Exploring 2D materials in emerging solar cells

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QUEENSLAND MICRO- AND NANOTECHNOLOGY CENTRE

SCHOOL OF ENVIRONMENT AND SCIENCE

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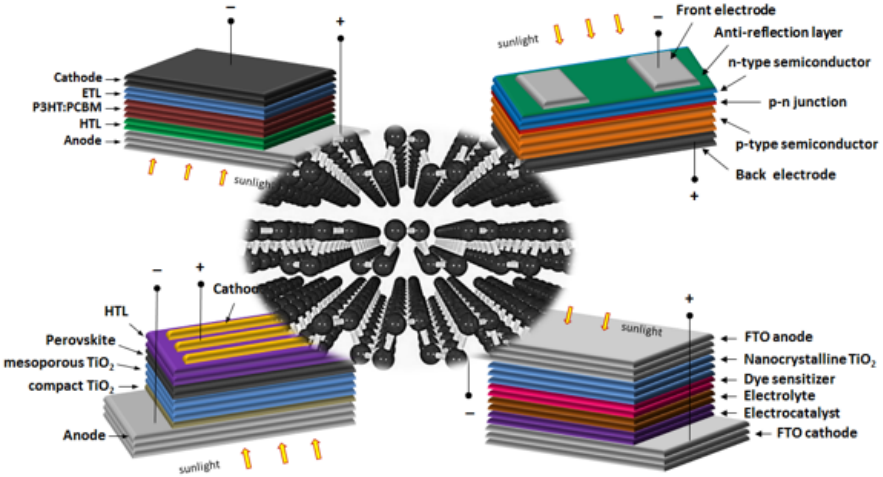
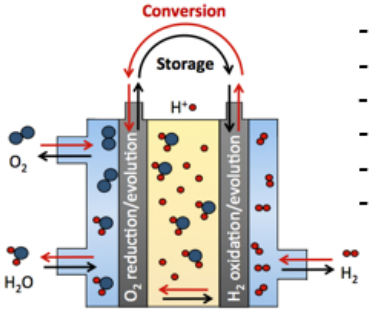
Research Interest in "Nanomaterials for Energy"

Solar Cells

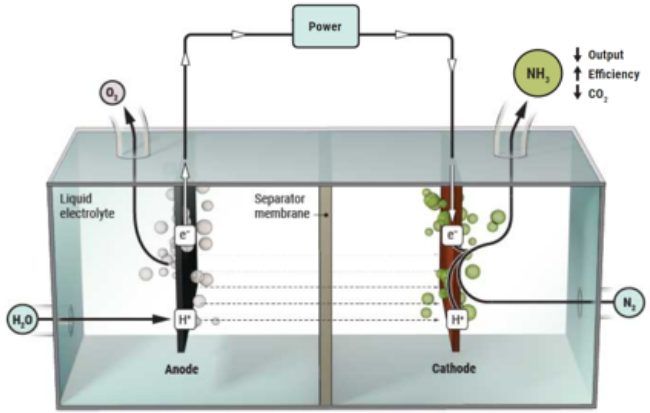


- *Adv. Mater*, **2020**, *32*, 2000631.
- *Adv. Energy Mater*, **2020**, *10*, 1902253.
- *Angew. Chem. Int. Ed*, **2019**, *58*, 5202.
- *Angew. Chem. Int. Ed*, **2018**, *57*, 2644.
- *Adv. Energy Mater*, **2018**, *8*, 1701832.
- *Adv. Sci*, **2017**, *4*, 1600504.
- *Adv. Mater*, **2016**, *28*, 8586.

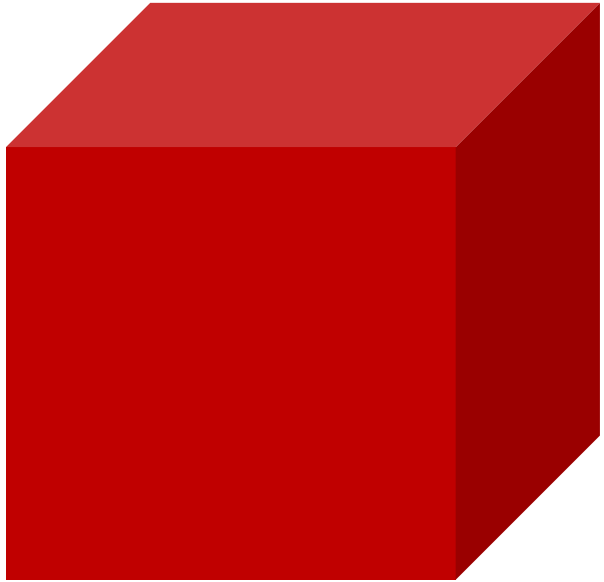
Catalysis



- *Adv. Funct. Mater*, **2022**, *32*, 1207280.
- *Small*, **2021**, *17*, 2102218.
- *Angew. Chem. Int. Ed*, **2020**, *60*, 2541
- *Adv. Mater*, **2019**, *31*, 1900546.
- *J. Mater. Chem. A*, **2020**, *8*, 4735.
- *J. Mater. Chem. A*, **2020**, *8*, 15875.



Sun Power – Solar Tech



Solar Energy on Earth's atmosphere
(10,000 times higher than GED)

Global Electricity Demand (GED)
(>25,000 terawatt hours)

Current PV installations
(~50 times lower than GED)

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Solar Cells in the Market

Silicon – Solar Cells

Performance: High efficiency
Cost: **High**

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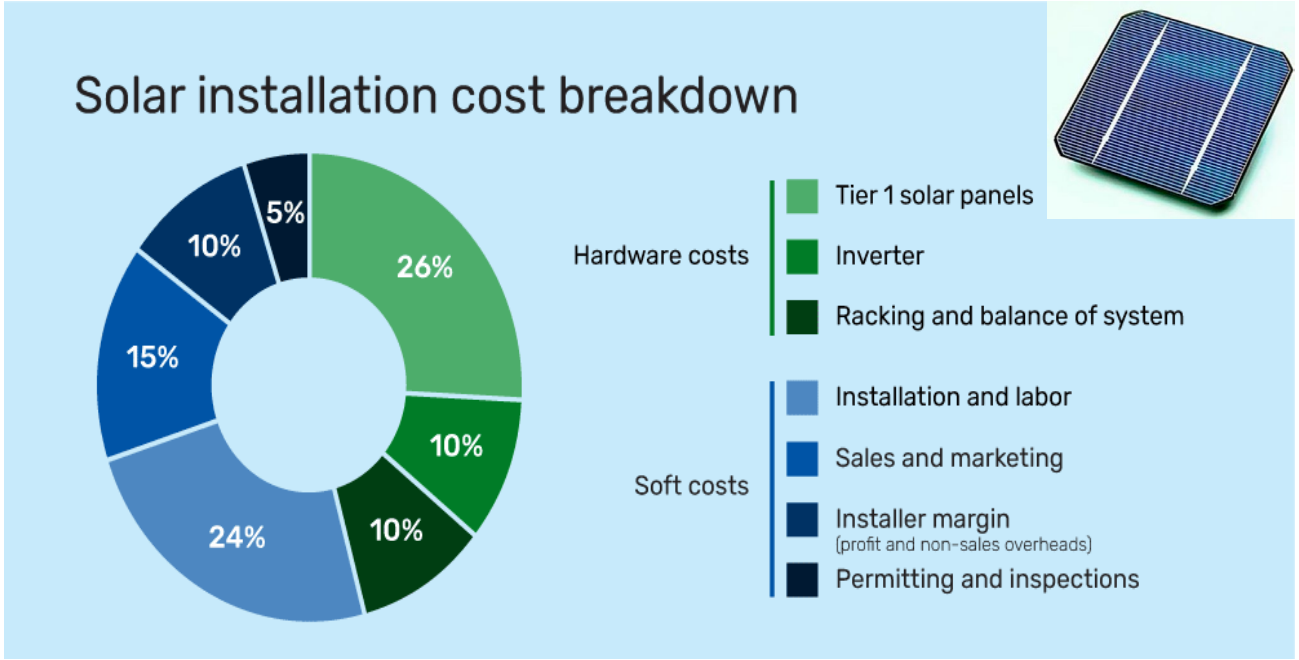
PV market



Potential solutions:

- BIPVs (other applications such as windows)
- Increase PV performances
- Constructing tandem solar panels (highly performance)
- Lowering the panel cost significantly
- Simplifying panel architecture

