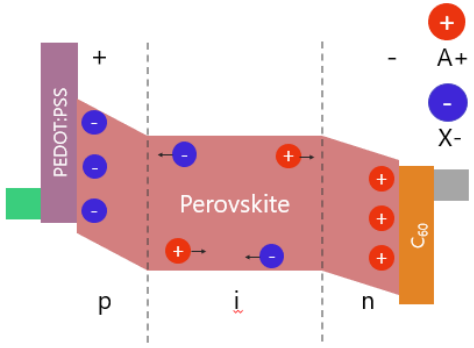
Polymer Modification of Perovskite Solar Cells to Increase Open-Circuit Voltage

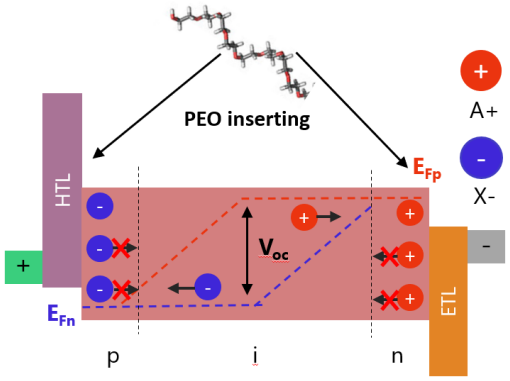
Mikhail Masharin,[1] Dmitry Gets,[1] Grigoriy Verkhoglyadov,[1] Sergey Makarov,[1] and Anvar Zakhidov[1,2]

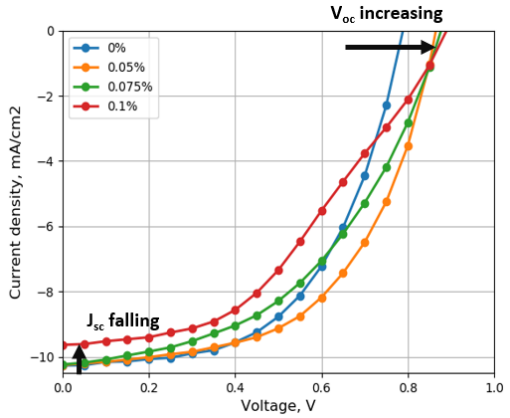
[1)]*Department of Physics, ITMO University, St. Petersburg 197101, Russian Federation*

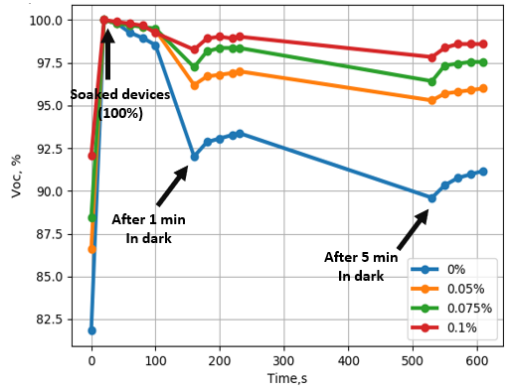
[2)]*Alan G. MacDiarmid NanoTech Institute, University of Texas at Dallas, Richardson, TX 75083, USA*

Introduction | Simulation | Experimental setup | Results | Conclusion









Organo-halide perovskites is a new perspective material for photovoltaics, especially for tandem solar cells. For three and more layers in perovskite tandem cells, mixed-anion perovskites are needed. However, there are several problems with mixed anion perovskite solar cells and one of the possible ways to increase its performance is to insert PEO inside perovskite layers to passivate defects and freeze p-i-n structure inside perovskite layer.

As a result, we obtained increasing of open-circuit voltage (V_{oc}), probably due to p-i-n structure formation, and falling of short-circuit current due to increasing series resistance. Also, we found slowing down V_{oc} falling with increasing PEO concentration after device biasing under external sun light and electric field, which could be associated with slowing down p-i-n structure disappearing.

