新型二维强关联材料与微纳器件的研究

2014 2 27

1.
2.
3.
4.
5.

“ ” “

”

“ ” LED

“ ”

p

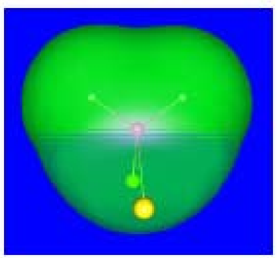
2010 9

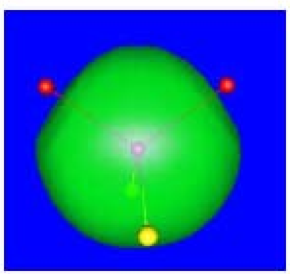
002199 30

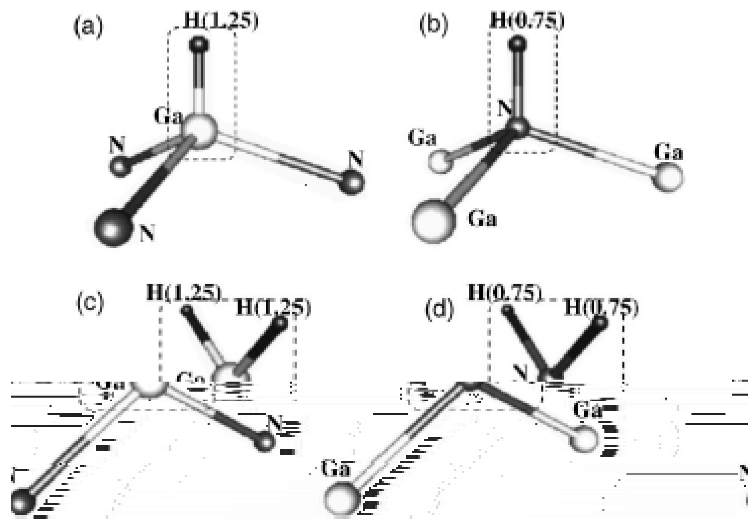
GaN LED

“ ” Charge Patching Method

- LDA motif
- : “ ”
- : “ ” “ ”





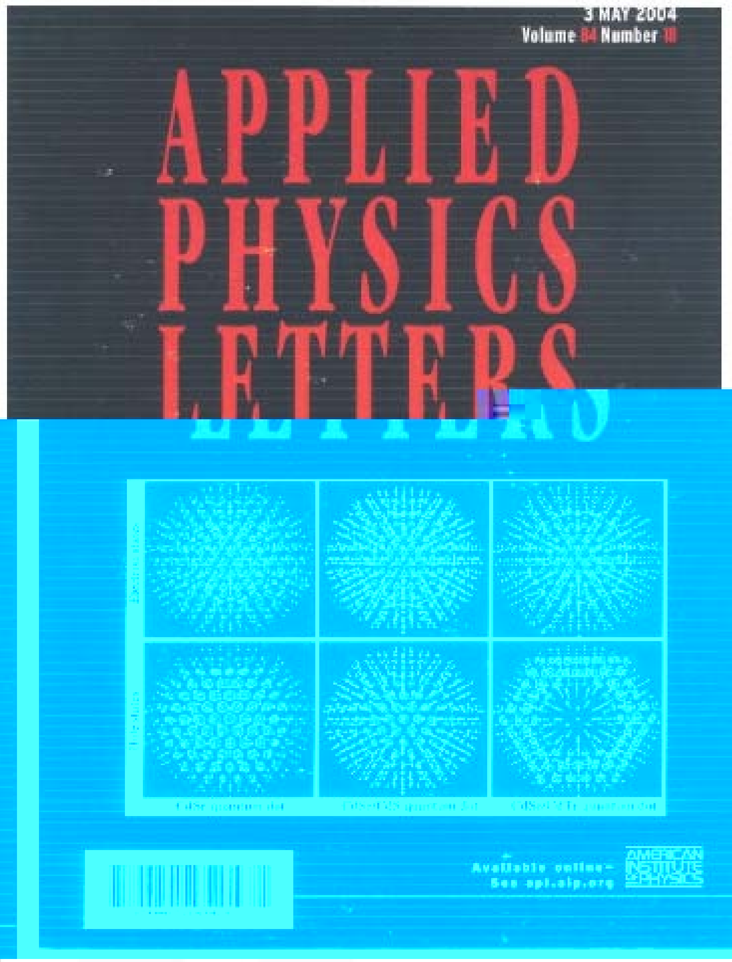


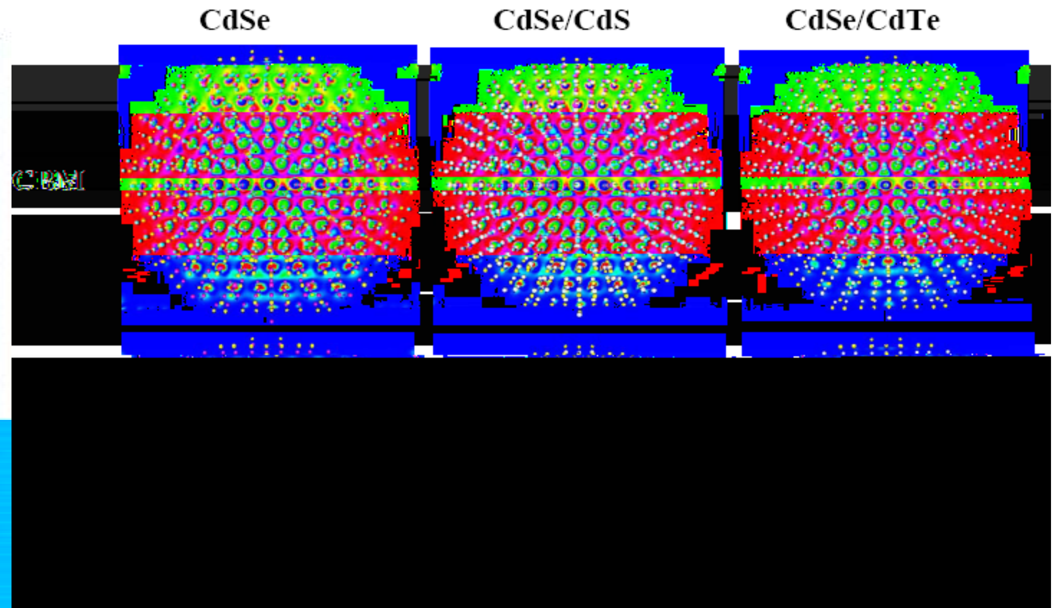
Ga N

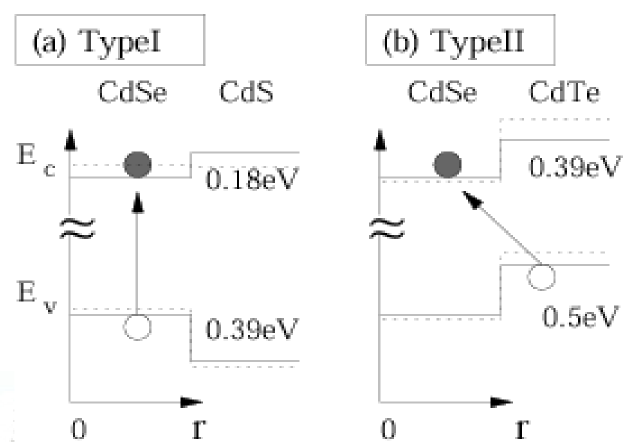
L.-W.Wang, PRL.88,256402(2002)

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

/

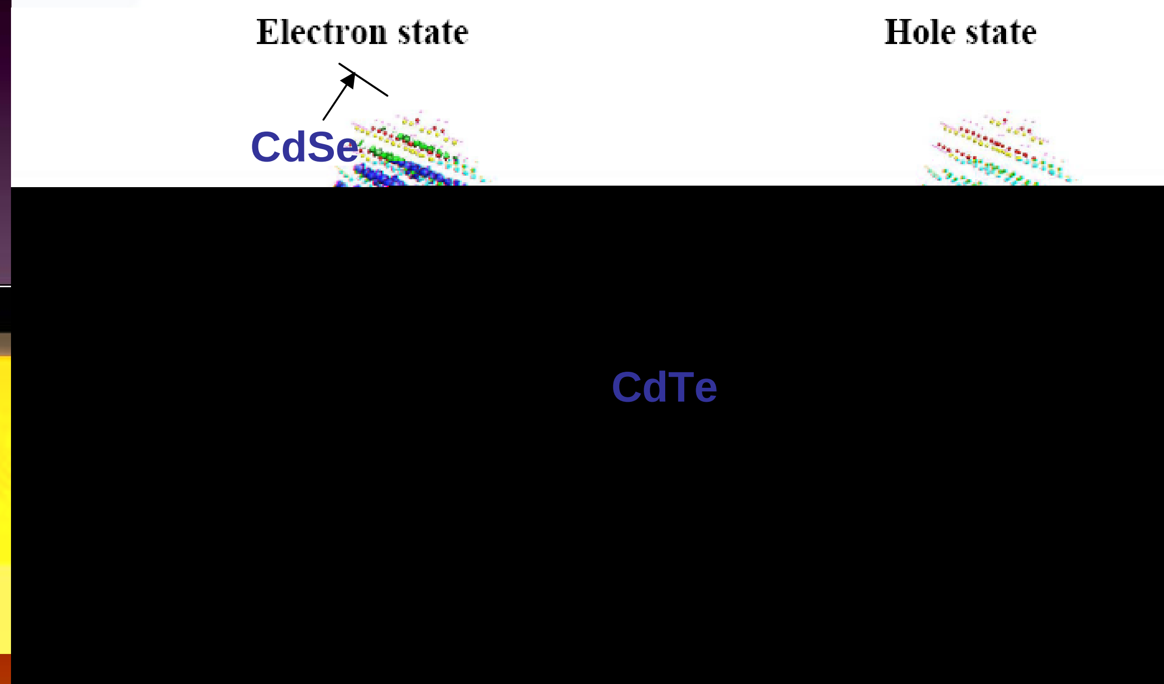






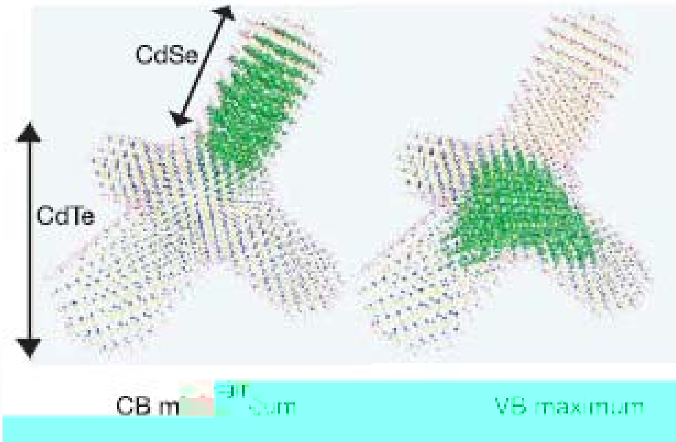
Jingbo Li and L.-W Wang, APL 84, 3648(2004)

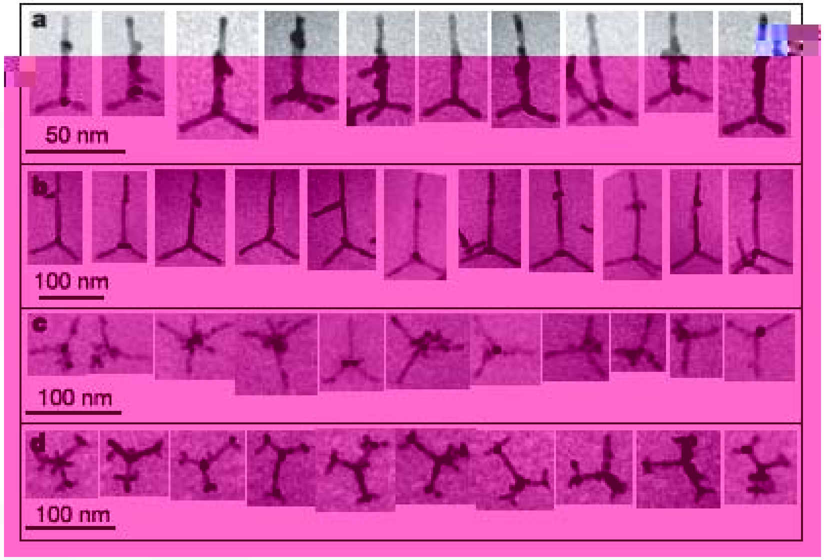
CdSe/CdTe tetrapod

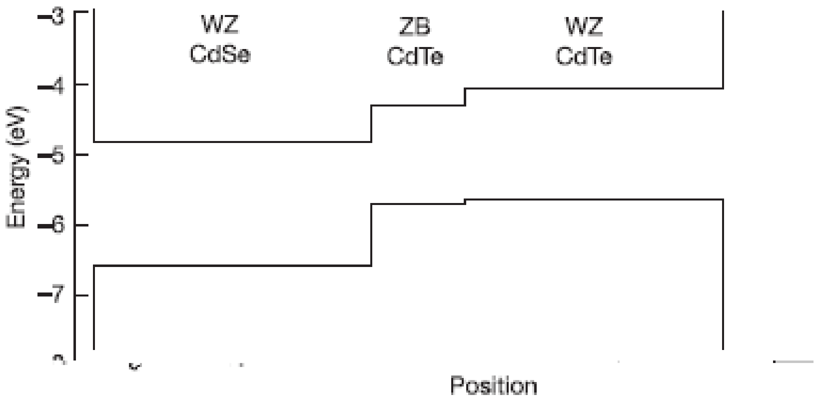


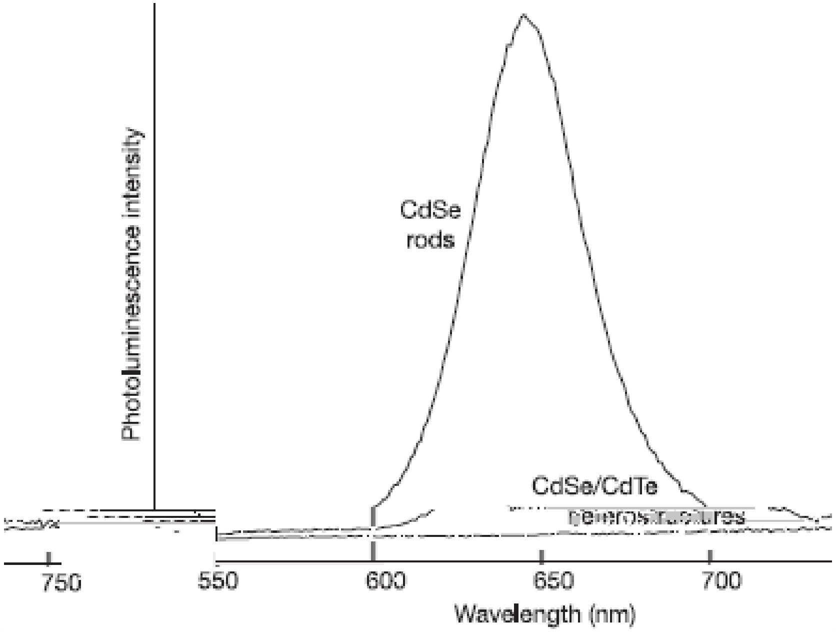
D. J. Milliron, S. M. Hughes, Yi Cui, L. Manna, Jingbo Li, L. W. Wang and A. P. Alivisatos, Nature 430, 190 (2004).

