Novel 2D Materials to study interactions between light and matter

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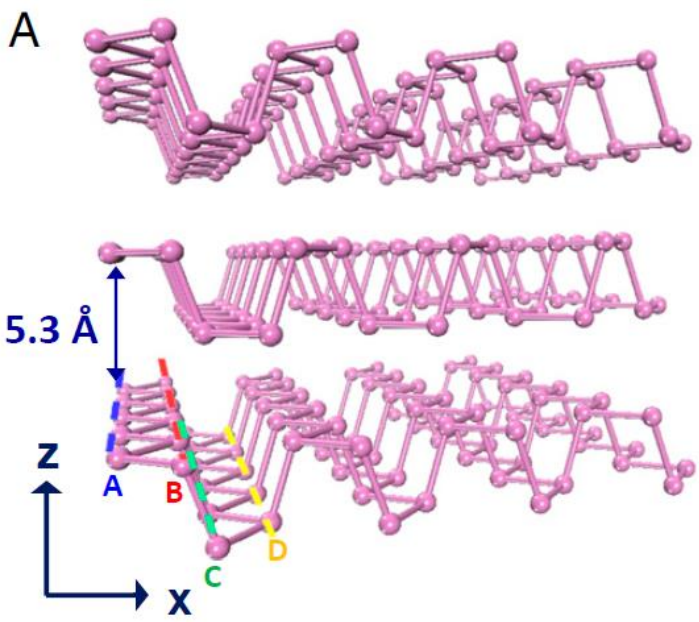
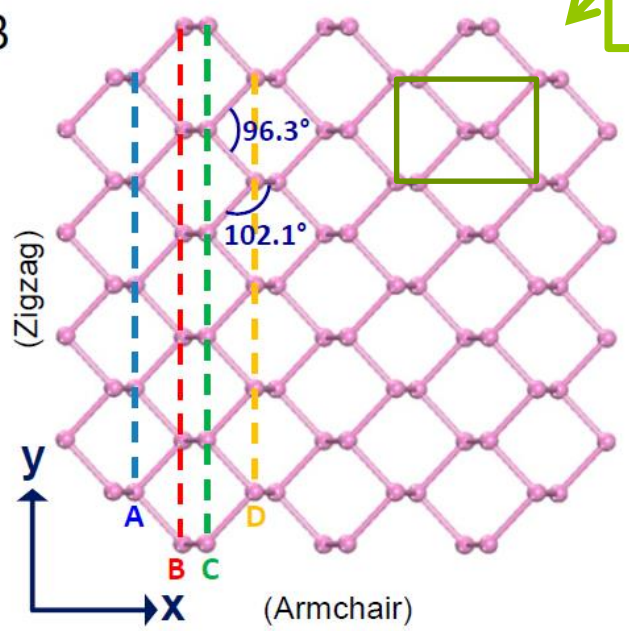
Black Phosphorus (bP) crystallography

- Layered structure with orthorhombic symmetry





Unit cell

P-P (A-B) = 2.224 Å
P-P (B-C) = 2.244 Å

Top view: hexagonal structure

X. Ling et al., PNAS 112 (2015) 4523

Band gap of bP

- Direct band gap of 0.3 eV in the bulk

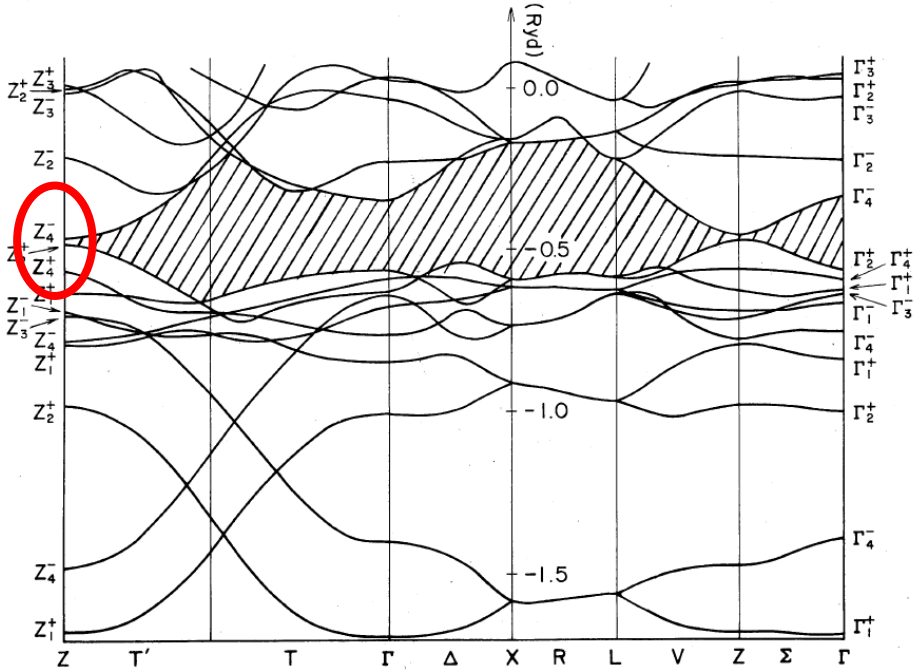
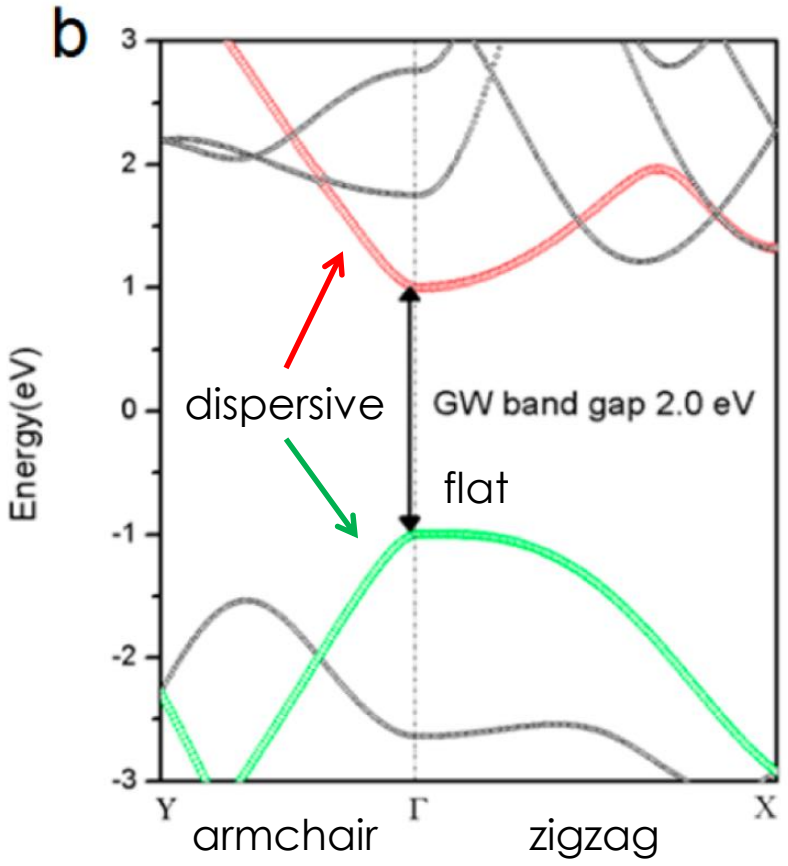