Emerging Solar Cells

Performance: High efficiency

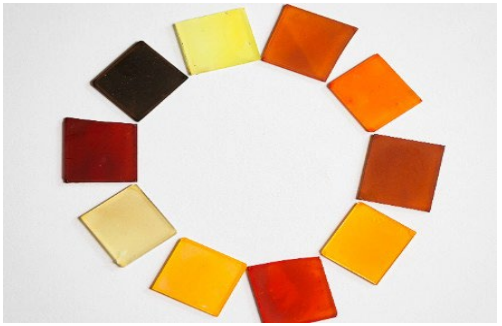
Production Cost: Low

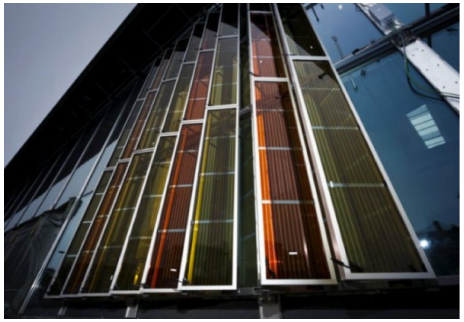
Fabrication : Simple

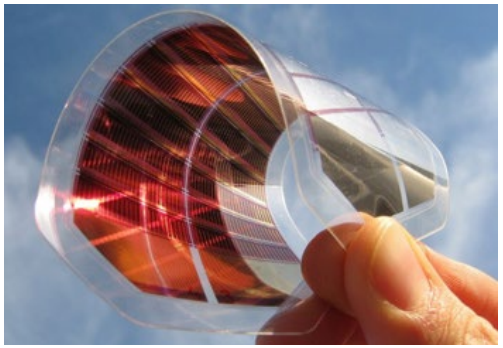
Others: Flexible

Portable

Light-weight







http://gcell.com/

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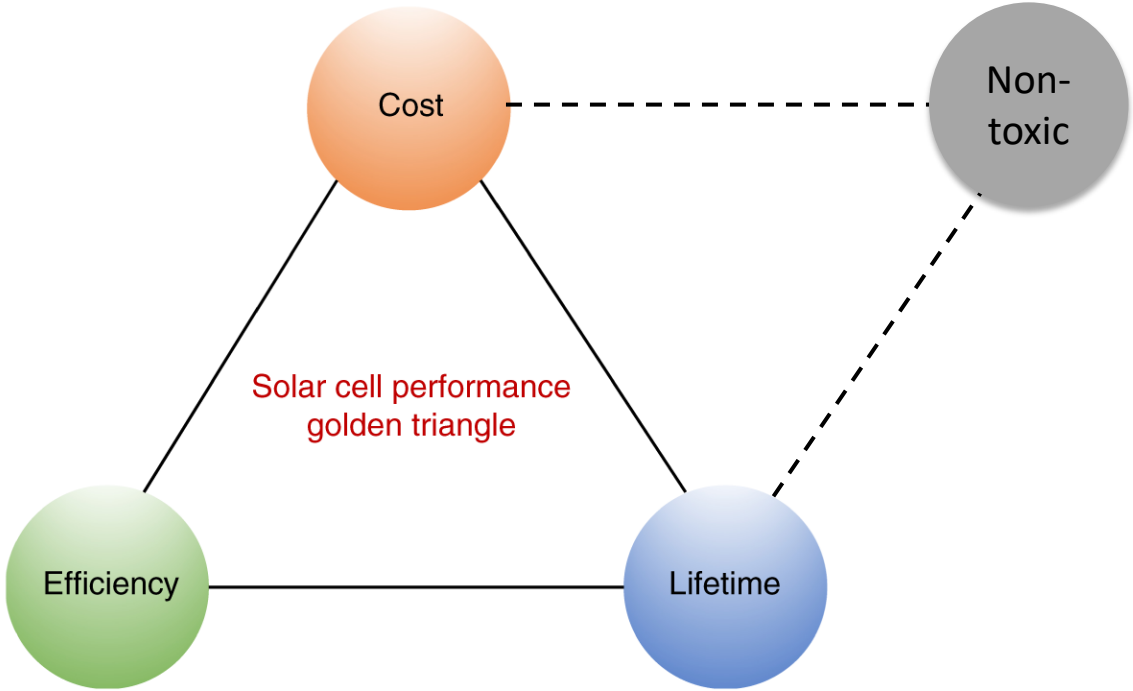
Golden Triangle



https://www.nature.com/articles/s41467-018-07255-1

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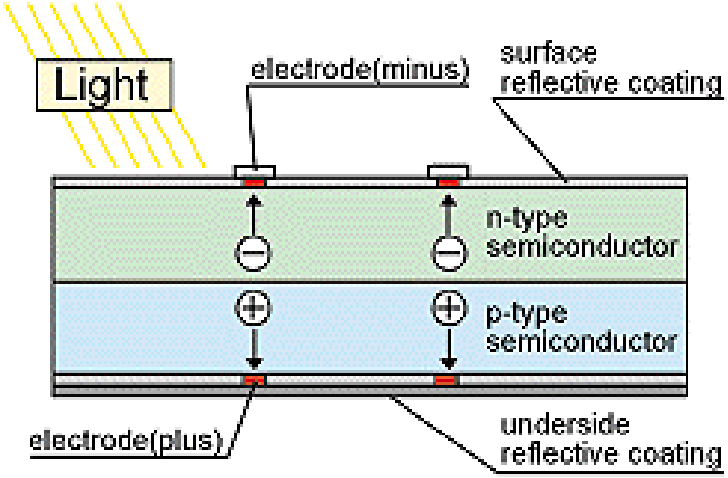
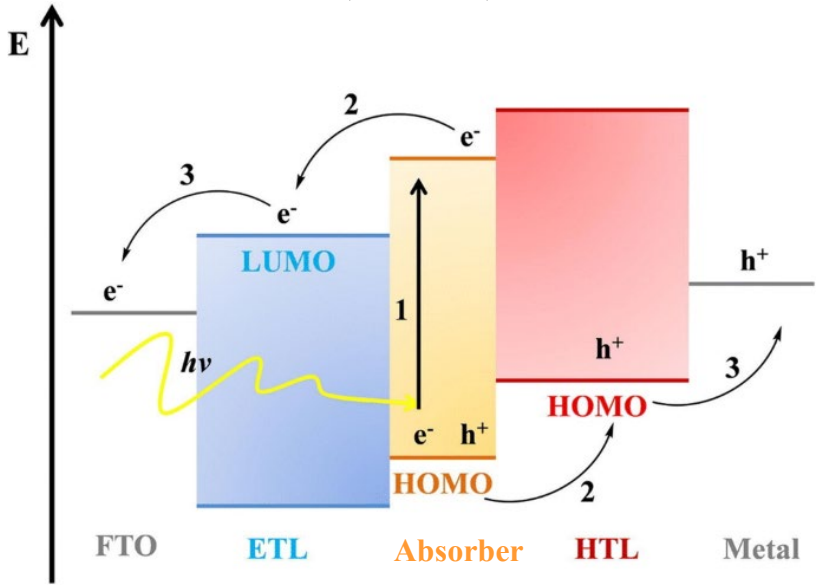
Working Principle of Solar Cells

Heterojunction solar cells



PSCs, OPV, DSSCs etc



The role of hole transporting materials is to efficiently select and transport the photogenerated holes.

HTM should be *p-type* semiconductor.

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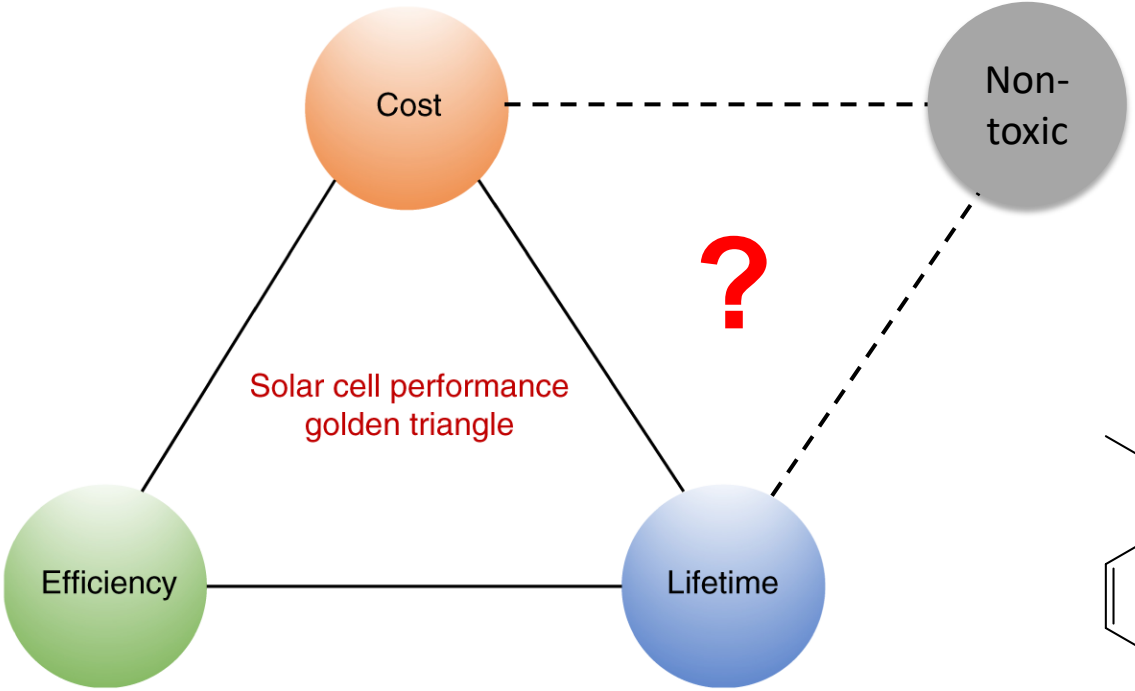
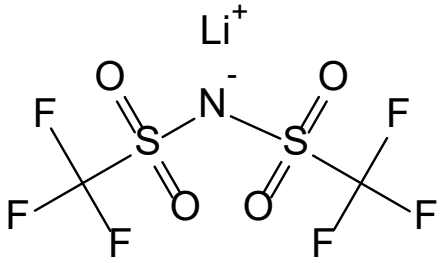
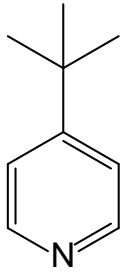
Hole Transporting Materials





