Integrating Hybrid Perovskite with 2D Materials For High Efficiency Solar Cells

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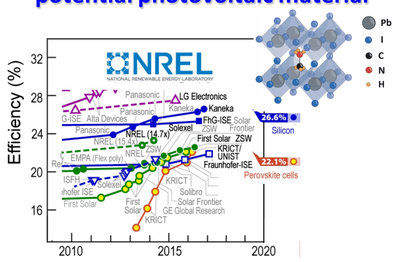
Abstract

In this work, we demonstrated up to 30-fold enhancement in the photoresponse of hybrid perovskite $CH_3NH_3PbI_3$ ($MAPbI_3$) polycrystalline thin film via interfacing with MoS_2. We prepared a few-layer MoS_2 device on SiO_2/Si substrate, with a 500 nm $MAPbI_3$ film uniformly spin-coated on top. Between the two parallel Au electrodes, half of the area contains the MoS_2-$MAPbI_3$ hybrid structure, while the other half contains only single layer $MAPbI_3$. By comparing the high-resolution photocurrent mapping data in those two regimes, we observed an up to two orders of magnitude enhancement in the photocurrent in $MAPbI_3$ by interfacing with MoS_2. The enhancement is attributed to the band alignment between these two materials, which facilitates photo-carrier separation. The MoS_2-$MAPbI_3$ hybrid device exhibits faster transient photoresponse of 200 μs, making it promising for constructing high performance photo-detectors.

Motivation

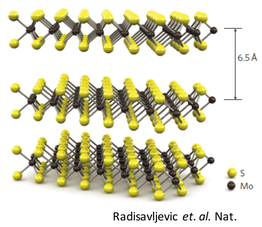
- **$CH_3NH_3PbI_3$ ($MAPbI_3$): a high potential photovoltaic material**



https://www.nrel.gov/pv/perovskite-solar-cells.html

- High Power conversion efficiencies ~22%
- Strong solar absorption
- Long charge diffusion length (>175 μm)

- **MoS_2: a 2D semiconductor material that is promising for developing nanoelectronics**

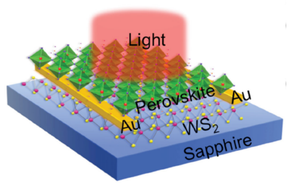


Radisavljevic *et. al.* Nat. Nanotech. **30**, 2010

- Layered van der Waal material
- Band gap 1.2 ~ 1.8 eV
- Direct band gap for the monolayer
- High mobility (1 - 60 cm^2/Vs)
- Stable in ambient

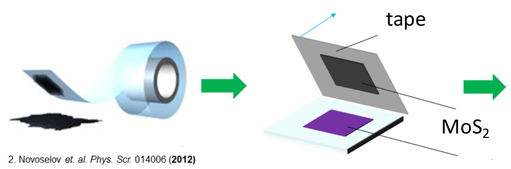
- **Developing high performance lateral structure photodector based on $MAPbI_3$ and transition metal dichalcogenide hybrid structure**

Ma et. al. *Adv Mater*, **2016**

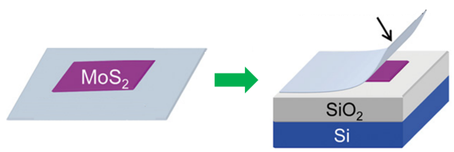


Previous studies
- Lateral hybrid structure.
- Up to × 10 enhanced photoresponse
- Suppressed dark current .
- Slow response time (2.7 ms~ 10 s)

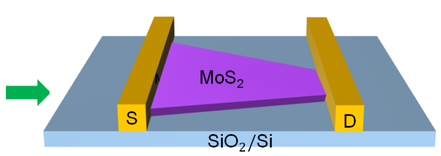
Fabrication of the $MAPbI_3$-MoS_2 hybrid structure



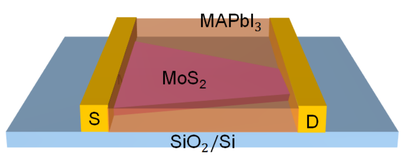
Step 1: Micromechanical exfoliation of MoS_2 using Scotch tape



Step 2: Transfer MoS_2 flakes from tape onto gel film and transfer from gel film onto silicon substrate

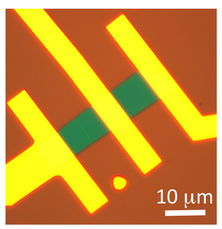


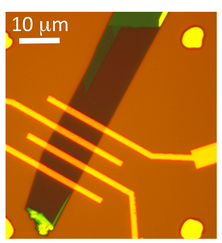
Step 3: Fabricate 2-point transistor device using E-beam lithography



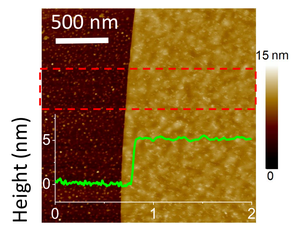
Step 4: Coat $CH_3NH_3PbI_3$ layer

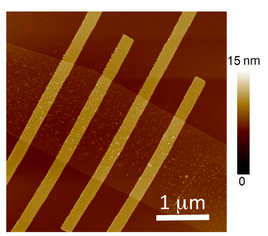
Optical image





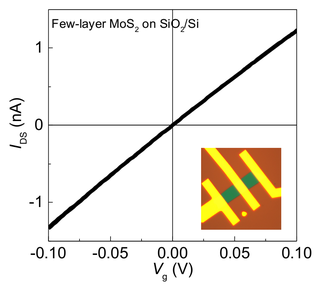
AFM images





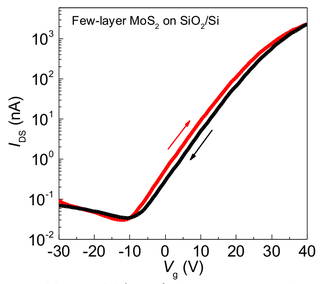
Photoresponse of the $MAPbI_3$-MoS_2 hybrid structure

I_{ds}-V_{ds} curve



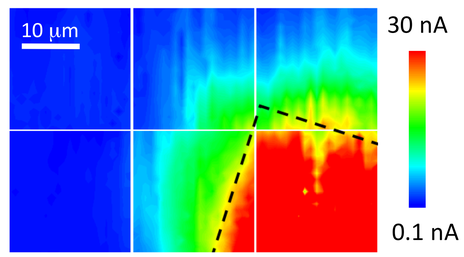
Linear *I-V* characteristics

I_{ds}-V_g curve



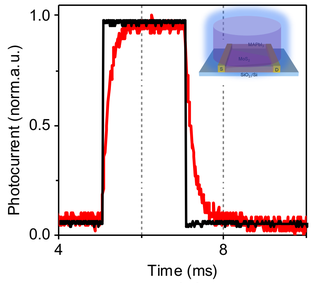
Up to 10^4 on/off ratio with field effect mobility of 53 cm^2/Vs

Photomapping of $MAPbI_3$-MoS_2 hybrid structure



Up to 30 times higher photoresponse from the $MAPbI_3$-MoS_2 hybrid structure

Transient photoresponse



Rising and decaying time about 200 μs

Conclusion

- We demonstrated up to 30 fold of enhancement in photoresponse by interfacing $MAPbI_3$ with MoS_2.
- The $MAPbI_3$-MoS_2 hybrid structures showed more than 10 times faster photoresponse compared with previous $MAPbI_3$/TMDC devices.
- The enhanced photoresponse is attributed to the band alignment between $MAPbI_3$ and MoS_2, which facilitates photocarrier separation.

Acknowledgement

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