References: [1] Deng, Y., Xiao, Z. & Huang, J. Light-induced self-poling effect on organometal trihalide perovskite solar cells for increased device efficiency and stability. *Adv. Energy Mater.* **5**, 1–6 (2015)

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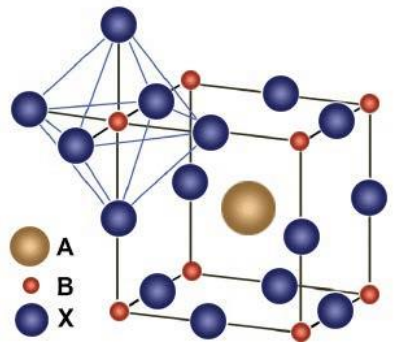
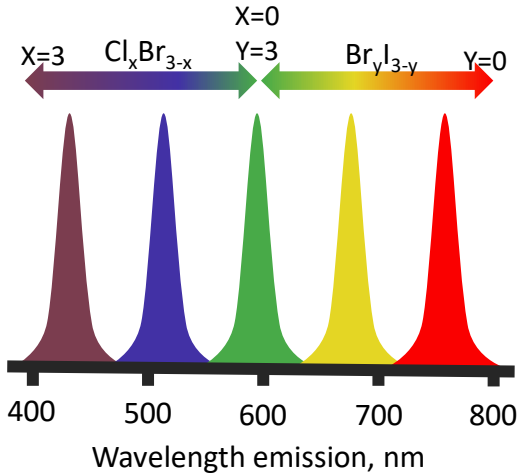
Perolab

Briefly about perovskites



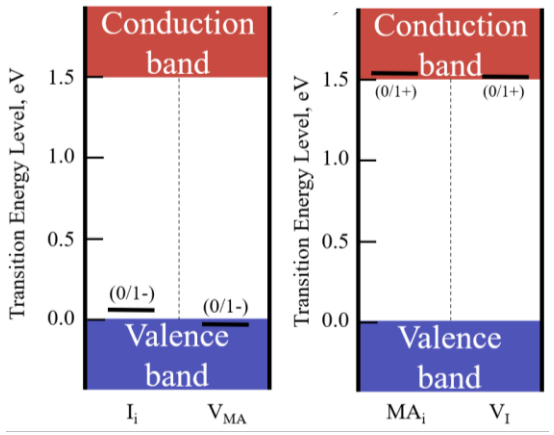


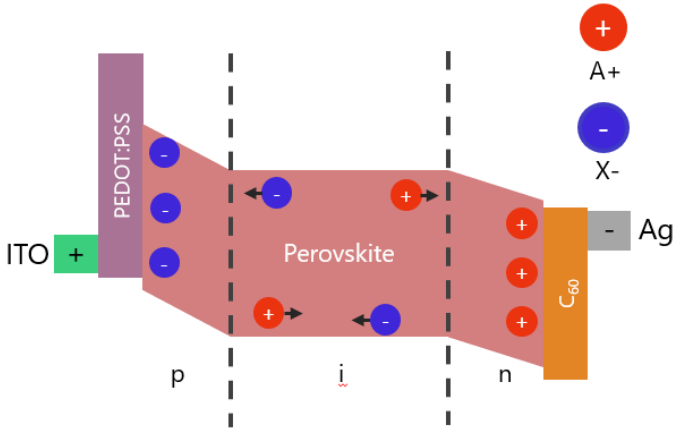
Organo-halide perovskite is a new perspective material for implementation in a very wide area, that has ABX_3 structure. Perovskite is a direct-gap semiconductor and its band gap is tunable by changing the perovskite composition (from 1.5eV to 3eV)[2]. Today, efficiency of perovskite solar cells achieved 25.2%

References

[2] Eperon, G. E. *et al Energy Environ. Sci.* **7**, 982–988 (2014).
[3] NREL. URL: https://www.nrel.gov/pv/cellefficiency.html.

Ion migration in perovskites





There is a phenomenon of an ion migration in perovskites. Ions of anion and cation have local levels near the valence and the conduction band and therefore perovskites is able to self-dope by its ions[4]. It can lead to increasing of open-circuit voltage of the device and thus to efficiency increasing. However, this phenomenon is temporally and to freeze it, we inserted polymer PEO in the perovskite layer to stabilize p-i-n structure

References

[4] Yin, W. J., Shi, T. & Yan, Y. *Appl. Phys. Lett.* **104**, (2014).