Fig. 8. The energy bands of black phosphorus.

Y. Takao et al.,
J. Phys. Soc. Jpn. 50 (1981) 3362

Band gap of bP

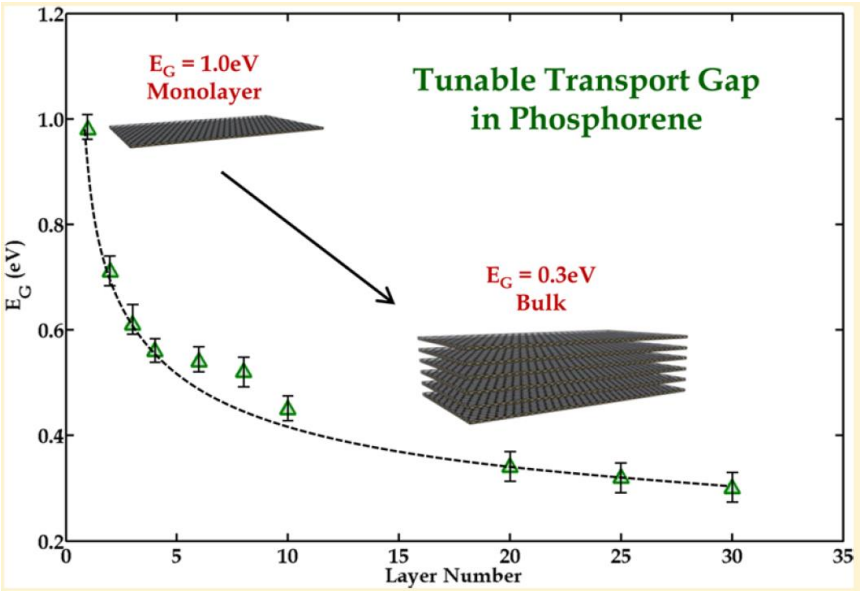
- Direct band gap of 0.3 eV in the bulk
- 2 eV for monolayer



R. Fei et al., Nano Lett. 14 (2014) 6393

Band gap of bP

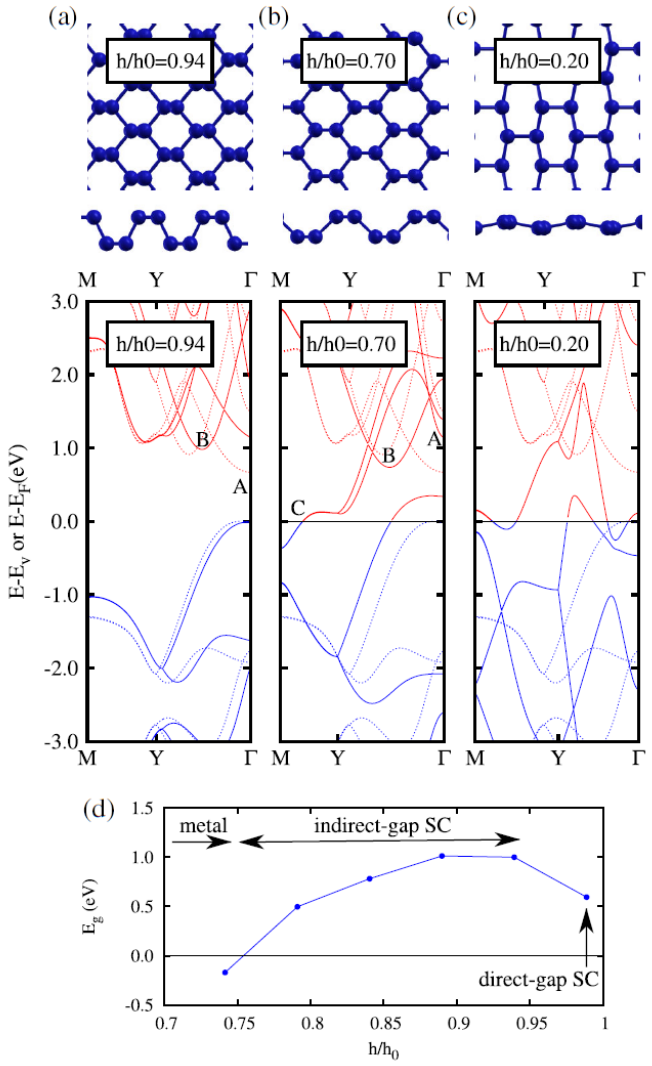
- Direct band gap of 0.3 eV in the bulk
- 2 eV for monolayer
- Gap can be tuned by bP thickness, from 0.3 eV (bulk) to 1 to 2 eV (ML)