Lithium bis-(trifluoromethanesulfonyl)imide (LiTFSI)



4-tertbutyl pyridine (4-tBP)

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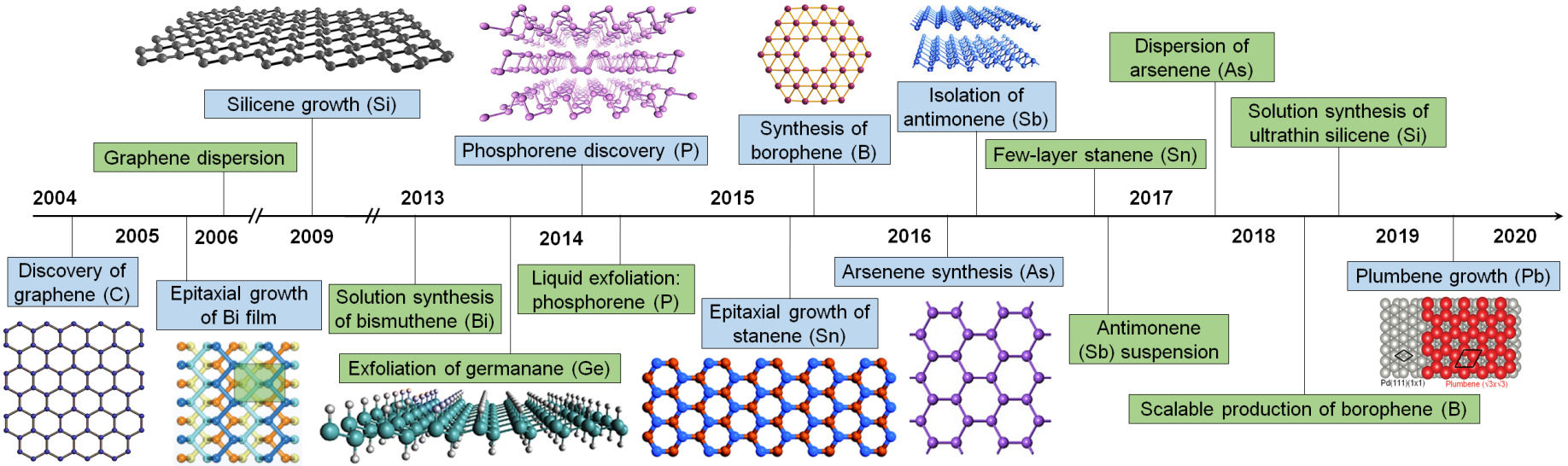
Development of 2D Materials



(MJ) Bat-Erdene et al. *Adv Funct Mater.,* **2022**, *32*, 2107280.

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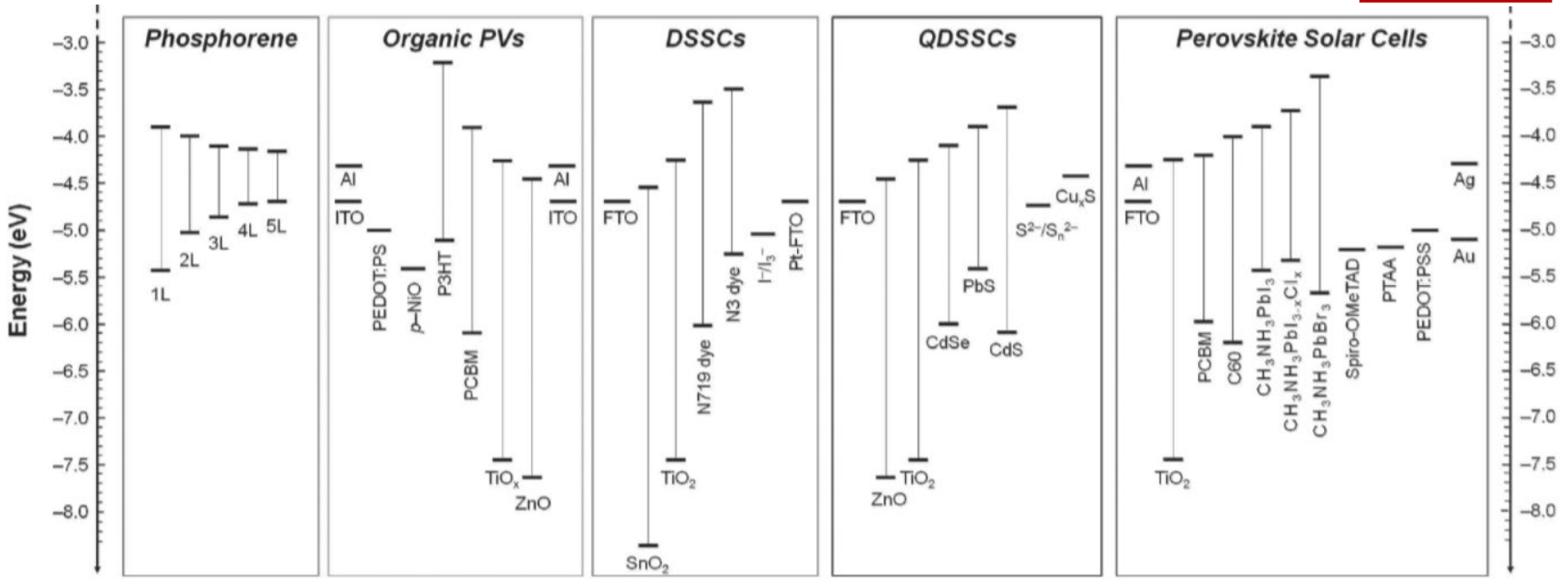
2D Black Phosphorus (BP)

Type	Phosphorene
	Semiconductor
Bandgap (eV)*	0.3 – 2.0
Carrier mobility, (cm^2 V^{-1} s^{-1})	≈1000
ON/OFF ratio	10^3 – 10^5
Thermal conductance (W m^{-1} K^{-1})	10 – 36
Thermoelectric performance, ZT	1 – 2.5



Batmunkh et al. *Adv. Mater.*, **2016**, 28, 8586.
Batmunkh et al. *Adv. Energy Mater.*, **2017**, 1701832.

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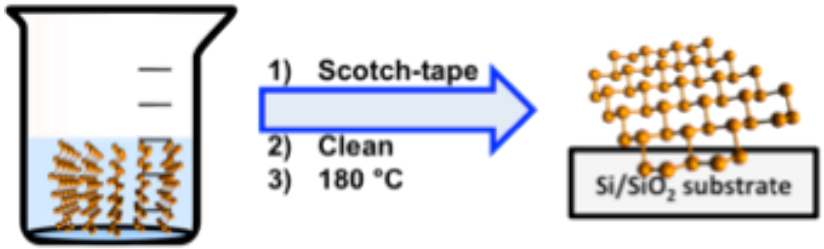
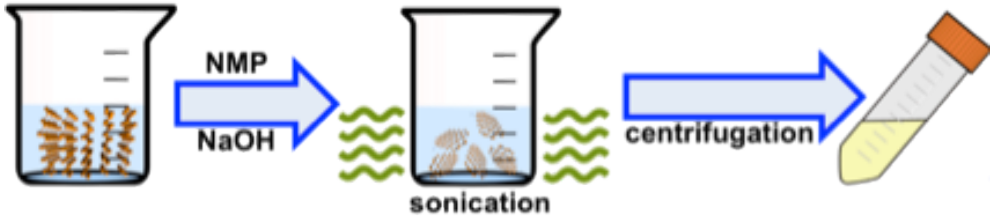
Conventional Preparation Methods (Phosphorene)



Mechanical Exfoliation (Scotch-Tape)

- Poor scalability
- Low production yield
- Instability



Sonication Based Liquid-Exfoliation

- Long processing time (~20 h)
- Damage to the flakes
- Poor quality

Li et al. *Nat Nanotechnol*, **2014**, *9*, 372.
Yasaei et al. *Adv. Mater*, **2015**, *27*, 1887.

