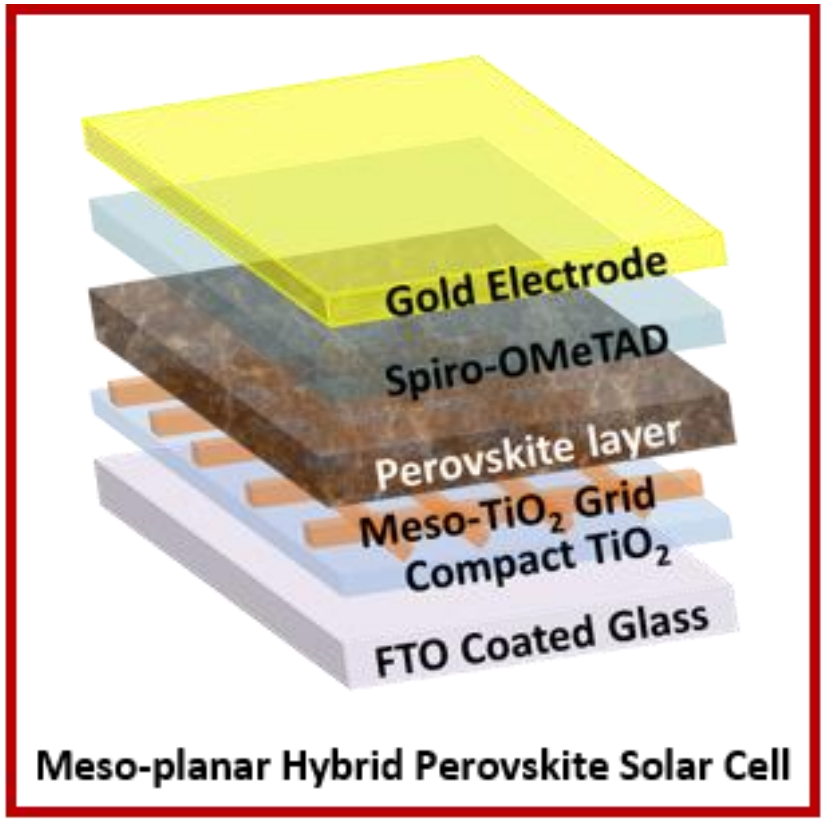
A Mesoporous-Planar Hybrid Architecture of $MAPbI_3$ Perovskite Based Photovoltaic Devices