S. Das et al., Nano Lett. 14 (2014) 5733

Band gap of bP

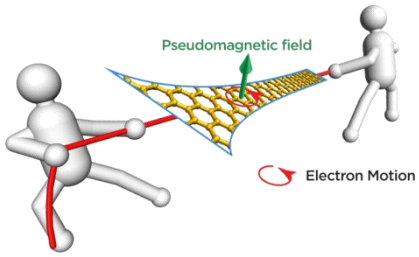
- Direct band gap of 0.3 eV in the bulk
- 2 eV for monolayer
- Gap can be tuned by bP thickness, from 0.3 eV (bulk) to 1 to 2 eV (ML)
- Can also be tuned by strain

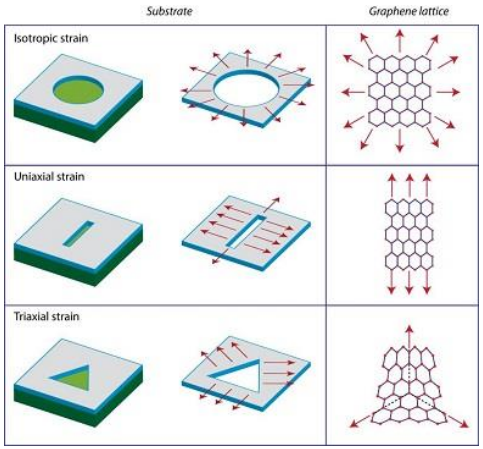


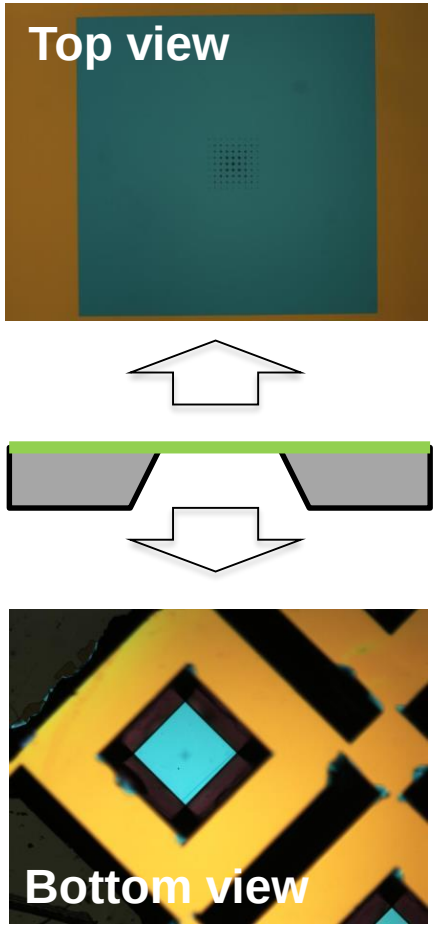
A. S. Rodin et al., PRL 112 (2014) 176801

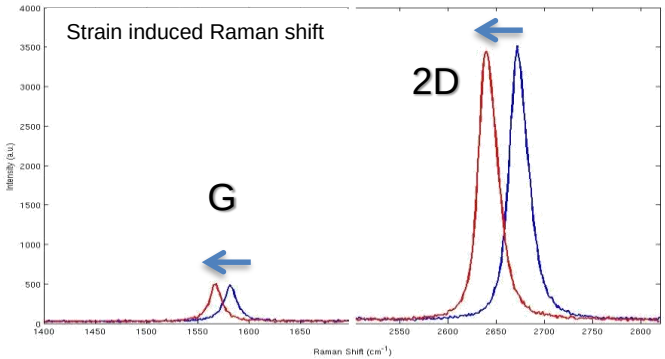
Strain-engineering in graphene & 2D materials