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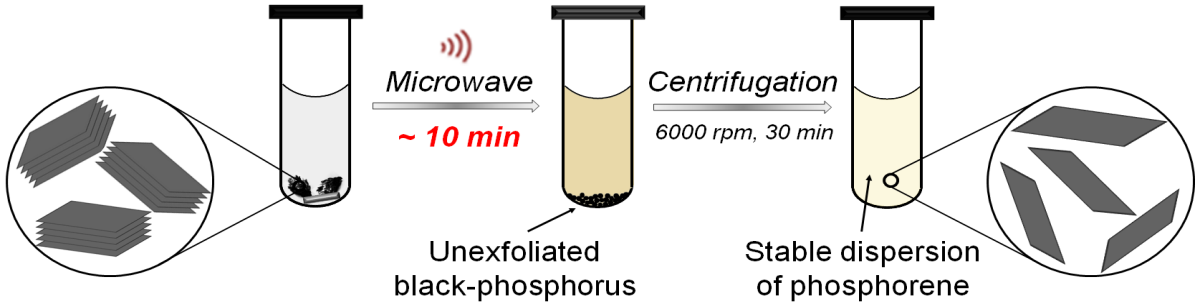
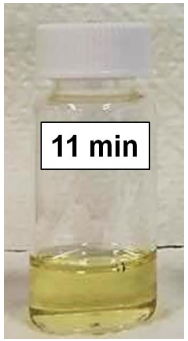
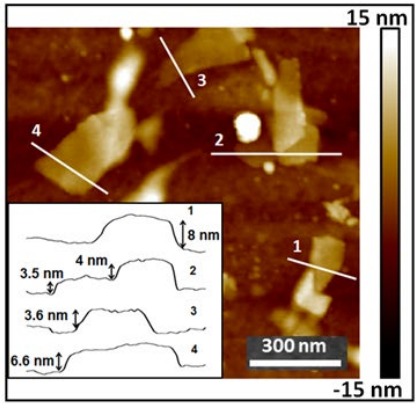
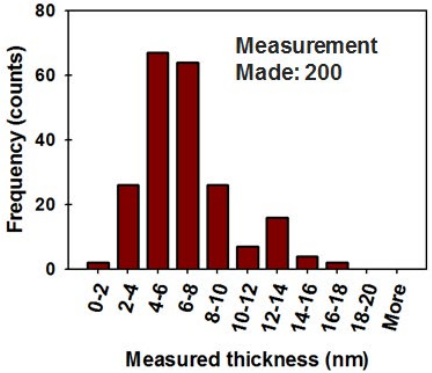
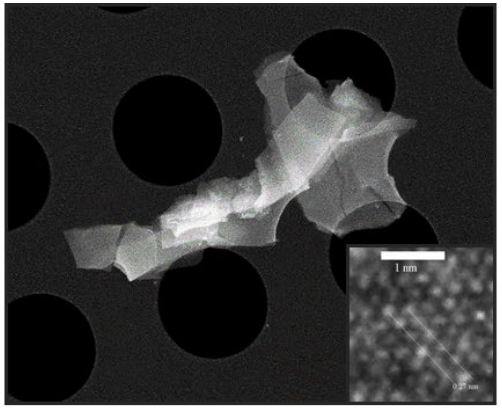
Microwave-Assisted Preparation (Phosphorene)











(MJ) Bat-Erdene et al. *Small Methods*, **2017**, *1*, 1700260.

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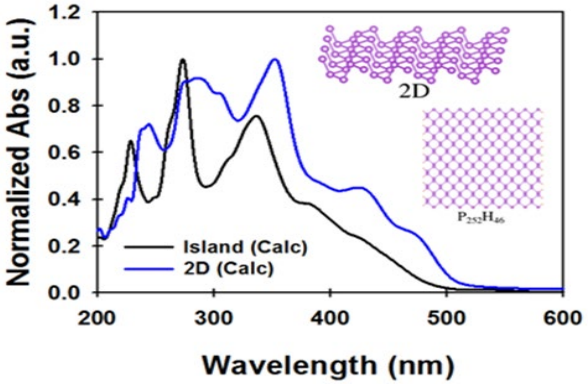
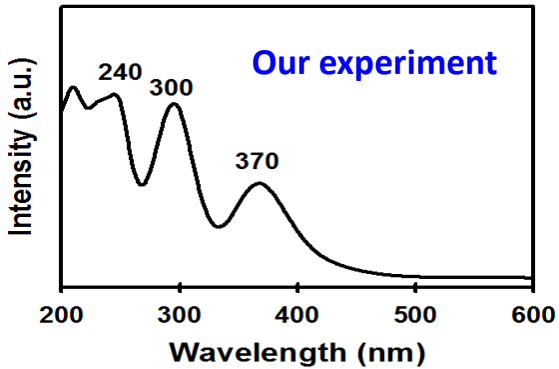
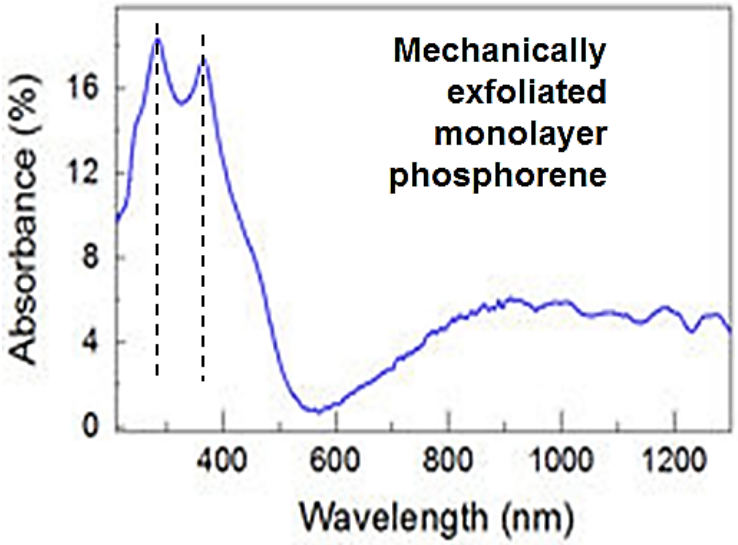
Microwave-Assisted Preparation (Phosphorene)







NPJ 2D Mater & Appl.
2017, *1*, 18.

Bat-Erdene et al. *Small Methods*, **2017**, *1*, 1700260.

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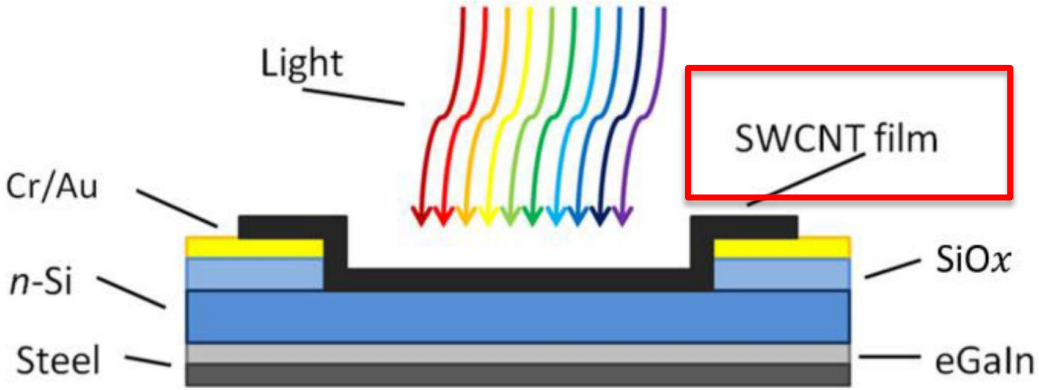
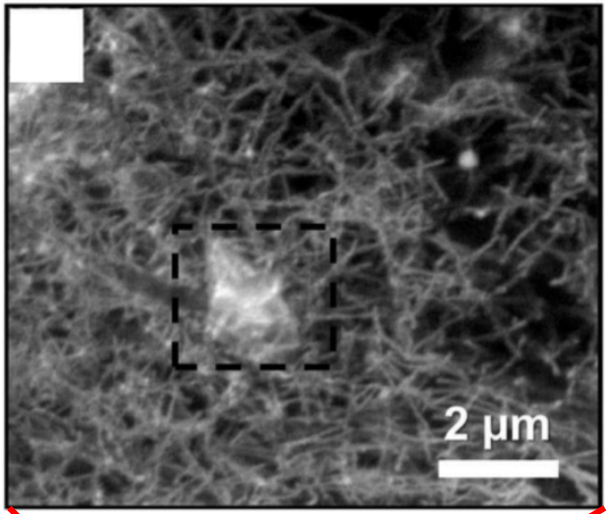
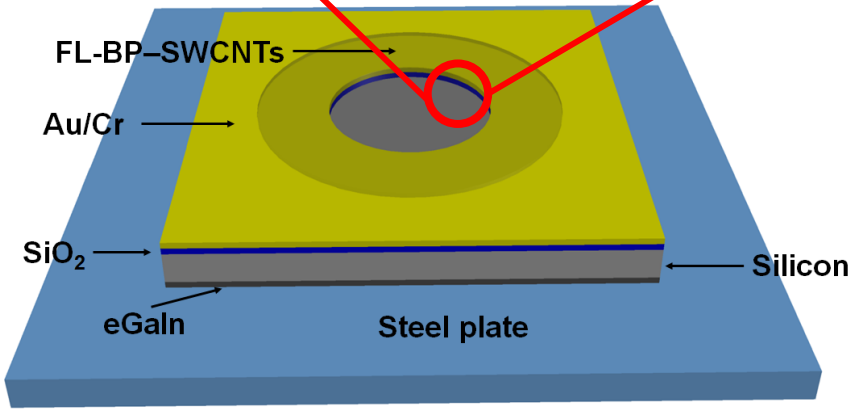
Si-CNTs Solar Cells