Ravi K. Misra
Institute of Chemistry
The Hebrew University of Jerusalem

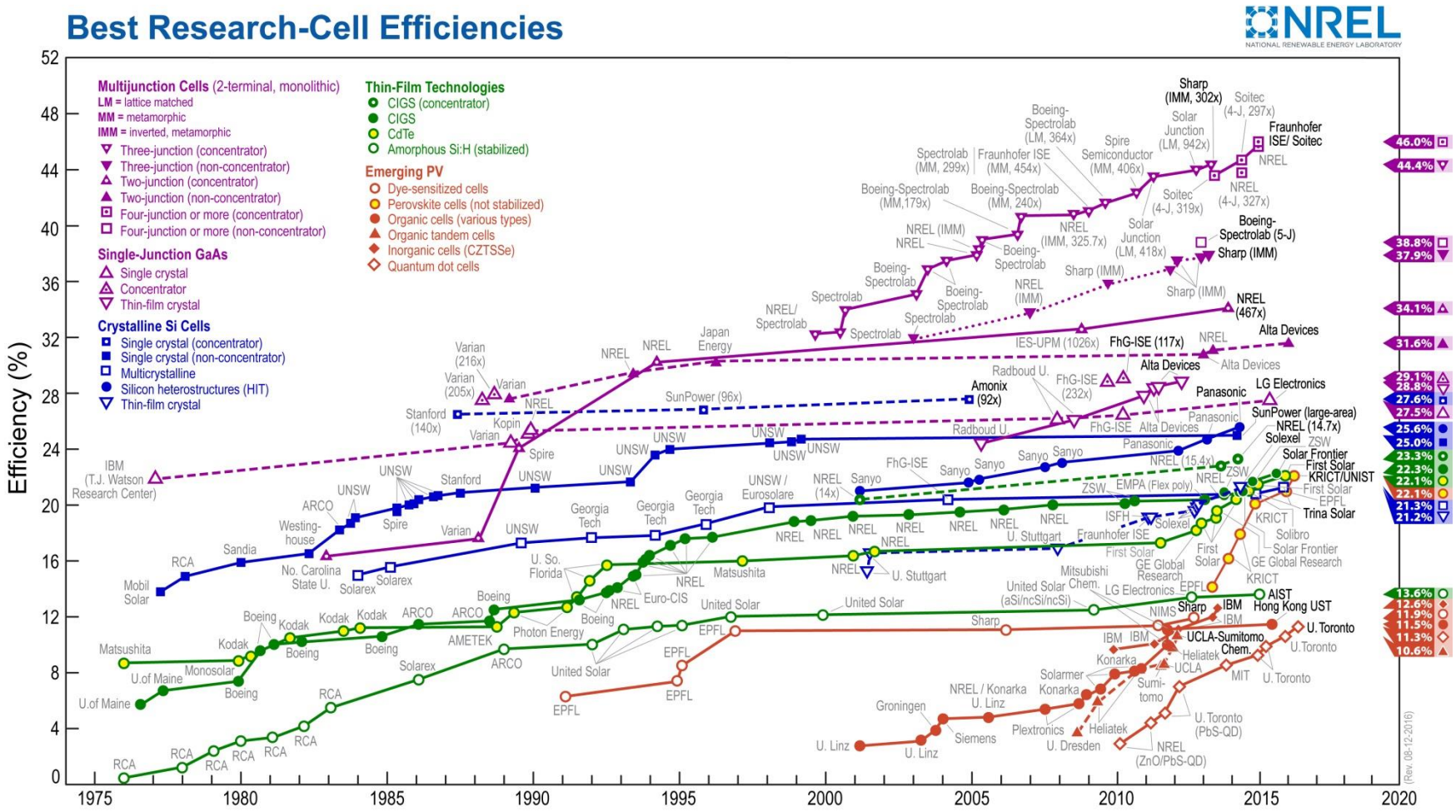
Outline

- Background
- Motivation
- Work done
- Conclusions



Meso-planar Hybrid Perovskite Solar Cell

Background


Best Research-Cell Efficiencies
NREL
NATIONAL RENEWABLE ENERGY LABORATORY
Efficiency (%)
Multijunction Cells (2-terminal, monolithic)
LM = lattice matched
MM = metamorphic
IMM = inverted, metamorphic
Three-junction (concentrator)
Three-junction (non-concentrator)
Two-junction (concentrator)
Two-junction (non-concentrator)
Four-junction or more (concentrator)
Four-junction or more (non-concentrator)
Single-Junction GaAs
Single crystal
Concentrator
Thin-film crystal
Crystalline Si Cells
Single crystal (concentrator)
Single crystal (non-concentrator)
Multicrystalline
Silicon heterostructures (HIT)
Thin-film crystal
Thin-Film Technologies
CIGS (concentrator)
CIGS
CdTe
Amorphous Si:H (stabilized)
Emerging PV
Dye-sensitized cells
Perovskite cells (not stabilized)
Organic cells (various types)
Organic tandem cells
Inorganic cells (CZTSSe)
Quantum dot cells
46.0%
44.4%
38.8%
37.9%
34.1%
31.6%
29.1%
28.8%
27.6%
27.5%
25.6%
25.0%
23.3%
22.3%
22.1%
22.1%
21.3%
21.2%
13.6%
12.6%
11.9%
11.5%
11.3%
10.6%
(Rev. 08-12-2016)