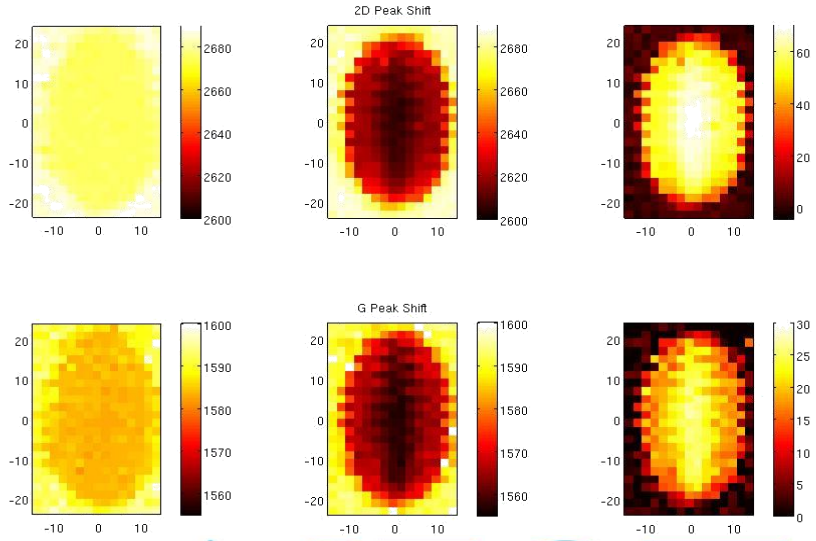
S. Roddaro



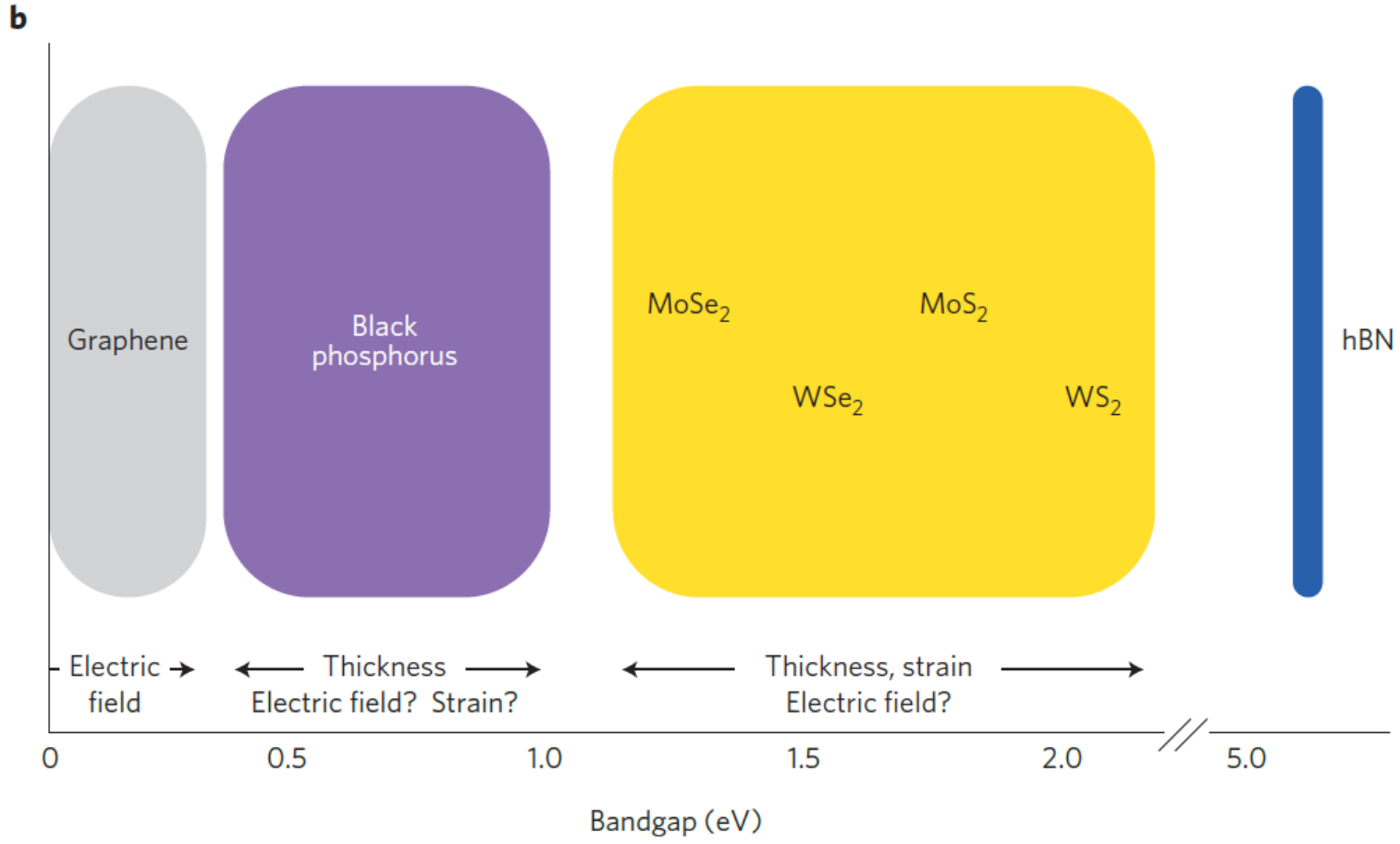






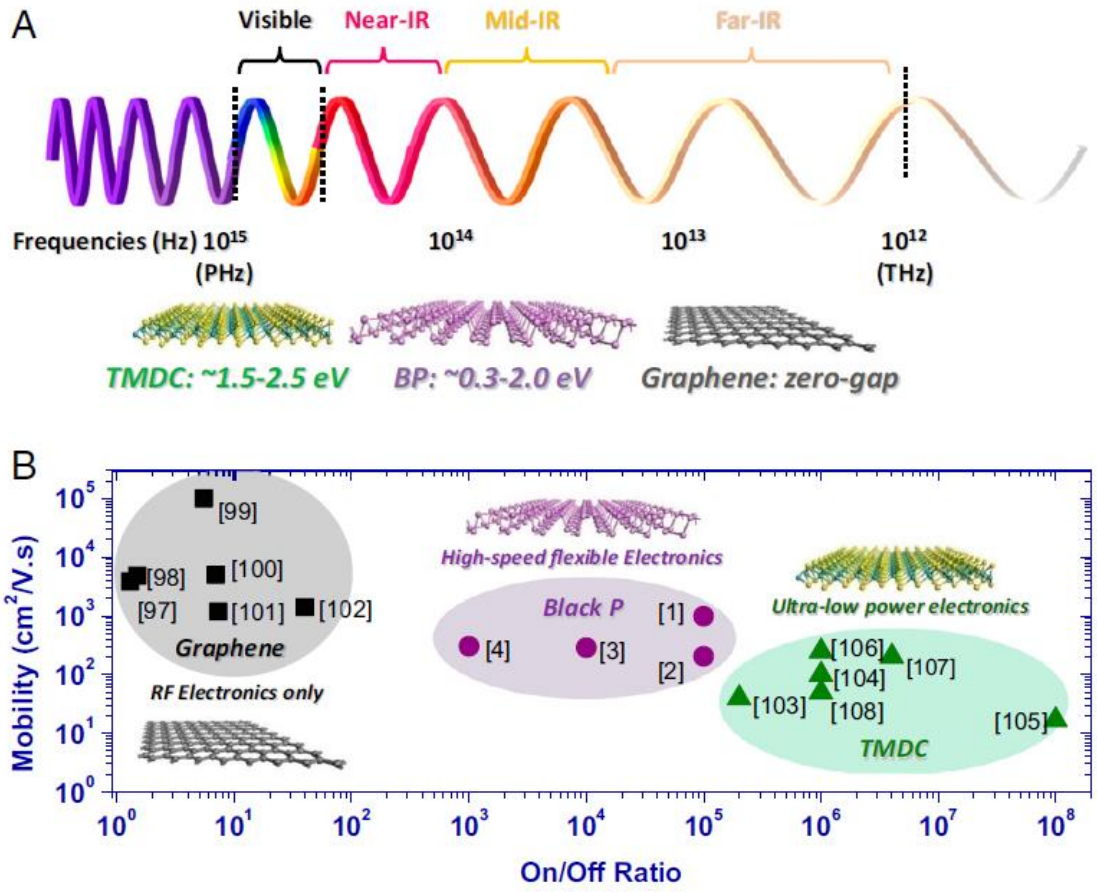


New 2d Materials



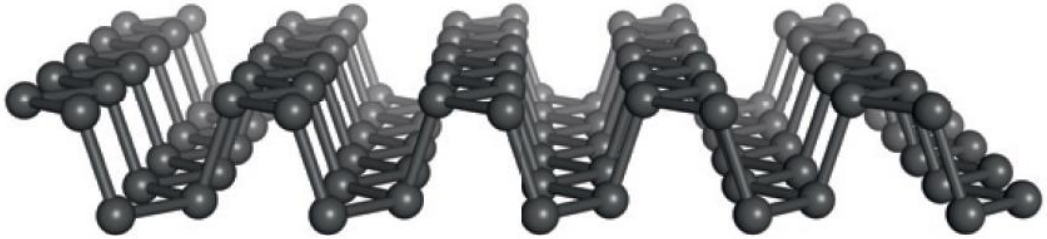
H. O. H. Churchill and P. Jarillo-Herrero, Nat. Nano 9 (2014) 330