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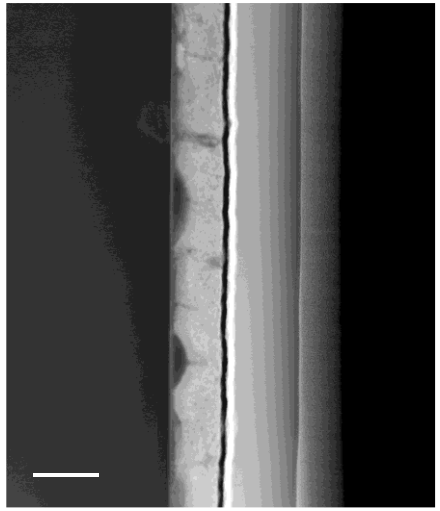
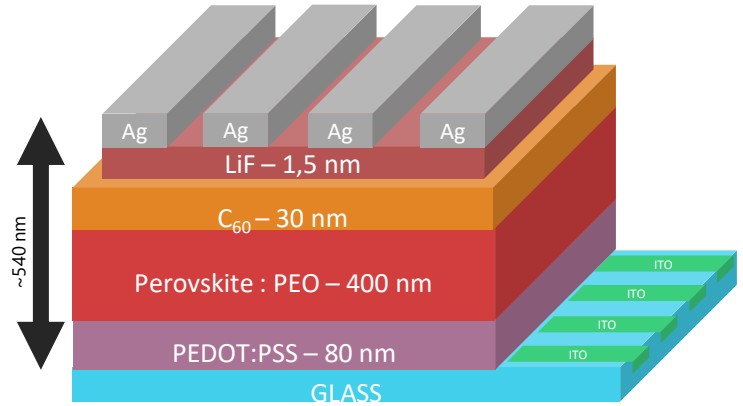
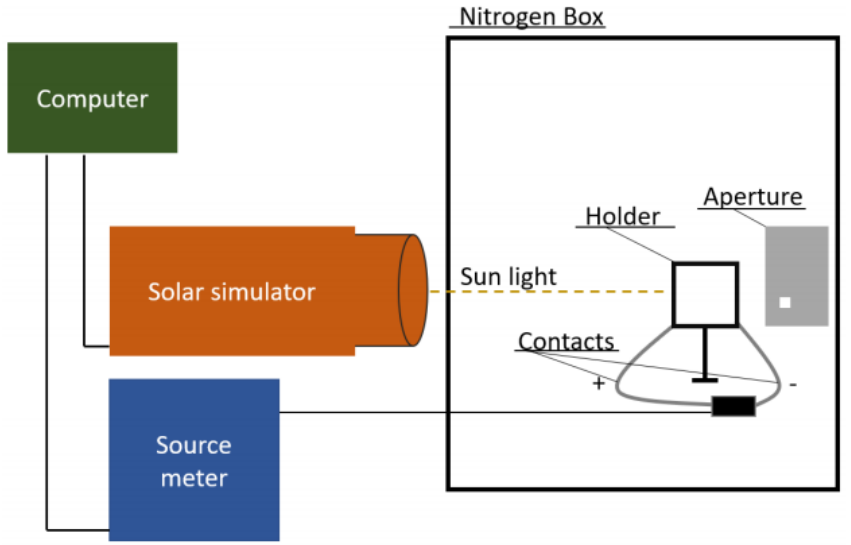
Experimental methods and setup for measuring solar cells performance







Hole transport layer PEDOT:PSS and polymer-perovskite composition was covered by spin-coating method. Electron transport layer C_{60} and silver contact was deposited in the evaporator vacuum chamber.

The performance of produced solar cells was investigated with solar simulator AM 1.5G, which is calibrated by the silicon HIT solar cell from HEVEL company and source-meter Keithley.

