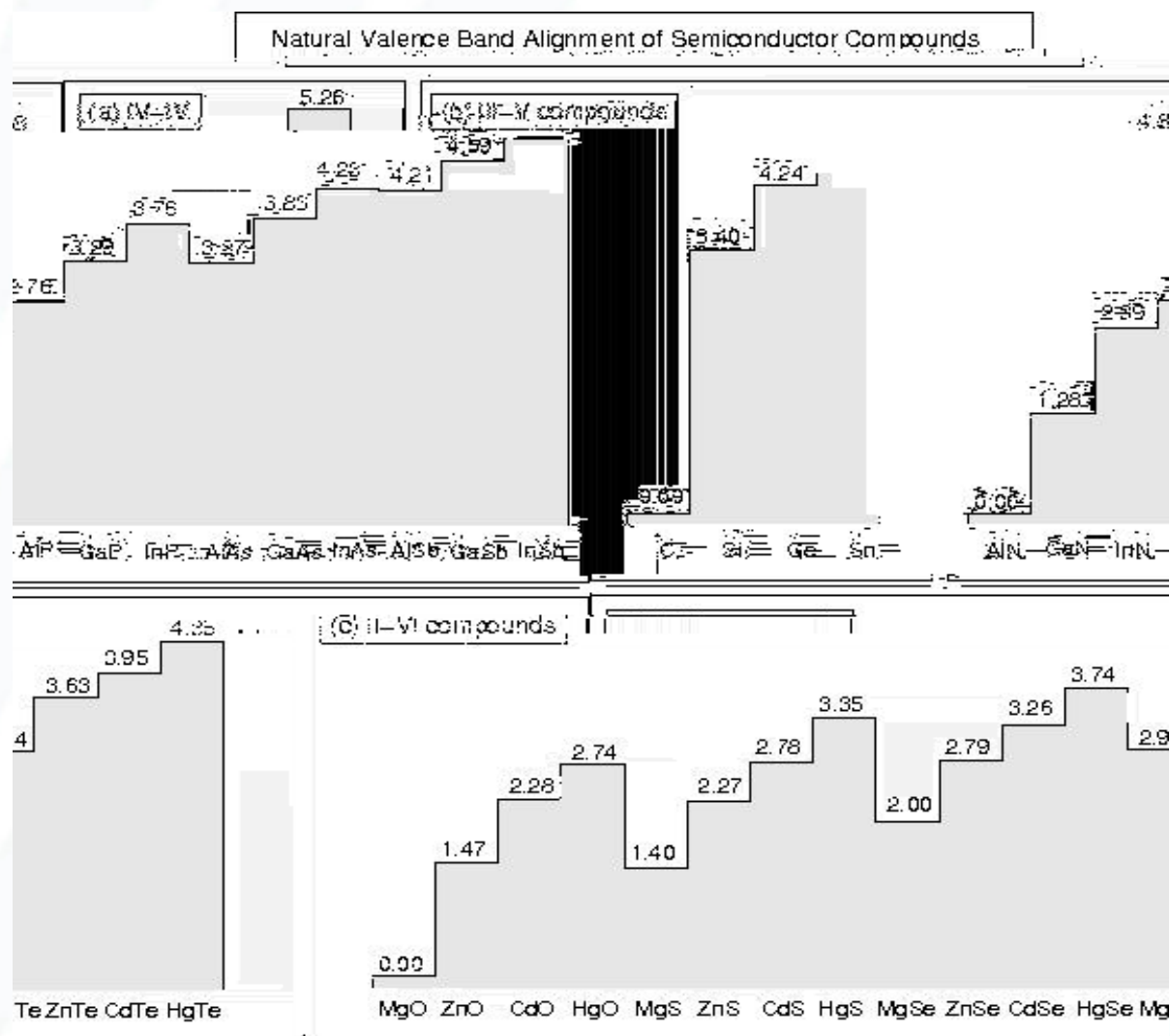


Jingbo Li and L.-W Wang, PRB 72, 125325(2005)

H.Yu, Jingbo Li, R. A. Loomis, L.W. Wang, and
W. E. Buhro, Nature Material, 2,517(2003)

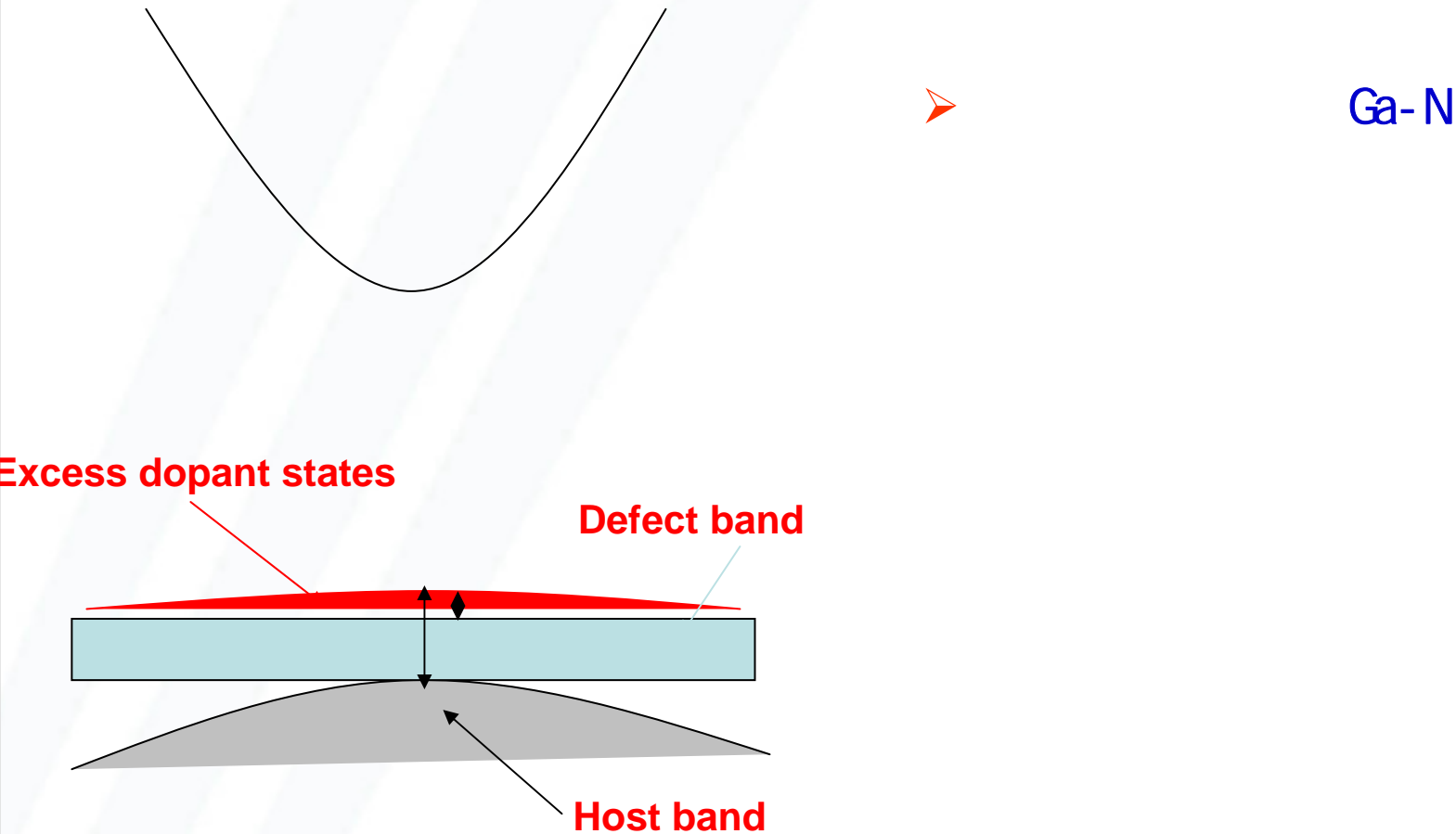


为什么宽禁带半导体材料很难实现p-型掺杂？



S.H.Wei and A. Zunger, App. Phys. Lett. 72,2011 (1998).

通过形成杂质能带以降低受主离化能



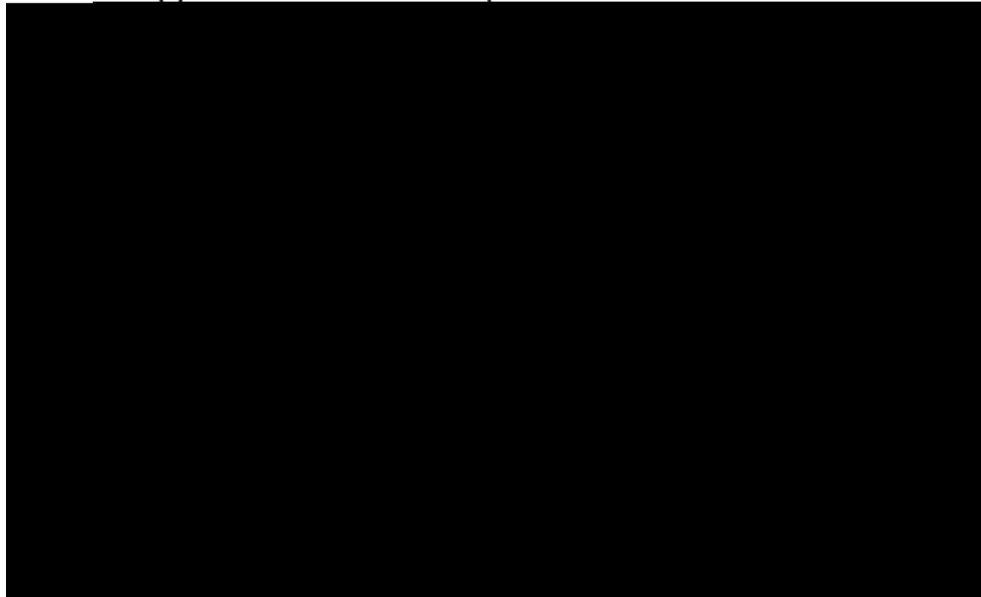
Y. Yan, **Jingbo Li**, S.-H. Wei, M. M. Al-Jassim, Phys. Rev. Lett. 98, 135506 (2007)



TiO_2

?

Vacuum level



Ti O_2

"

"