Background

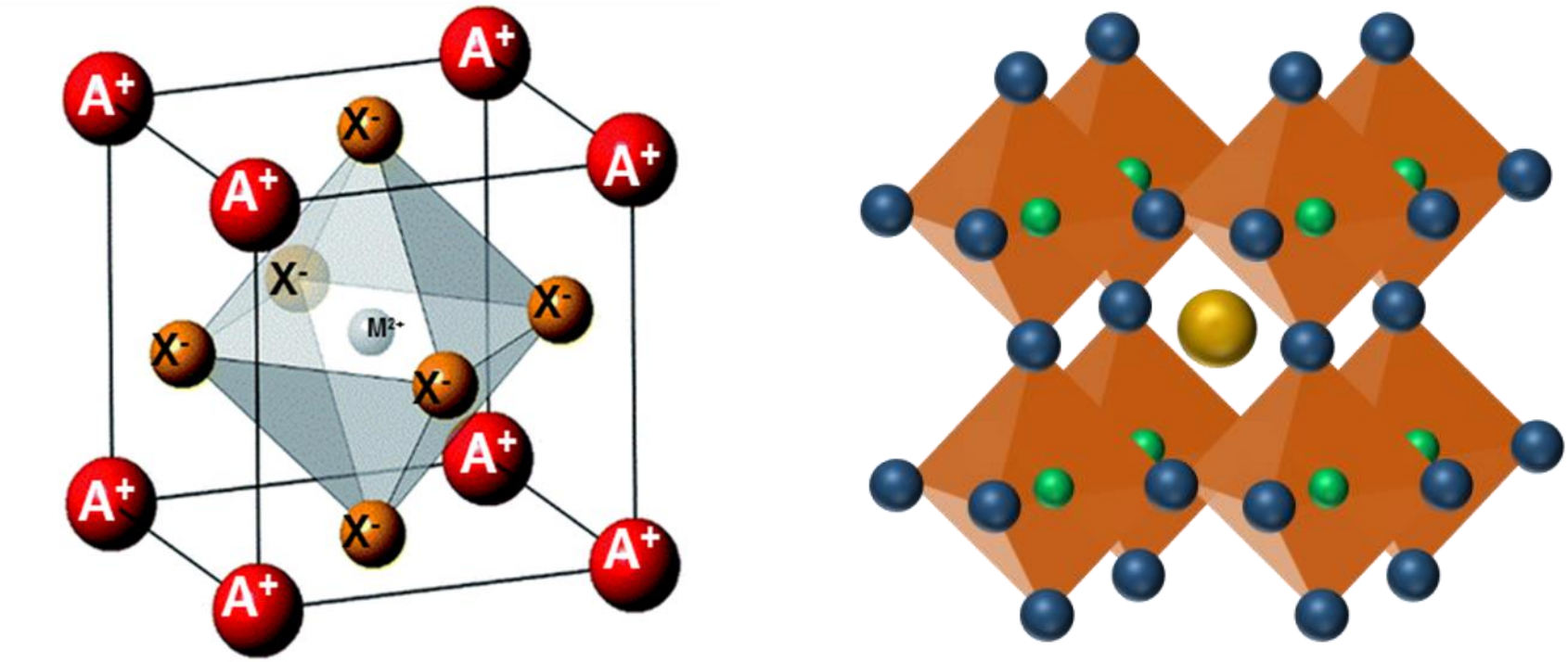


Fig. Organic-inorganic hybrid perovskite unit cell with $[MX_6]^{4-}$ octahedral anion surrounded by organic cations in cubic arrangement. A- organic cation, M- divalent metal cation, X- halide anion.

Motivation

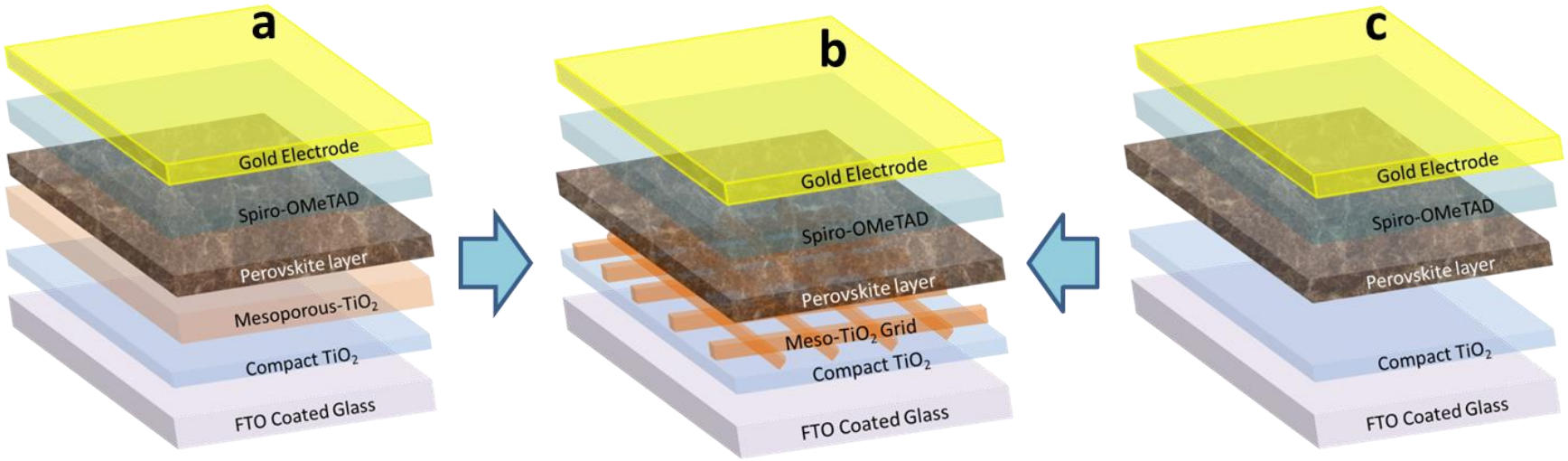


Fig. Schematic diagram of (a) mesoporous structure; (b) meso-planar hybrid structure; and (c) planar structure, of perovskite solar cells.