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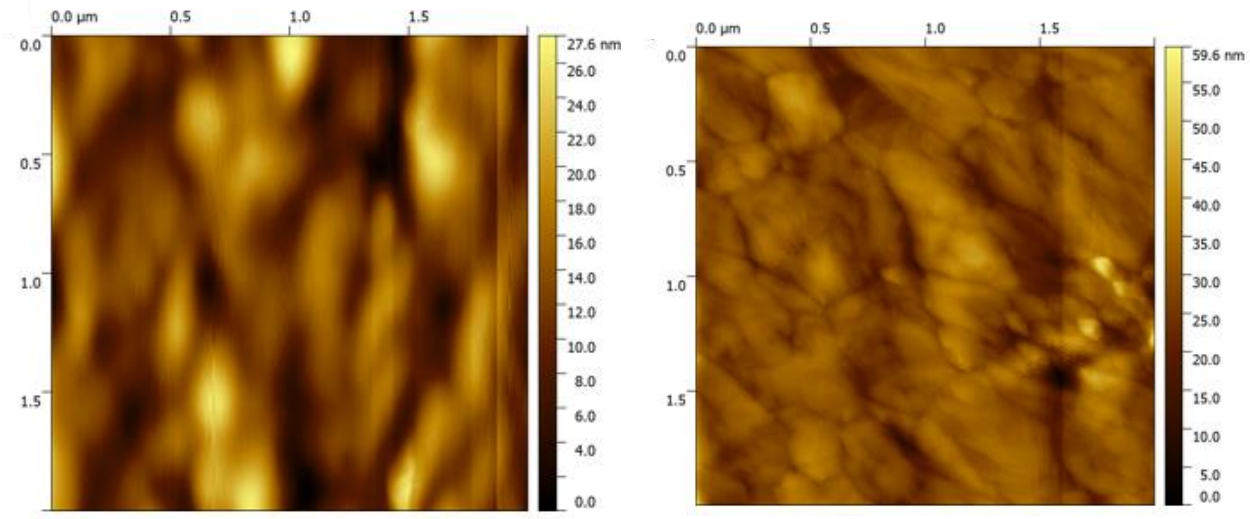
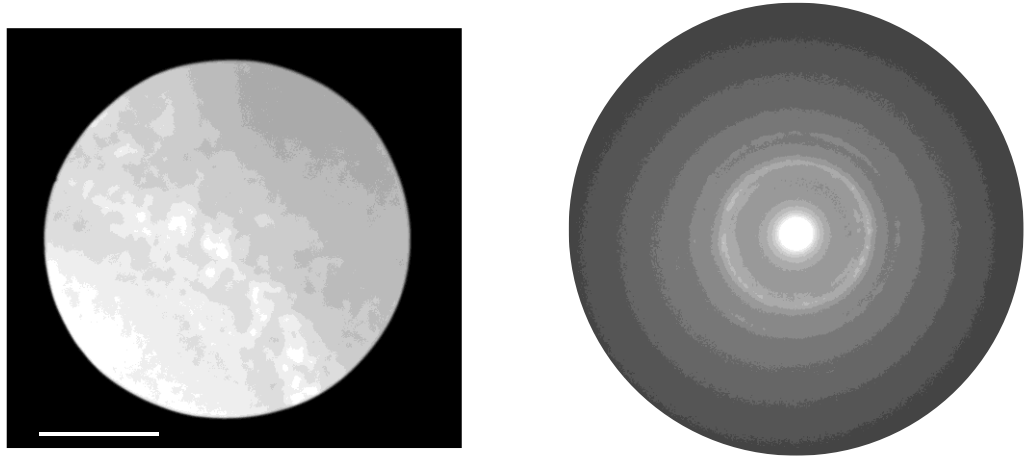
AFM images of the perovskite surface



$FAPbBr_2I$ | $FAPbBr_2I$ + 0,1% PEO

Atomic force microscopy images proved the uniformly PEO distribution on the surface of the $FAPbBr_2I$. It was obtained, that morphology of polymer film is smoother, which can lead to passivating surface defects.

TEM images of the perovskite-polymer films



Zoomed TEM area | Diffraction pattern

On the transmission electron microscopy we obtained rings on the diffraction pattern and amorphous area simultaneously, which can be associated with perovskite crystal lattice and amorphous PEO