$\text{Mo}+\text{C}$

Ti O_2



Y. Gai, **Jingbo Li***, S.S.Li, J.B.Xia, S.H.Wei* Phys. Rev. Lett. 102
036402 (2009).

2009

201

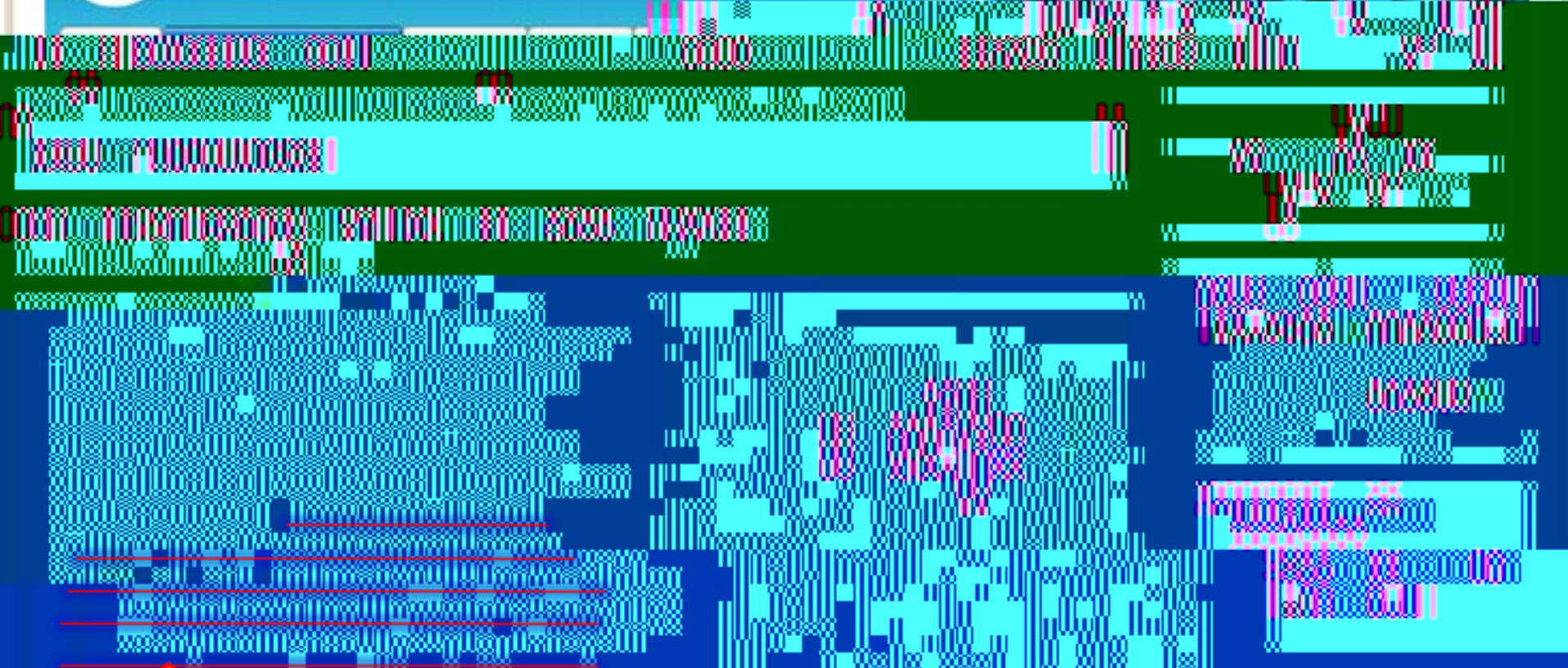
2009





Nature (Asia Materials): featured Highlight

Website: <http://www.natureasia.com/asia-materials/highlight.php?id=408>

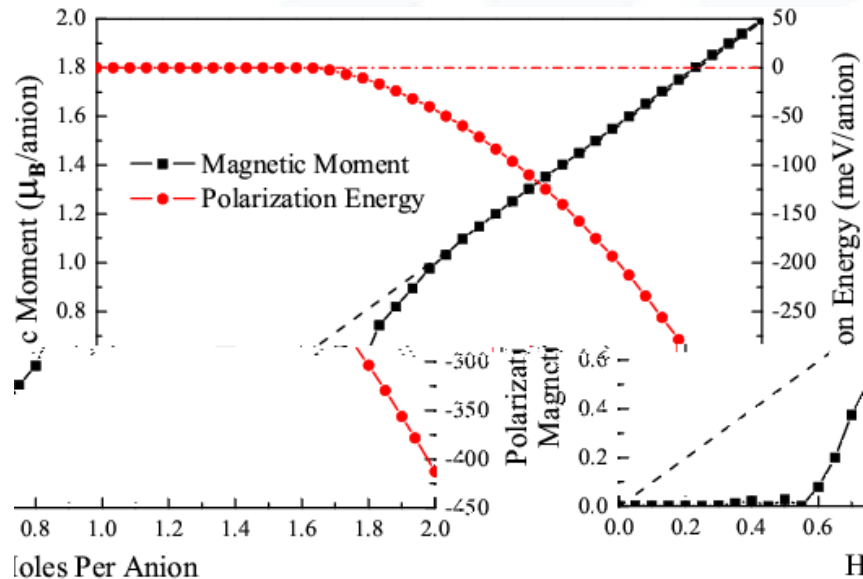


TiO₂

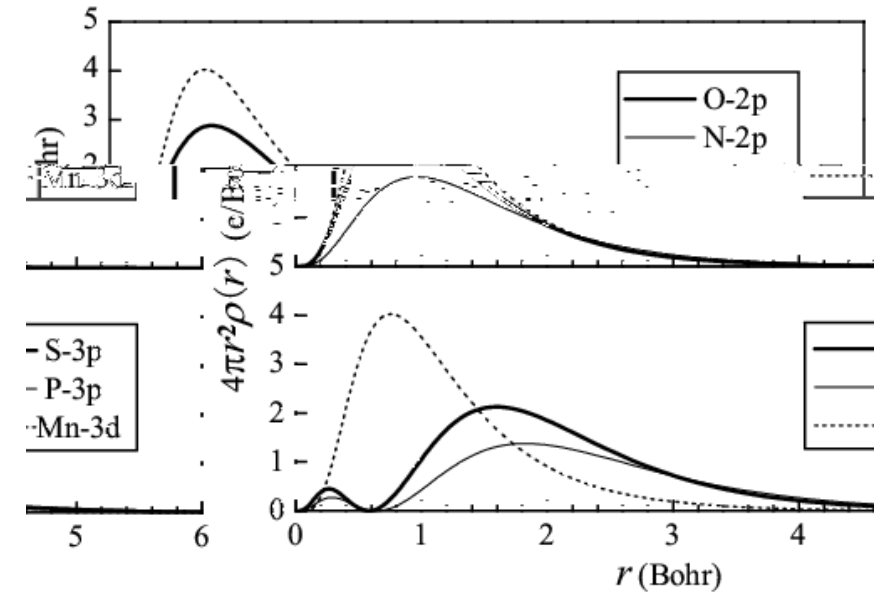
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ZnO GaN



ZnO



N Q P, S p-
Mn 3d-

H. Peng, H.J.Xiang, S.H.Wei*, S.S.Li, J.B.Xia, **Jingbo Li,*** Phys. Rev. Lett.
102 017201 (2009).

2009

145

2009

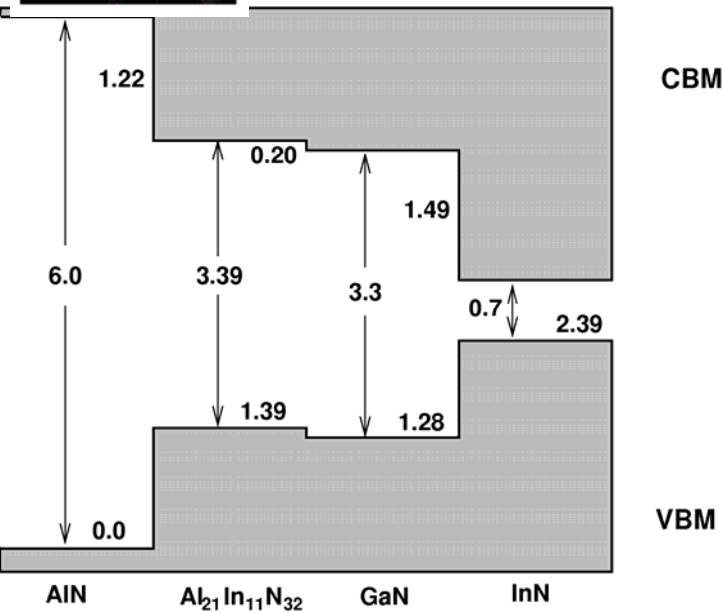
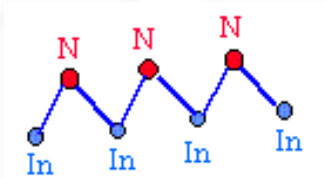
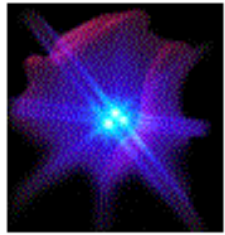




AlGaInN

GaN

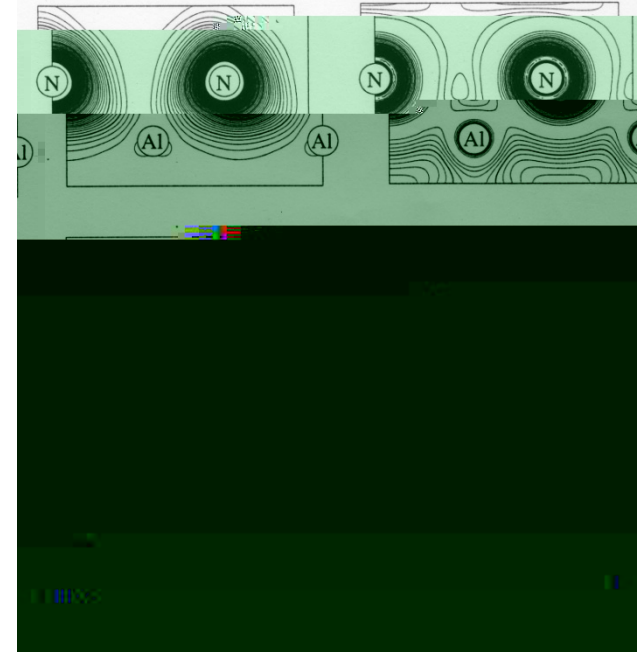
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Band Edge Charge Density

VBM

CBM



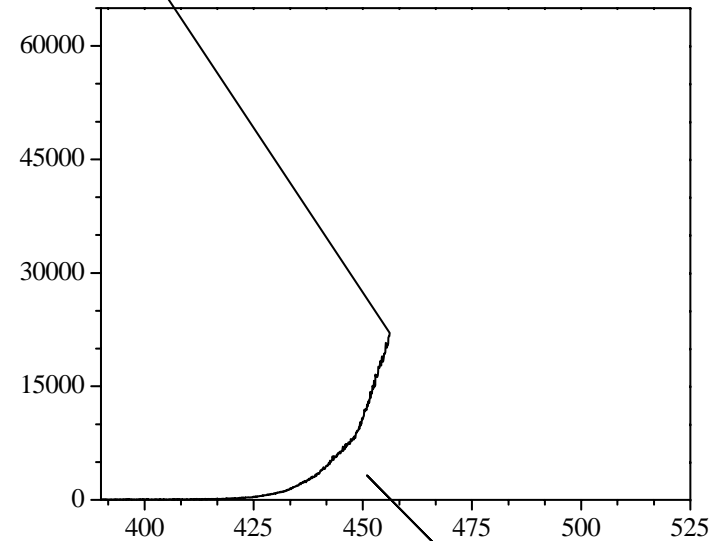
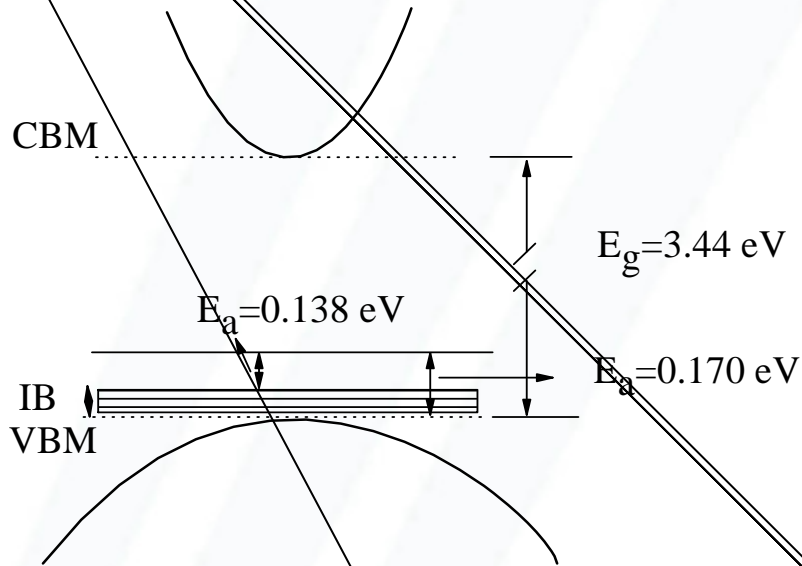
InN

AlInGaN
VBM

GaN

p-

F. Wang, Jingbo Li*, S.S.Li, J.B.Xia, S.-H. Wei, Phys. Rev. B 77, 113202 (2008)



P. Ma, Y. Q. Gai, J. Wang, F. Yang, Y. Zeng, Jinmin Li, **Jingbo Li,***
Appl. Phys. Lett. 93 102112 (2008).

ZnS, MgO

ZnO

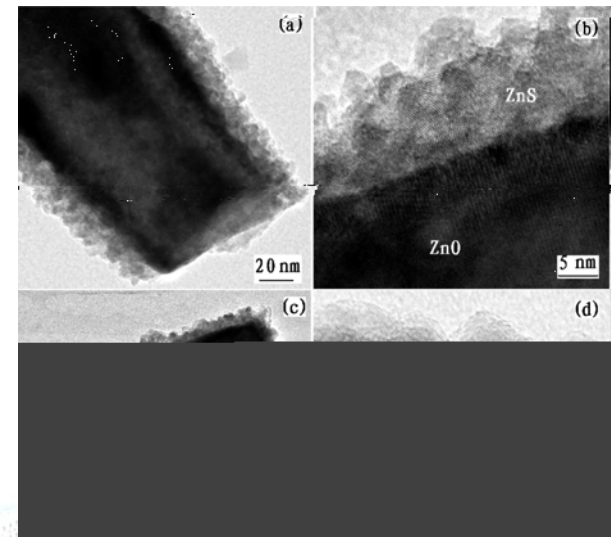
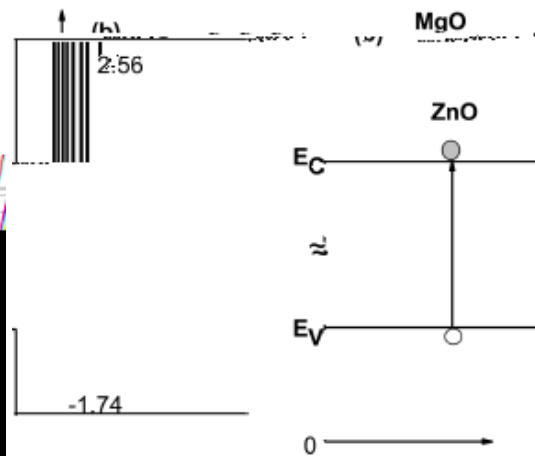
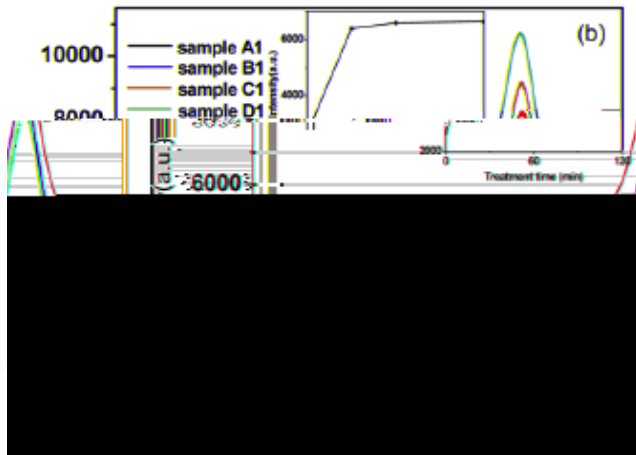
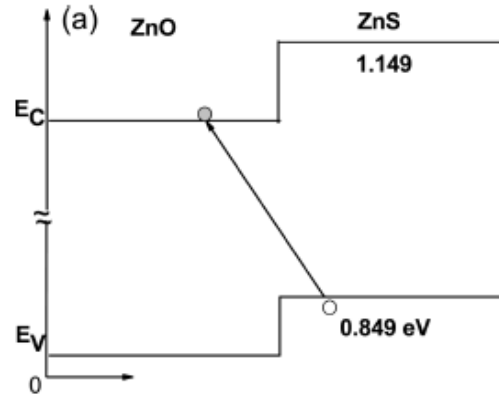
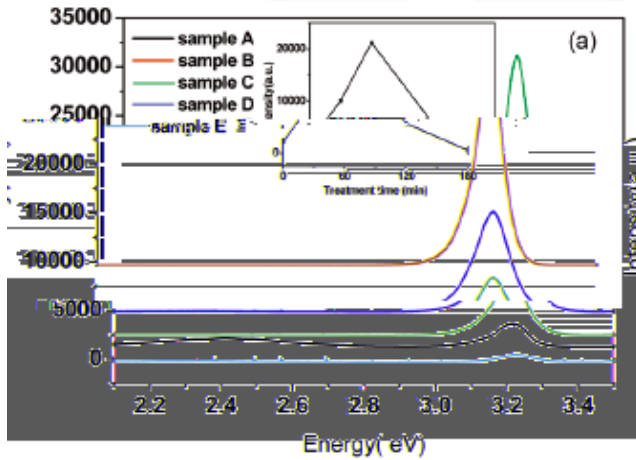
PL

◇ ZnO/ZnS

PL

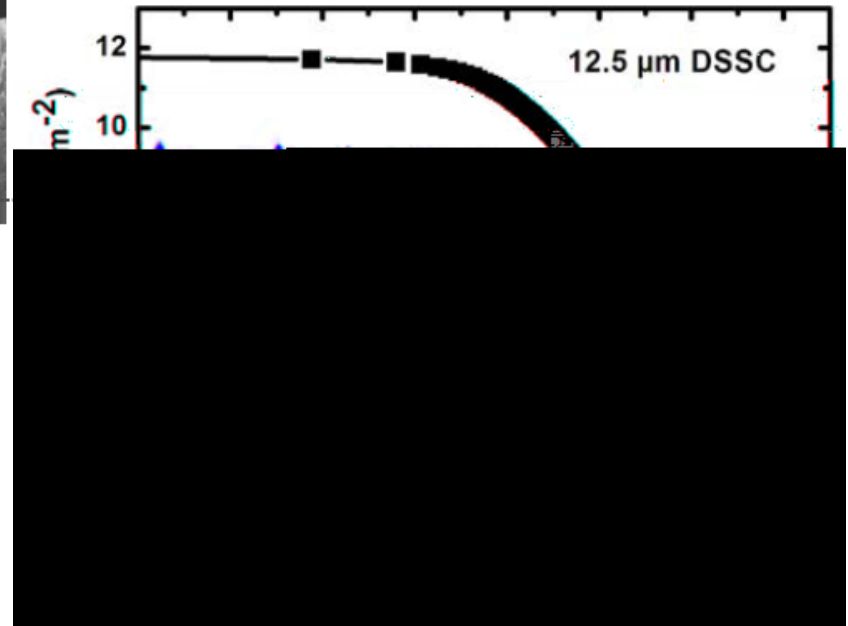
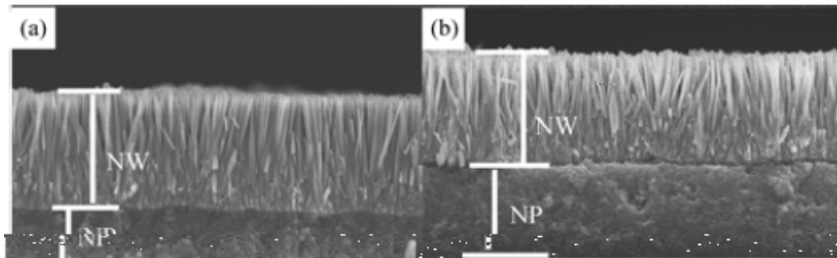
◇ ZnO/MgO