CdSe/CdTe tetrapod



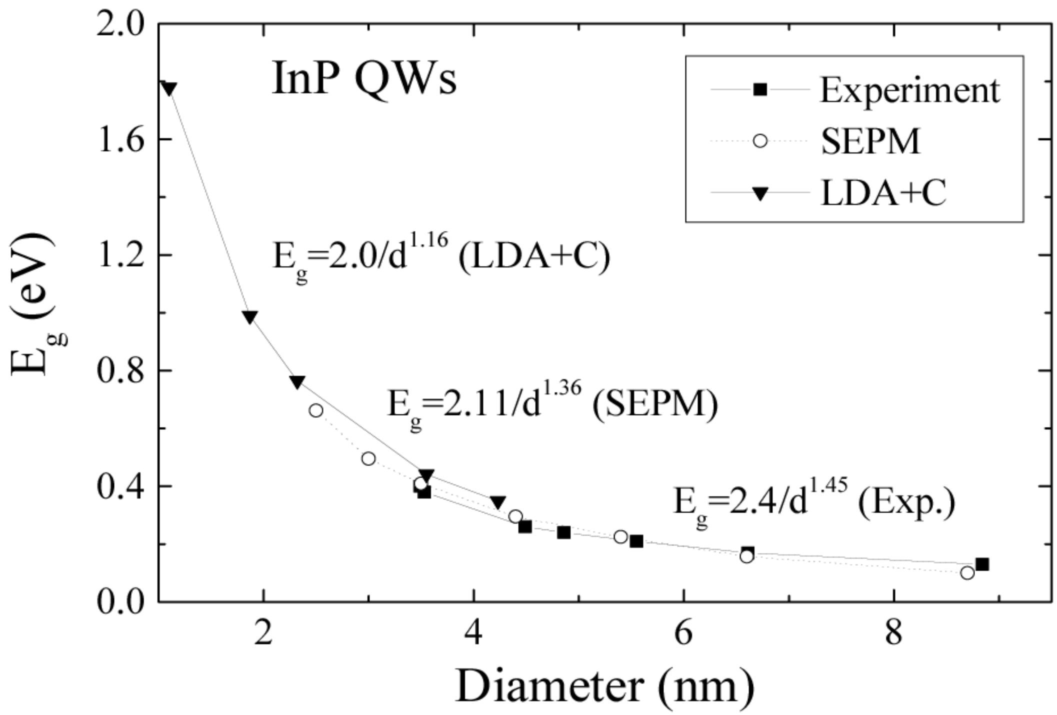


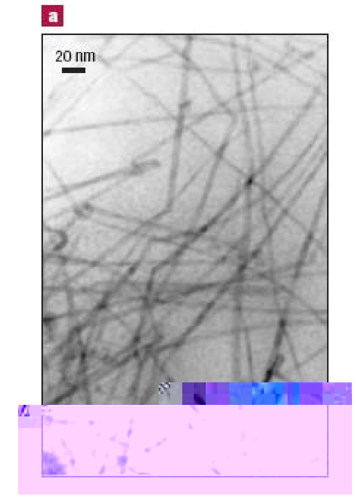


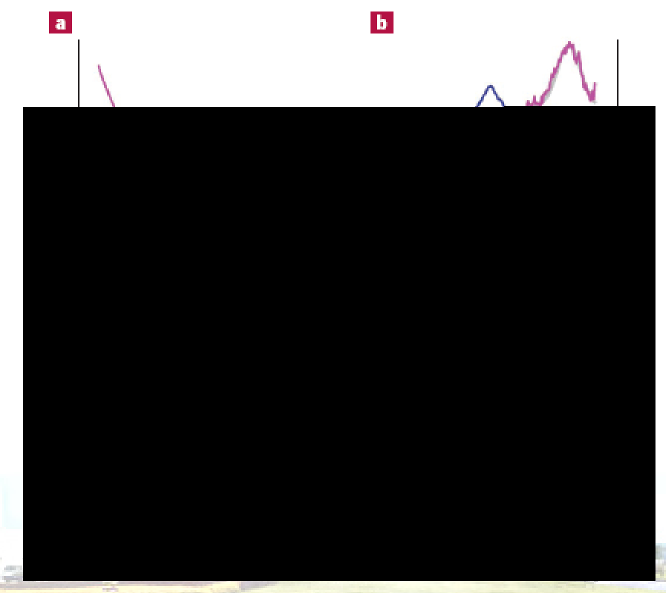


D. J. Milliron, S. M. Hughes, Yi Cui, L. Manna, Jingbo Li, L. W. Wang and A. P. Alivisatos, Nature 430, 190,(2004).

InP



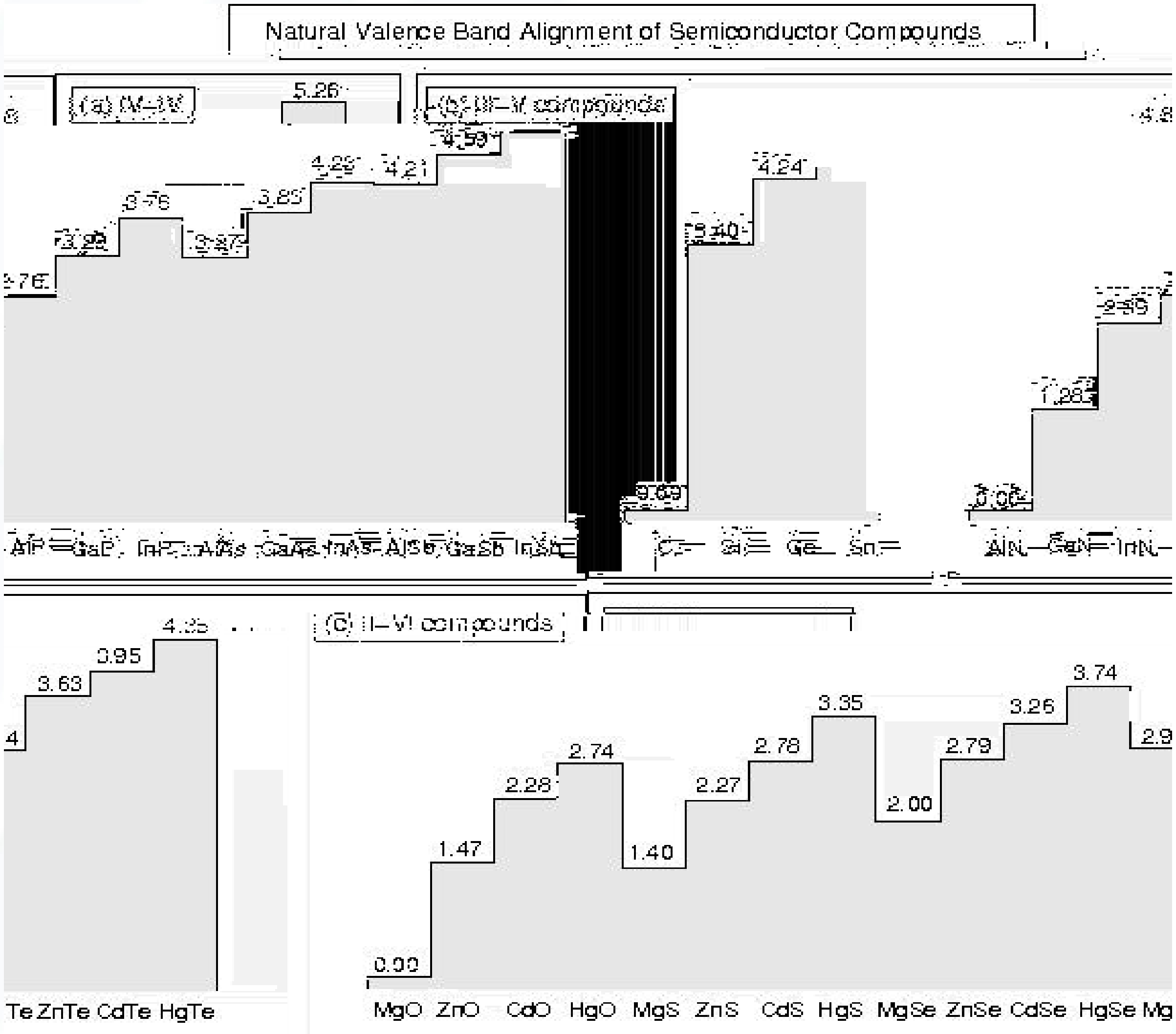




Jingbo Li and L.-W Wang, PRB 72, 125325(2005)

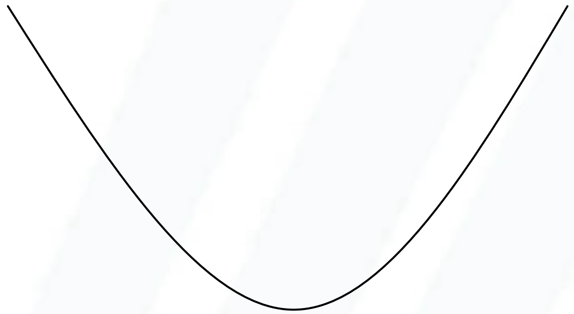
H.Yu, Jingbo Li, R. A. Loomis, L.W. Wang, and W. E. Buhro, Nature Material, 2,517(2003)

为什么宽禁带半导体材料很难实现p−型掺杂？

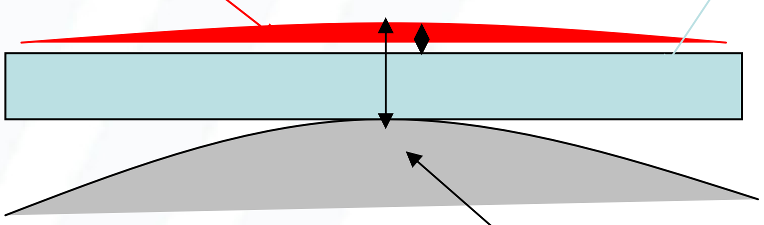


S.H.Wei and A. Zunger, App. Phys. Lett. 72,2011 (1998).

通过形成杂质能带以降低受主离化能

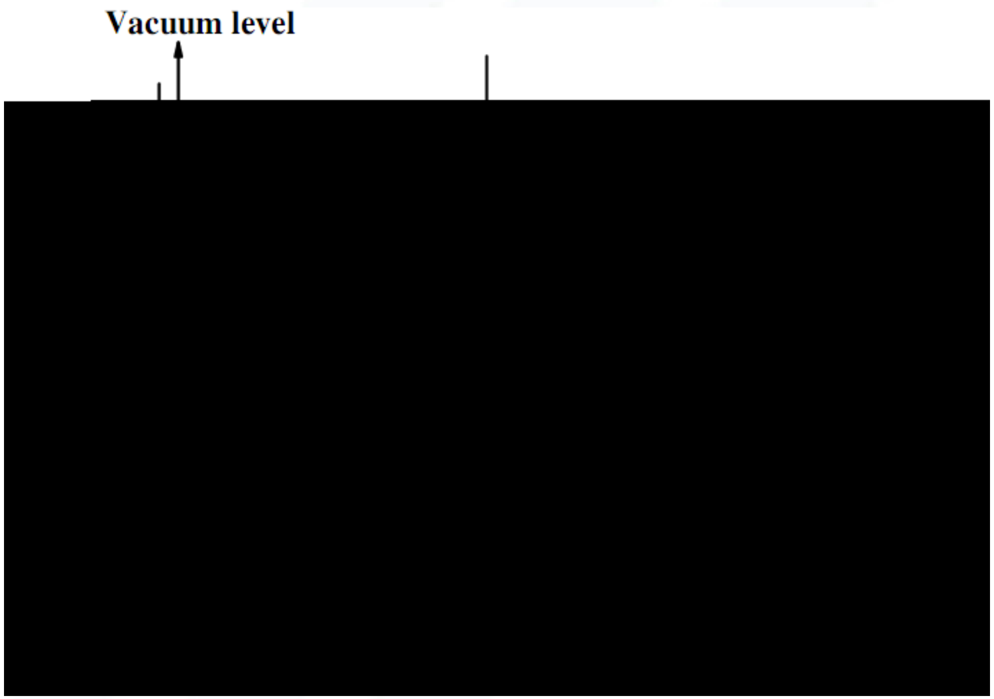


➢ Ga-N



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

TiO_2 ?



- TiO_2 “ ”
- Mo+C TiO_2
-

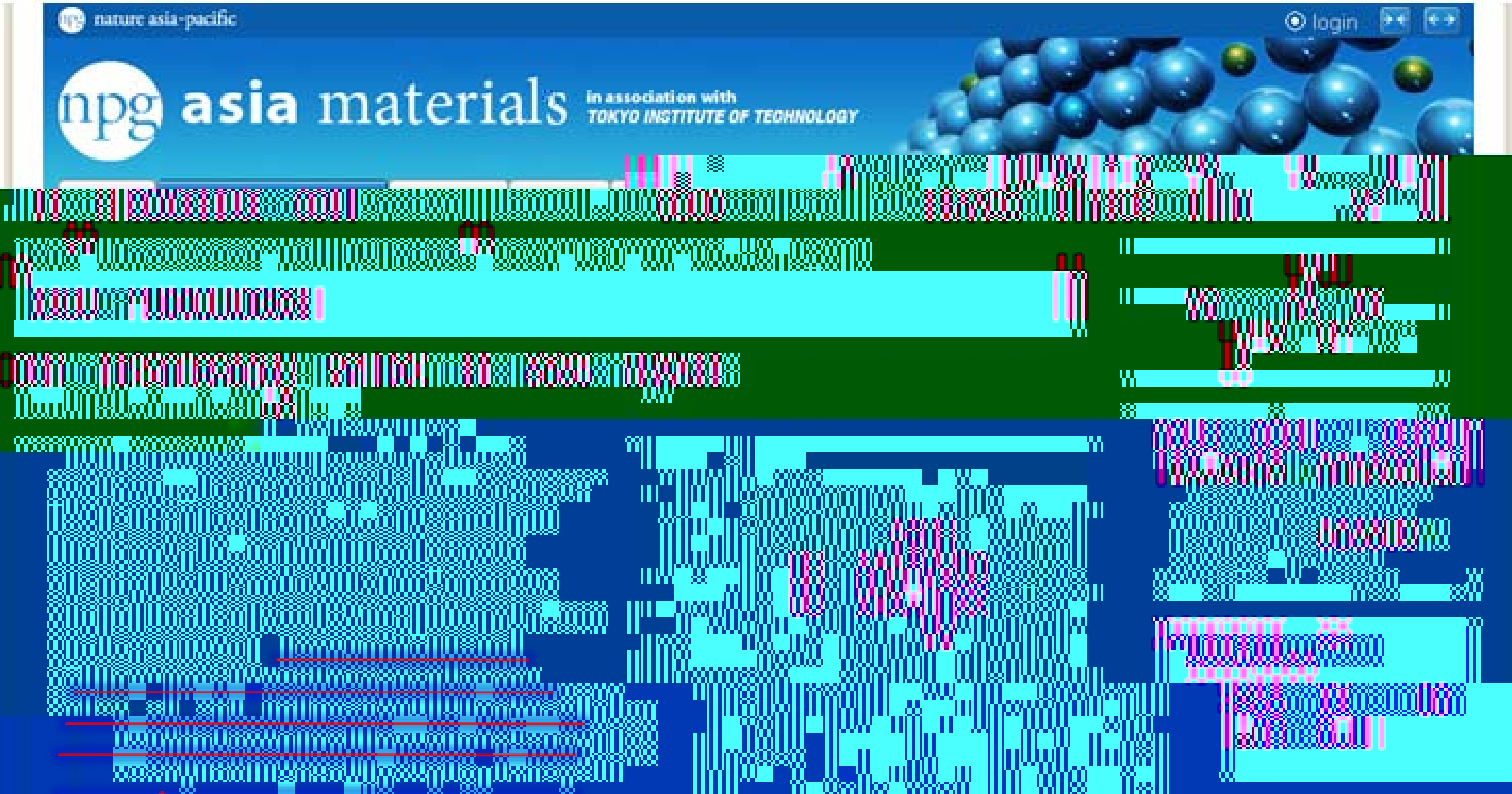
Y. Gai, Jingbo Li*, S.S.Li, J.B.Xia, S.H.Wei* Phys. Rev. Lett. 102 036402 (2009).