Method: Mesh assisted self assembly

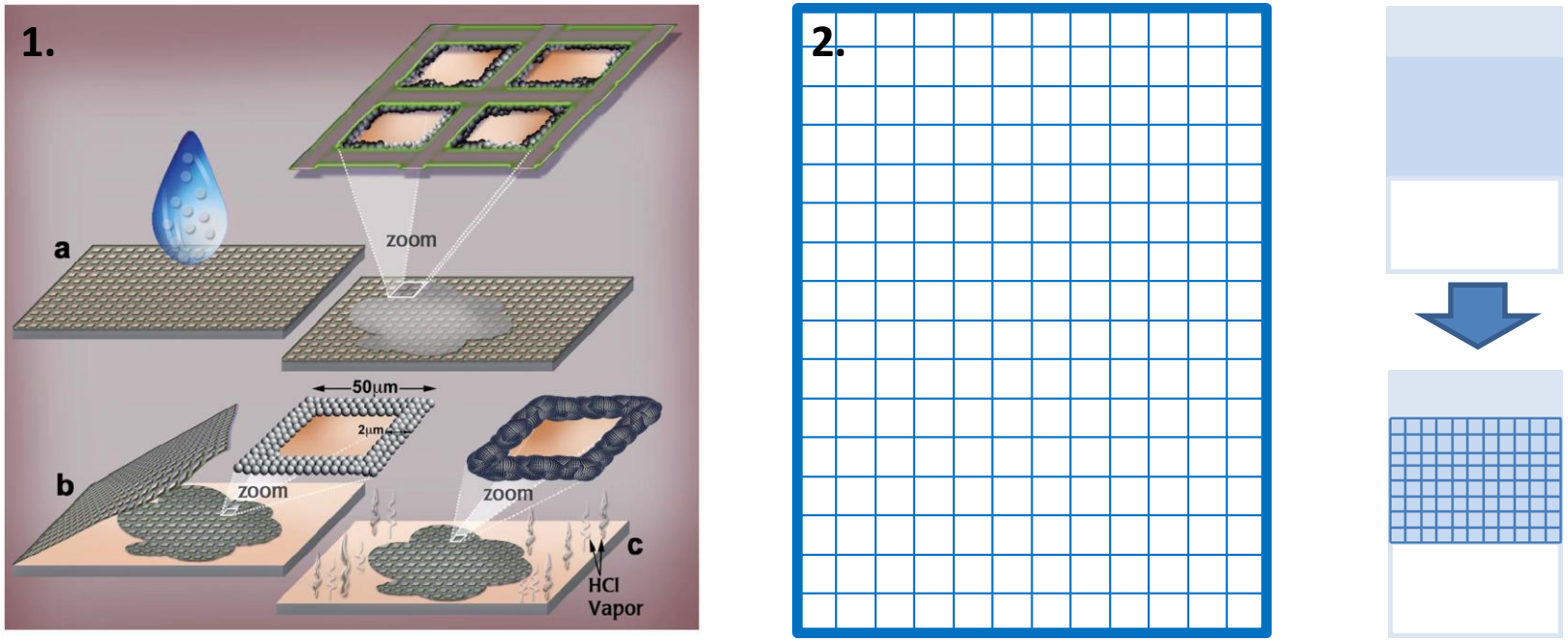


Fig.1. Schematic of process, 2. Printing mesh , Blocking layer on FTO, sellf assembly of meso-TiO_2

1. M. Layani and S. Magadassi, J. Mater. Chem., 2011, 21, 15378.

Self assembled meso-TiO_2 grid

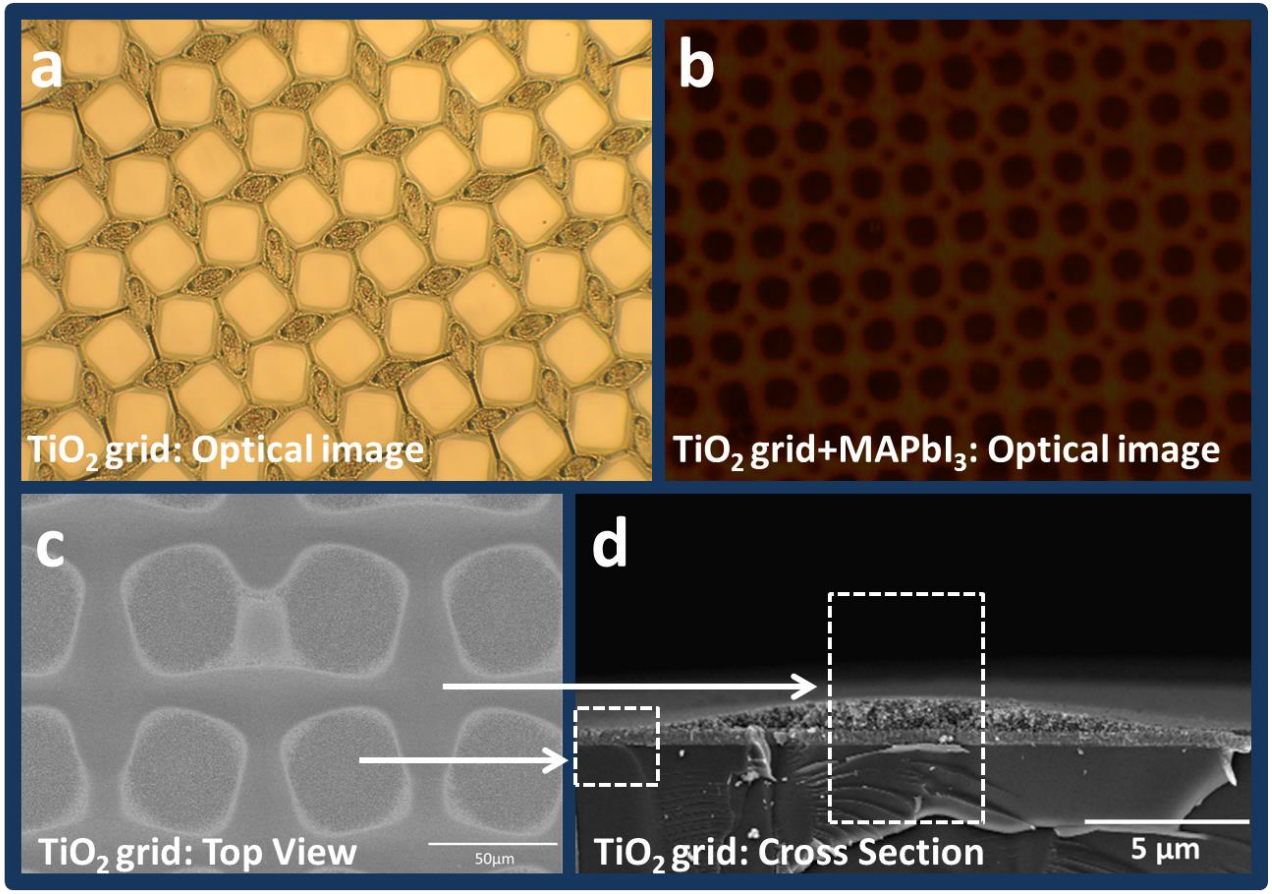


Fig. Optical image of the (a) mesoporous-titania grid deposited with the help of a mesh (mesh size 50 micron), Perovskite deposited on TiO_2 grid; (c) Top view SEM image, (d) cross sectional SEM image of the grid.