PL



ZnO

TiO₂



◇ TiO₂

◇ ZnO

◇

4.52%

ZnO

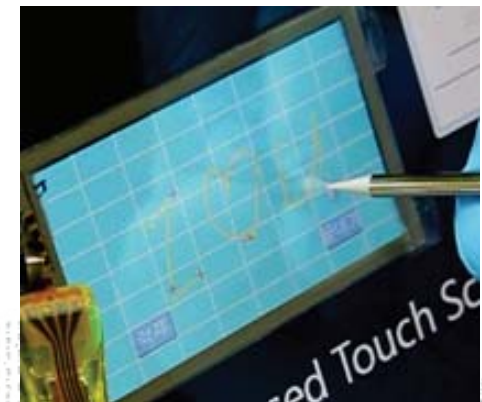
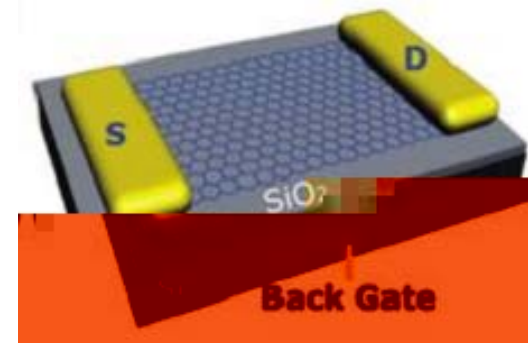
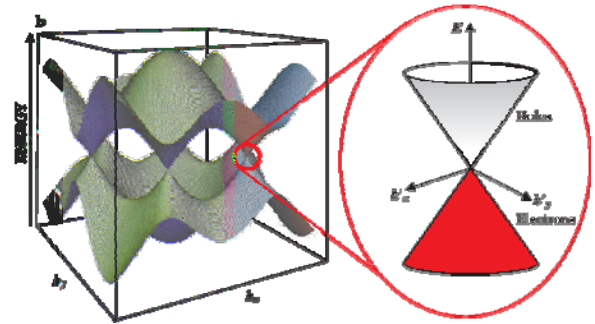
TiO₂

Meili Wang, Yan Wang, Jingbo Li*, **Chem. Commun.** 47, 11246 (2011)



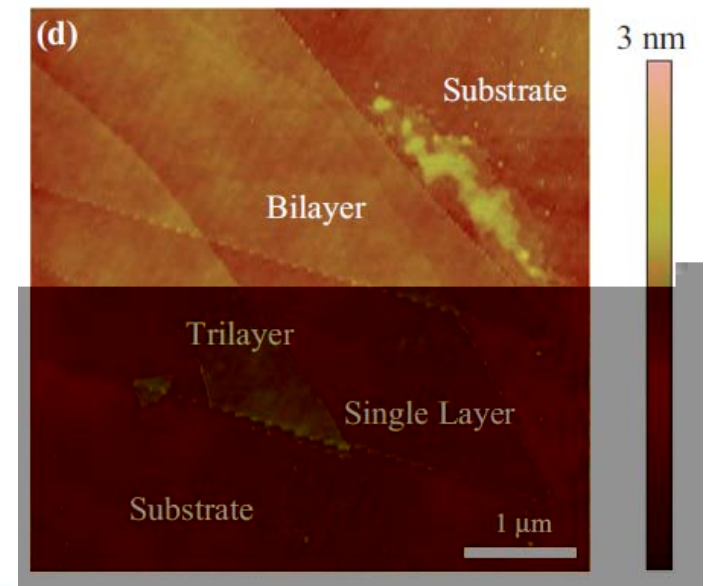
Why 2D Materials Are So Interesting?-Graphene

100
1, 100 GPa
125 GPa
97.7
2630 m^2g^{-1}
5000 $\text{Wm}^{-1}\text{K}^{-1}$ 10
 10^{13} cm^{-1}
200,000 $\text{cm}^2\text{V}^{-1}\text{s}^{-1}$
100
400 GHz



Graphene— Mechanical Exfoliation

- Mechanical exfoliation. Cheap&Fast, can be used for almost any layered materials.
- Not every material can be exfoliated to monolayer/few layer thick.
- Typically the thin flakes are so small that micro/nano scale electrodes are necessary for measurements.

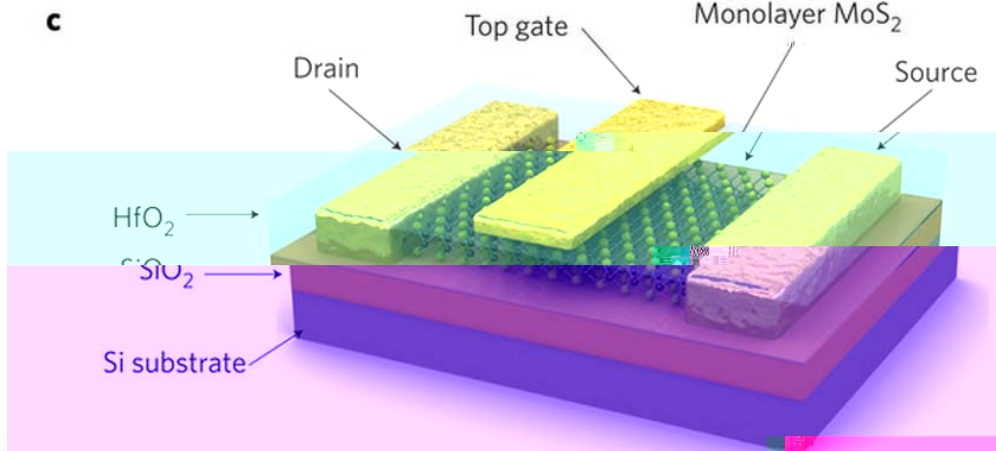


Materials Beyond Graphene—MoS₂

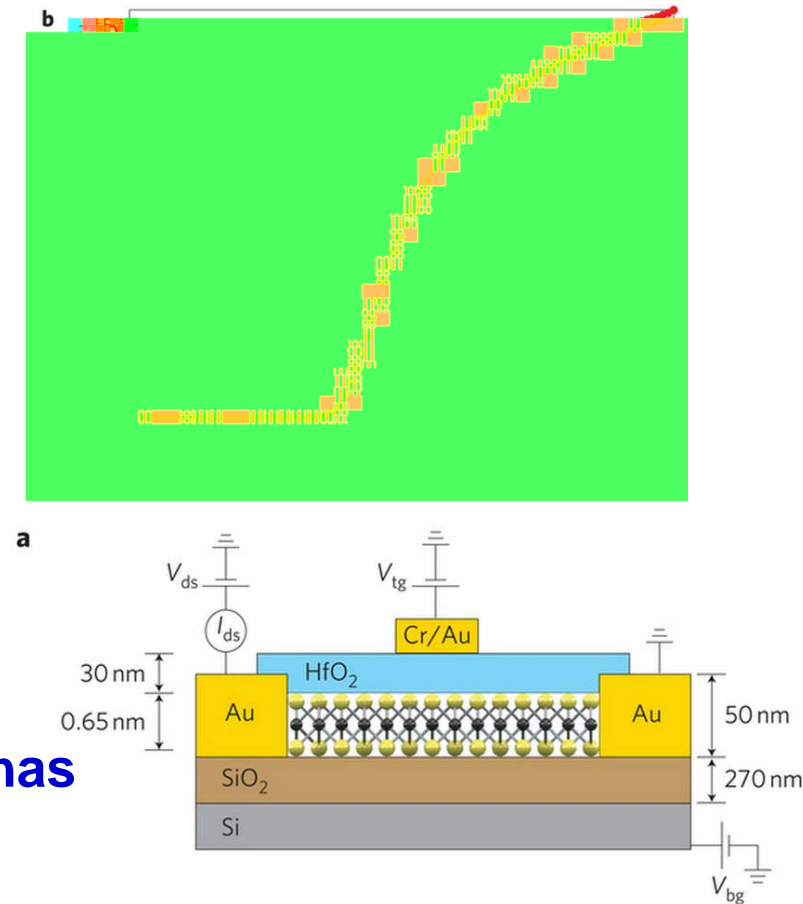


Single-layer MoS₂ transistors

B. Radisavljevic, A. Radenovic, J. Brivio, V. Giacometti & A. Kis



200 cm²/SV mobility and 10⁸ on/off ratio has been demonstrated!

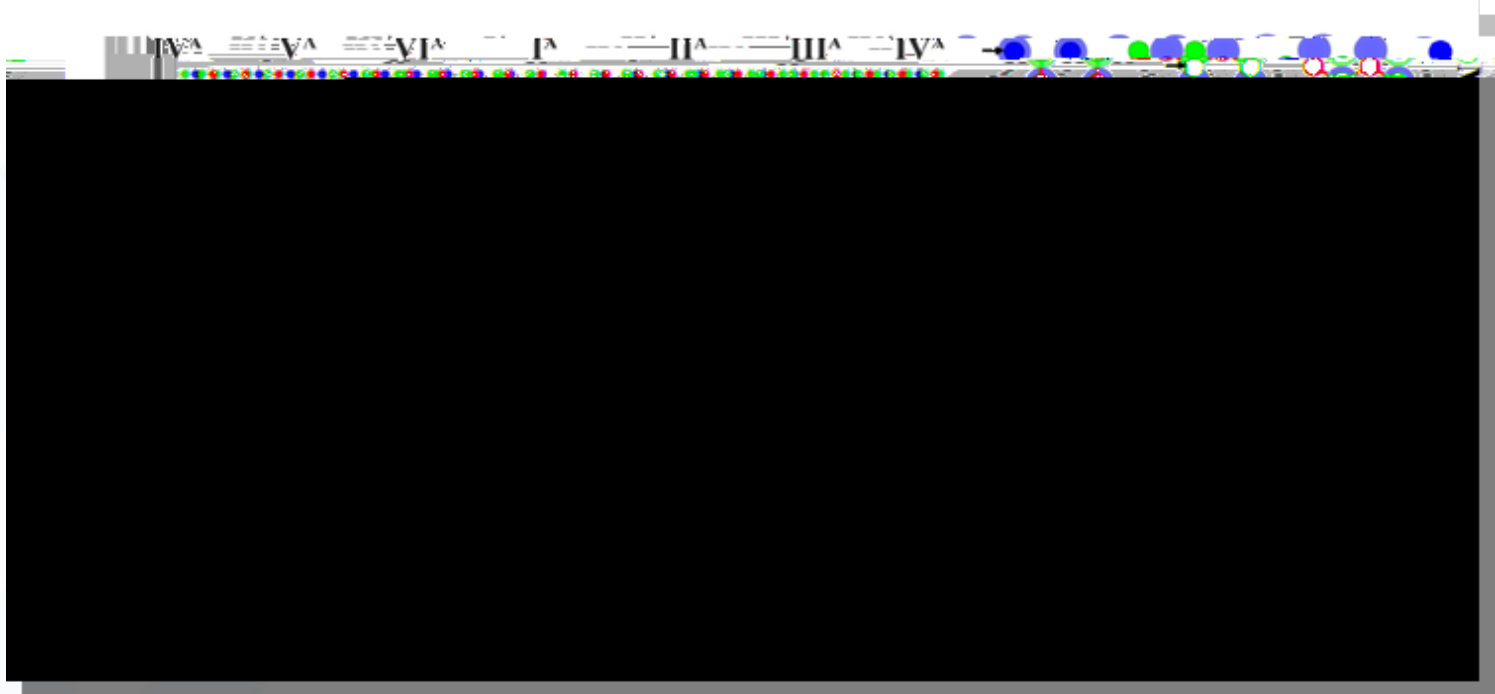


This paper has been cited 678 times in three years!

***Nature Nanotechnology* 6, 147 (2011)**

Why 2D Materials Are So Interesting?