2009 201

2009

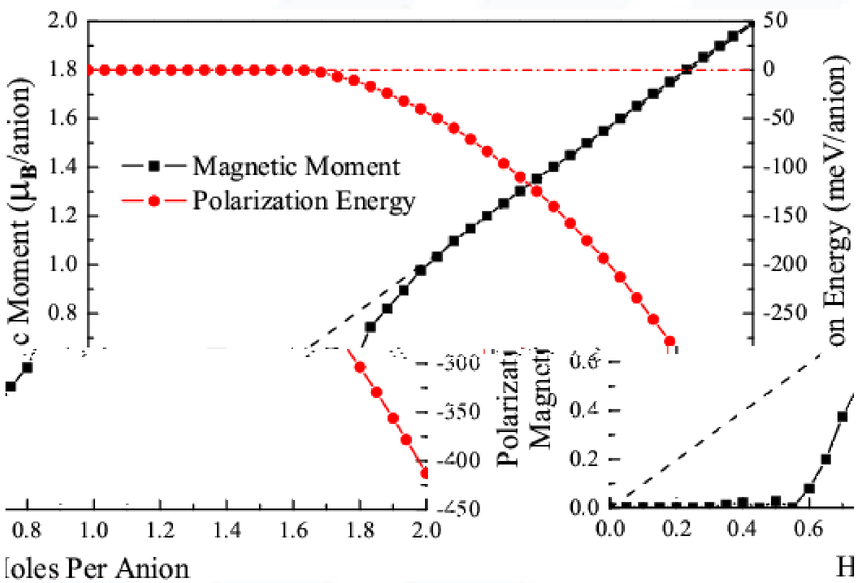
Nature (Asia Materials): featured Highlight

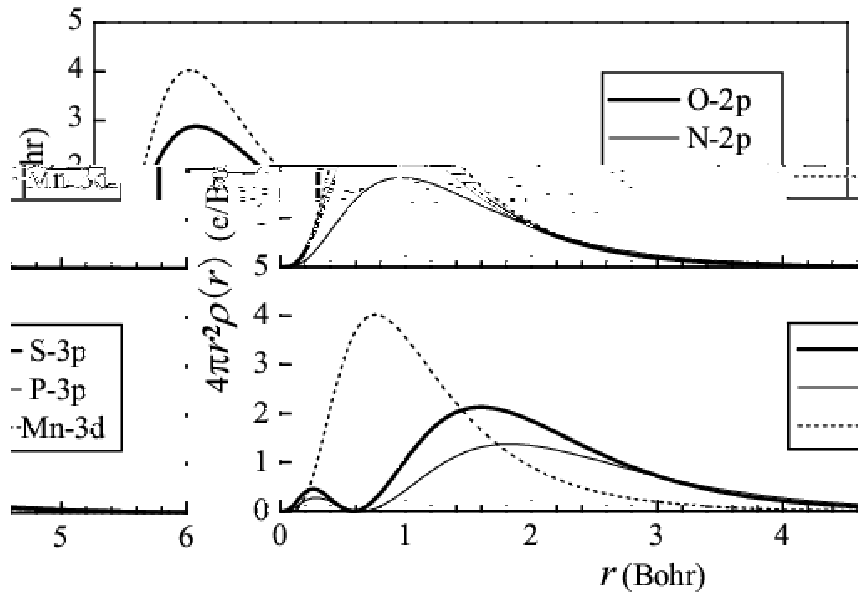
Website: http://www.natureasia.com/asia-materials/highlight.php?id=408



TiO_2 ……

ZnO GaN





ZnO

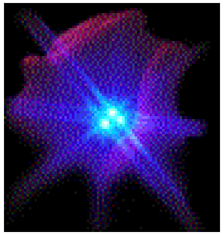
N, O, P, S p-
Mn 3d- .

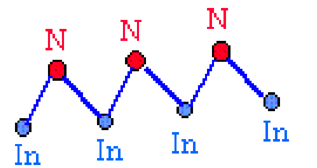
H. Peng, H.J.Xiang, S.H.Wei*, S.S.Li, J.B.Xia, Jingbo Li,* Phys. Rev. Lett. 102 017201 (2009).

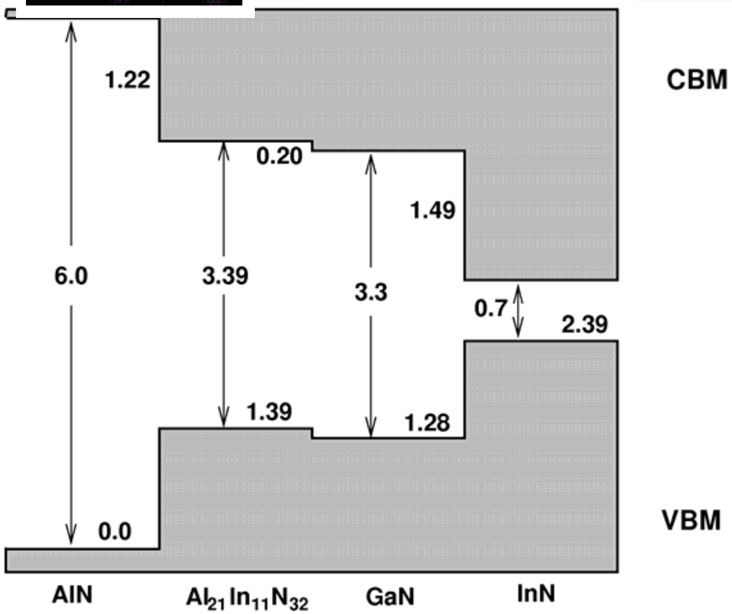
2009 145

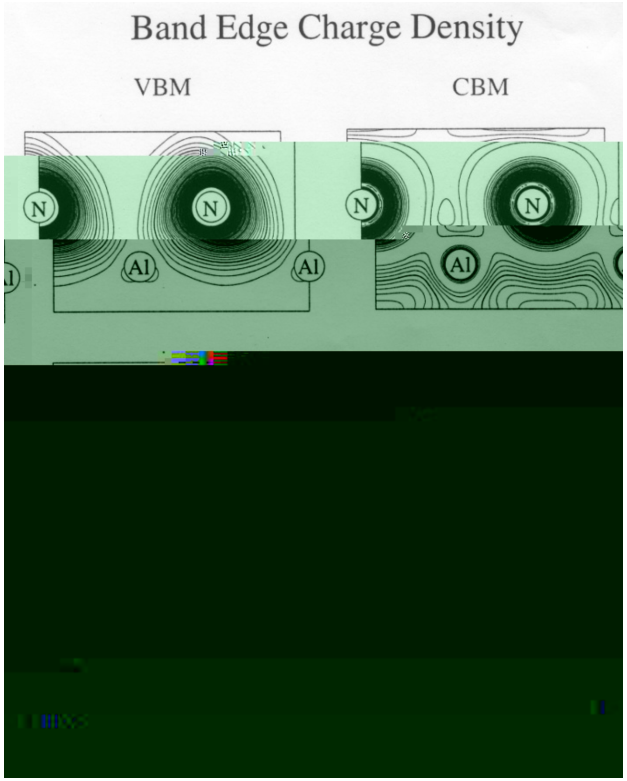
2009

AlGaInN GaN p-







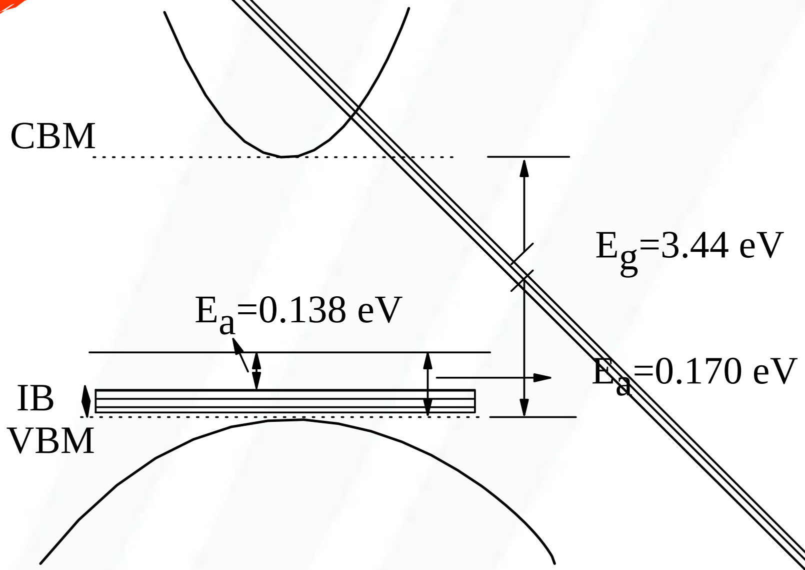


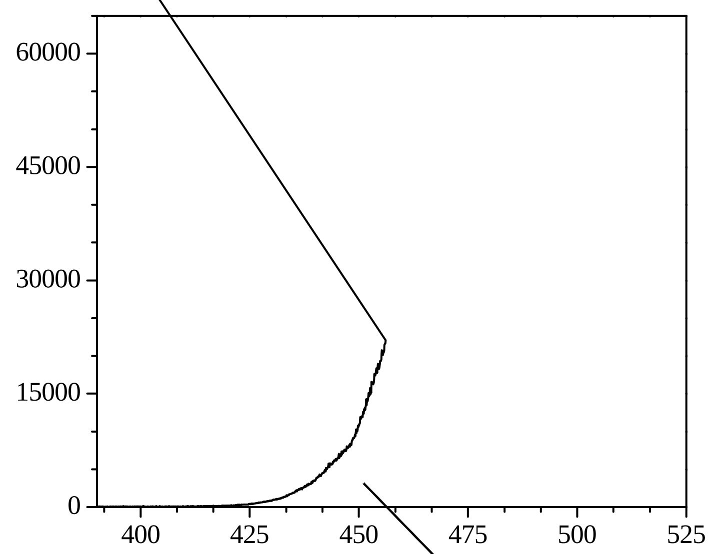
InN

AlInGaN GaN ,

VBM p- .

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



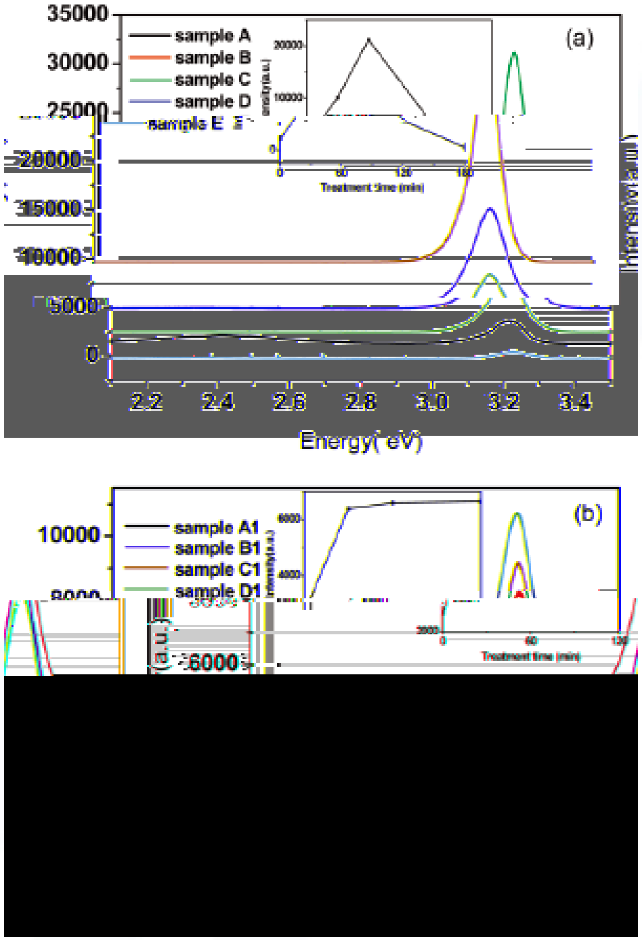


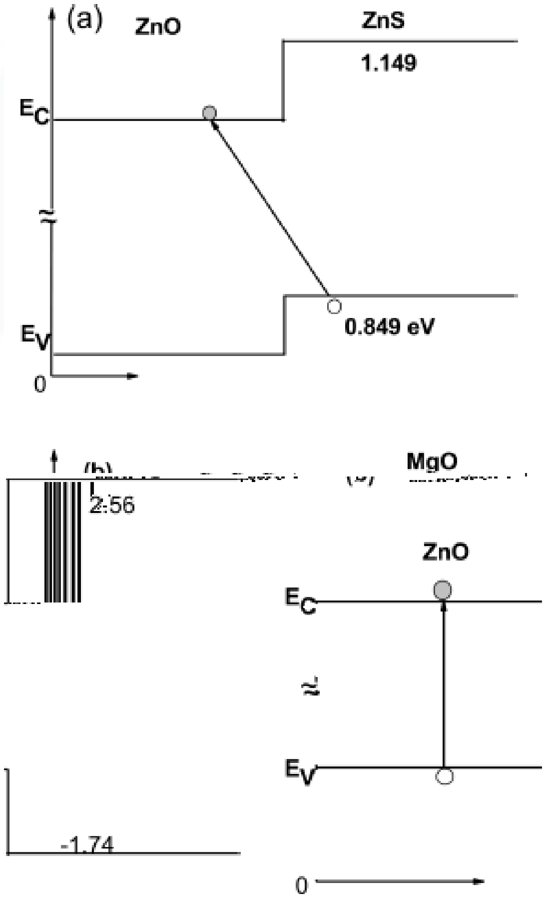
P. Ma, Y. Q. Gai, J. Wang, F. Yang, Y. Zeng, Jinmin Li, Jingbo Li,*
Appl. Phys. Lett. 93 102112 (2008).