Self assembled meso-TiO_2 grid

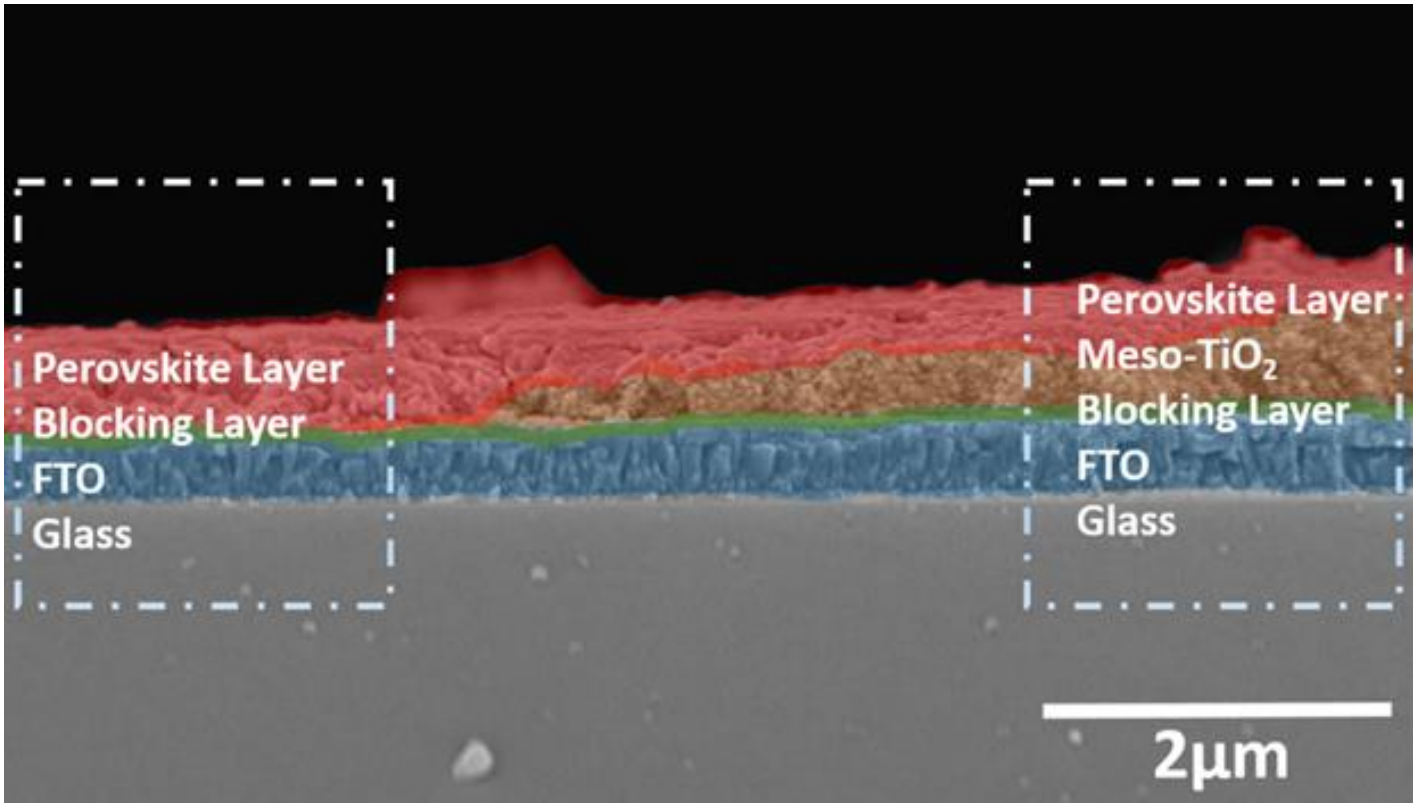


Fig. Cross sectional HR-SEM image of cell showing the planar part without meso-TiO_2, and mesoporous part with TiO_2 can be clearly seen on from left to right part of the image.