- **Electronic band structure transition– direct/indirect band transition in MoS_2 .**
- **Large surface area, properties can be strongly affected by the substrate and the environment, e.g. sensing.**
- **Reduced dimensionality– enhanced electron/electron correlation, e.g. Superconductivity in 2D materials.**
- **Carrier concentration in the material can be effectively modulated by solid state/ ionic liquid gating.**

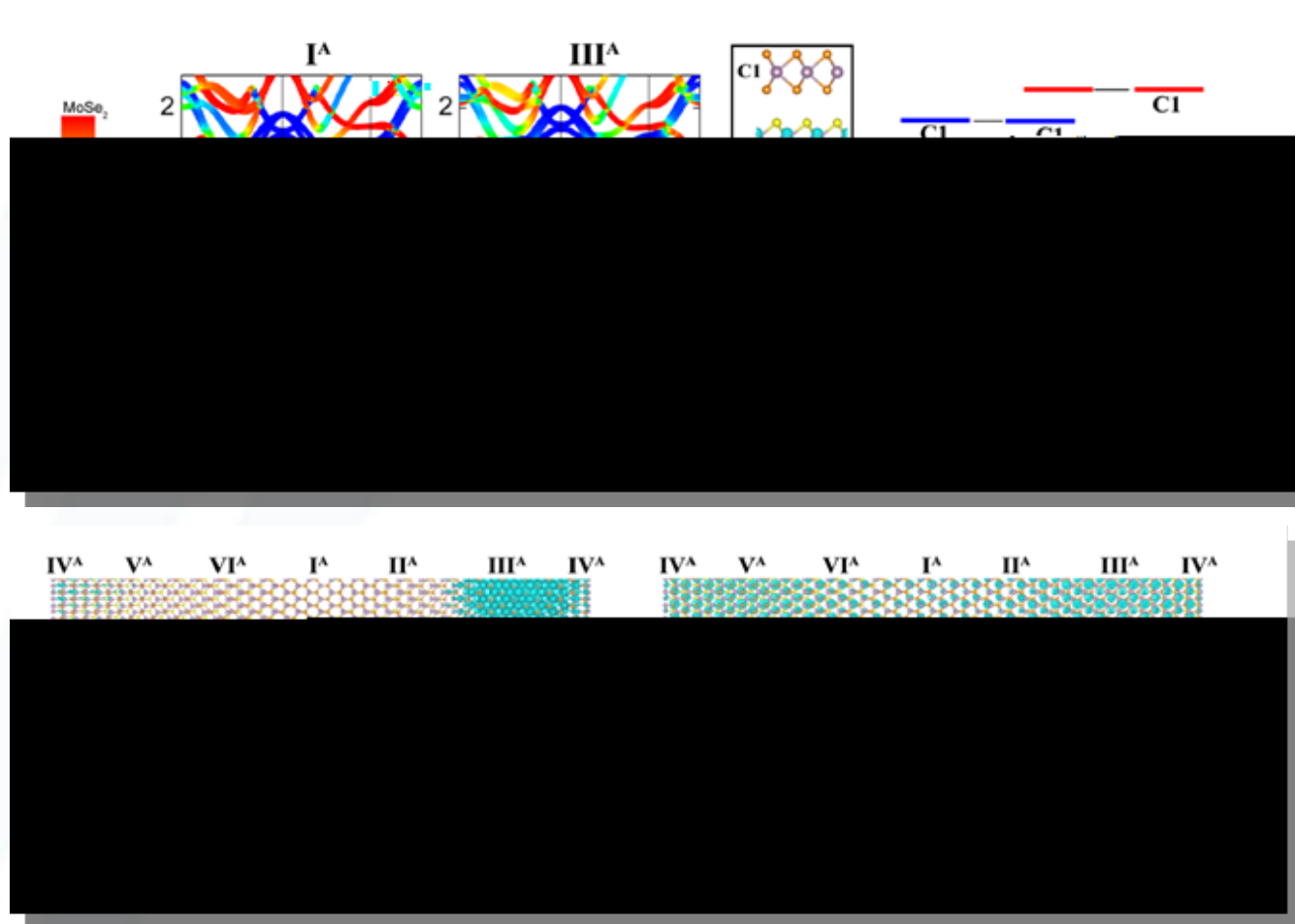


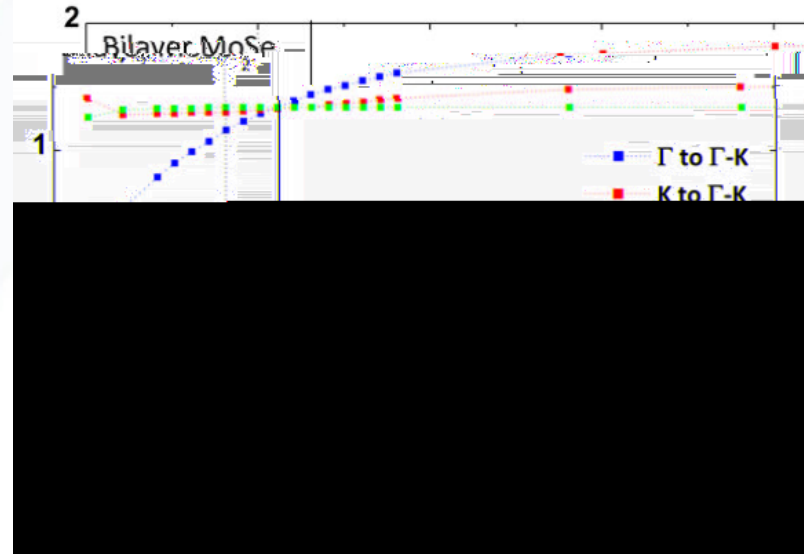
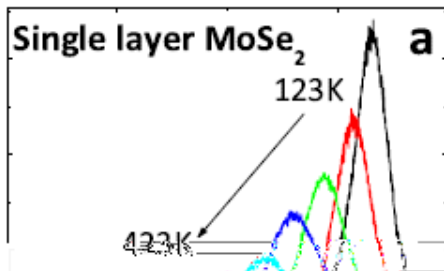
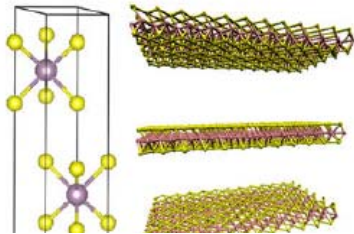
◇ $\text{MoS}_2/\text{MoSe}_2$ " " (Moire pattern)

◇ MoS_2 24*24 MoSe_2 23*23 6630

J. Kang, Jingbo Li*, S. S. Li, J.B. Xia, and L-W. Wang*, **Nano Letters**, 13 5485 (2013)

$\text{MoS}_2/\text{MoSe}_2$







2012 12 7



<http://www.nature.com/nnano/journal/v7/n12/full/nnano.2012.226.html>

The screenshot shows the Nature Nanotechnology journal homepage. At the top, there is a yellow banner with the journal title 'nature nanotechnology' and a search bar. Below the banner, there are navigation links: 'nature.com', 'journal home', 'current issue', 'research highlights', and 'full text'. The main content area features the article 'Metal dichalcogenides: The hotter the brighter' by Stefaatin Tongay, Junqiao Wu, et al. The article is highlighted with a red background. To the right of the article, there are links for 'Download PDF', 'Citation', 'Reprints', and 'Rights & permissions'. Below the article, there is a section for 'Postdoctoral Positions in Biophysics and Nanotechnology' and 'Associate or Assistant Professor (tenure-track)'. The bottom of the page has a footer with 'Post a free job' and 'More science jobs'.

Full text access provided to Institute of Semiconductors, CAS by x

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Our choice from the recent literature

Nature Nanotechnology **7**, 772 (2012) | doi:10.1038/nnano.2012.226
Published online 05 December 2012

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Metal dichalcogenides: The hotter the brighter

Nanomaterials: Tools for Sherlock Holmes • Metal dichalcogenides: The hotter the brighter •
Metal–organic frameworks: A very fine sieve • Self-assembly: Tied up

Nano Lett. **12**, 5576–5580 (2012)

Photoluminescence emission following excitation with laser radiation is an optoelectronic process that occurs in most semiconductors. The laser excitation provides energy for electrons to be promoted from the valence to the conduction band. After a short time the electrons relax back to the valence band and in doing so they emit light (photoluminescence). In common semiconductors, the photoluminescence intensity is higher at lower temperatures, as thermal energy induces ways for the electrons to relax other than by photoluminescence emission. Stefaatin Tongay, Junqiao Wu

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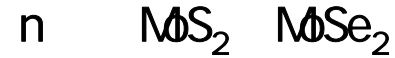
Postdoctoral Positions in Biophysics and Nanotechnology
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Associate or Assistant Professor (tenure-track)
Osaka University

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Purdue University

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S. Tongay, J. Zhou, C. Ataca, J. Liu, J. S. Kang, T. S. Matthews, L. You, Jingbo Li, J. C. Grossman, and J. Wu, **Nano Letters**, 13, 2831(2013).

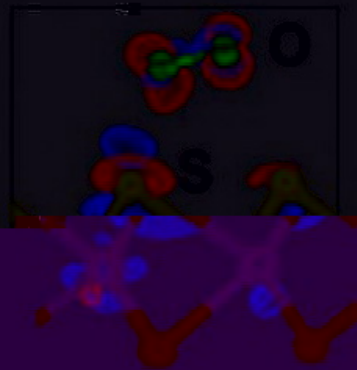
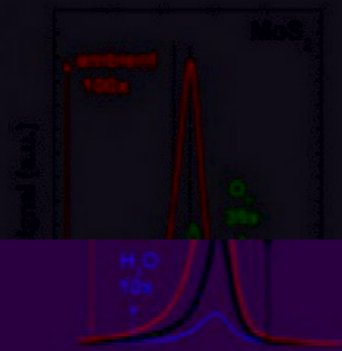


Scientists enhance light emission in 2D semiconductors by a factor of 100

May 08, 2013 by Lisa Zyga [report](#)

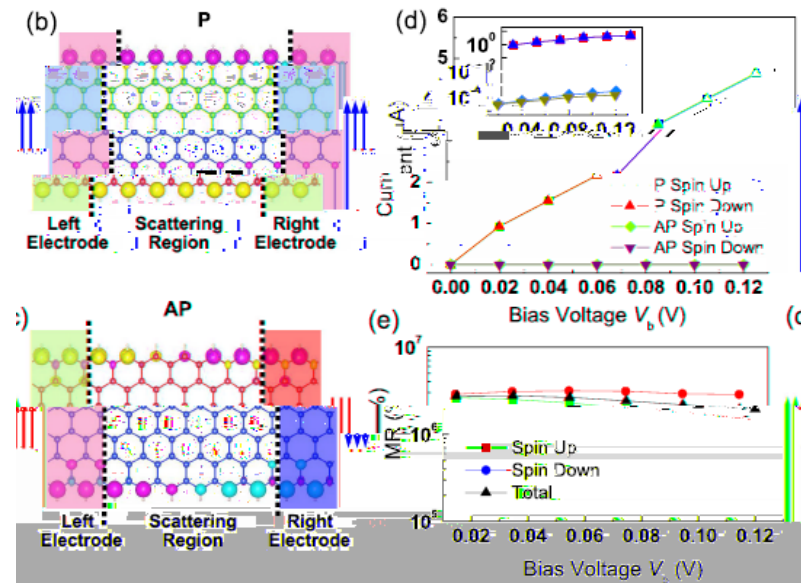
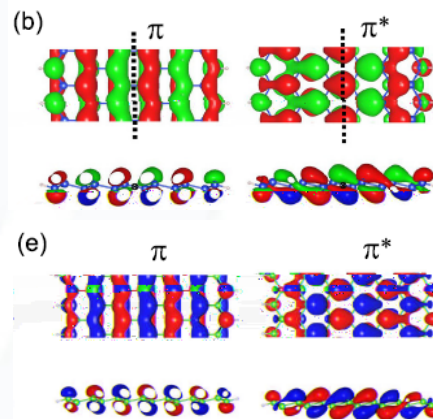
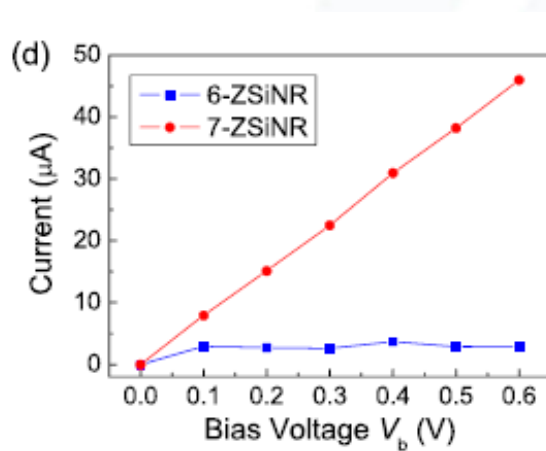
2013 5 8
(Phys.Org)

<http://phys.org/news/2013-05-scientists-emission-2d-semiconductors-factor.html>

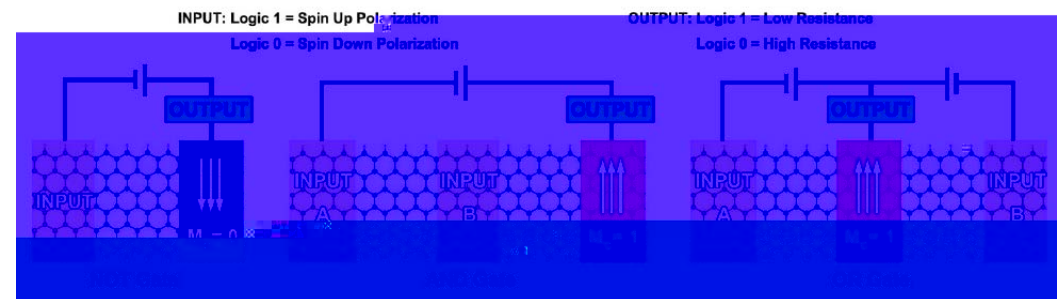


Abstract: MoS₂ is a promising material for optoelectronic applications. However, its light emission is very weak under ambient conditions. Here, we report a significant enhancement of light emission in MoS₂ by exposing it to water vapor. The enhancement factor is as high as 100. This enhancement is attributed to the formation of a water layer on the surface of MoS₂, which increases the carrier concentration and reduces the non-radiative recombination. This work provides a simple and effective way to enhance the light emission of 2D semiconductors.

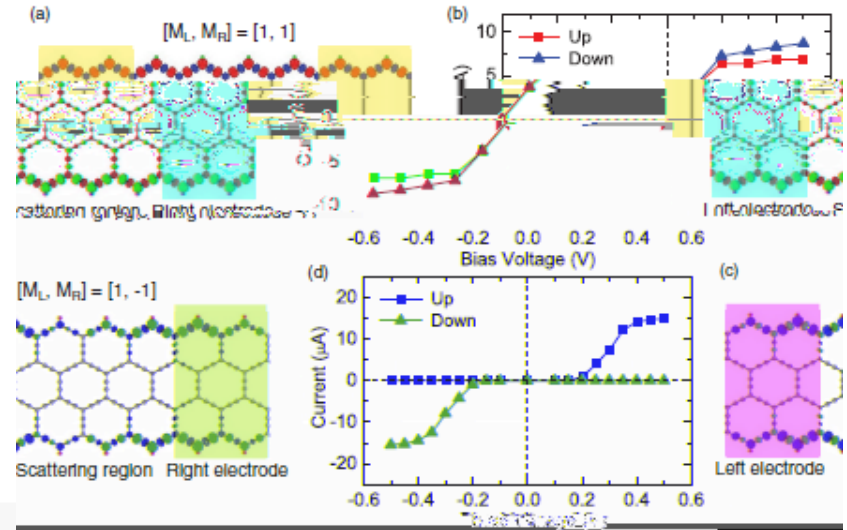
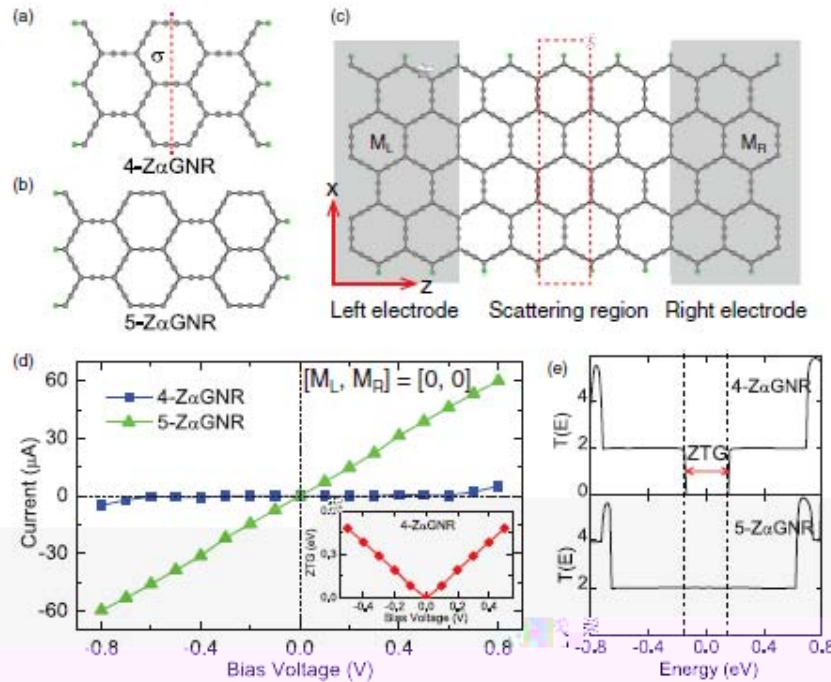
Introduction: Two-dimensional (2D) materials have attracted much attention in recent years due to their unique properties. Among them, MoS₂ is a promising material for optoelectronic applications. However, its light emission is very weak under ambient conditions. Here, we report a significant enhancement of light emission in MoS₂ by exposing it to water vapor. The enhancement factor is as high as 100. This enhancement is attributed to the formation of a water layer on the surface of MoS₂, which increases the carrier concentration and reduces the non-radiative recombination. This work provides a simple and effective way to enhance the light emission of 2D semiconductors.