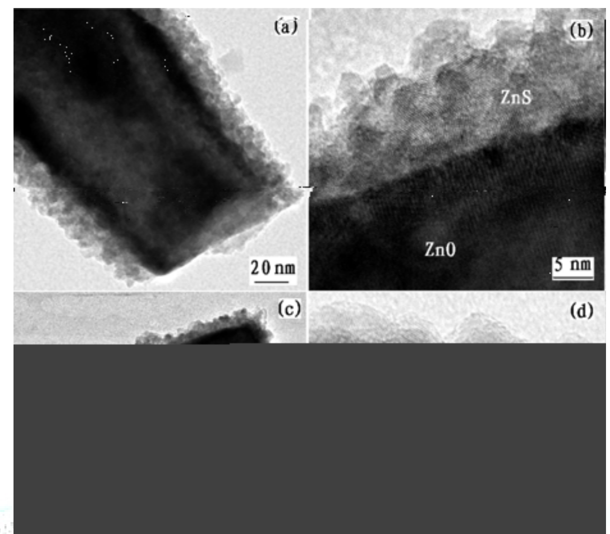
ZnS,MgO ZnO PL

◈ZnO/ZnS PL

◈ZnO/MgO PL

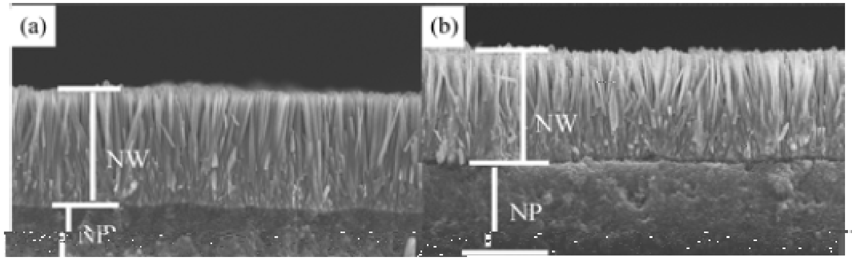


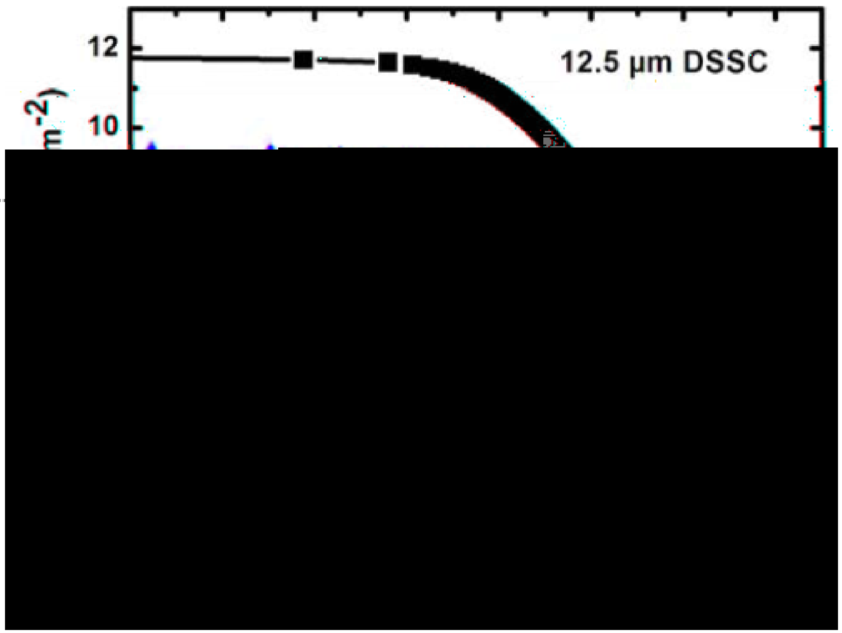




X. Q. Meng, H. W. Peng, Y. Q. Gai, Jingbo Li* J. Phys. Chem. C, 114，1467（2010）

ZnO TiO2

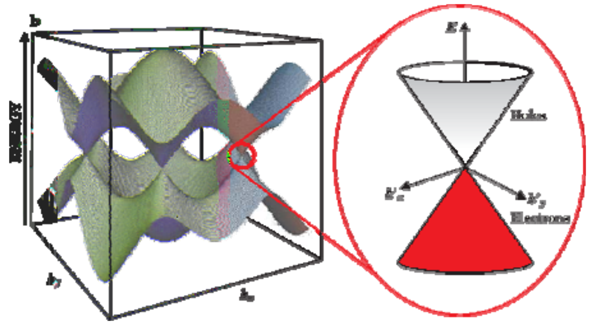




- TiO_2
  - ZnO
- 4.52% ZnO TiO_2

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

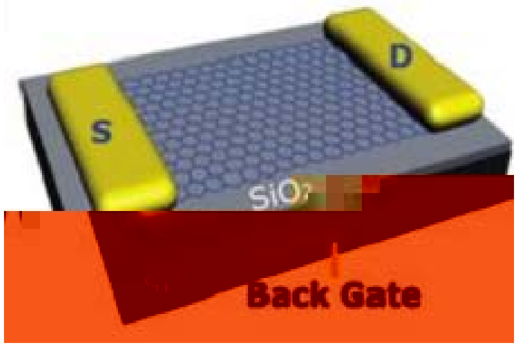
2630 m^2g^{-1}

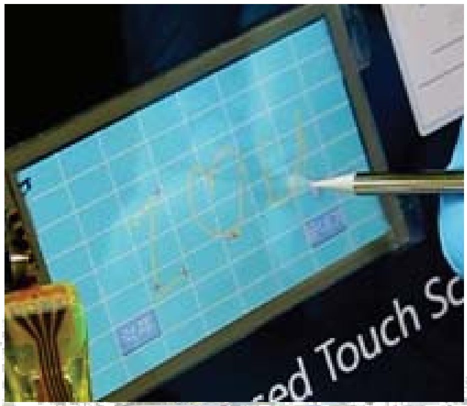
5000 $Wm^{-1}K^{-1}$ 10

10^{13} cm^{-1}

200,000 $cm^2V^{-1}s^{-1}$(
100

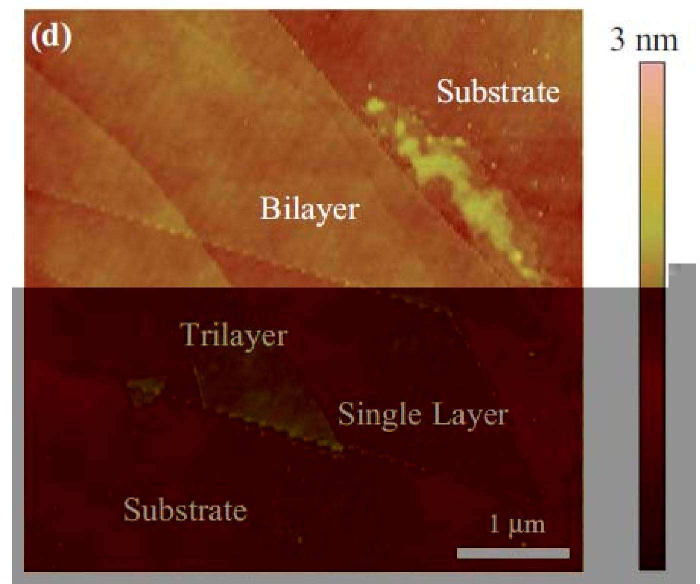
400 GHz





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.

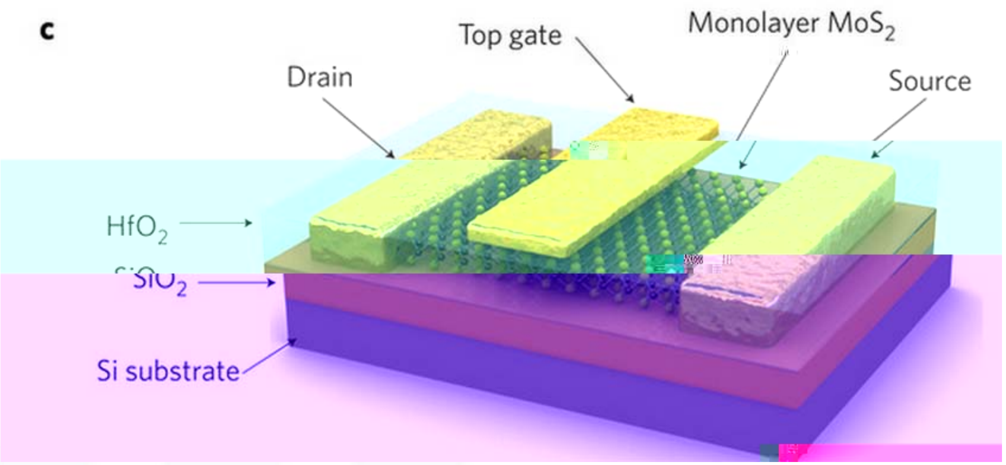


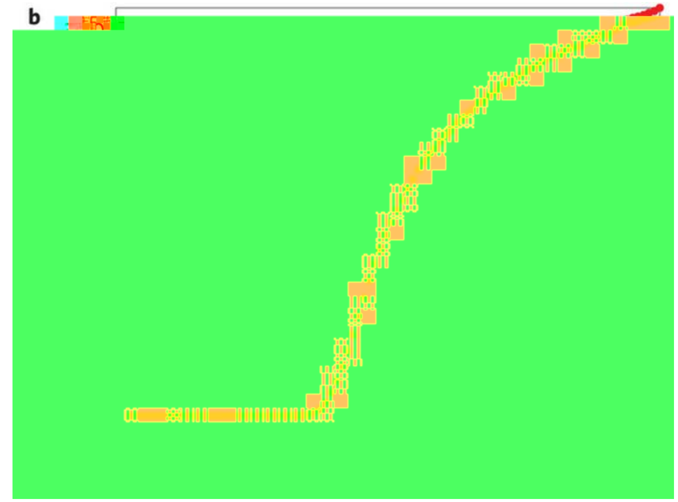
Materials Beyond Graphene— MoS_2

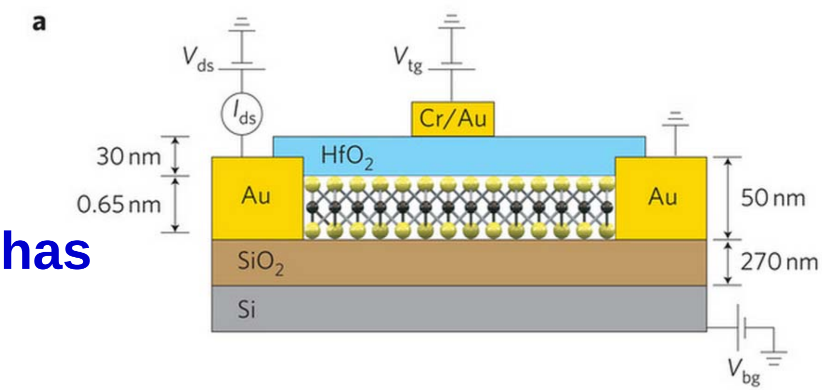
nature nanotechnology

Single-layer MoS_2 transistors

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







200 cm²/SV mobility and 10^8 on/off ratio has been demonstrated!

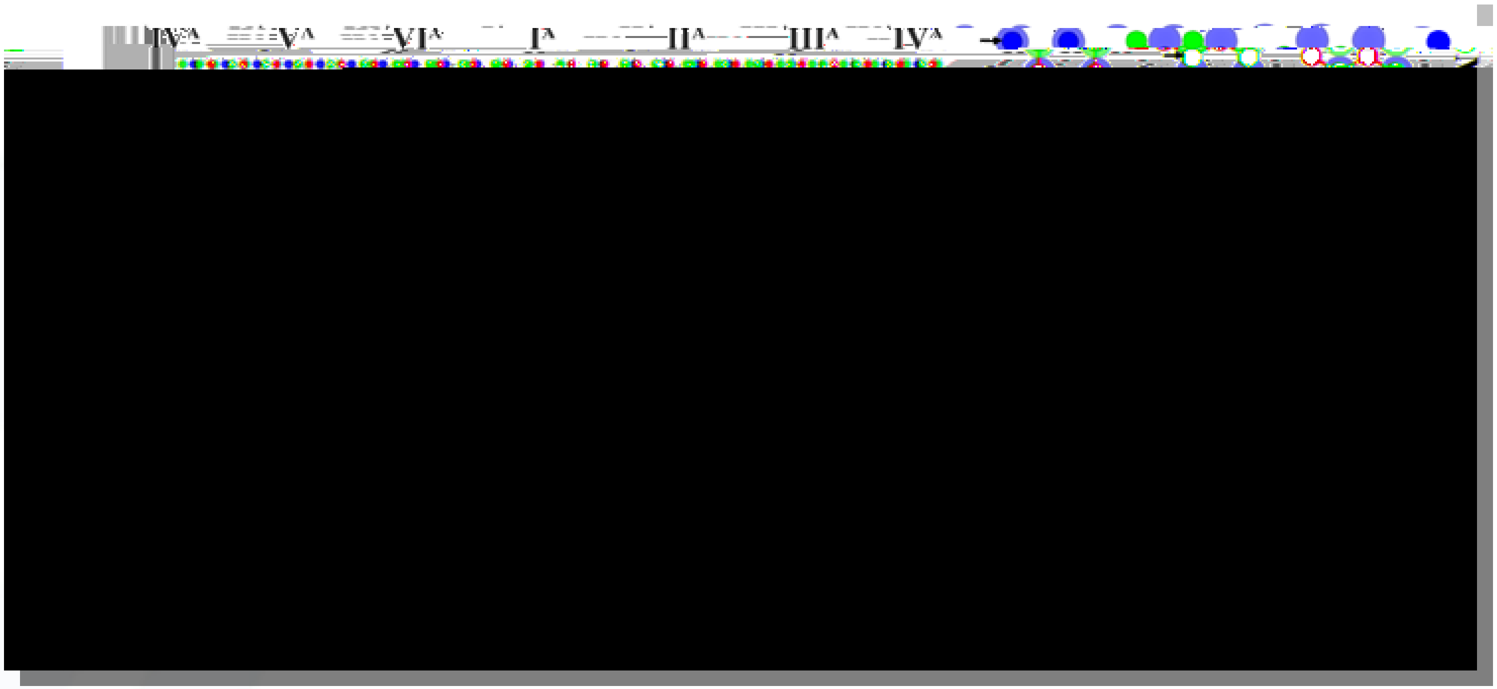
This paper has been cited 678 times in three years!

***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.

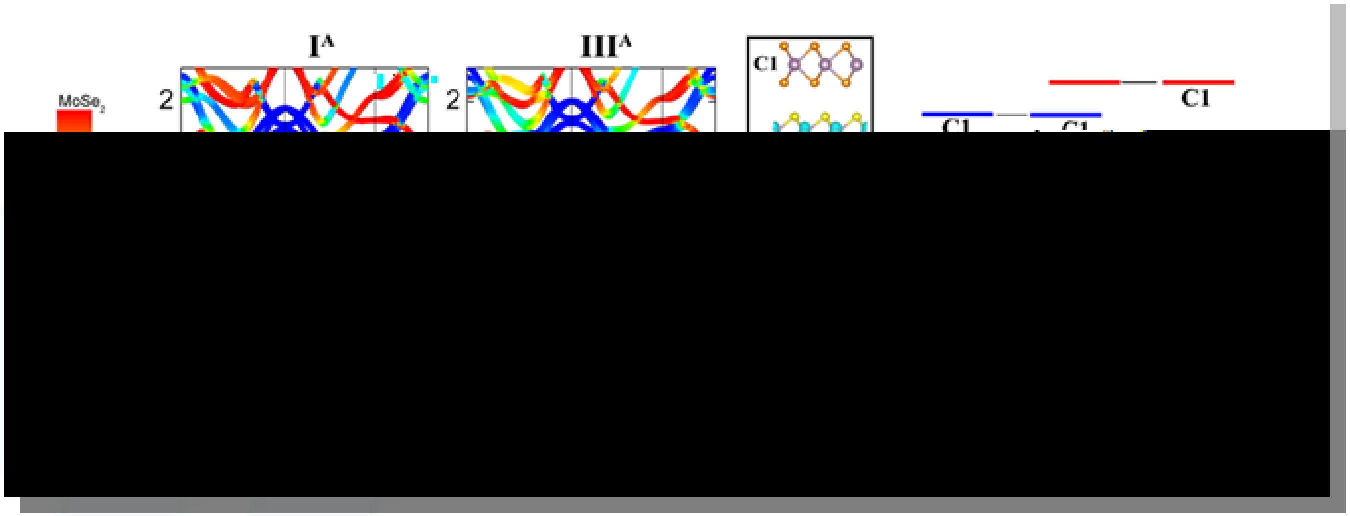
$MoS_2/MoSe_2$



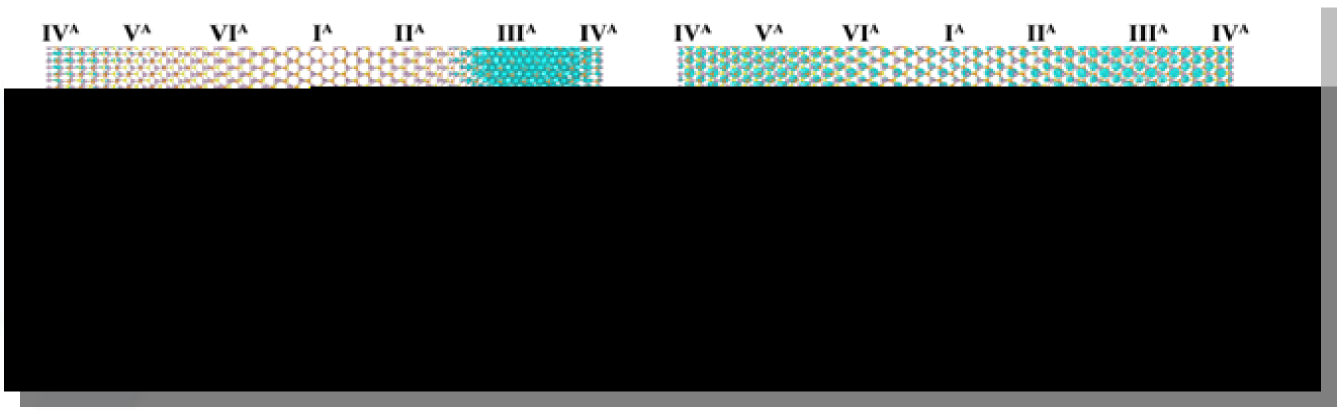
- $MoS_2/MoSe_2$
  “ ” (Moire pattern)
- MoS_2 24*24 $MoSe_2$ 23*23 6630

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

MoS_2 / $MoSe_2$



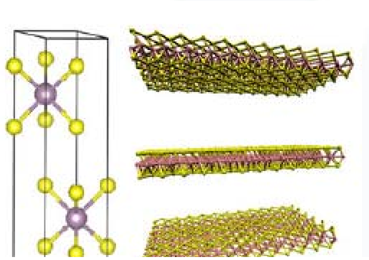
[redacted]

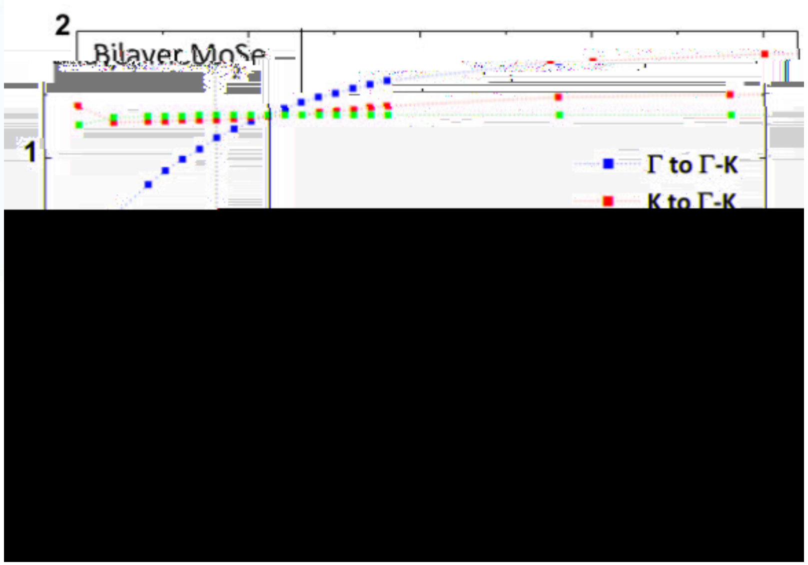


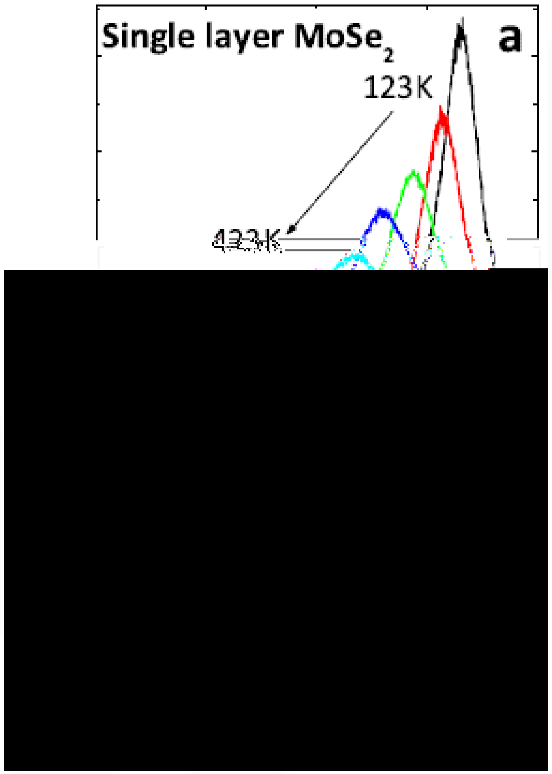
[redacted]