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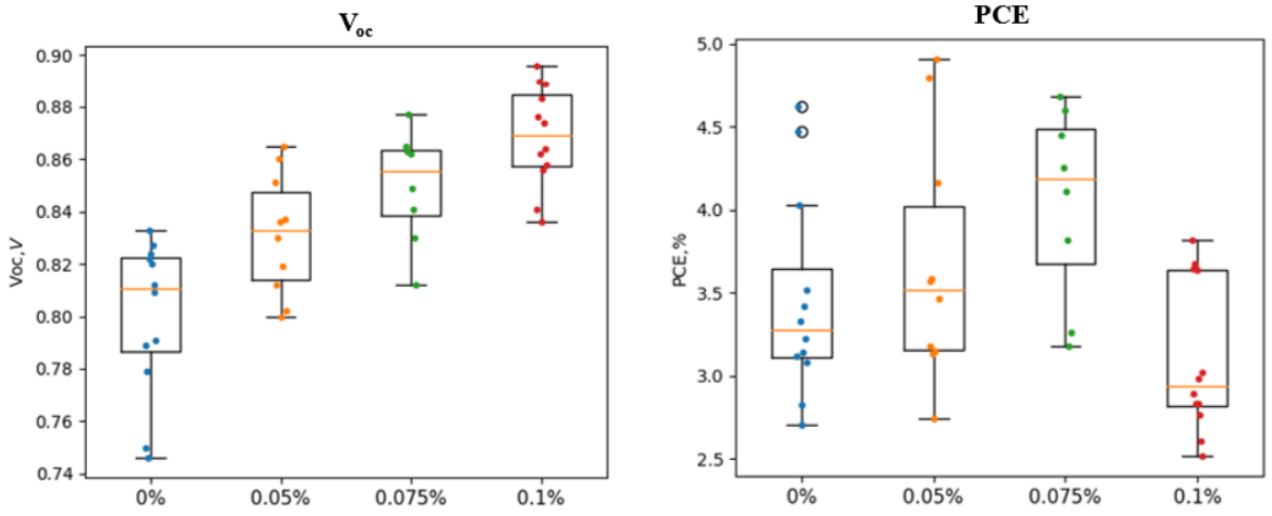
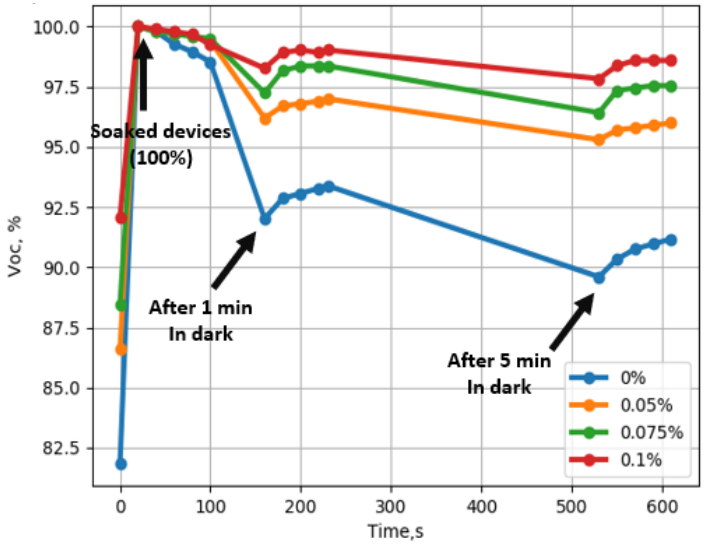
Statistics of perovskite solar cells parameters



Open circuit voltage increases with increasing of PEO concentration. It can be associated with defect passivation and p-i-n structure formation. However, PEO is an insulator and whole efficiency falls with big PEO concentration due to increasing of series resistance.

Persisting of soaked open circuit voltage



Under external conditions (sun and voltage forward biasing) open circuit voltage increases. And after turning off the effect starts to disappear, however devices with PEO almost persist its soaked state. It can be related to freezing p-i-n structure inside perovskite layer in solar cells.

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1. PEO inside perovskite layer increases open-circuit voltage, but decrease the fill factor
2. Due to local defect states from the migrated ions in perovskite, under external voltage p-i-n structure can be formed, which can increase the open-circuit voltage.
3. Migrated ions can be slowed down by PEO near the boundaries, that makes p-i-n structure stable without any external influence on the device.
4. There is an optimal concentration of PEO, which maximizes the solar cell efficiency.
5. The results of this work can be used in production high efficient wide bandgap perovskite solar cell with mixed anion, which is necessary for creating extremely efficient perovskite tandem solar cells with more then two layers

Contacts:
Masharin Mikhail
email: masharin.mikhail@metalab.ifmo.ru