N ZSi NR



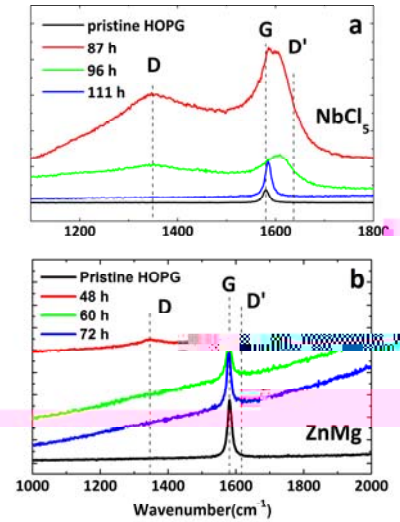
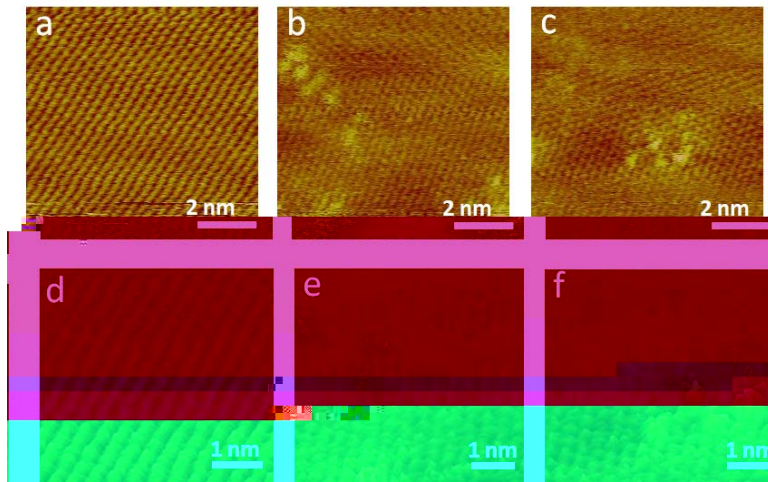
Jun Kang, Fengmin Wu, and Jingbo Li*,
Appl. Phys. Lett. 100, 233122 (2012)



Q. Yue, S. L. Chang, J. C. Tan, S. Q. Qin,
J. Kang, and Jingbo Li*, **Phys. Rev. B**
86, 235448 (2012)



p n



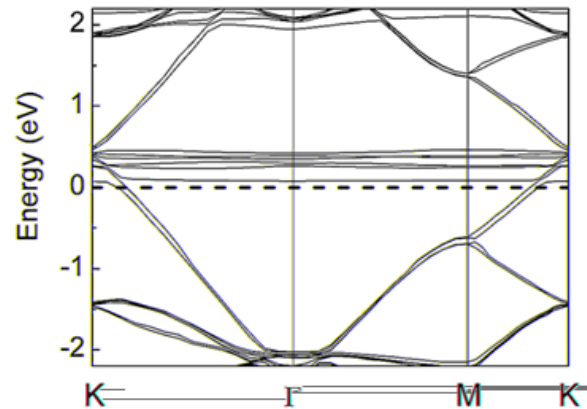
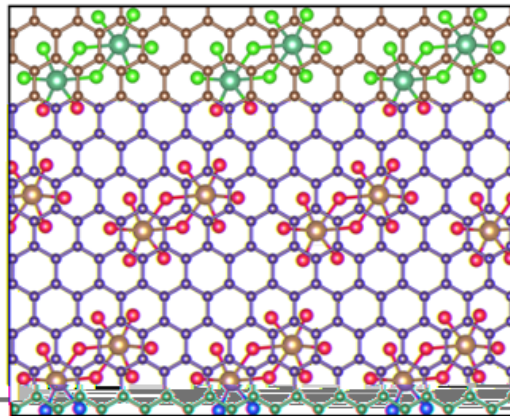
ZnMg NbCl₅



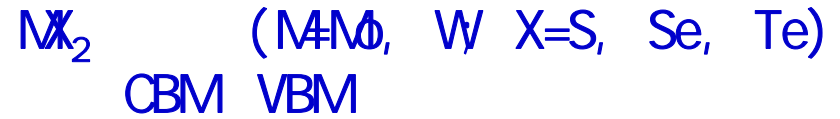
ZnMg NbCl₅
p n



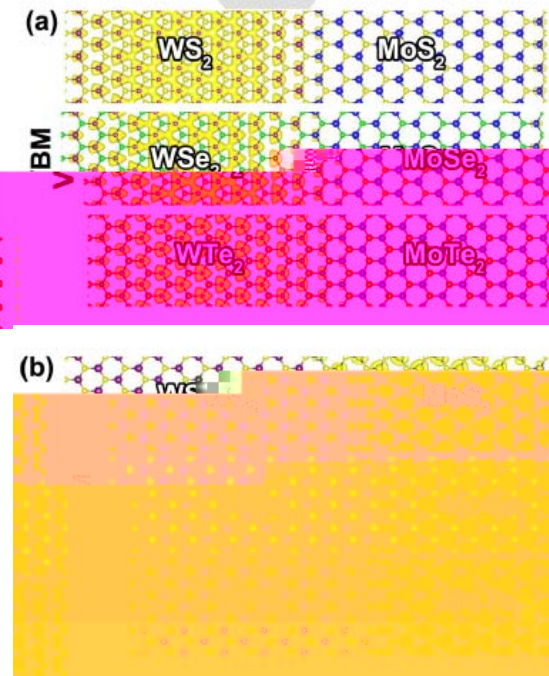
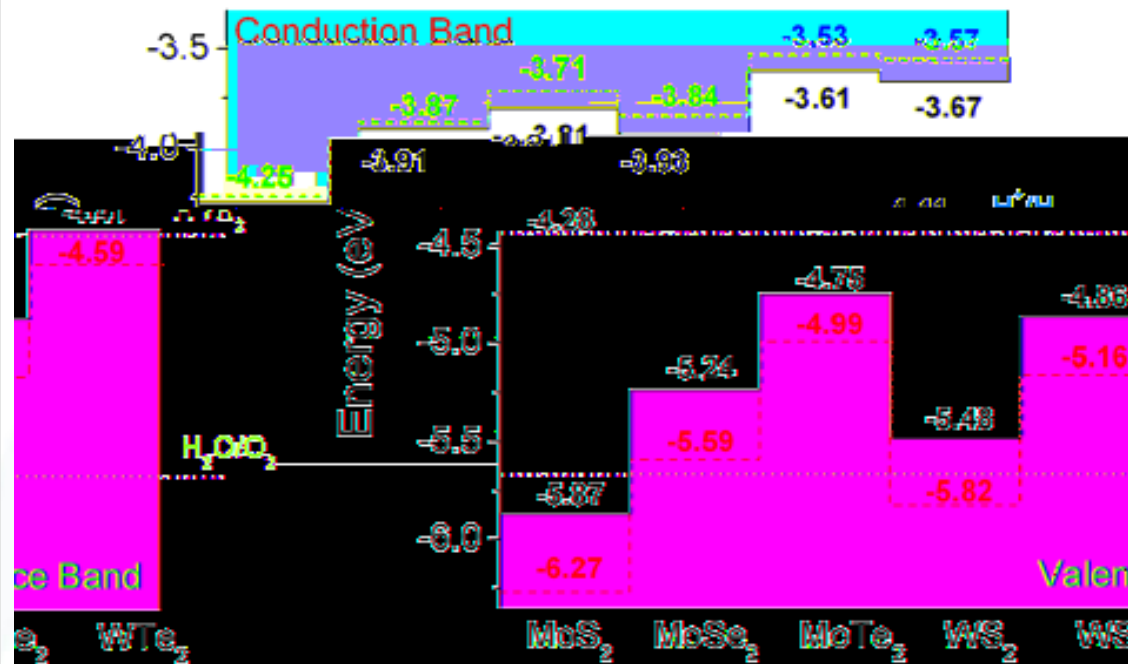
p n
10¹⁹ cm³ 10¹⁸ cm³

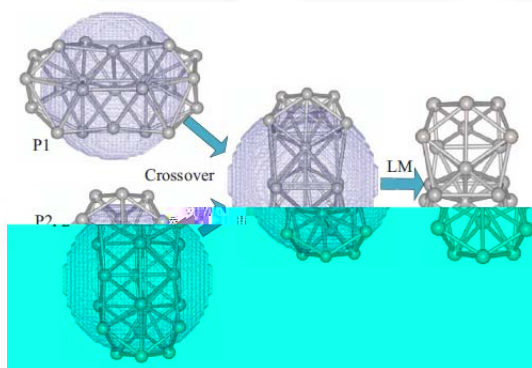


X.Q. Meng, S. Tongay, J. Kang, Z.H. Chen, F. M. Wu, S.-S. Li, J.-B. Xia, Jingbo Li* and J. Q. Wu, **Carbon**, 57, 507 (2013).