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

$MoSe_2$ -







- MoSe2 MoSe2
- MoSe2
- MoSe2

S. Tongay, J.Zhou, C. Ataca, K. Lo, Jingbo Li, J. C. Grossman, and J. Wu,
Nano Letters 12, 5576 (2012)

2012 12 7 . “ ”

$MoSe_2$

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

nature nanotechnology

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

Search Go Advanced search

nature.com · journal home · current issue · research highlights · full text

Our choice from the recent literature

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

Download PDF | Citation | Reprints | Rights & permissions

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. Stefaattin Tongay, Junqiao Wu

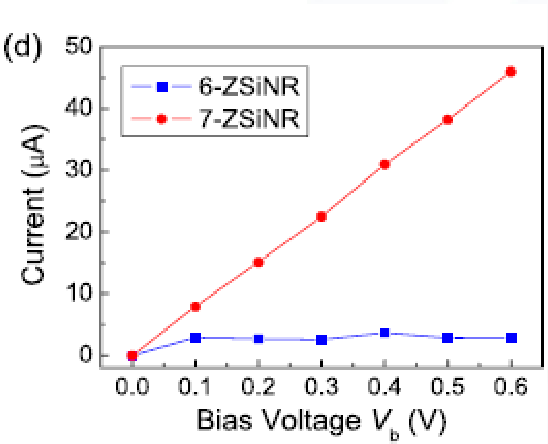
Journal home · Subscribe · Current issue · E-alert sign up · For authors · RSS feed

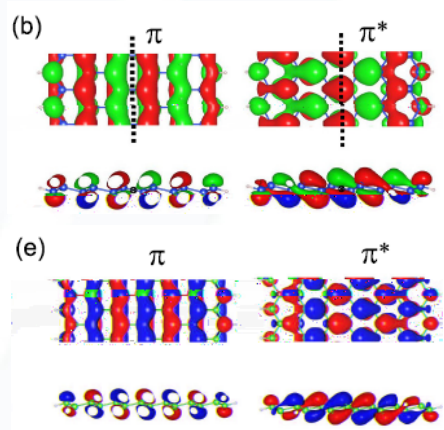
- O_2 H_2O
- n MoS_2 $MoSe_2$
- p WSe2
- O_2 H_2O

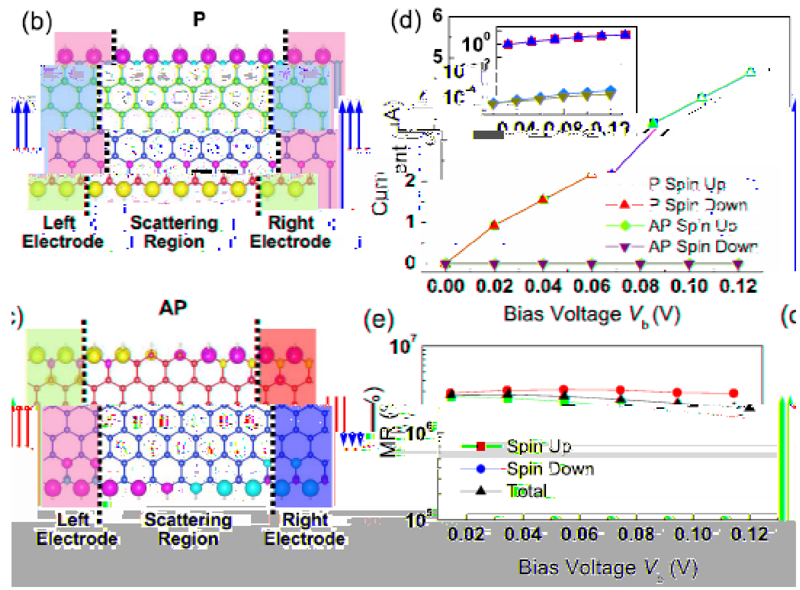
S. Tongay, J. Zhou, C. Ataca, J. Liu, J. S. Kang, T. S. Matthews, L. You, Jingbo Li, J. C. Grossman, and J. Wu, Nano Letters, 13, 2831(2013).

2013 5 8
(Phys.Org)

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







◈

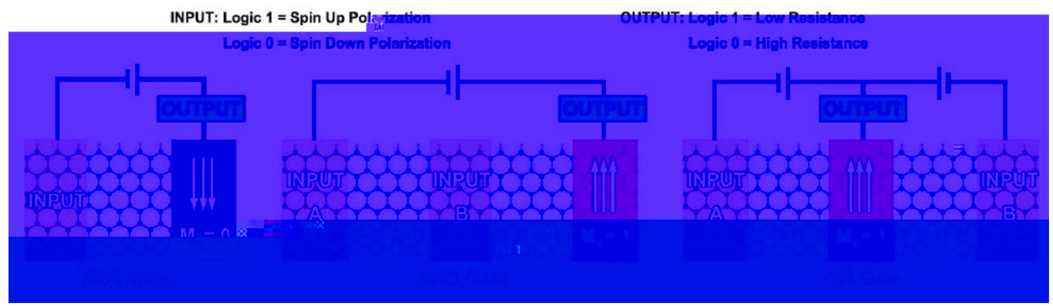
(ZSiNR)

π π*

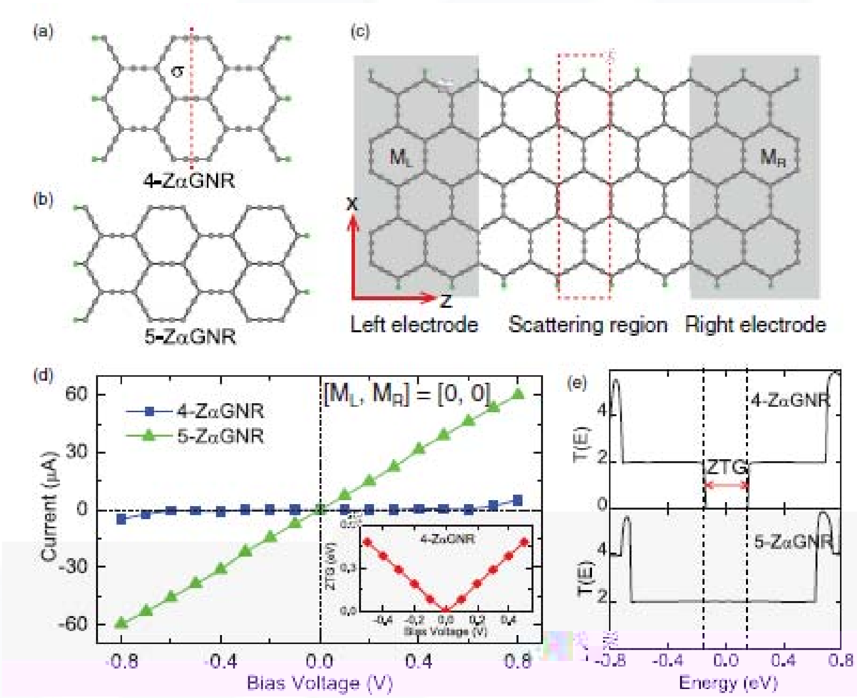
◈ N ZSiNR

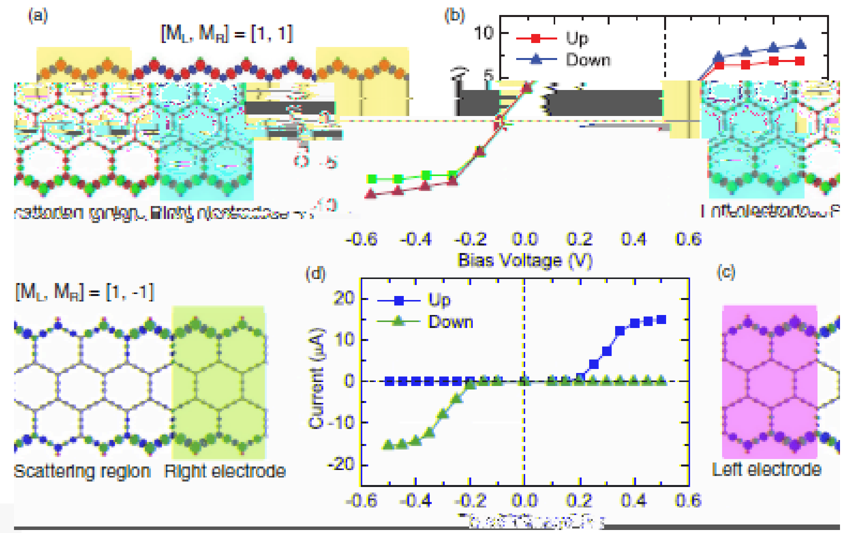
10^4

◈



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



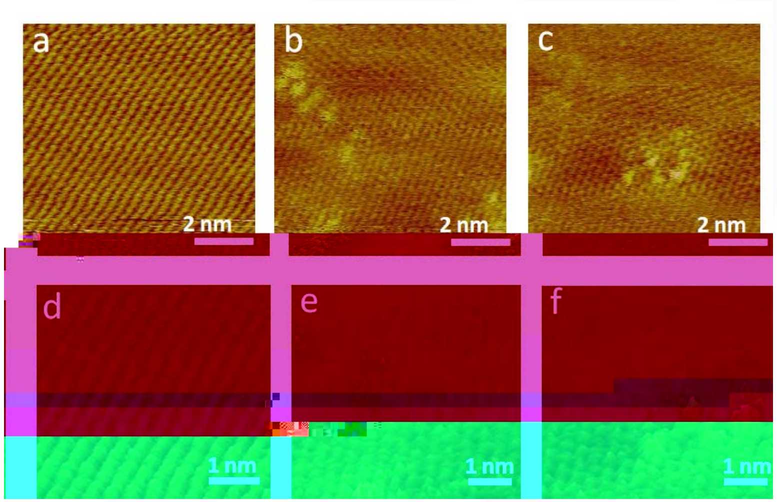


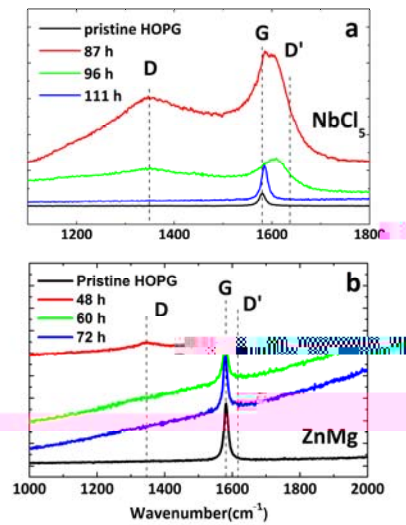
- α

-

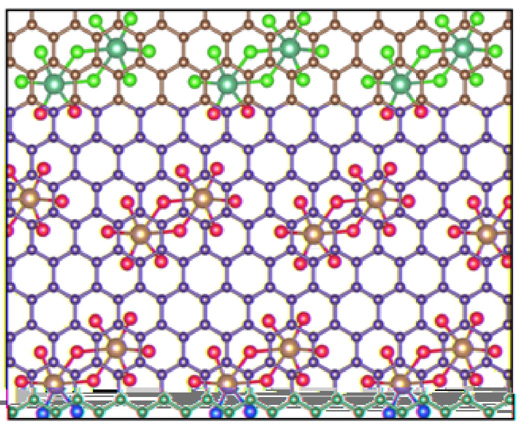
Q. Yue, S. L. Chang, J. C. Tan, S. Q. Qin, J. Kang, and Jingbo Li*, Phys. Rev. B 86, 235448 (2012)

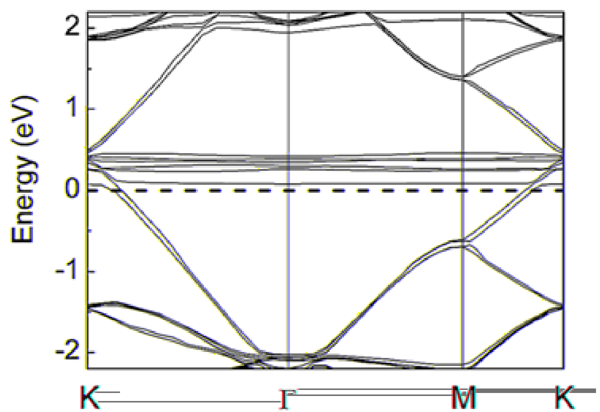
p n





- ◈ ZnMg $NbCl_5$
- ◈ ZnMg $NbCl_5$ p n
- ◈ p n 10^{19} cm^{-3} 10^{18} cm^{-3}



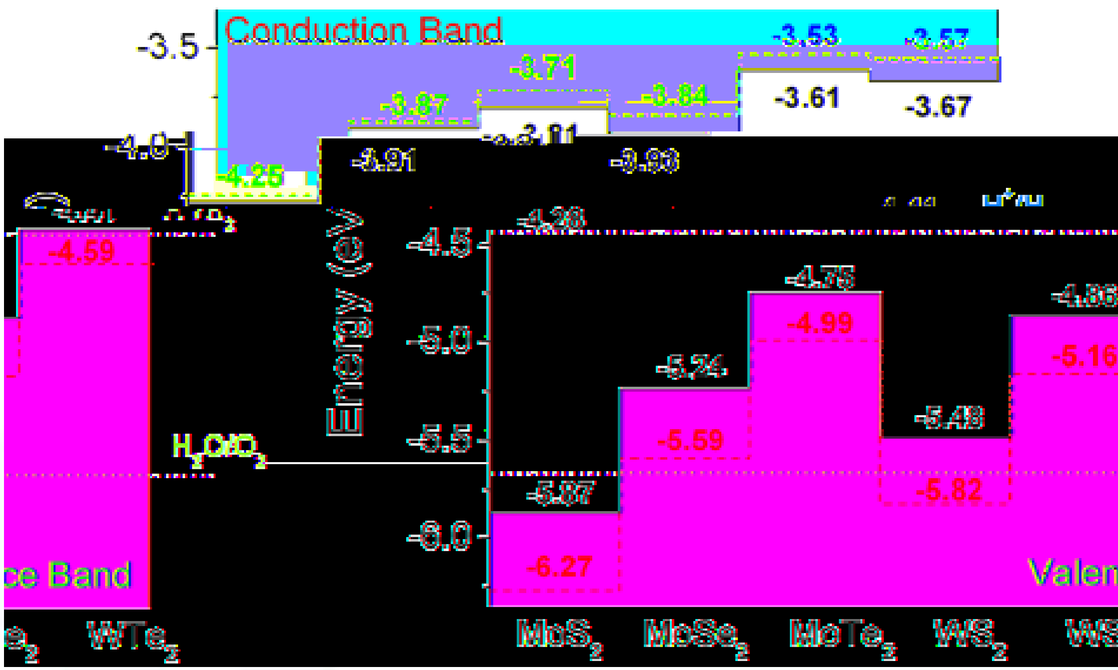


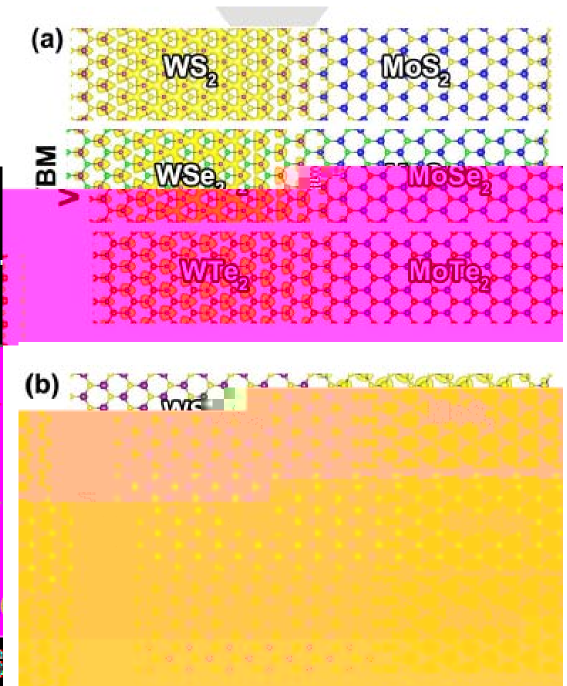
- ◈

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).