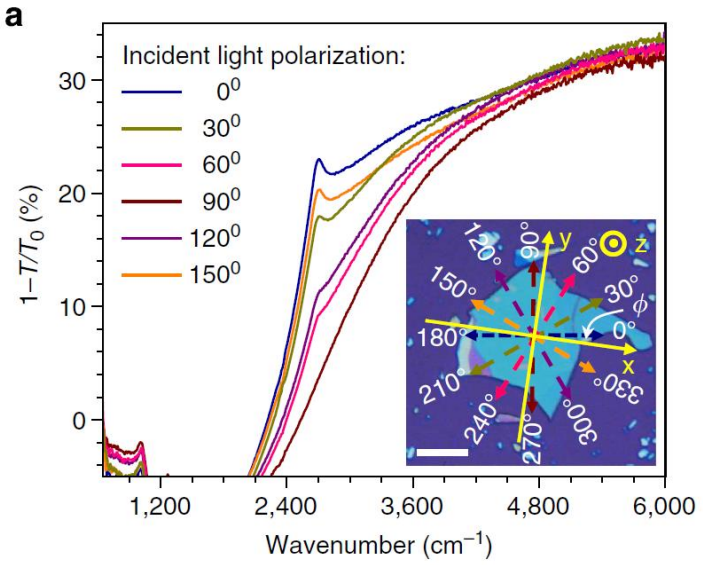
New 2d Materials



X. Ling et al., PNAS 112 (2015) 4523

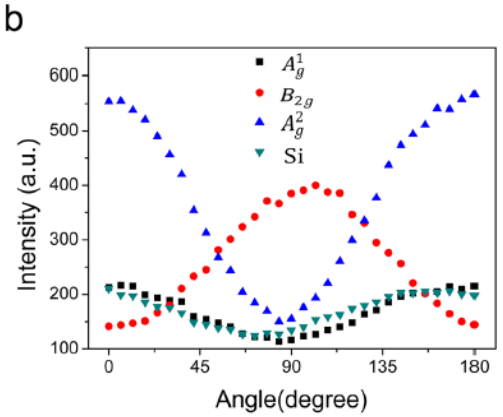
bP in-plane anisotropy





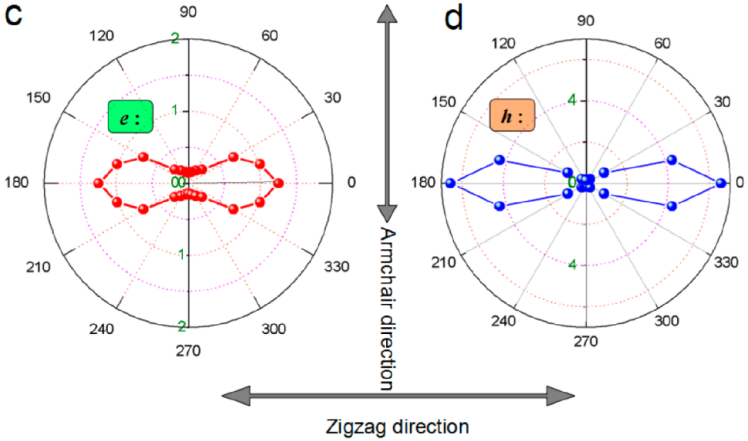
F. Xia et al., Nat. Comm. 5 (2014) 4458

Angle-dependent Raman



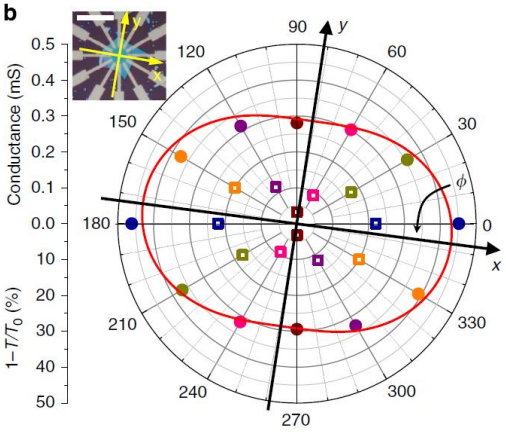
S. Zhang et al., ACS Nano 8 (2014) 9590

Effective mass anisotropy



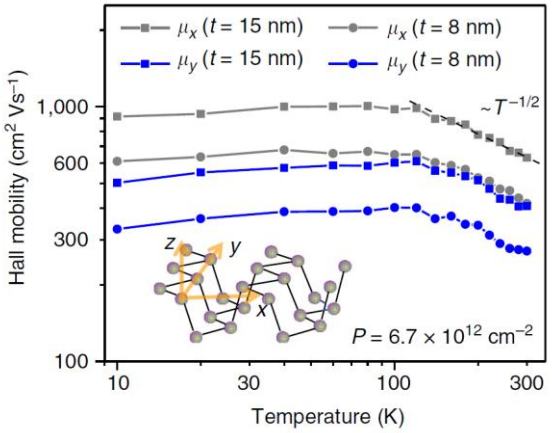
R. Fei et al., Nano Lett. 14 (2014) 6393