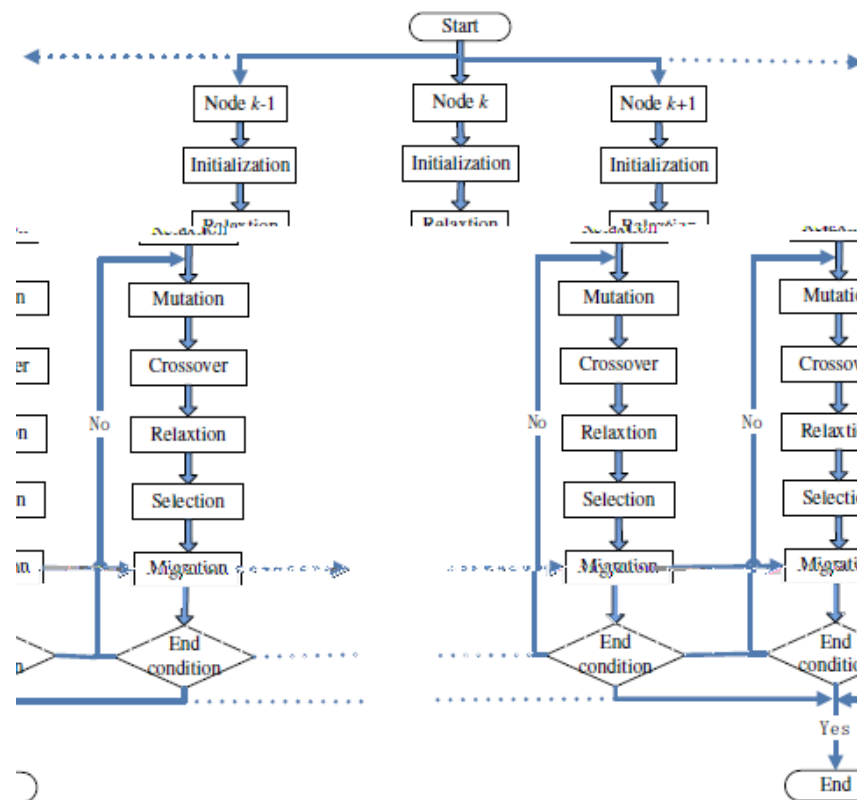
||





PDECO
2-5

Co Pt

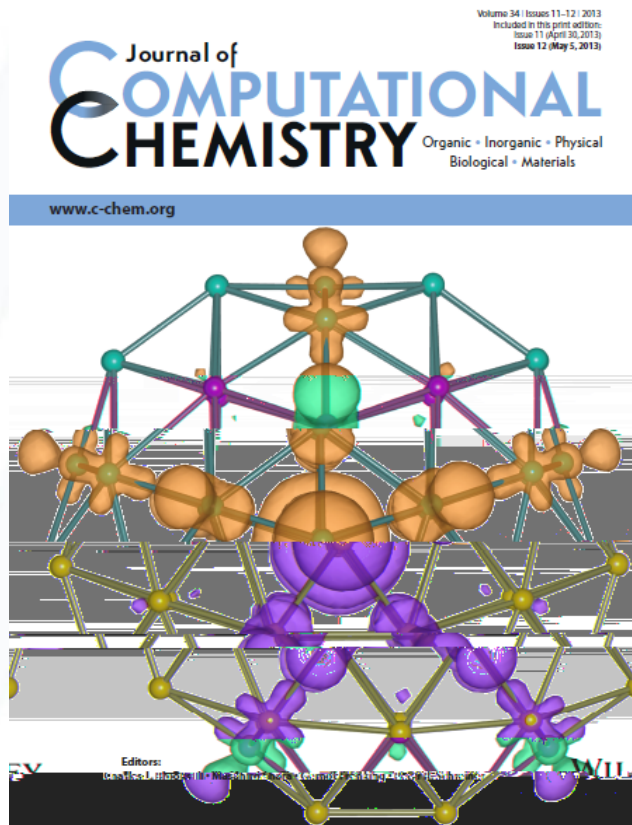


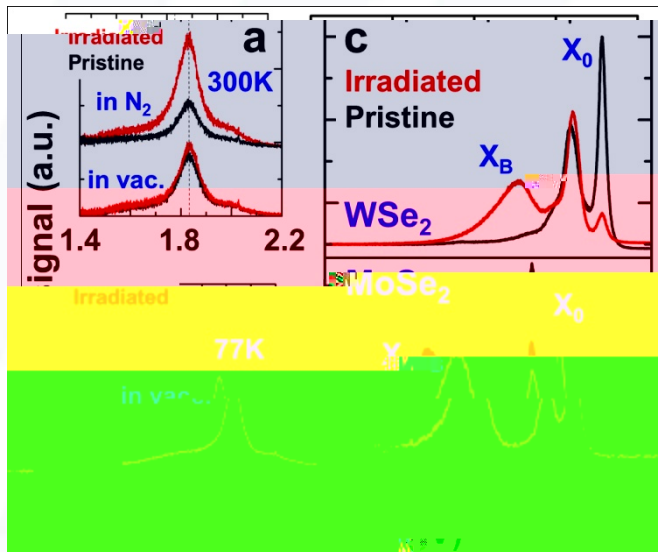
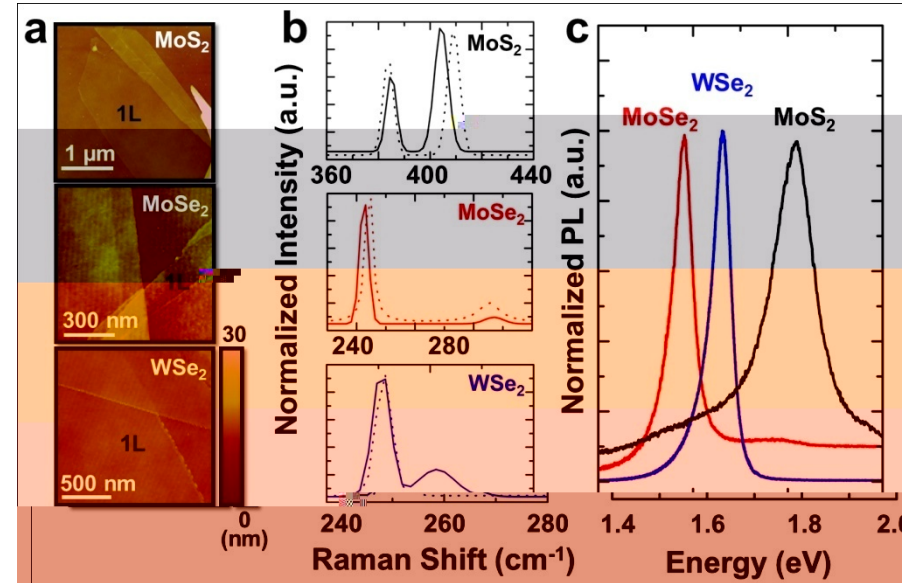
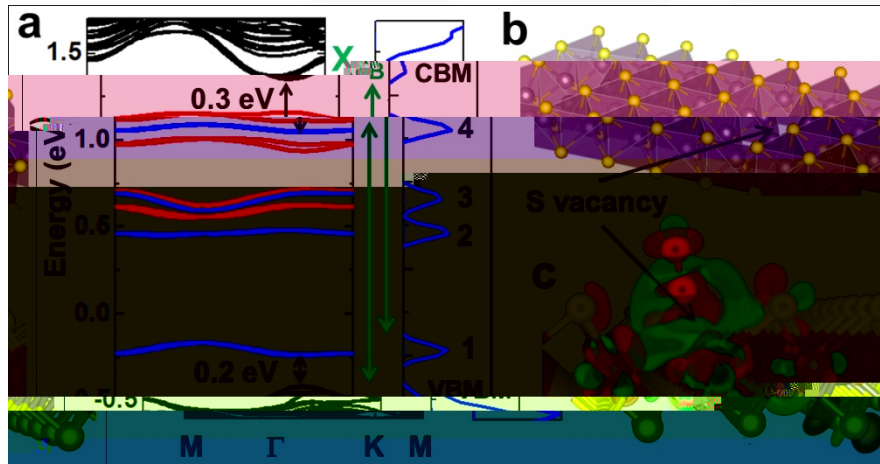
Zhanghui Chen, Xiangwei Jiang, **Jingbo Li***, Shushen Li, and Linwang Wang*, J. Comp. Chem. 34, 1046 (2013).

Zhanghui Chen, Xiangwei Jiang, **Jingbo Li***, and Shu-Shen Li. J. Chem. Phys., 138, 214303, (2013).



J. Chem. Phys. J. Comp. Chem.

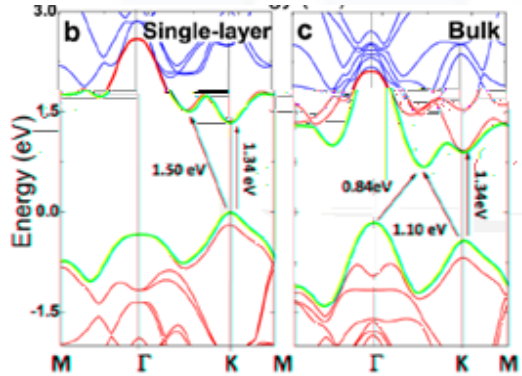




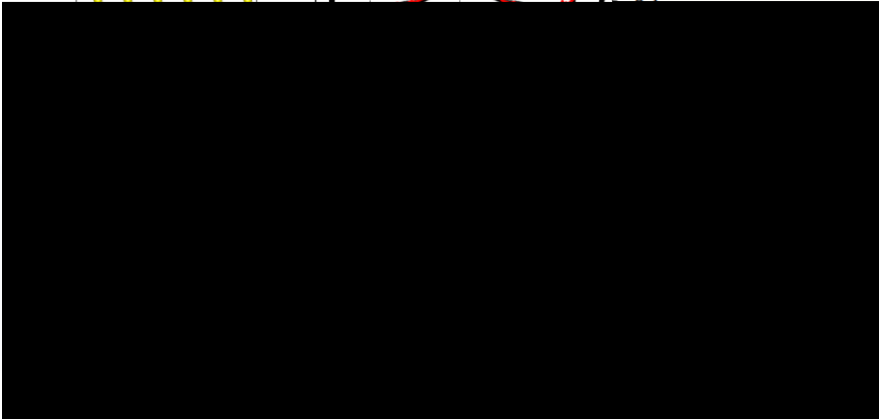
PL

S. Tongay, J. Suh, C. Ataca, W. Fan, A. Luce, J. S. Kang, J. Liu, C. Ko, R. Raghunathan, J. Zhou, F. Ogletree, Jingbo Li, J. C. Grossman, and J. Wu, **Scientific Report**, 3, 2657, 2013.

ReS₂



a



MoSe₂

ReS₂

?
ReS₂ 1T

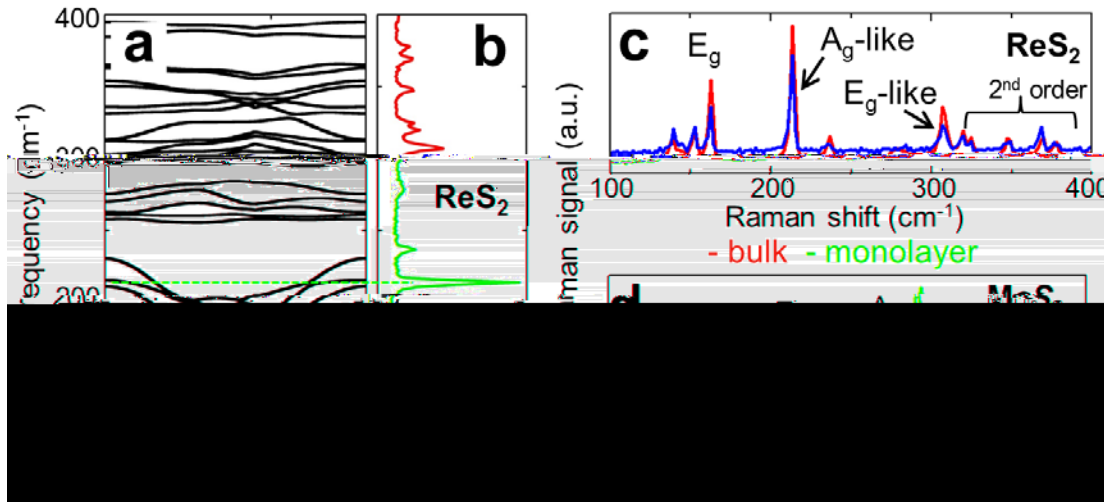
ReS₂

S. Tongay, H. Sahin, C. Ko, A. Luce, W. Fan, J. Zhou, Y. S. Huang, J. Yan, F. Ogletree, S. S. Li, Jingbo Li, F. M. Peeters, and J. Wu, **Nature Comm.**, 5, Article number: 3252 doi:10.1038/ncomms4252 (2014).



ReS₂—

:



ReS₂ Raman

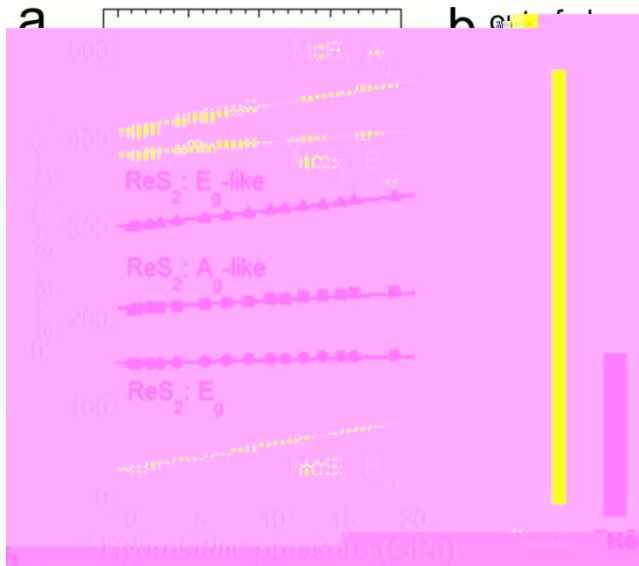
MoS₂

Raman

ReS₂ Raman

MoS₂

Raman

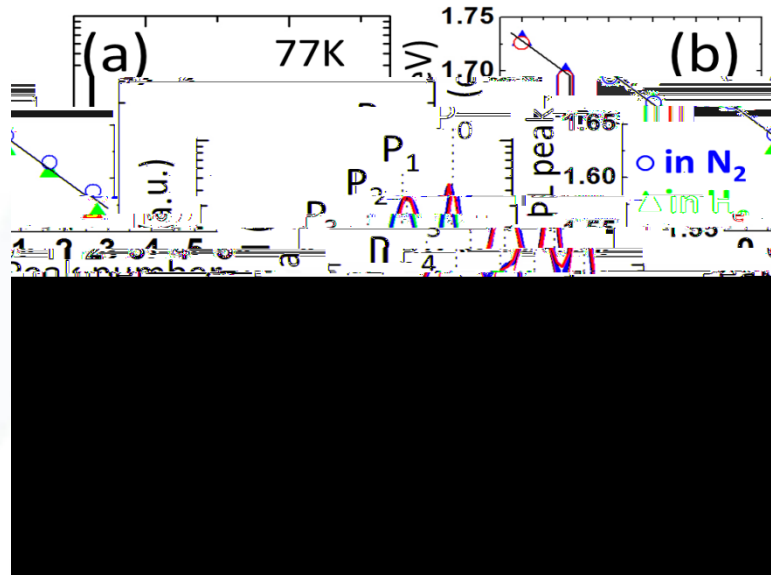
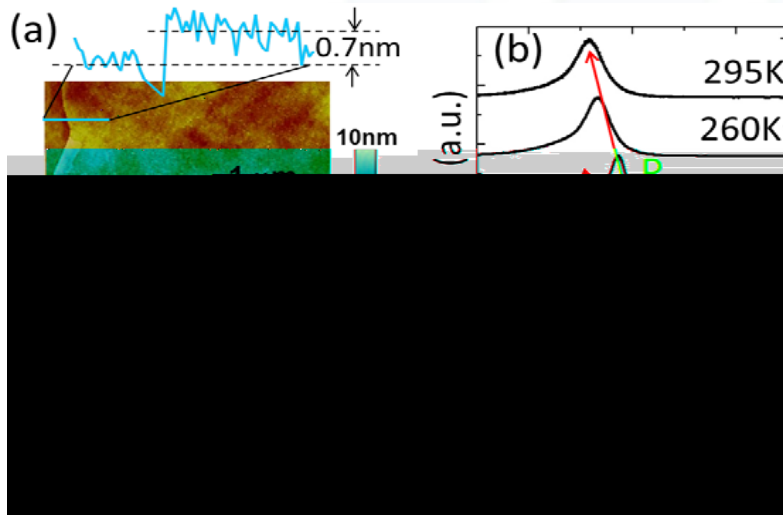


ReS₂

!

S. Tongay, H. Sahin, C. Ko, A. Luce, W. Fan, J. Zhou, Y. S. Huang, J. Yan, F. Ogletree, S. S. Li, Jingbo Li, F. M. Peeters, and J. Wu, **Nature Comm.**, 5, Article number: 3252 doi:10.1038/ncomms4252 (2014).

~~VSe₂~~



~~VSe₂~~

PL
P1

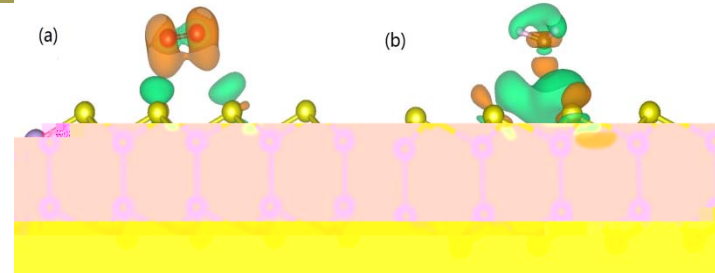
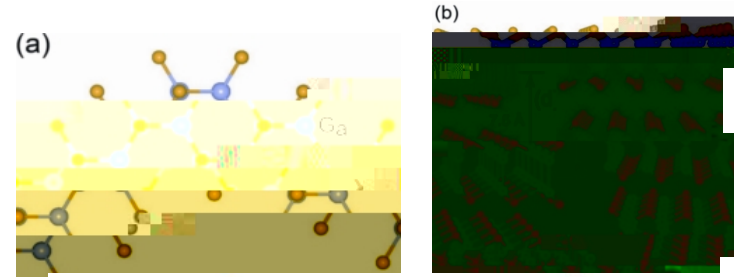
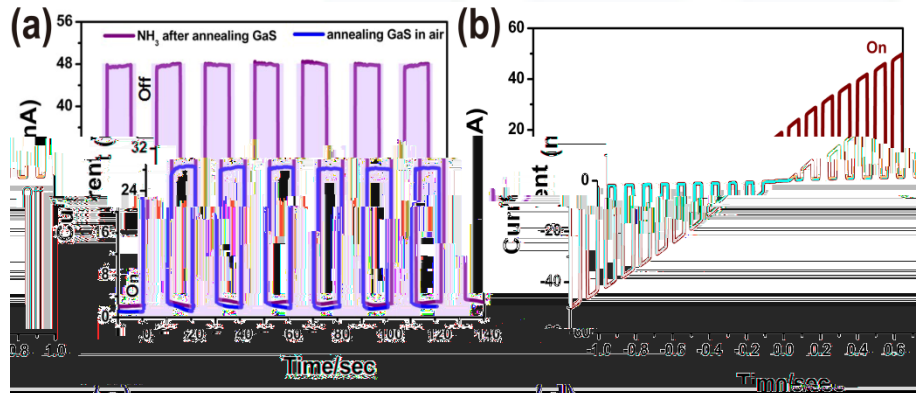
PO
PL

N₂

P1, P2, P3, P4
Huang-Rys
PL
0.3



GaS



(NH₃, air, O₂)

◆ NH₃

64.43 AW¹
12621%

S. Yang, Y. Li, X. Wang, N. Huo,
J. Xia, S. Li, J. Li,* **Nanoscale**, 6,
2582 (2014).



2014 2 7

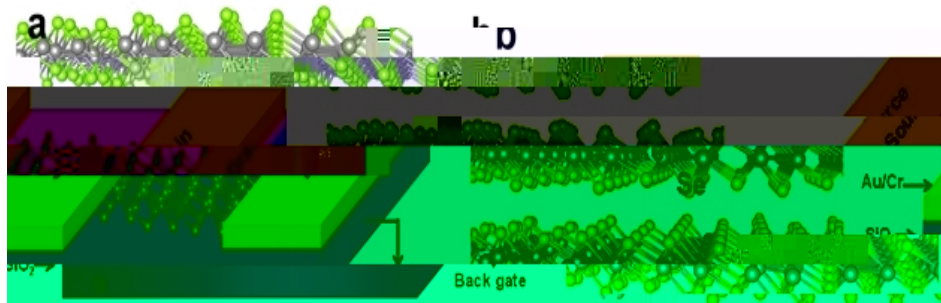
Nanoscale
GaS

"

"

<http://blogs.rsc.org/nr/>

The screenshot shows the Nanoscale Blog homepage. At the top, there's a blue banner with the text "Publishing Journals, books and databases" and the Royal Society of Chemistry logo. Below the banner, the page is titled "Nanoscale Blog". A navigation bar includes "Home", "Nanoscale Blog RSS", and a search bar. The main content area features a post titled "Nanoscale Issue 4 of 2014 out now!" dated "04 Feb 2014" by Katherine Dunn, Publishing Assistant. The post includes a small image of the journal cover and a link to "Nanoscale". To the right, there's a "Links" section with links to "About the journal", "Editorial Board", and "Journal Homepage". The background of the page is a light blue and green abstract design.