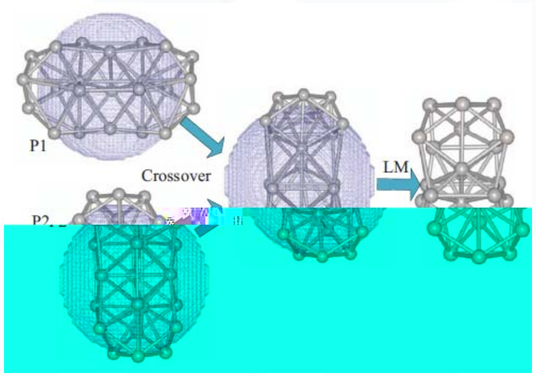
MX_2

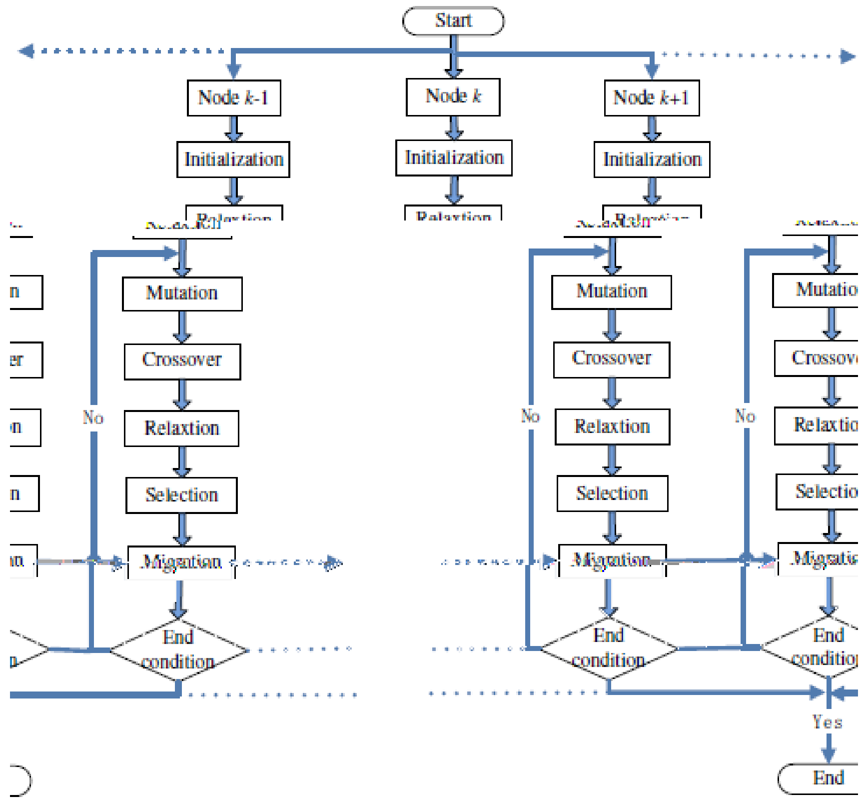
- ◈ MX_2 (M=Mo, W; X=S, Se, Te) CBM VBM WX_2 MX_2
- ◈ MX_2-WX_2 II





J. Kang, S. Tongay, J. Zhou, Jingbo Li*, and J. Q. Wu*, Appl. Phys. Lett ,102, 012111 (2013).





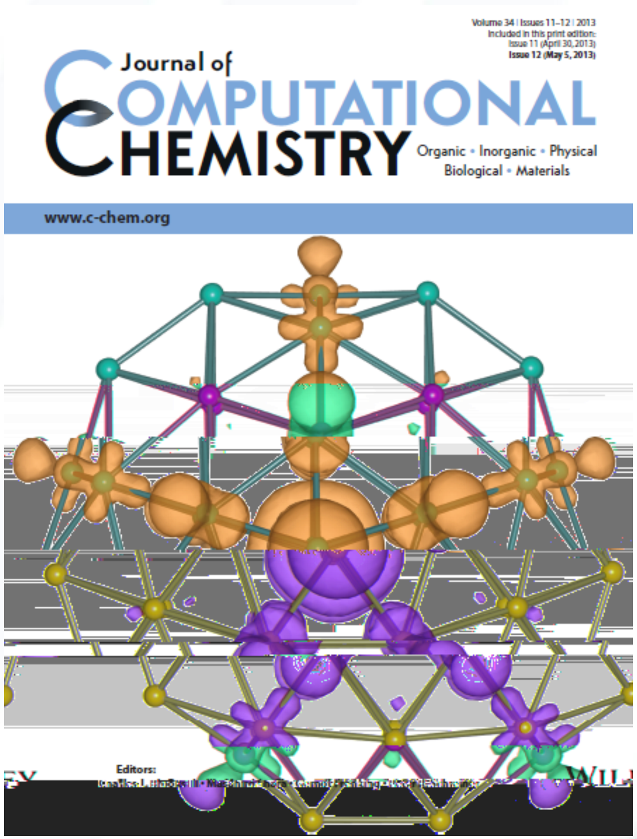
- PDECO
  2-5 Co Pt

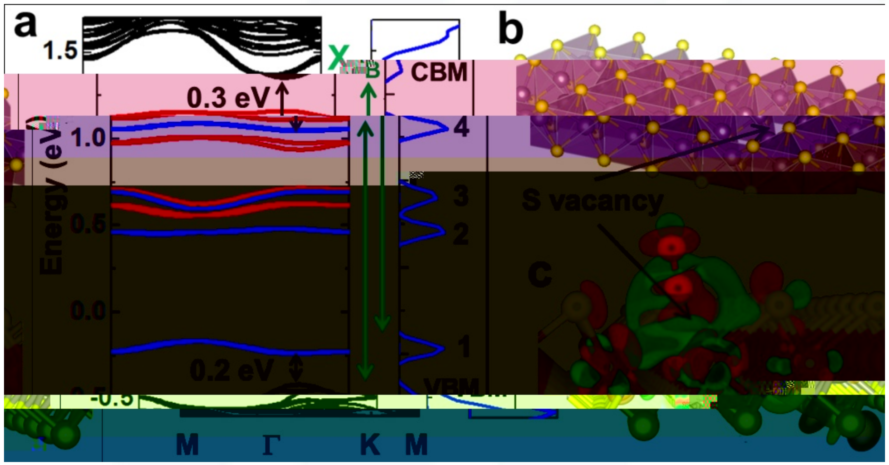
-

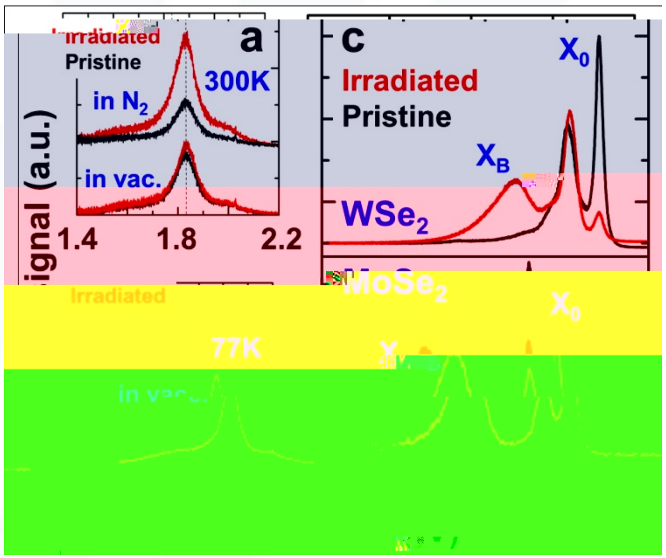
Zhanghui Chen, Xiangwei Jiang, Jingbo Li*, Shushen Li, and Linwang Wang*, J. Comp. Chem. 34, 1046 (2013).

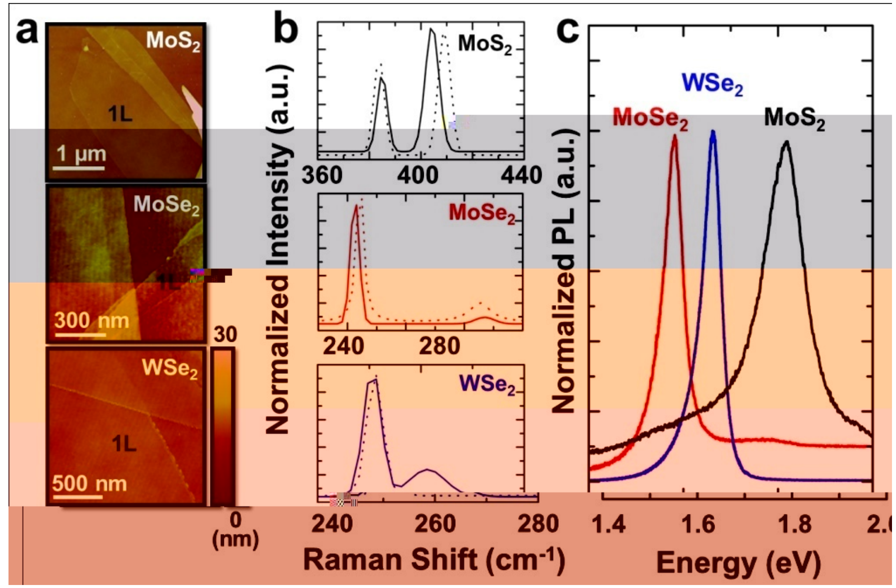
Zhanghui Chen, Xiangwei Jiang, Jingbo Li*, and Shu-Shen Li. J. Chem. Phys., 138, 214303, (2013).

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





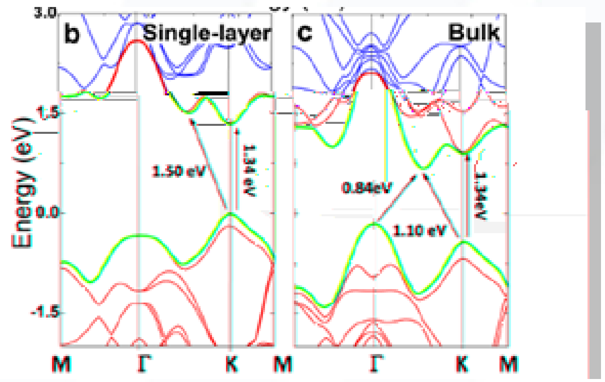




PL

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

ReS_2— :



[redacted]

, :

$MoSe_2$,

ReS2

.

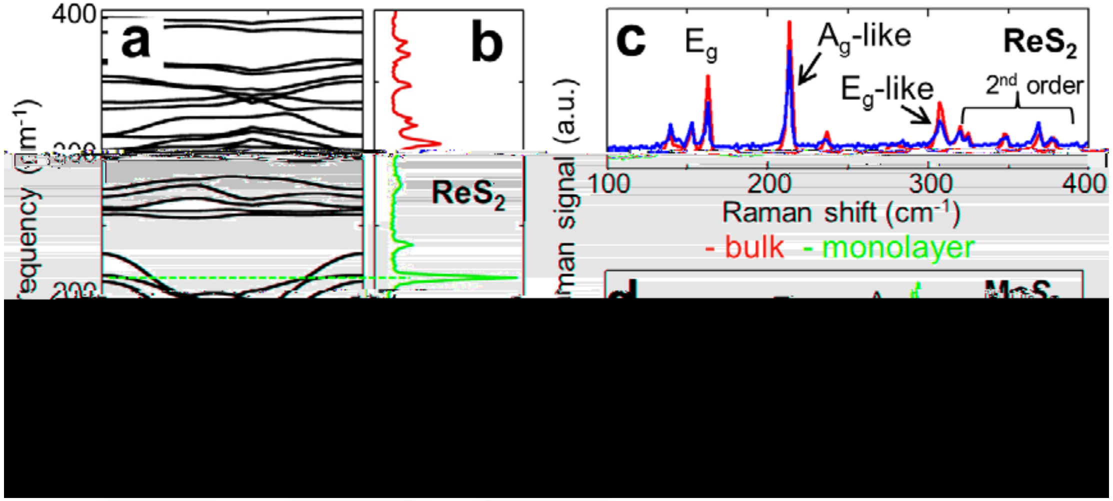
?

ReS_2 1T

ReS_2

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).

ReS_2— :



ReS_2 Raman

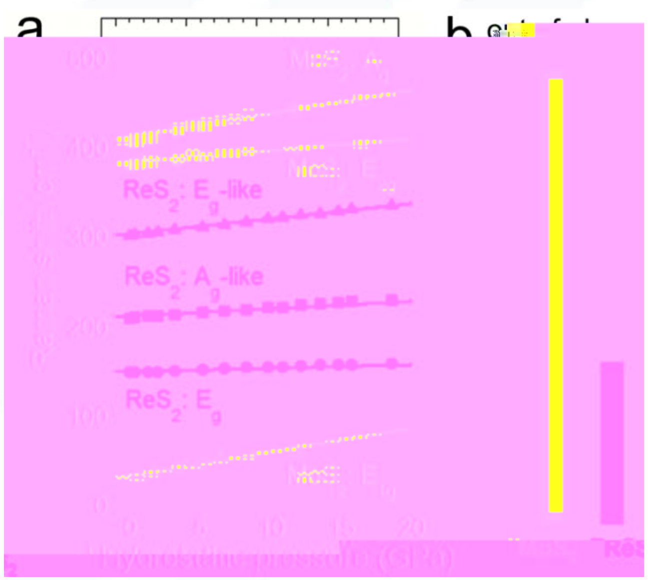
MoS_2

Raman

ReS_2 Raman

MoS_2

Raman

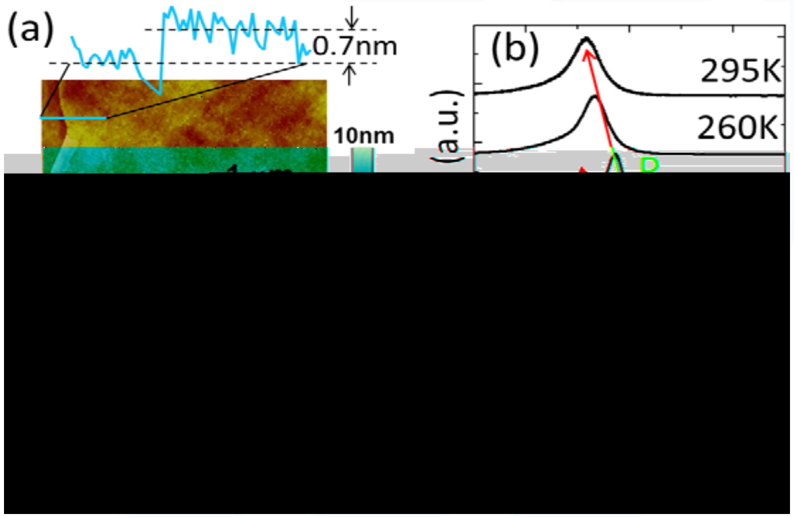


ReS_2

!

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).