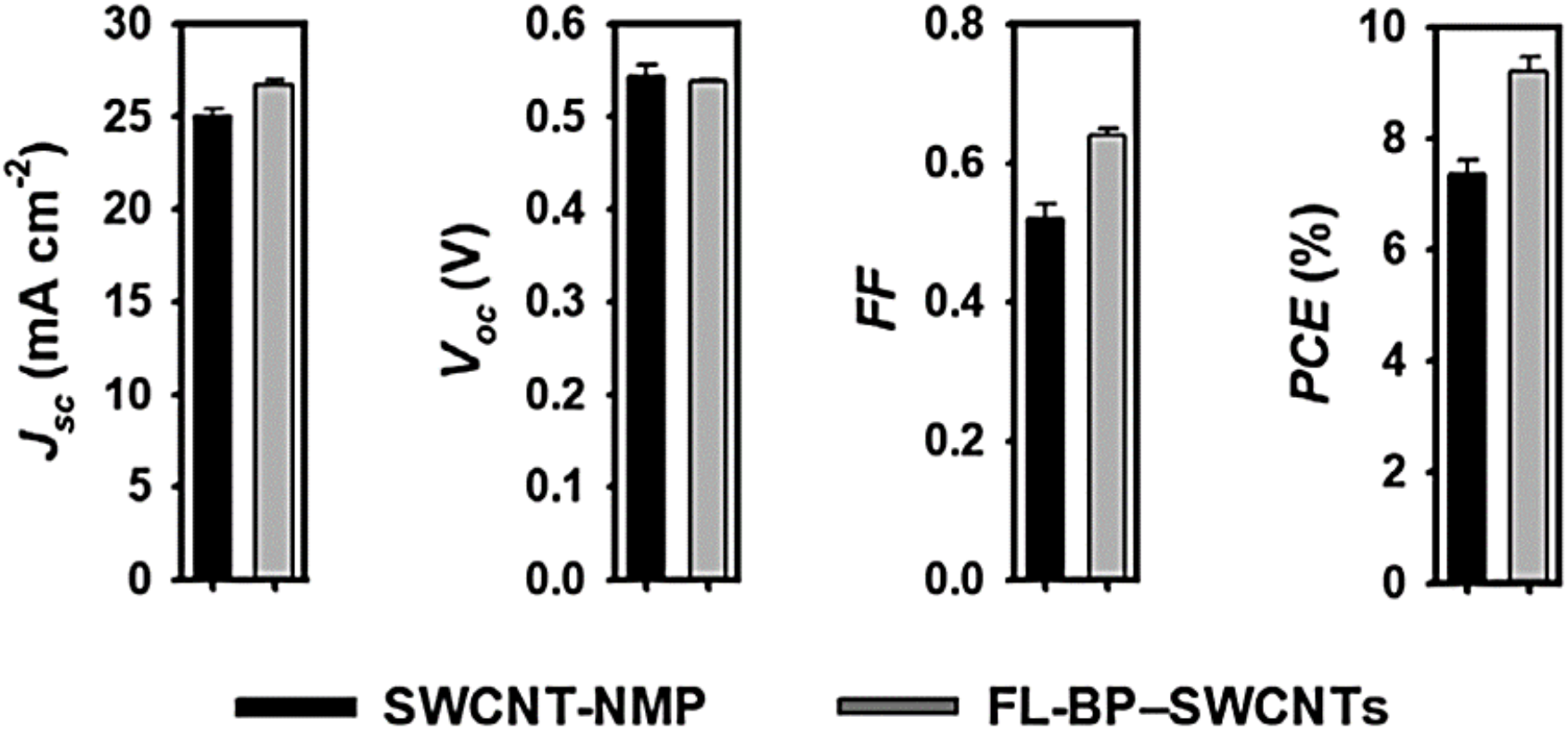


Disadvantages of CNTs:

- Formation of sparse network
- Poor hole selectivity

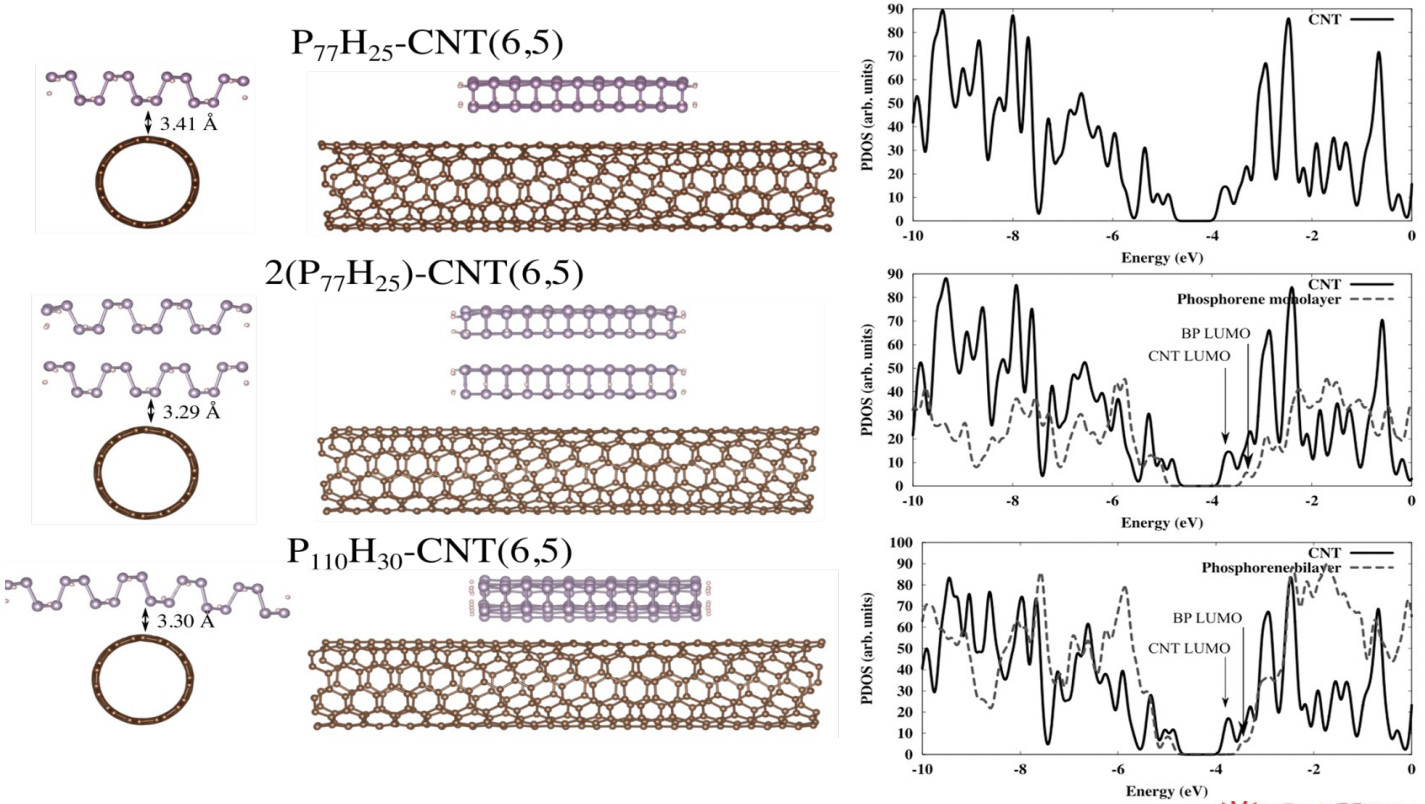
(MJ) Bat-Erdene et al. *Adv. Funct Mater*, **2017**, *27*, 1704488.

Si-CNTs Solar Cells



(MJ) Bat-Erdene et al. *Adv. Funct Mater*, **2017**, *27*, 1704488.

Si-CNTs Solar Cells



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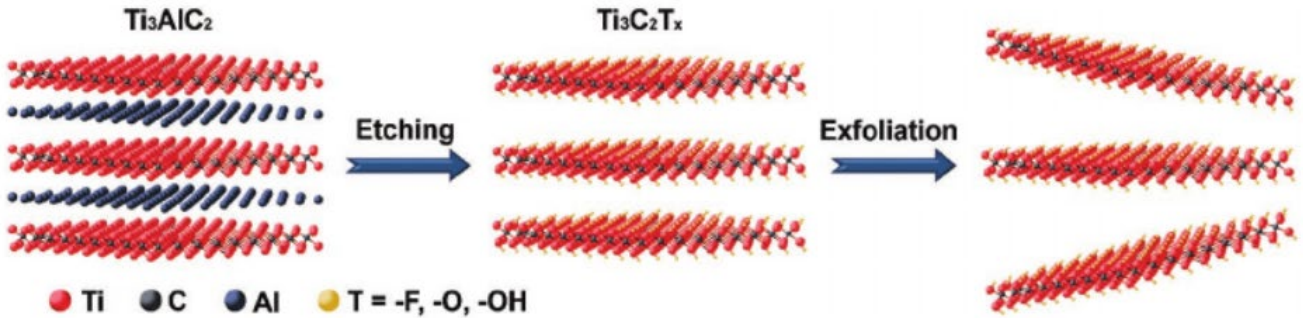
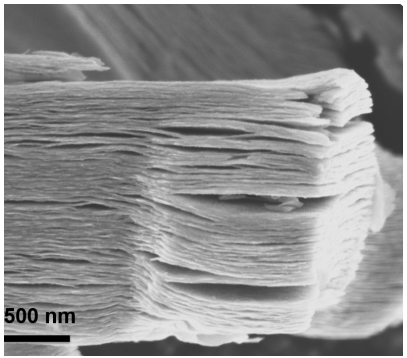
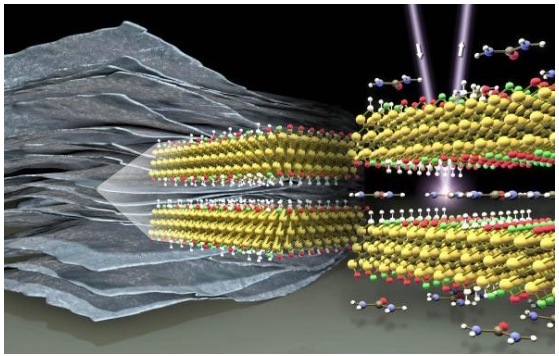
MXene ($Ti_3C_2T_x$)







Yu and Bati *et al. Adv. Energy Mater.* **2019**, *9*, 1901063.

