Space Charge Region and Diffusion Length of $CsPbBr_3$ Solar Cells

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Talk of Nir Kedem, MS3, today at 17:10

מכון ויצמן למדע
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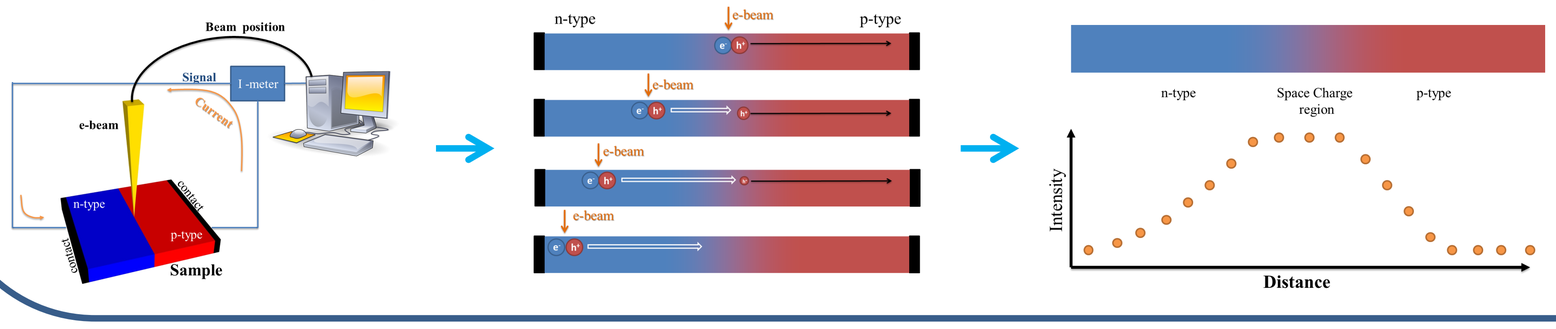
Background

Hybrid organic-inorganic lead halide perovskites with the generic structural formula AMX_3 (where 'A' is a usually an organic monovalent cation, 'M' is the divalent metal center and 'X' is a halide) have been thoroughly studied in the last few years but still face stability issues. Among the possible solutions replacing the organic moiety by cesium has gained increasing attention [1], [2]. While it has been shown that high-band gap (>2 eV) devices made from $CsPbBr_3$ as an absorber layer can work equally well as, and with better stability than devices based on CH_3NH_3[MA]$PbBr_3$ [3], there are still large gaps in our knowledge regarding how the inorganic halide perovskite photovoltaic devices operate.

In this presentation we discuss what the working mechanisms of $CsPbBr_3$-based devices are, by comparing the Cs with the organic perovskite in terms of how free carriers are separated, the width of the space charge region and the diffusion length as measured by Electron Induced Beam Current (EBIC) under different conditions in the scanning electron microscope.

EBIC uses the electron beam to act as a light source equivalent (electrovoltaic, instead of photovoltaic effect), generating electron-hole pairs in the junction area. If these pairs separate into free carriers, and are collected at the contacts, we measure a current in real time and a current collection efficiency image can be drawn.



References

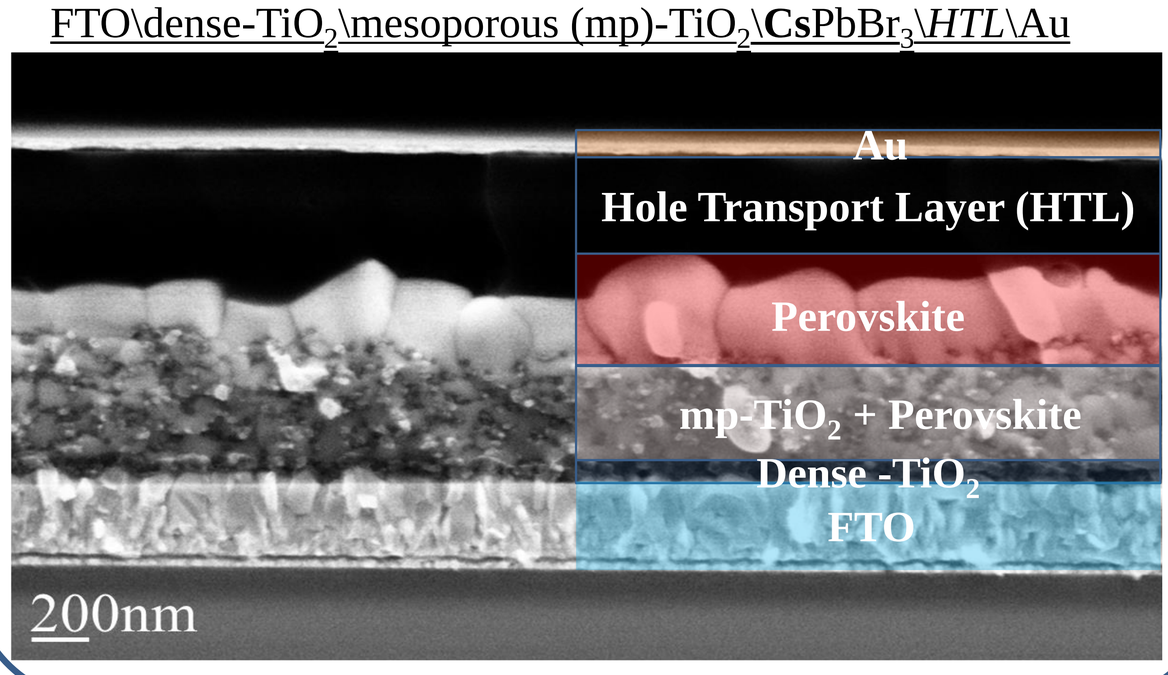
[1] McMeekin, D. P.; et al., *Science* (2016), *351*, 151–155.