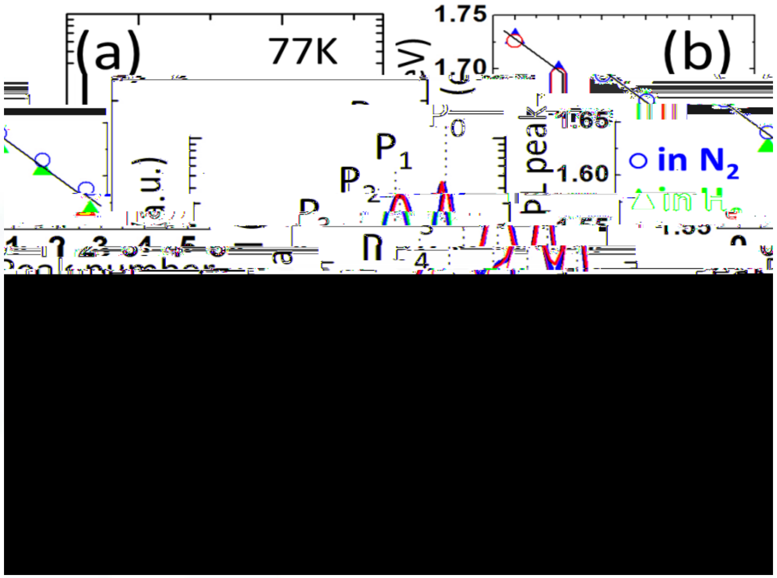
WSe2 -



, WSe2

PL P0

P1 PL



, N_2

-

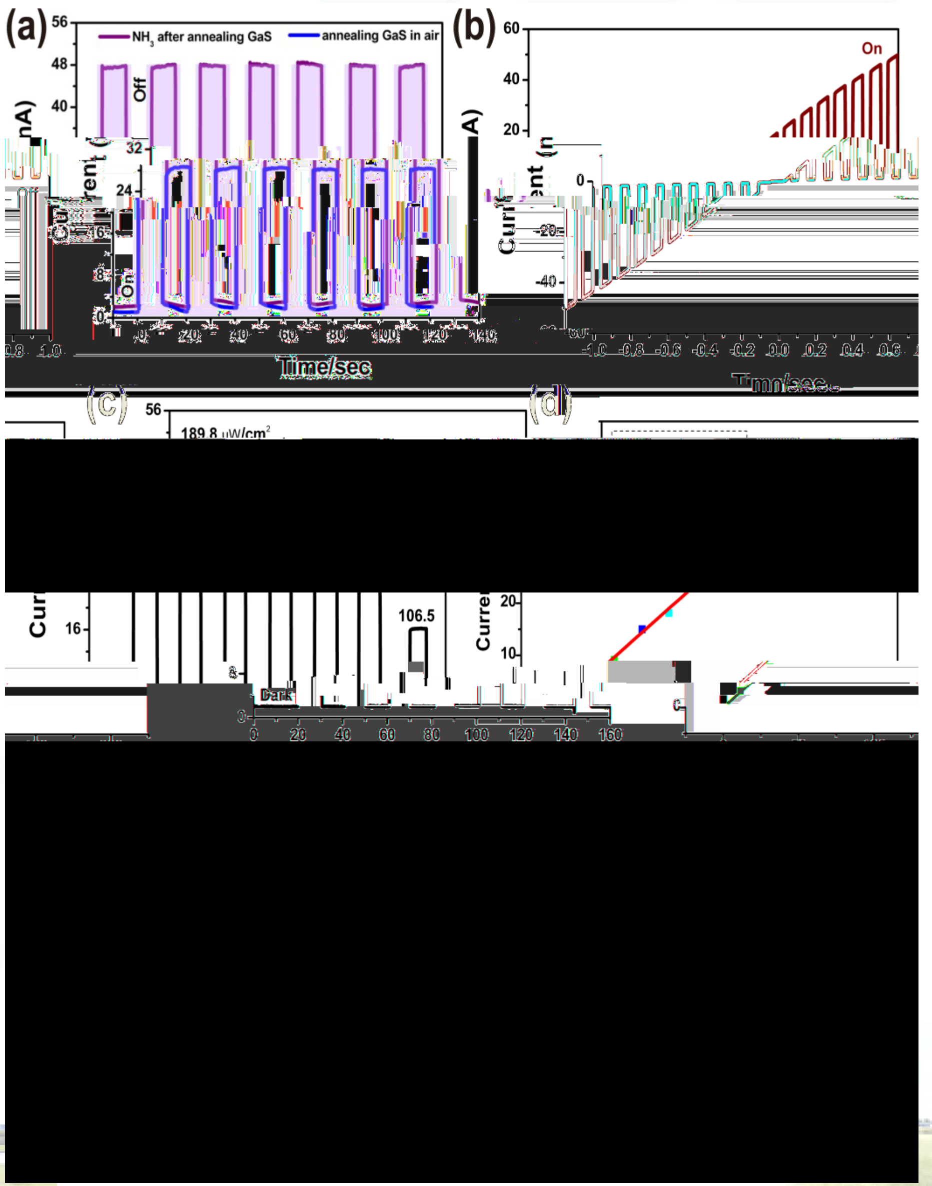
, PL ,

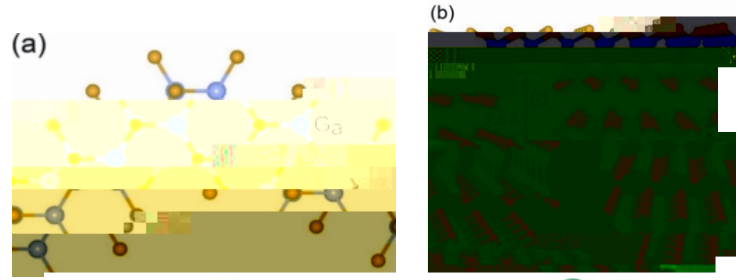
P1,P2,P3,P4 .

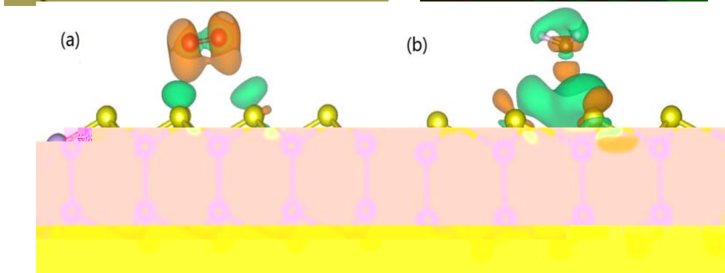
Huang-Rys 0.3

S. Tongay, J. Zhou, C. Ataca, J. Liu, J. S. Kang, T. S. Matthews, L. You, Jingbo Li, J. C. Grossman, and J. Wu PRB 87 165409 (2013).

GaS







- (NH_3, air, O_2)

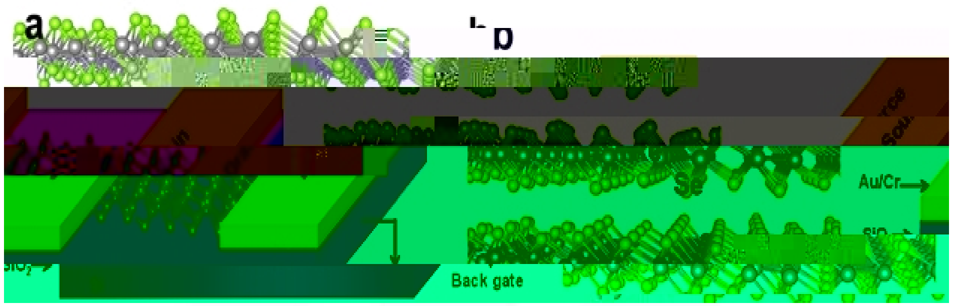
- NH_3
  64.43 AW^{-1}
  12621%

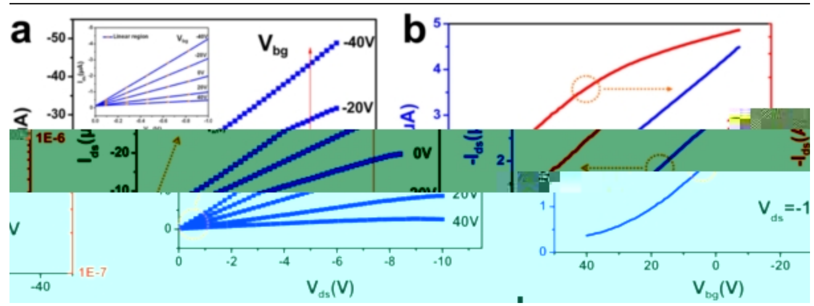
S. Yang, Y. Li, X. Wang, N. Huo, J.Xia, S. Li, J. Li,* Nanoscale, 6, 2582 (2014).

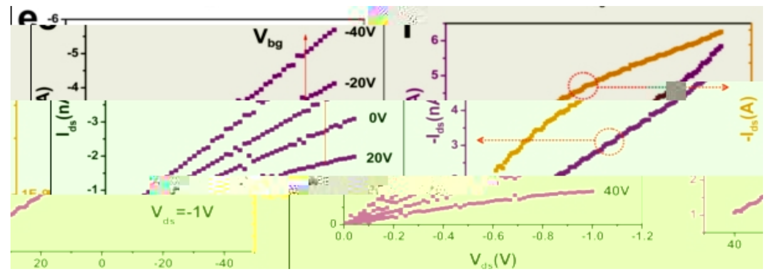
2014 2 7 Nanoscale “ ” GaS

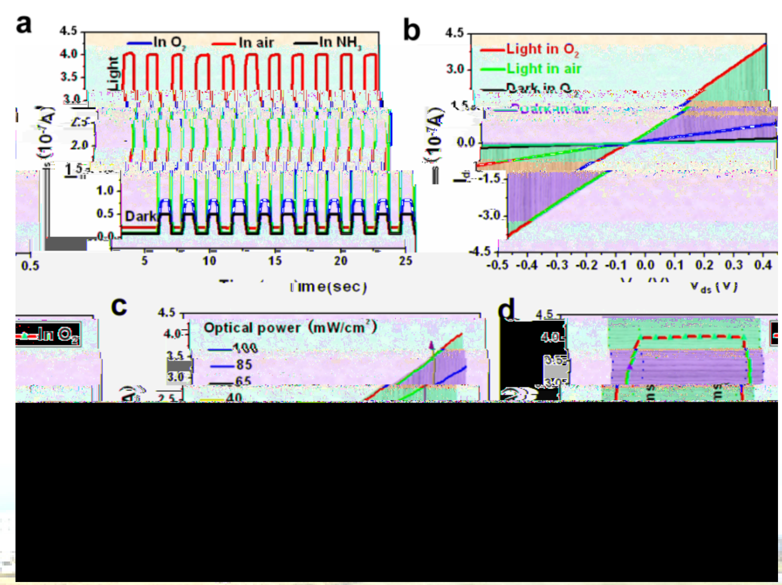
http://blogs.rsc.org/nr/

$ReSe_2$









◈ $ReSe_2$

$ReSe_2$

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

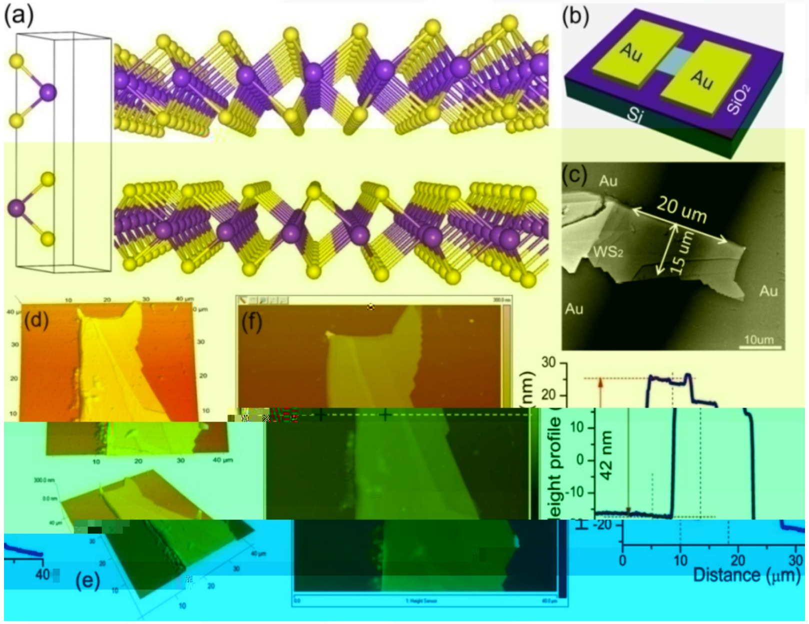
14.1 $cm^2V^{-1}s^{-1}$

◈ 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



◈ WS2 n-type 12 cm^2/Vs

◈ <20 ms 5.7 A/W
1118 %

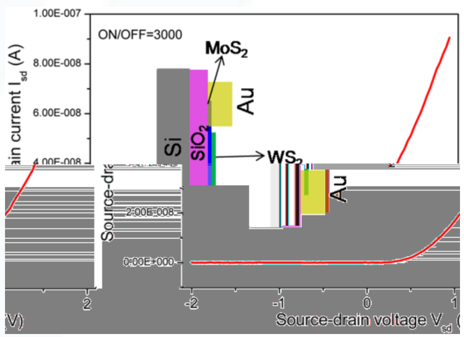
◈ O2 NH3

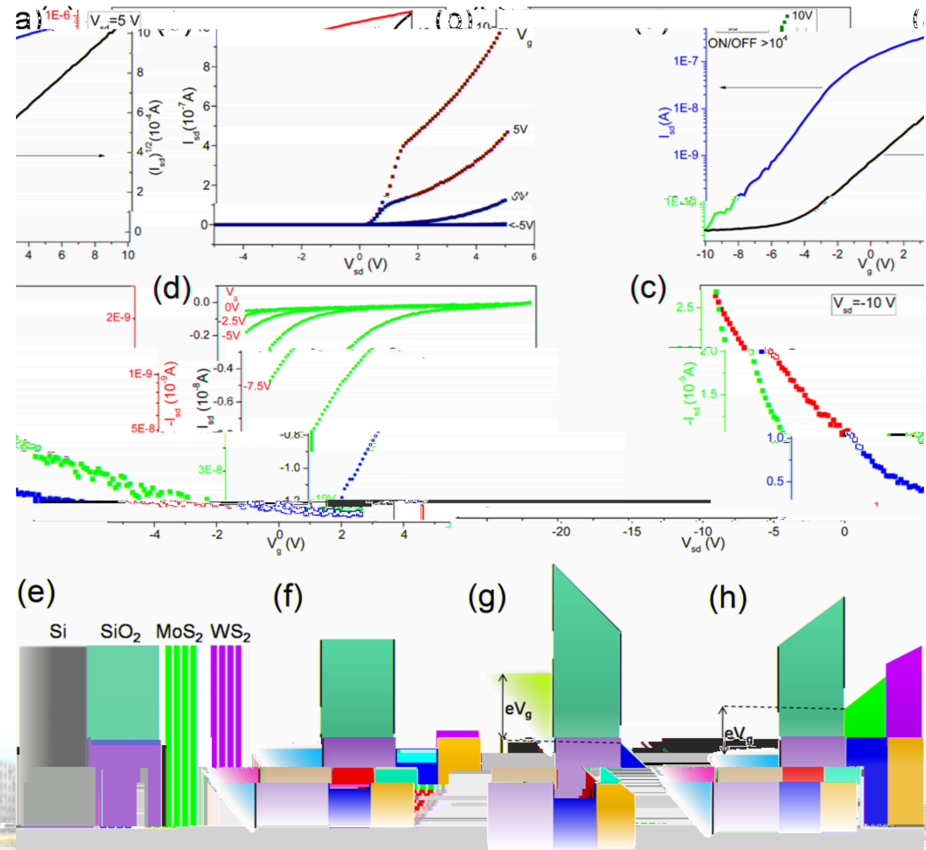
◈ NH3 ethanol NH3
884 A/W 1.7×10^5 %

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

Layered MoS_2-WS_2

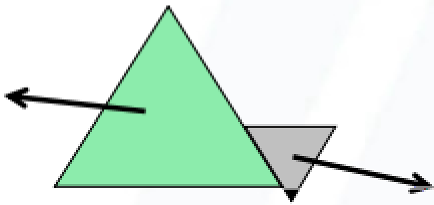
- MoS2-WS2 Vertical and Planar transistors
- Vertical transistors
  n-type 10^4 P-type 0.25 V
  10^3
- planar transistors MoS2-WS2 10^5
  v 5 cm^2/Vs 1.42 A/W



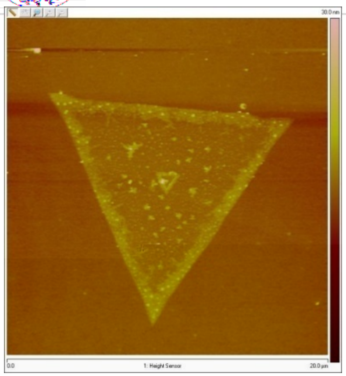


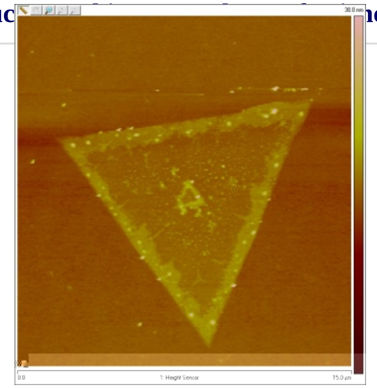
Nengjie Huo, Jun Kang, Shu-Shen Li, Jian-Bai, Xia, Jingbo Li*, Su-Huai Wei*.
Nature Communications **(2014), submitted.**