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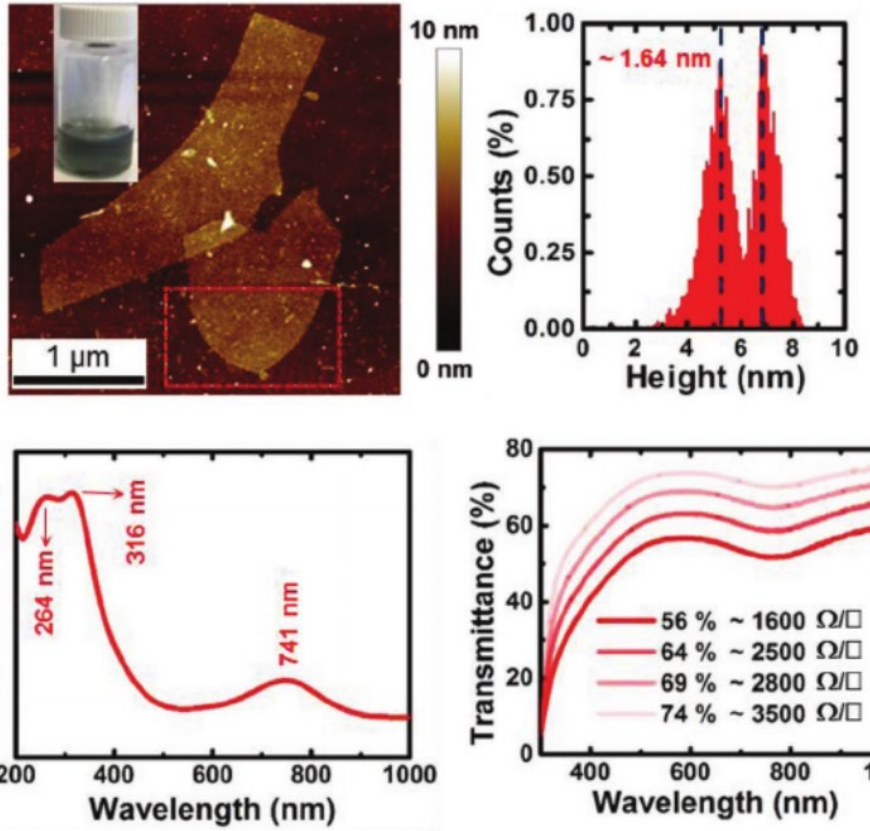
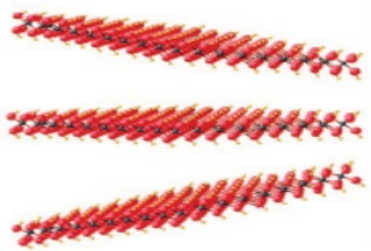
Yu and Bati *et al. Adv. Energy Mater.* **2019**, *9*, 1901063.

n-Si/MXene Heterojunction





n-Silicon

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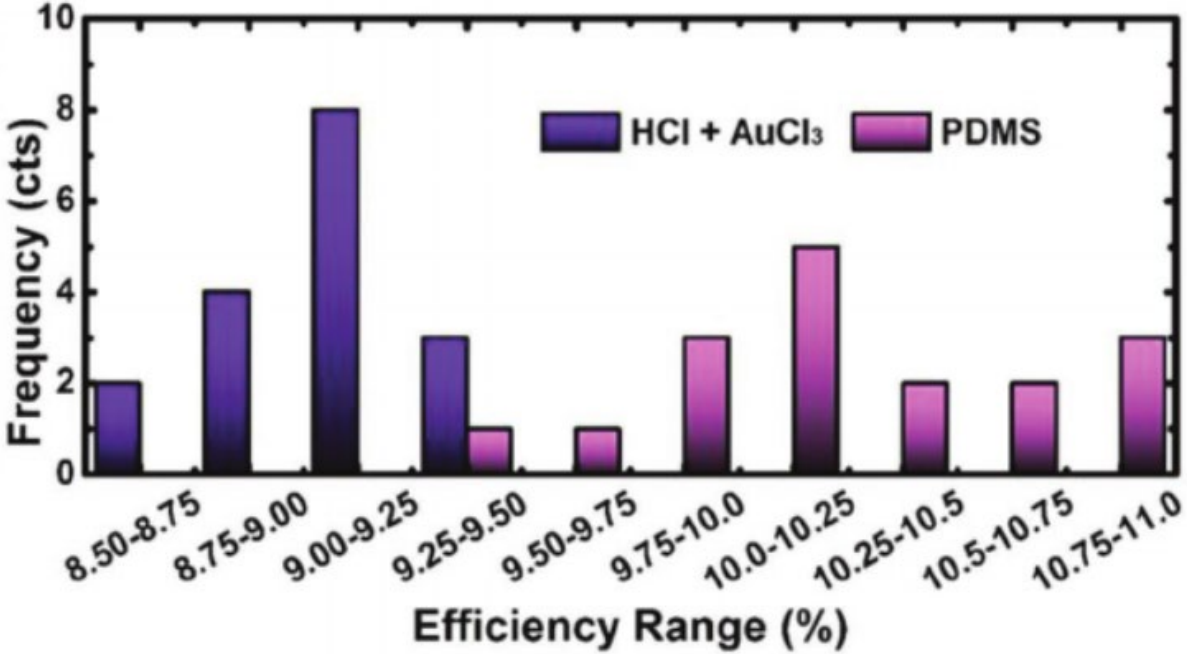
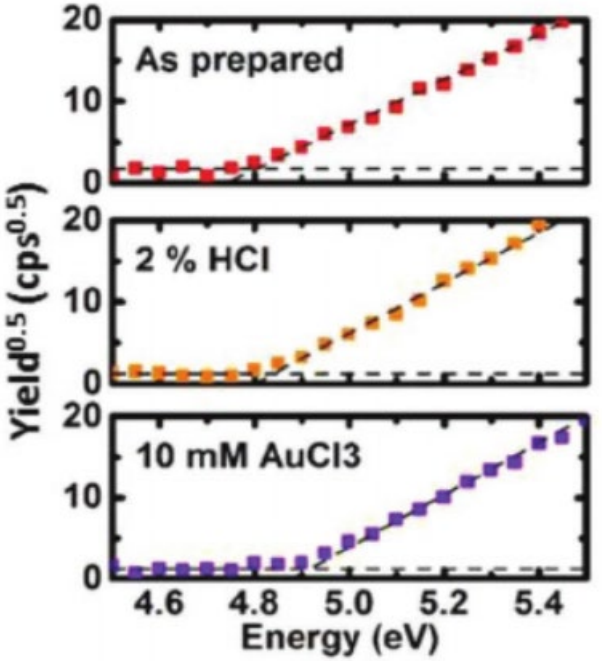
Yu and Bati *et al. Adv. Energy Mater.* **2019**, *9*, 1901063.

n-Si/MXene Solar Cells





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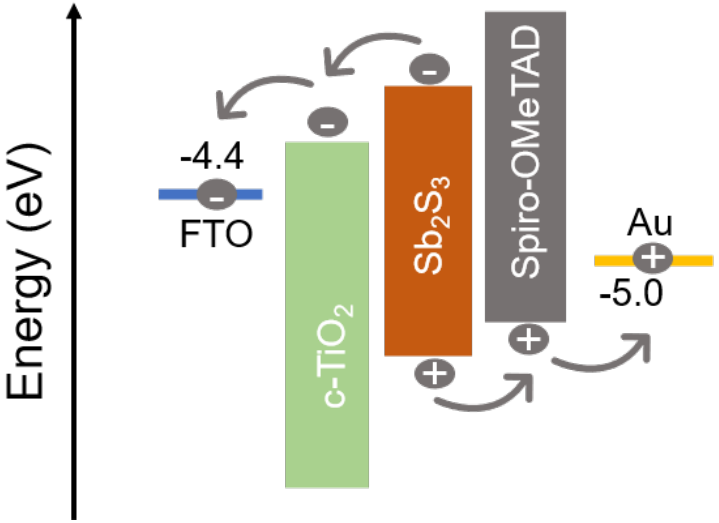
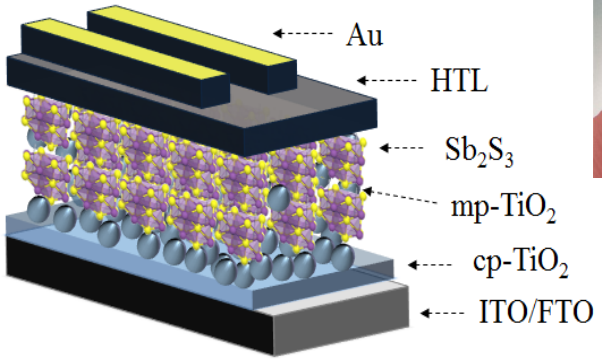
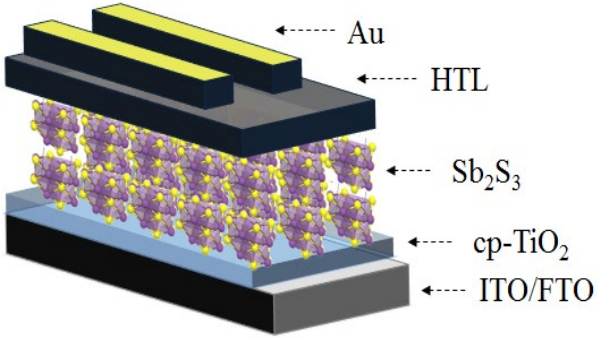
Sb_2S_3 solar cells





Mesoporous Sb_2S_3 solar cells



Planar Sb_2S_3 solar cells

Purevlkham et al. *Small.*, **2021**, *17*, 2100241.