Device performance

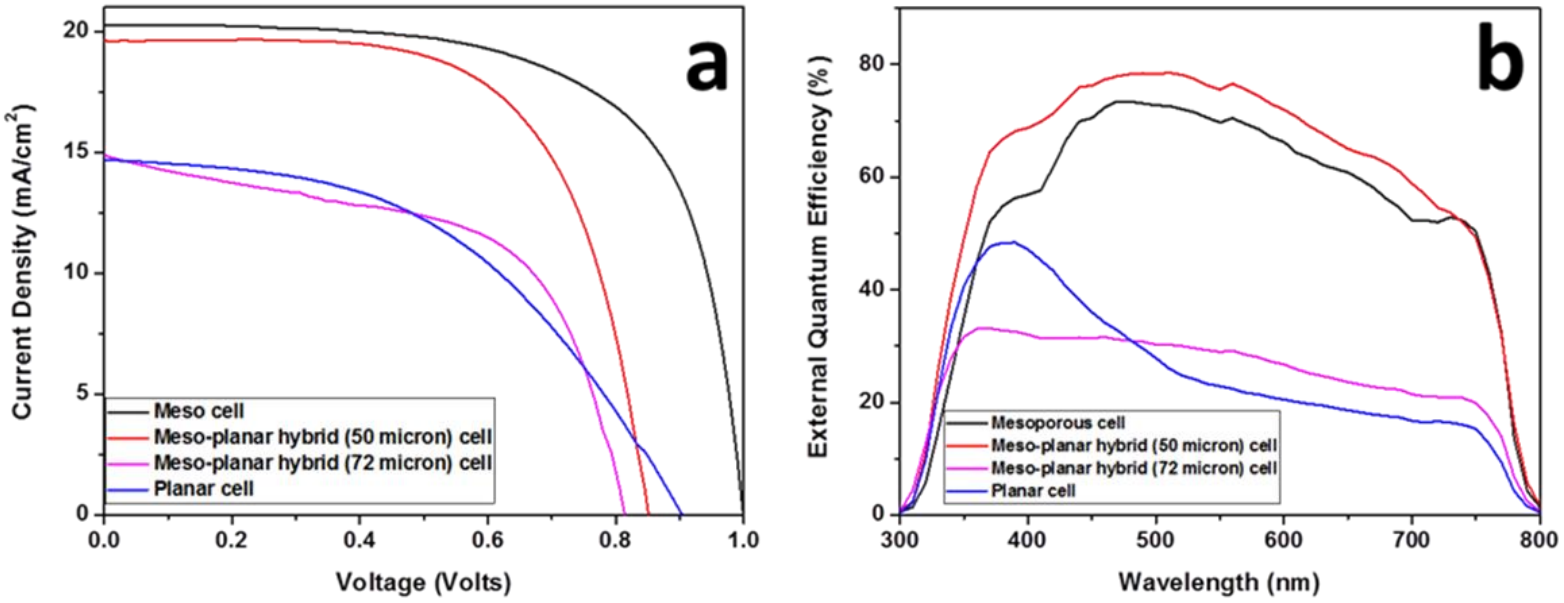


Fig. (a) J-V characteristics of perovskite solar cells (PSCs) for the different architectures, and (b) the comparative EQE curve for these cells.

Device performance

Cell architecture	Jsc (mA/cm^2)	Voc (V)	FF (%)	PCE (%)
Meso	**20.28 (18.76±1.36)**	**0.99 (0.98±0.03)**	**66.0 (65.4±2.9)**	**13.50 (12.08±1.40)**
Meso-planar hybrid (meso/planar = 1.08)	**19.63 (18.05±1.07)**	**0.86 (0.86±0.01)**	**68.9 (68.2±3.5)**	**10.76 (9.63±0.66)**
Meso-planar hybrid (meso/planar = 0.77)	**14.99 (13.25±1.55)**	**0.81 (0.80±0.03)**	**56.9 (59.6±1.8)**	**6.93 (6.35±0.49)**
Planar	**14.67 (13.77±2.37)**	**0.90 (0.81±0.11)**	**47.4 (49.7±2.1)**	**6.29 (5.39±1.55)**

Table. Photovoltaic performance of the best performing cells during the forward scan, the average values and standard deviation from the four cells of each type are provided in The parenthesis.

Charge extraction analysis

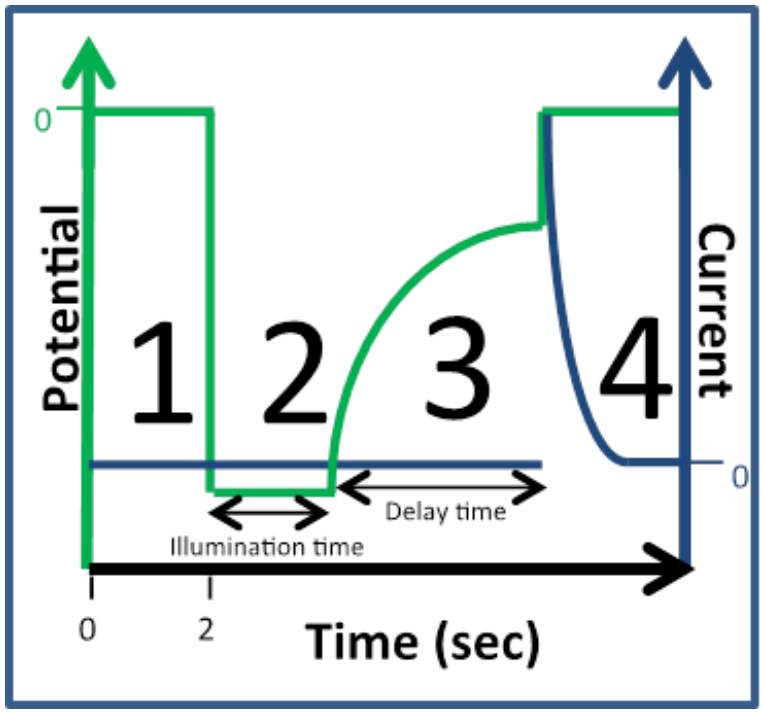


Fig. The steps involved in the charge extraction measurements.