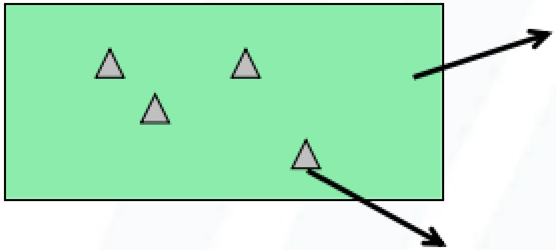
MoS$_2$



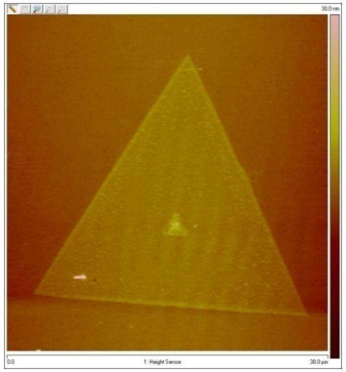
可能WS_2，需进一步表征

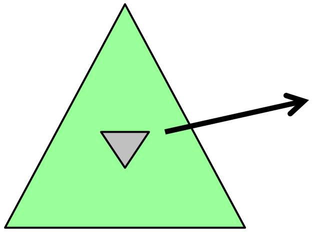






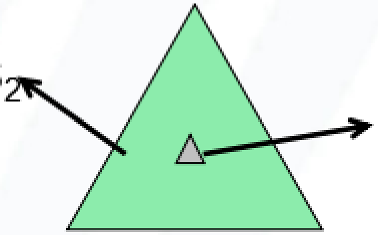
大片MoS_2，但是表面不是很干净



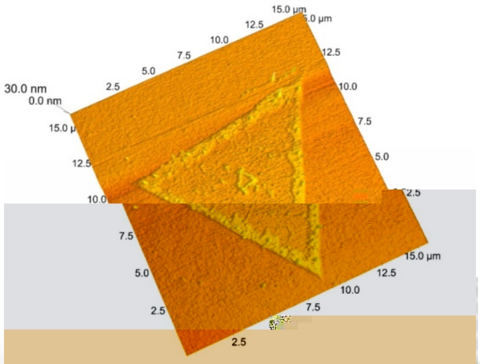


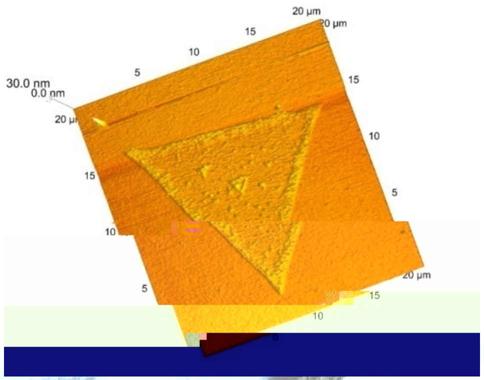
ABAB

MoS_2



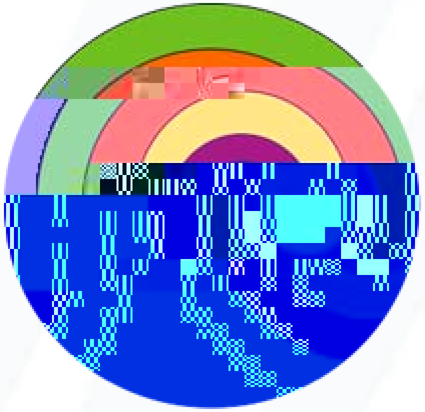
AAAA

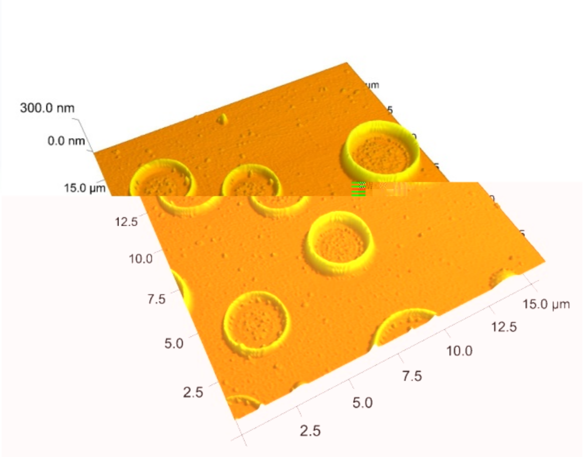


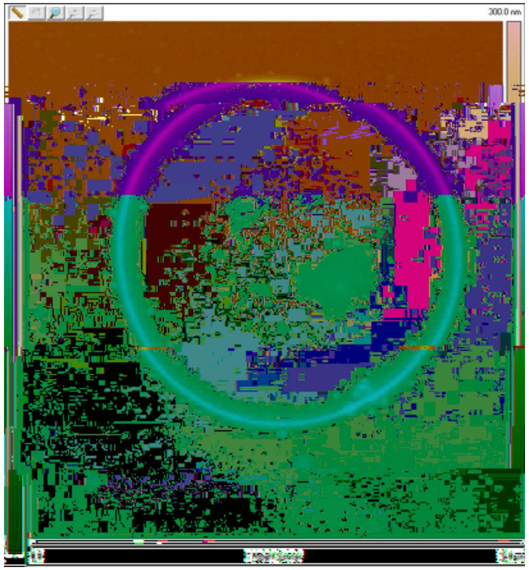


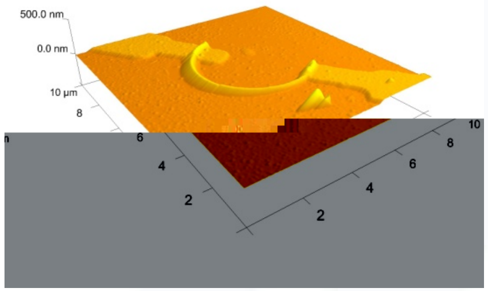
MoS_2/WS_2

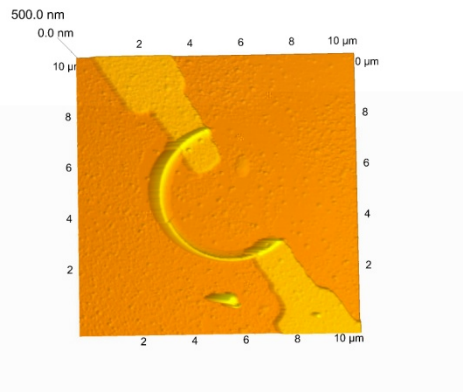
Sef

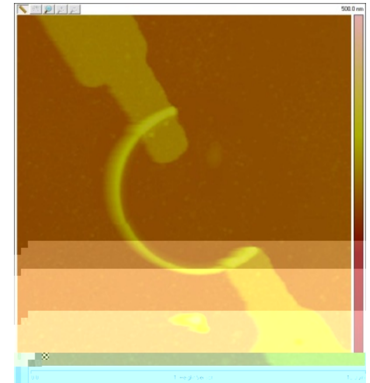


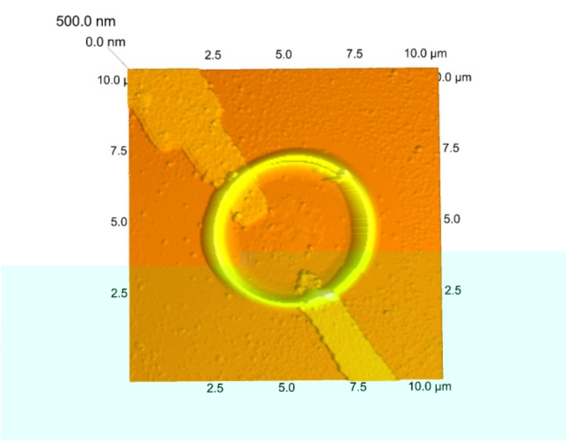


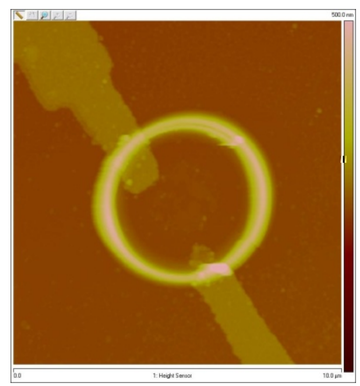


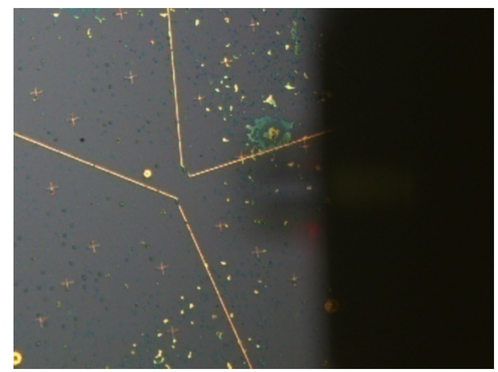








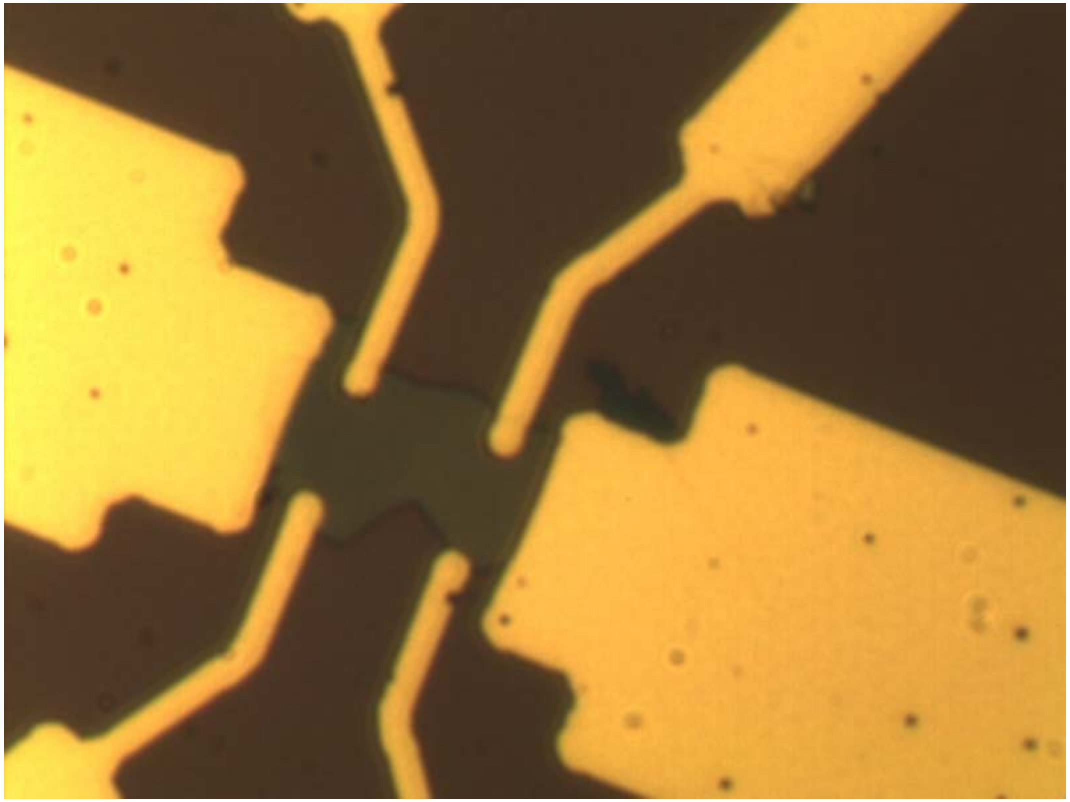




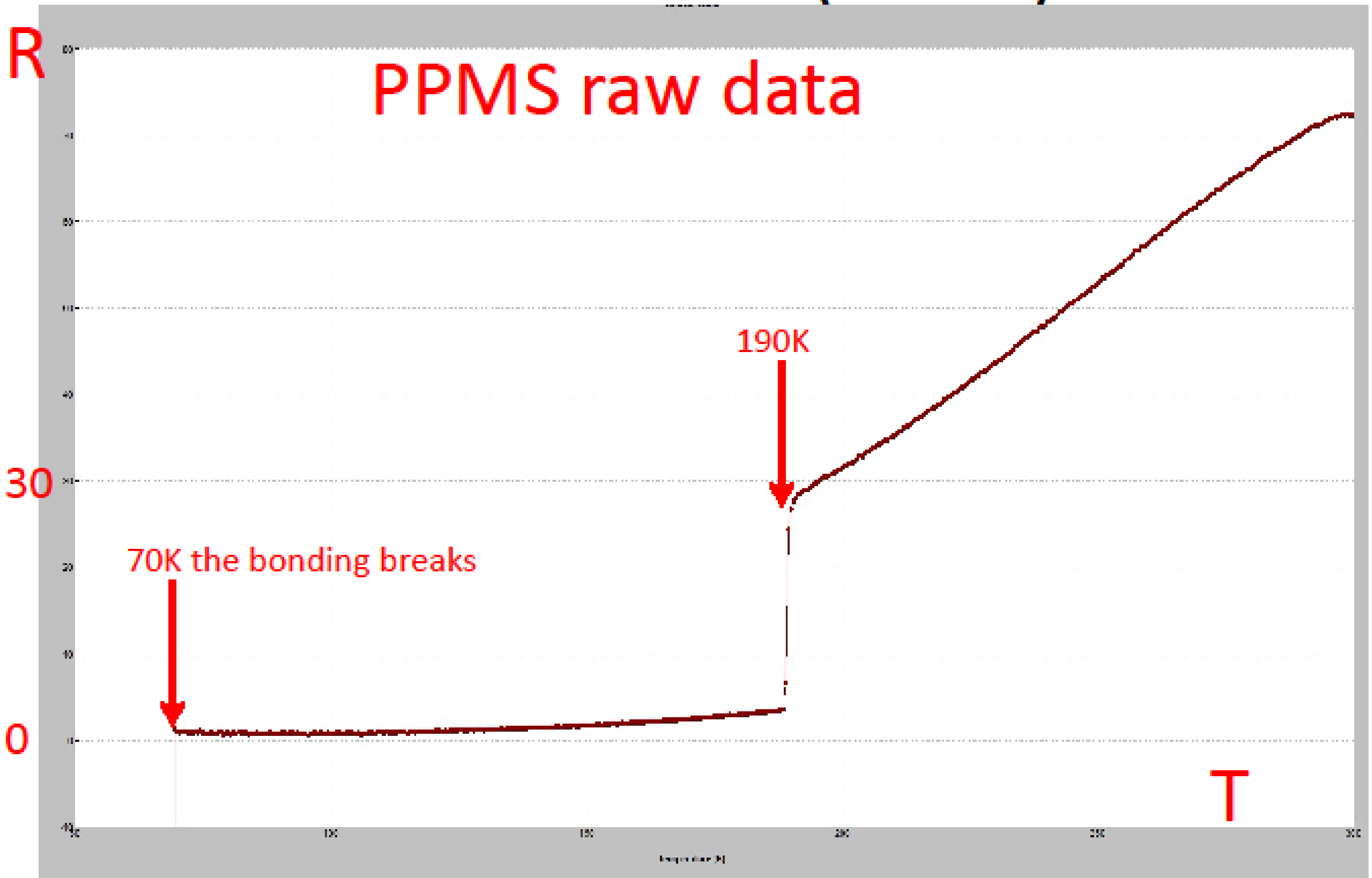
MoS2 ring AFM 1 2 3 4 1

MoS2

2D Superconducting FeTeSe Flake



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

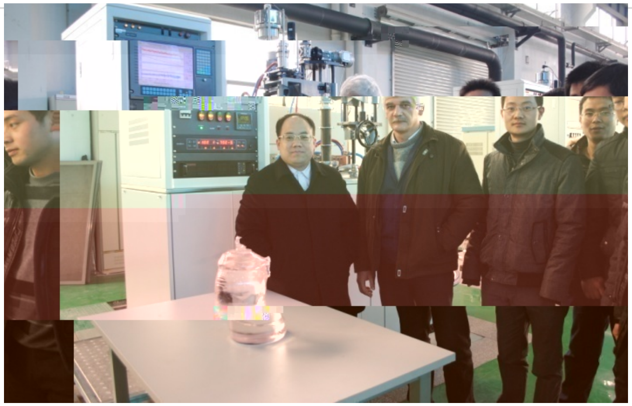


2012 7 4

2012 4 19

“ ”

“ ”



80

GSRiabtchenko

2012 6 20

-

2012 6 19

2011 8 11

1 CVD ,

MoS_2 $MoSe_2$ WS_2 WSe_2 VS_2 HfS_2 NiS_2 TiS_2 ReS_2

GaSe GaTe CuS CoS

2

MoS_2 Heterostructures

3 “ ” “

” “ ”

→ →

→ → →

1 “ ”

2

3

4

“ ” “ ” “ 863 ” “ 973 ”