Angle-resolved DC conductivity



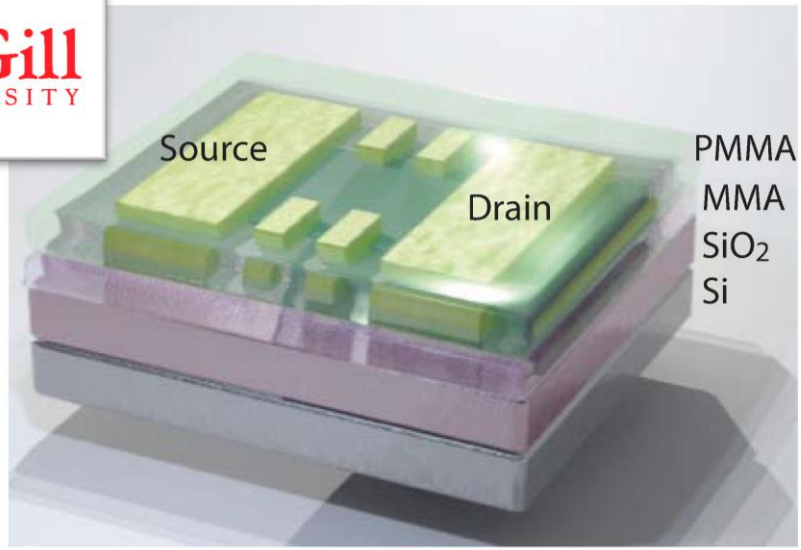
F. Xia et al., Nat. Comm. 5 (2014) 4458

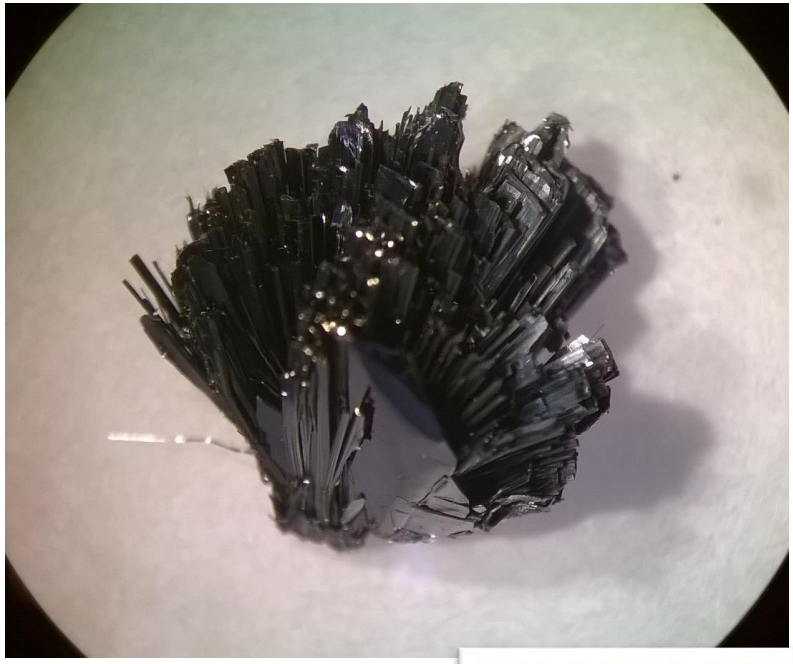
Angle-resolved Hall mobility

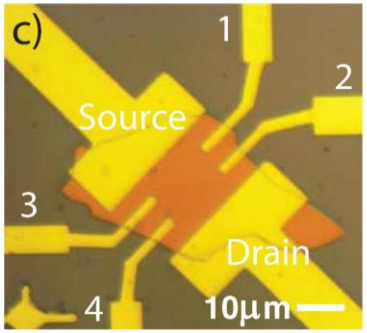


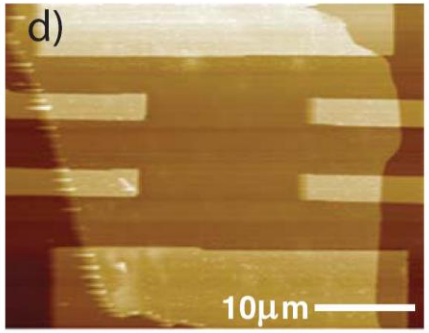
F. Xia et al., Nat. Comm. 5 (2014) 4458

bP Field Effect Transistor









R_{xx}: 1-2
R_{xy}: 1-3

Flake thickness:
65 ± 2 nm

N. Hemsworth *et al.*, arXiv:1607.08677.

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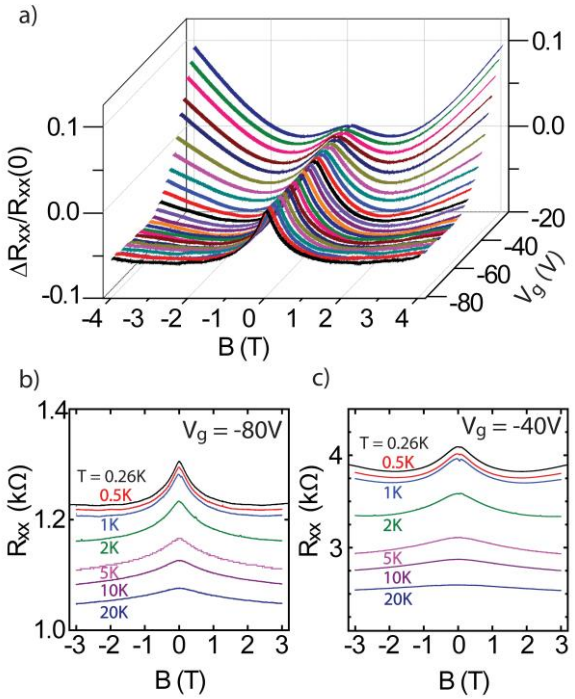
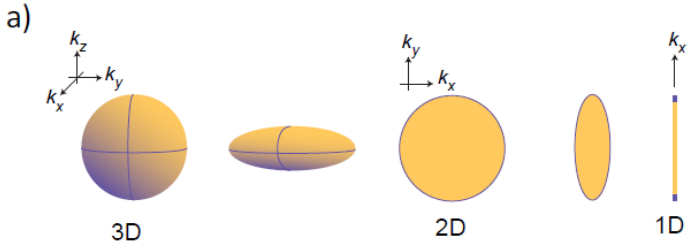
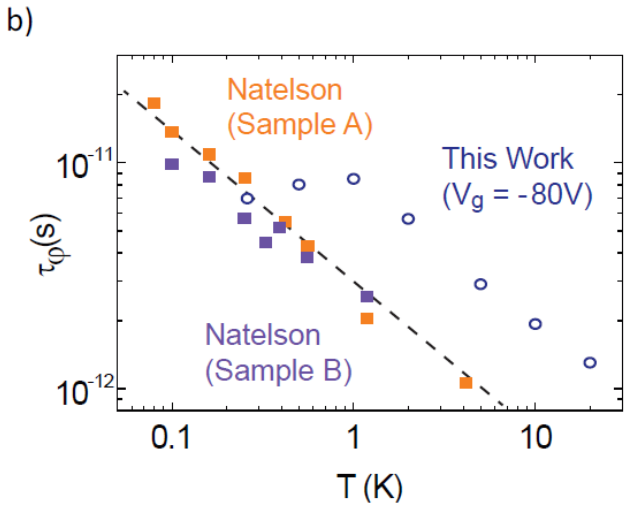
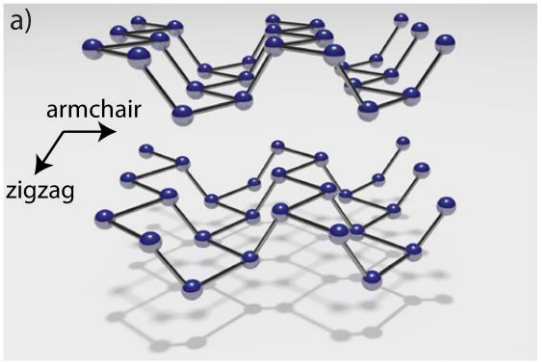
Comparison with quasi-1D wire