1s^{-1}
1

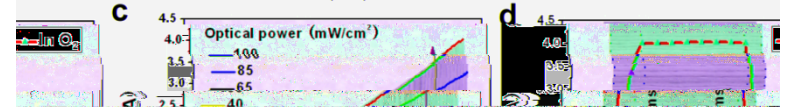
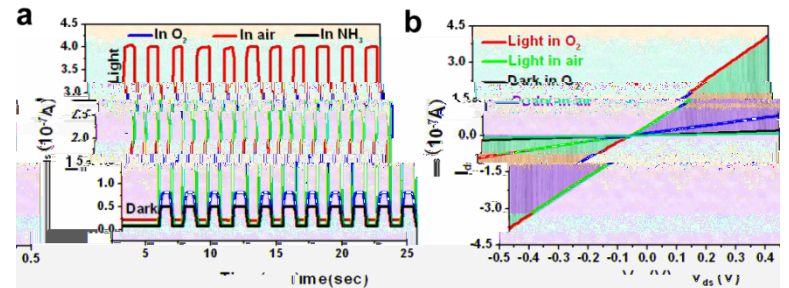
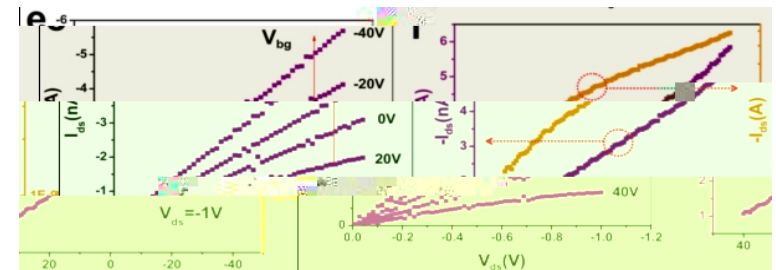
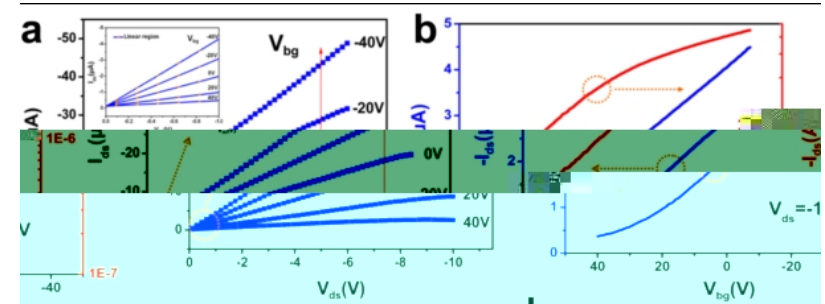
$9.78\text{ cm}^2\text{V}^{-1}\text{s}^{-1}$
 $0.10\text{ cm}^2\text{V}^{-1}\text{s}^{-1}$



$14.1\text{ cm}^2\text{V}^{-1}\text{s}^{-1}$

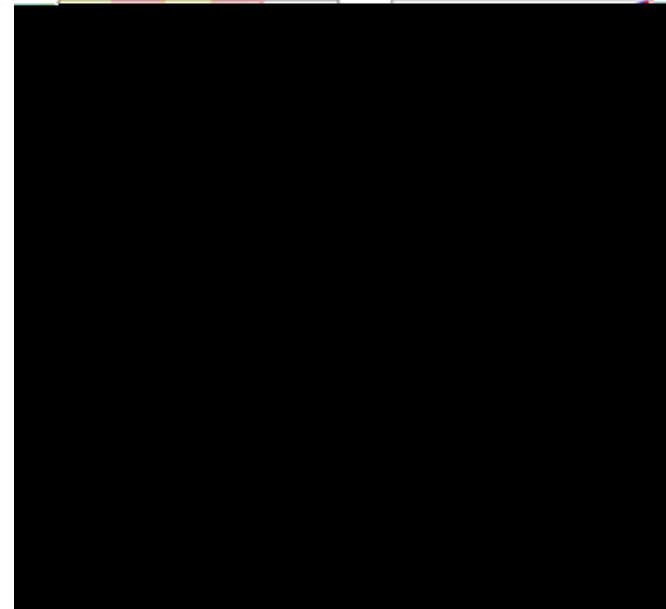
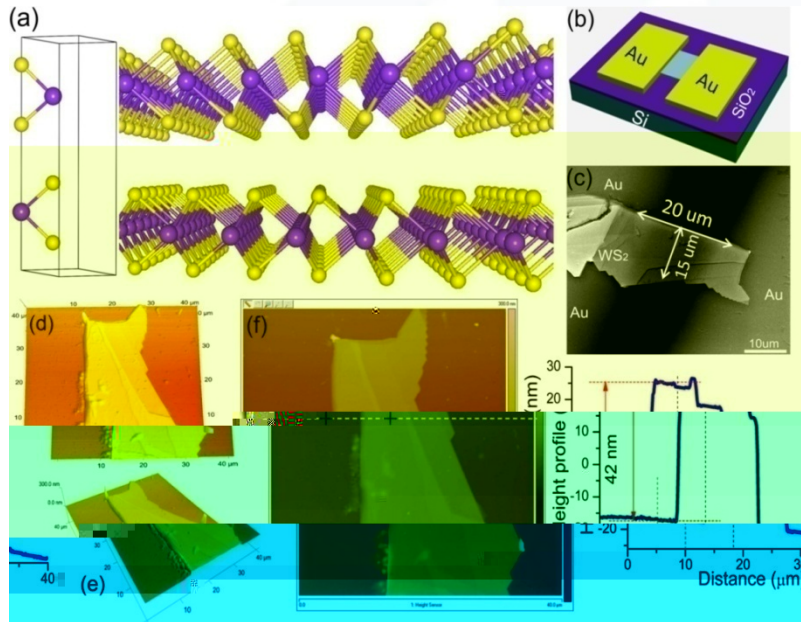
95 AW^{-1}

18645%



S. Yang, Y. Li, X. Wang, N. Huo, J. Xia,
S. Li, J. Li*, S-H. Wei*, submitted, 2014

WS₂ nanoflakes



- ◇ V_g 2 n- type
- ◇ 1118 %
- ◇ O₂ NH₃
- ◇ NH₃ ethanol 884 A/W 1.7 × 10⁵ %

12 cm²/Vs
<20 ns
5.7 A/W

NH₃

Nengjie Huo, Shengxue Yang, Zhongming Wei, Shu-Shen Li, Jian-Bai Xia & Jingbo Li*. *Scientific Reports* (2014), under review.

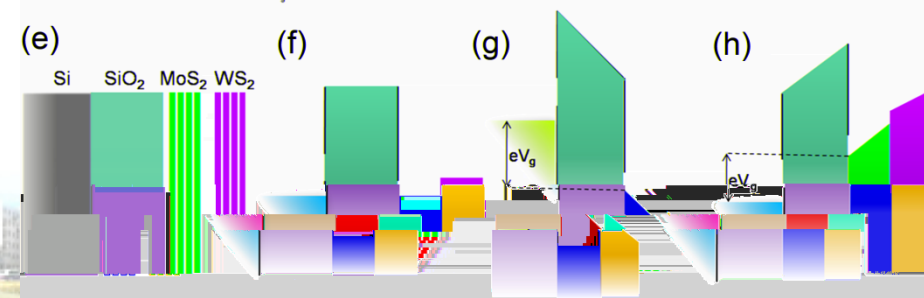
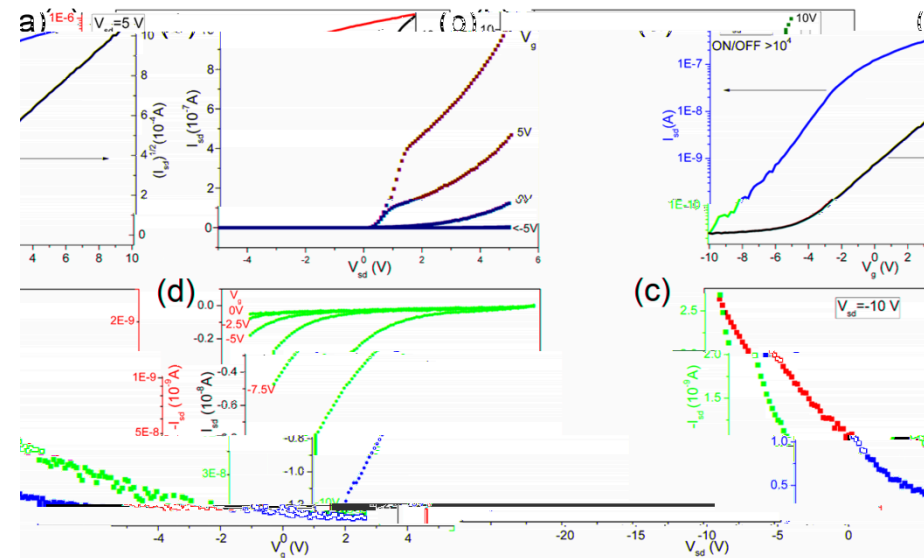
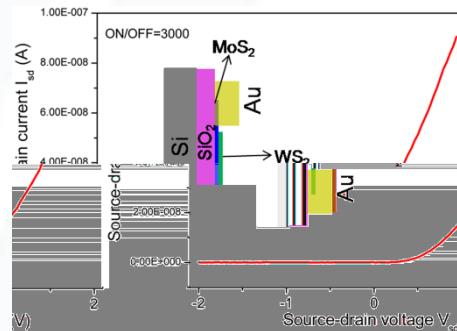
Layered MoS₂-WS₂

- ◆ MoS₂-WS₂
- ◆ Vertical transistors
 - n-type 10^4
 - P-type 10^3
- ◆ planar transistors MoS₂-WS₂
 - 5 channels
 - 1.42 AtW

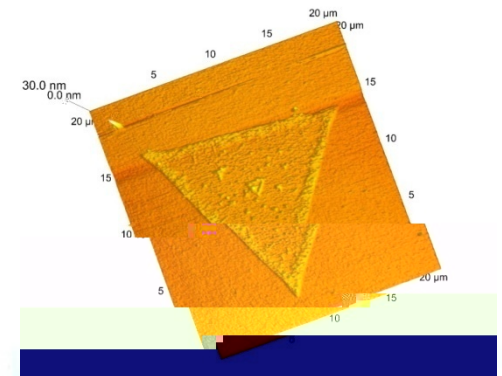
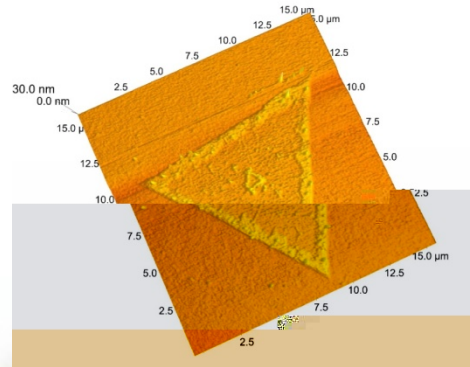
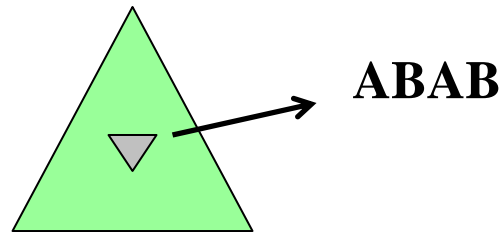
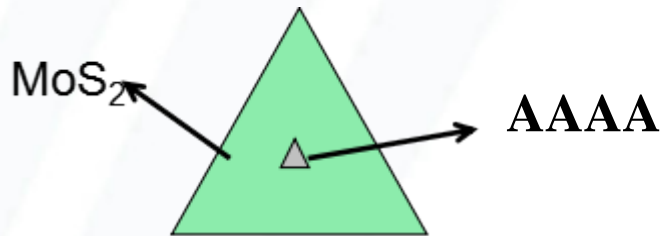
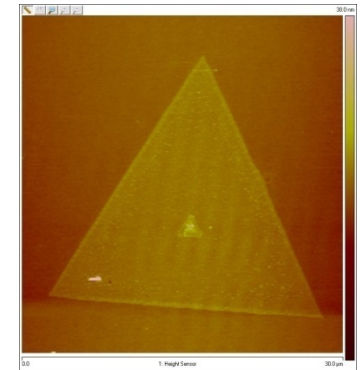
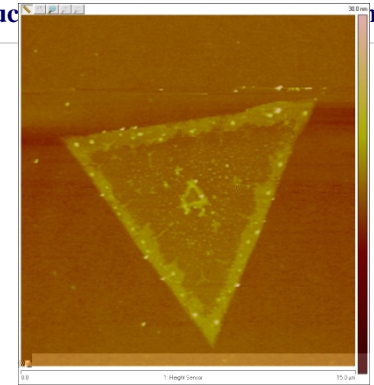
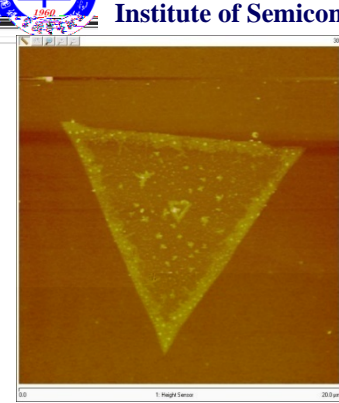
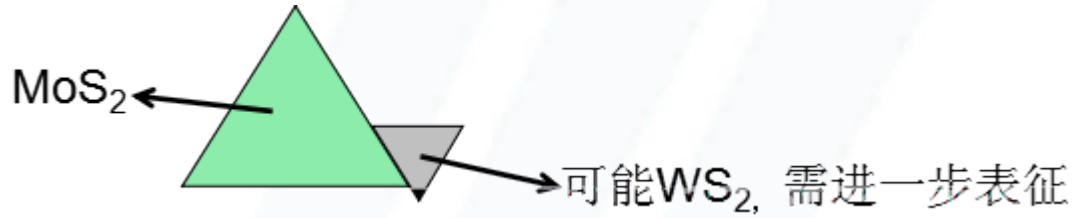
Vertical and Planar transistors