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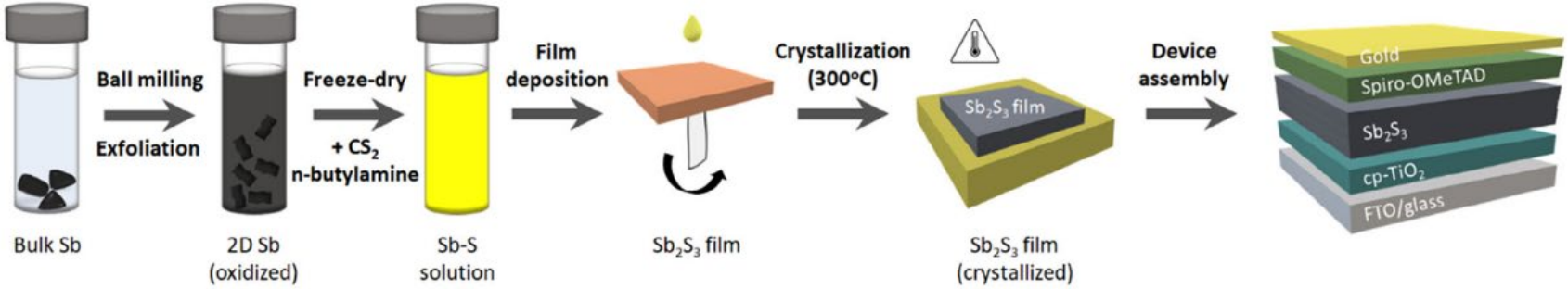
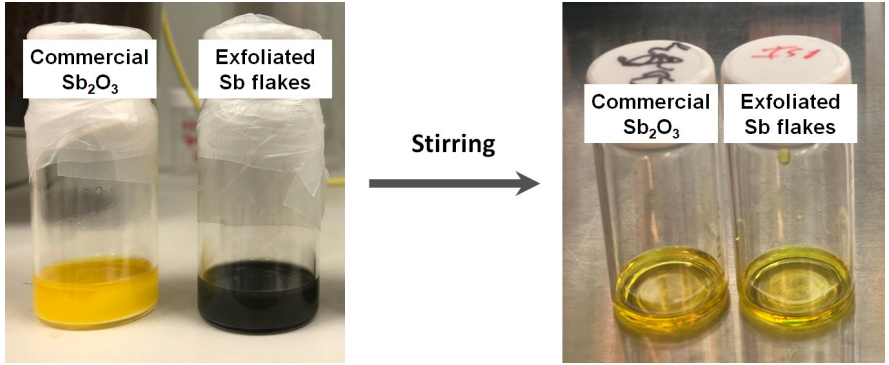
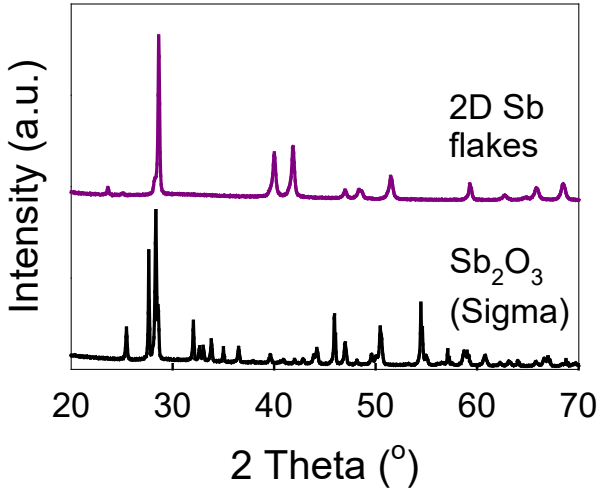
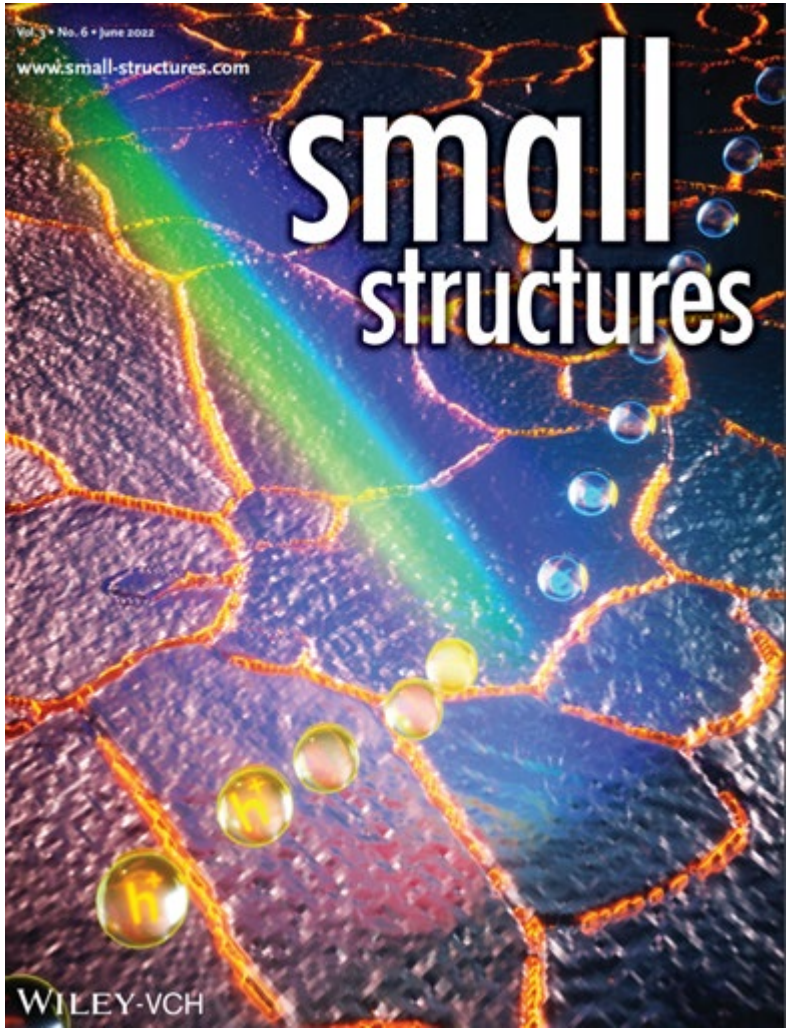
Making Sb_2S_3 Solar Cells



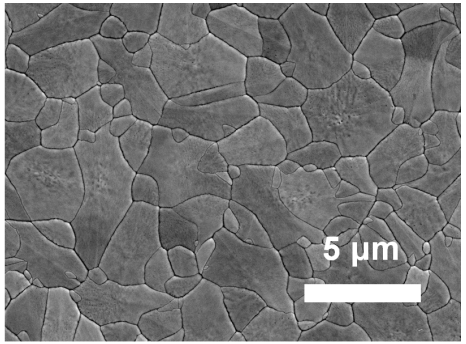


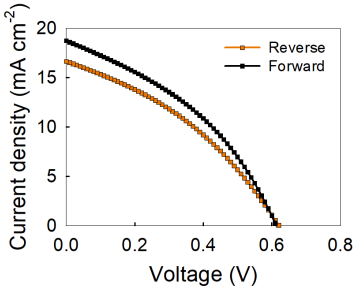


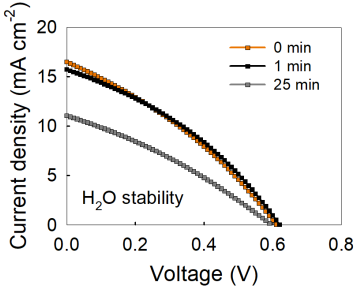
(MJ) Bat-Erdene et al. *Small Structures.*, **2022**, *3*, 2200038.