A typical charge extraction experiment composed of

(1) A two second step in which the cell is being discharge at the dark

(2) The cell is then being disconnected and illuminated for 2 seconds (illumination time)

(3) The light is then switched off and the system waits a certain time called delay time. In this step a charge recombination occurs inside the cell

(4) the cell is reconnected and the charges which were left and didn't recombine are extracted and measured.

This process is repeated for different delay times, from 0.5 seconds to 15 seconds. The charges collected were plotted against delay time to give insight on the life-span of the charges after certain delay time.

Charge extraction analysis

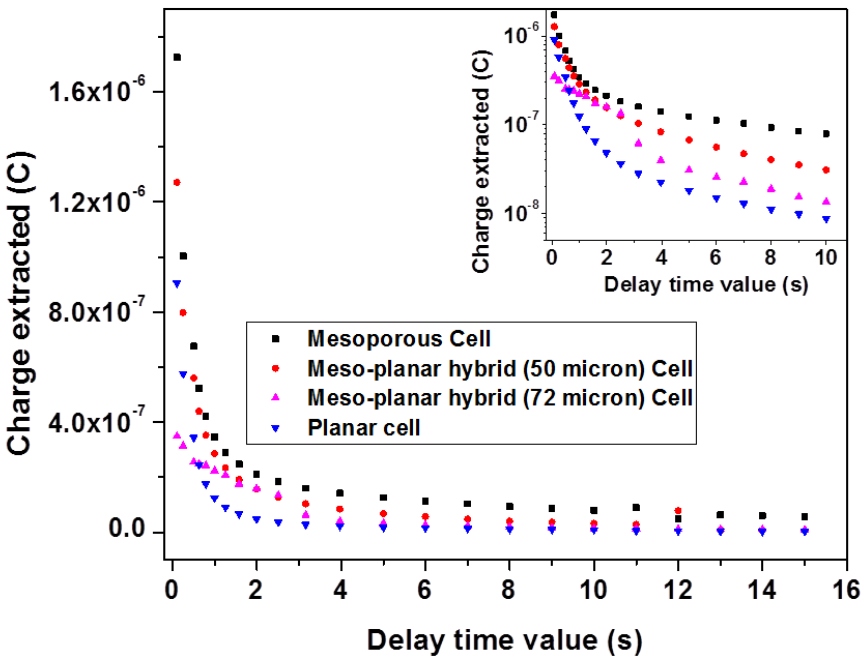


Fig. Charge extraction of different types of cells using white LED, inset: semi-logarithmic graph of the charge extraction.

The amount of charge extracted follow:

- **The order of the meso > hybrid > planar cells.**
- **More charges left means lower the recombination rate and higher the V_{oc}**
- **The CE curves of the hybrid cells are in between the meso and the planar structures**
- **Suggesting the intermediate rate of recombination in the hybrid cells.**
- **It can be attributed to the high junctions of the TiO_2 grid possessing direct contact between the TiO_2 and the Spiro, resulting in recombination centers.**

Concluding remarks

- Meso-planar hybrid perovskite solar cells with varying meso to planar ratio successfully fabricated and characterized
- These hybrid cells were compared with the mesoporous and planar PSCs.
- The hybrid cells showed up to 10.7% PCE as compared to 13.5% and 6.3% for their meso and planar counterparts.
- Interestingly, the hybrid cells conserved the current even in the absence of meso-TiO_2 from planar parts of the hybrid cells.
- The cells showed the best fill factor of 68% as compared to 66% and 47.4% for their meso and planar counterparts
- Charge extraction measurements provided insight on the recombination behavior of charges in the different device architectures.

Acknowledgements

- Dr. Lioz Etgar
- Sigalit Aharon
- Michael Layani
- Prof. Shlomo Magdassi
- and Ministry of Science, Technology & Space for funding

Thank you

Questions and Comments!!!