0.25 V

10^5

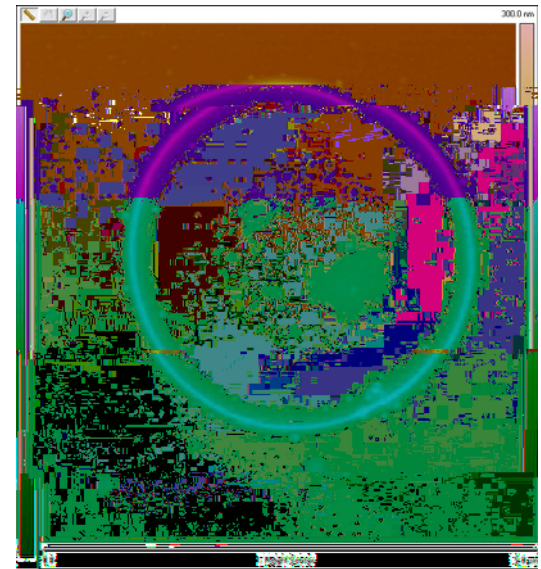
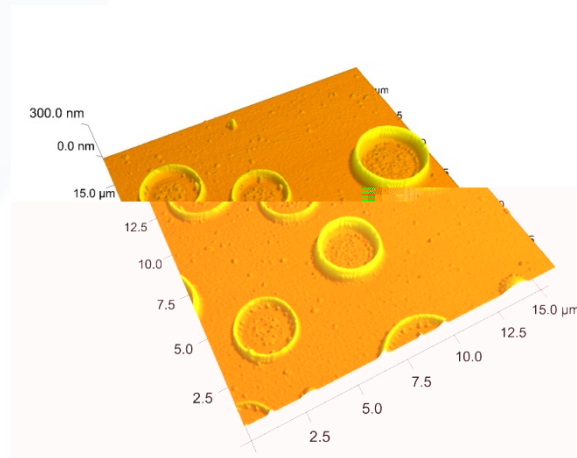
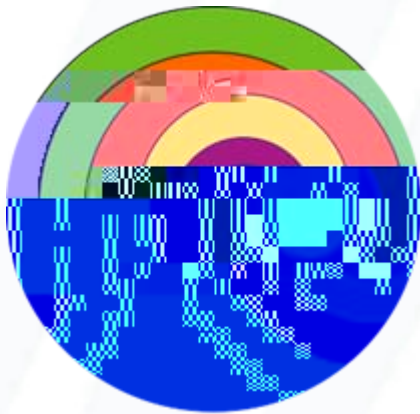


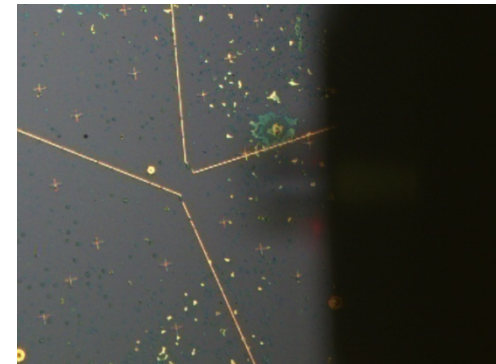
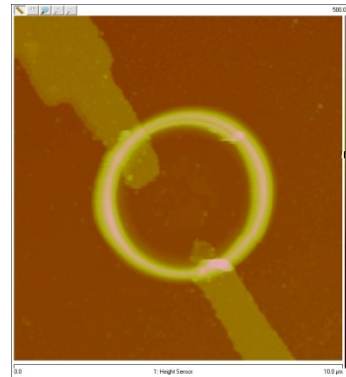
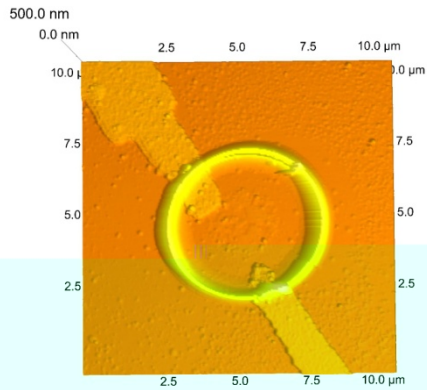
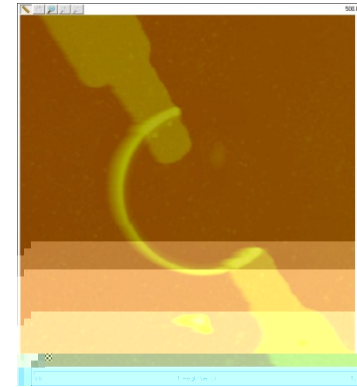
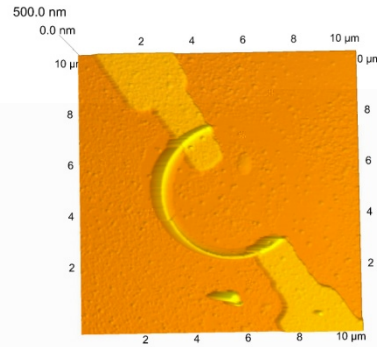
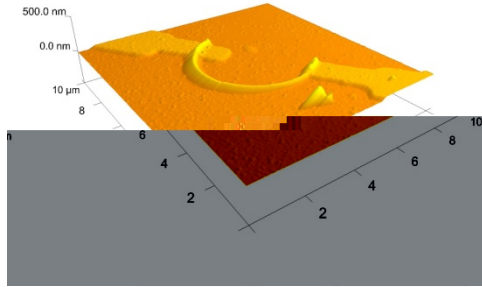
Nengjie Huo, Jun Kang, Shu-Shen Li,
Jian-Bai, Xia, Jingbo Li*, Su-Huai Wei*.
Nature Communications (2014), submitted.



MoS_2/WS_2

Sef





MoS2 ring

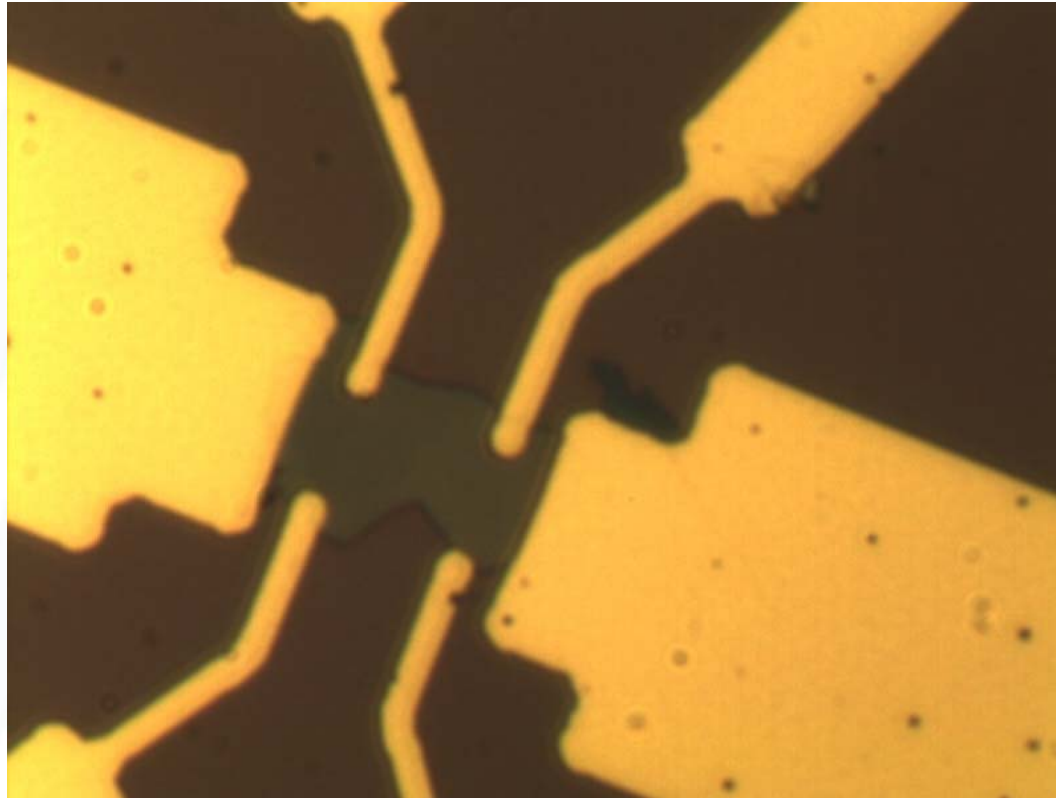
AFM

1 2 3 4 1

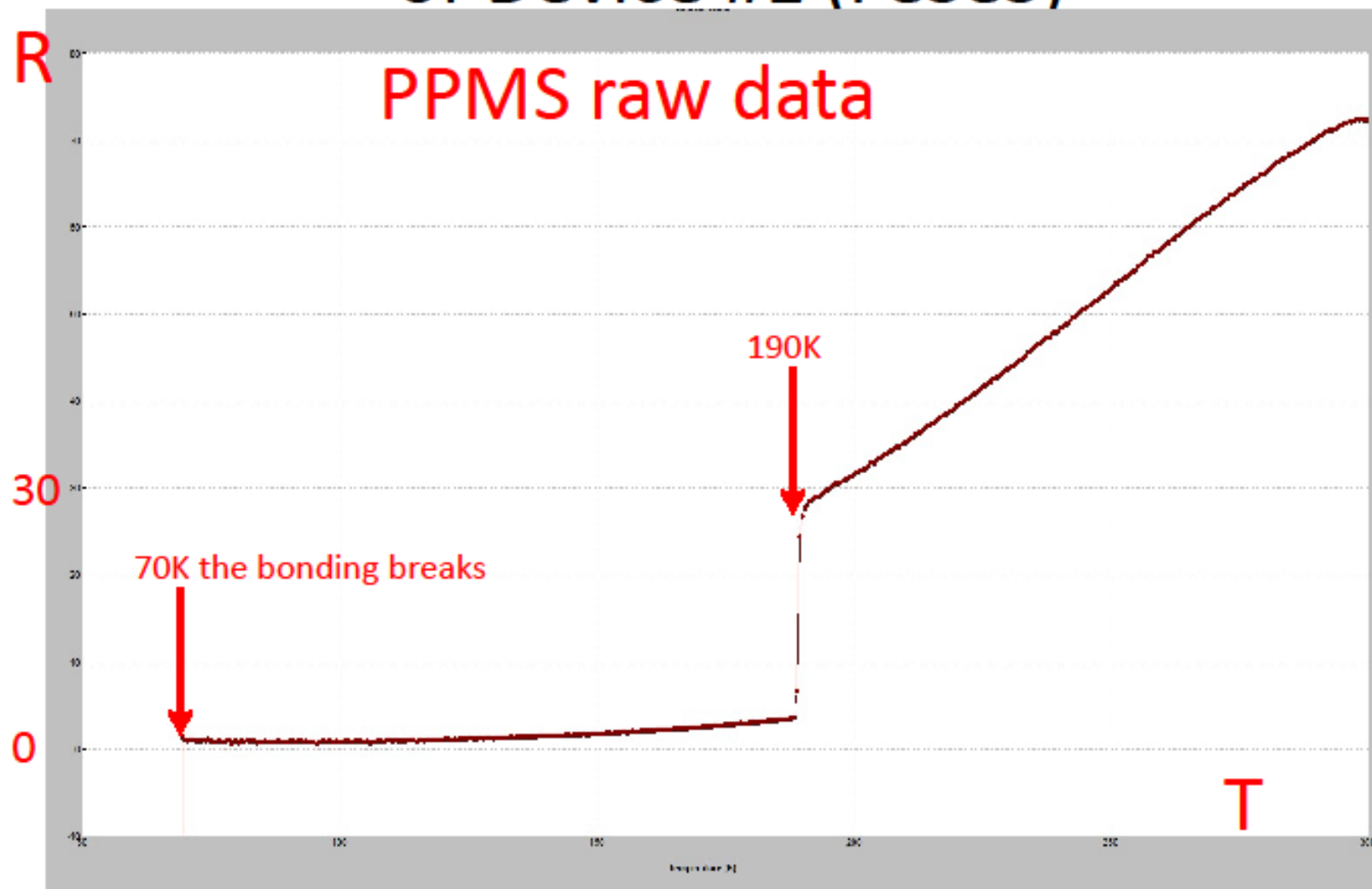
MoS2



2D Superconducting FeTeSe Flake



Four-Probe Resistance Vs Temperature of Device #1 (FeSeS)





2012 7 4



2012 4 19



“

”



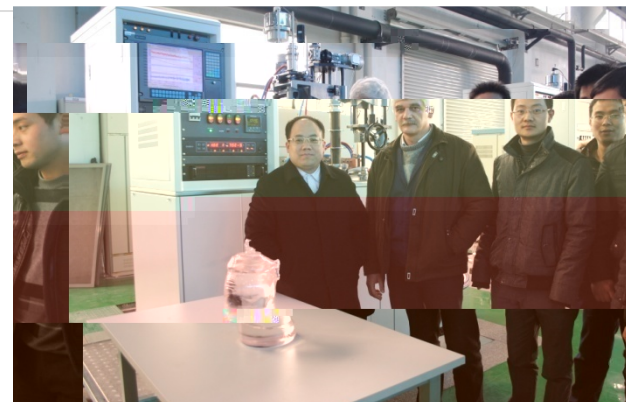
”

“





80



GSRI abt chenke



2012 6 20

-

2011 8 11

2012 6 19





1

CVD

~~MoS₂~~ ~~MoSe₂~~ ~~VS₂~~ ~~VSe₂~~ VS₂ HfS₂ NiS₂ TiS₂ ReS₂
GaSe GaTe CuS CoS

2

~~MoS₂~~

Heterostructures

3

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1

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2

3

4





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863"

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973"