Weak Localization





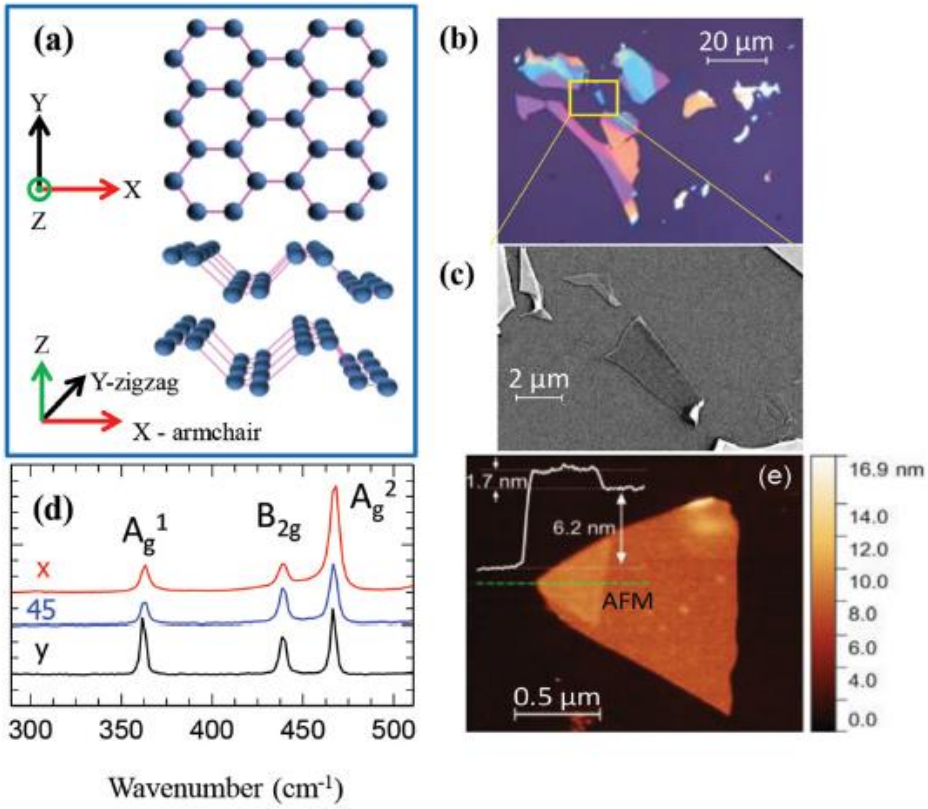


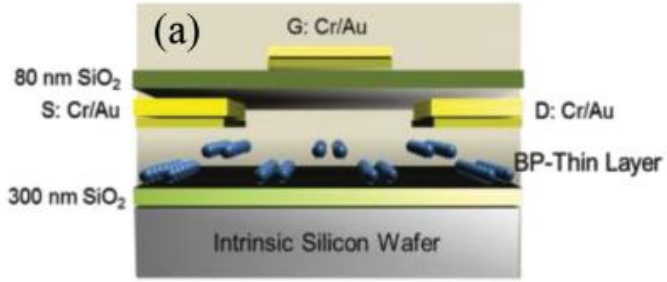


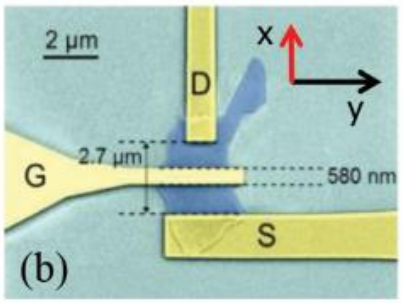
N. Hemsworth *et al.*, arXiv:1607.08677.

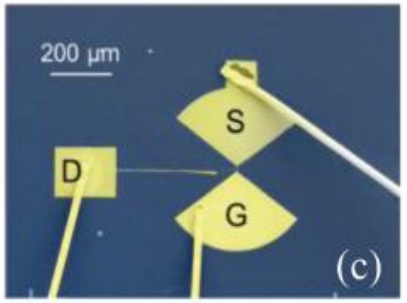
Black Phosphorus THz Photodetectors

M. Vitiello









L. Viti et al., Adv. Mater. 27, 5567 (2015).

Summary

- Activities:
  - Consolidated Research Activities on bP since 2014
- Competences:
  - Material
  - Device fabrication
  - Characterization (low-temperature magneto-transport and scanning probe microscopy)
- Potential Research Topics:
  - Optoelectronic Devices, gap tuned by layer thickness or strain