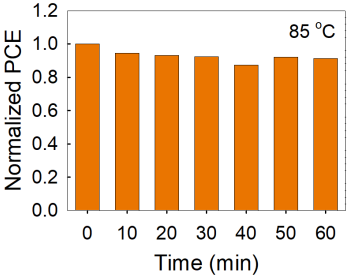


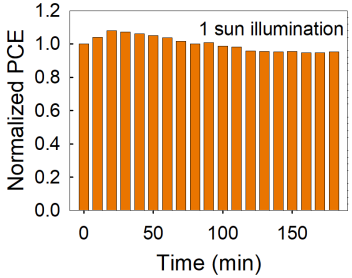
Crystallized in Air + Glovebox (>2 min)











PEROVSKITE SOLAR CELLS

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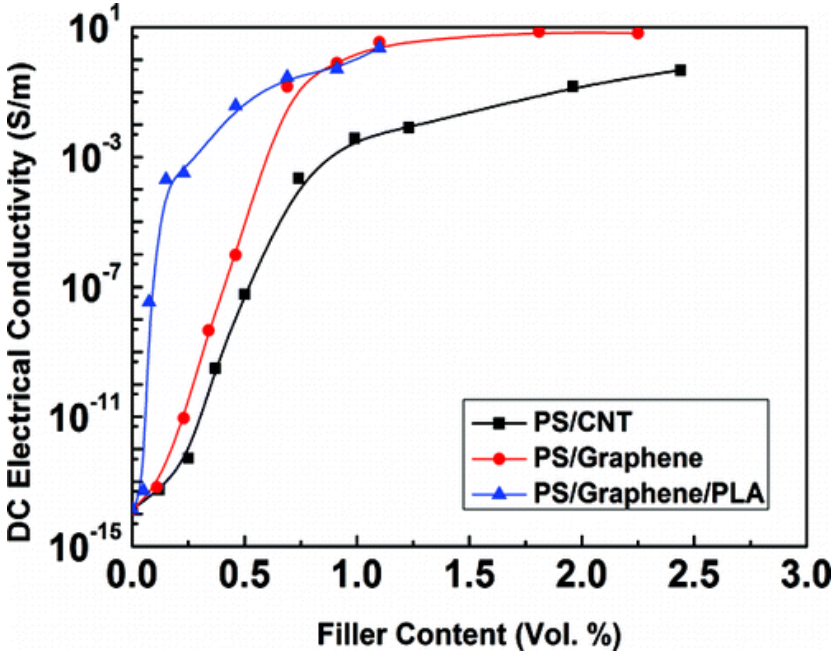
Polystyrene – insulator



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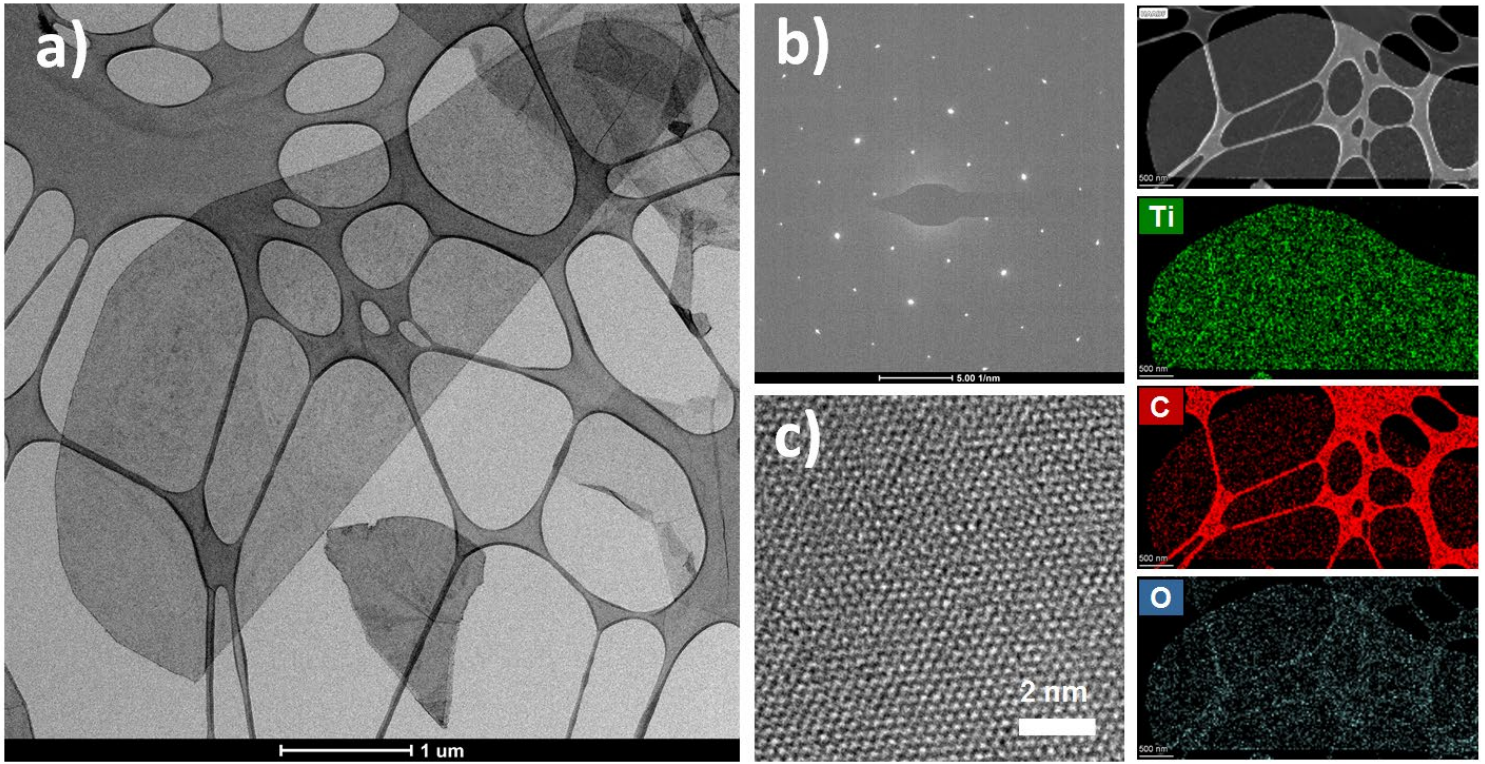
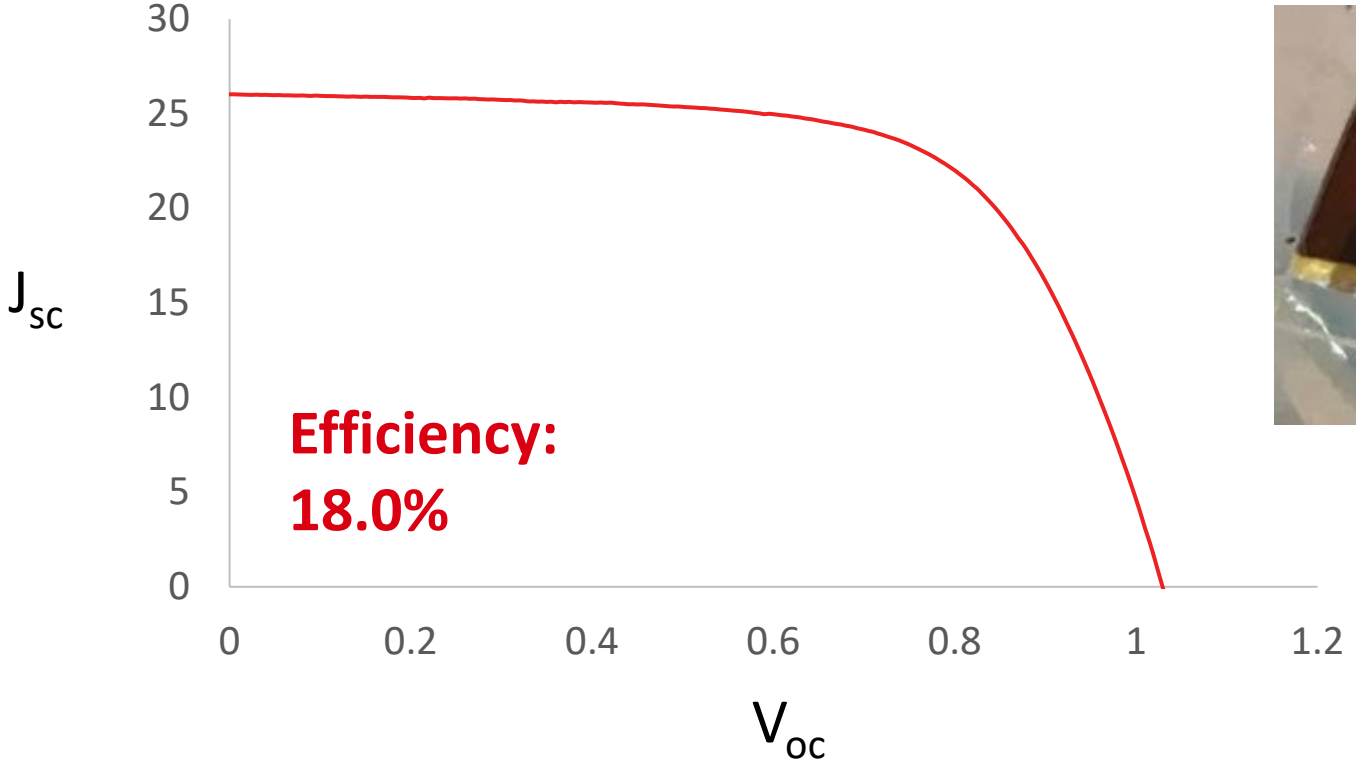
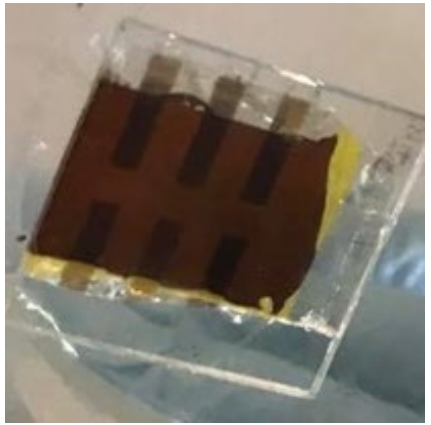
MXene ($Ti_3C_2T_x$)



MXene ($Ti_3C_2T_x$)-PS for Perovskite Solar Cells
In ambient air





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Conclusion

2D materials such as MXene, black phosphorus and graphene are promising candidates as p-type hole selective and conductive materials for solar cells.

A lot still remains to be done in the development of facile, cost-effective, scalable and green production methods for these 2D materials.

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