Self assembled meso-TiO_2 grid

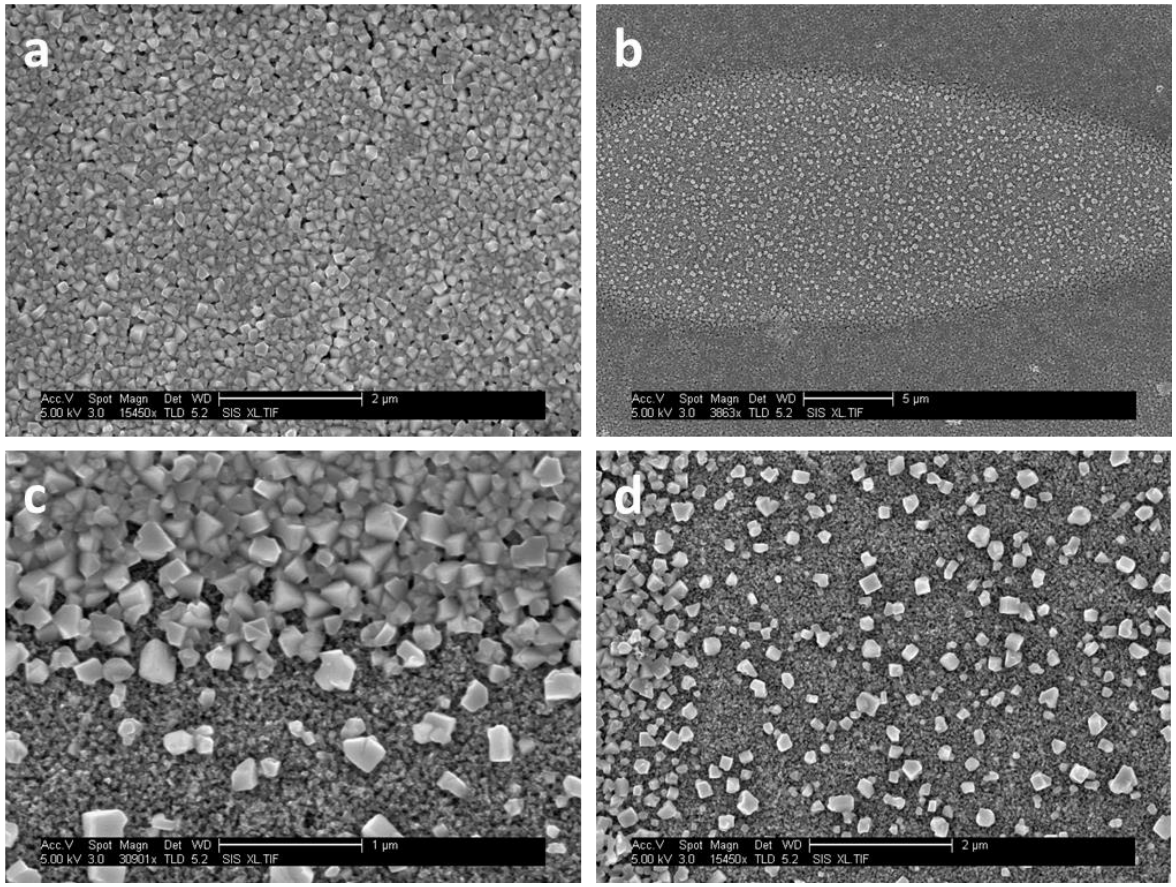
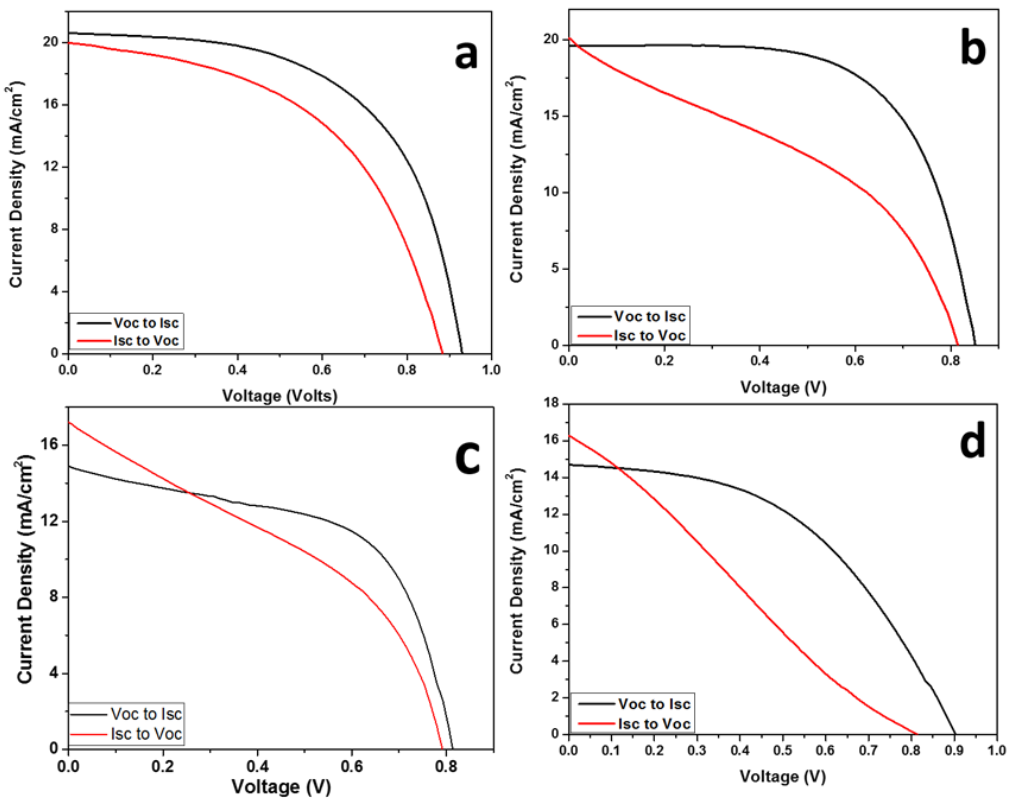


Fig.: a-d are showing the perovskite density at different locations of grid cells, the much dense perovskite coverage is evident in image a, the valley region of the titania grid, whereas b-d are showing enlarged view of the junction of meso-planar area and peaks of titania at mesh junction points.

Hysteresis



- All the cells were found to show hysteresis in some extent.
- It was maximum in case of planar, and decreased from hybrid to meso architecture.
- The reason of hysteresis is still less explained.
- The unequal mobilization of charges i.e. electron and ions has been recognized as a source of hysteresis so far.

Comparative absorption spectra of mesoporous and planar cells