[2] Kulbak, M.; Cahen, D.; Hodes, G., *J. Phys. Chem. Lett.* (2015), *6*, 2452–2456.

[3] Kulbak, M.; Gupta, S.; Kedem, N.; Levine, I.; Bendikov, T.; Hodes, G.; Cahen, D., *J. Phys. Chem. Lett.* (2016), *7*, 167–172.

1 – Device structure

FTO\dense-TiO_2\mesoporous (mp)-TiO_2**Cs**$PbBr_3$*HTL*\Au



2 – Beam damage

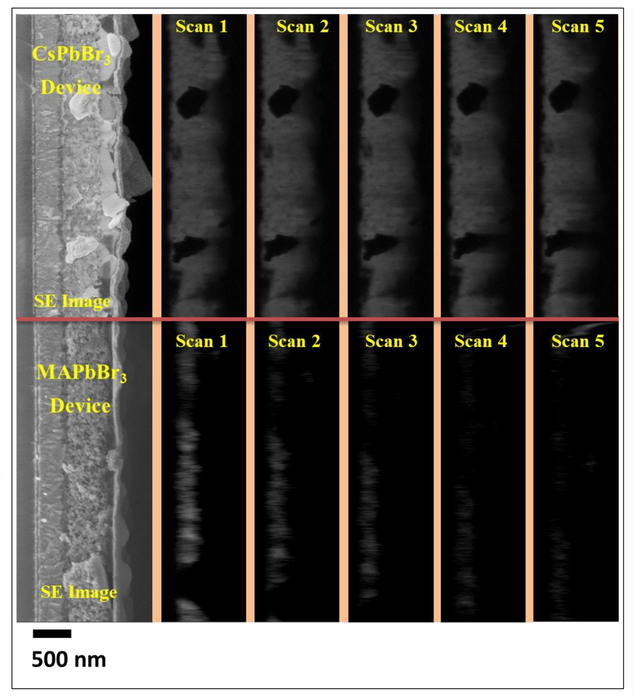
- $CsPbBr_3$ device

The EBIC signal is stable throughout the whole device with is no apparent loss in charge collection efficiency when scanning multiple times, suggesting $CsPbBr_3$ does not degrade under the electron beam.

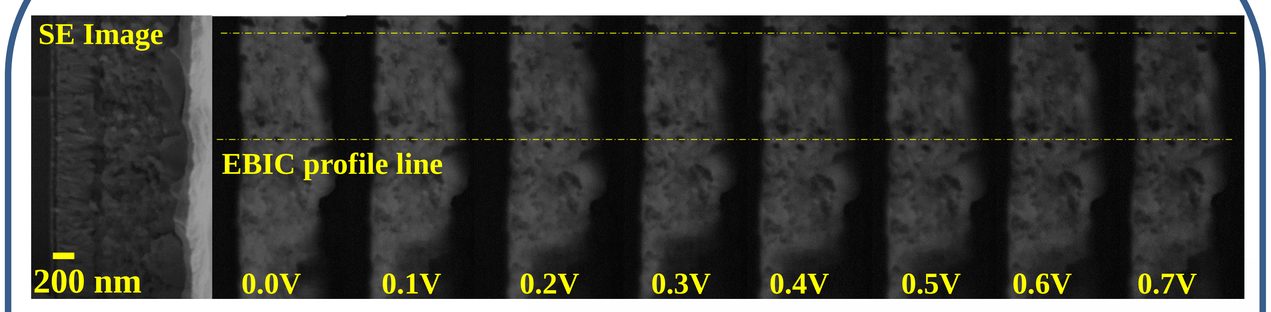
- $MAPbBr_3$ device

The EBIC signal indicates efficient charge collection at the FTO/dense-TiO_2 interface in the first scan, but a steady decease in collection efficiency in multiple scans, suggesting there's severe beam damage cause by local heating.

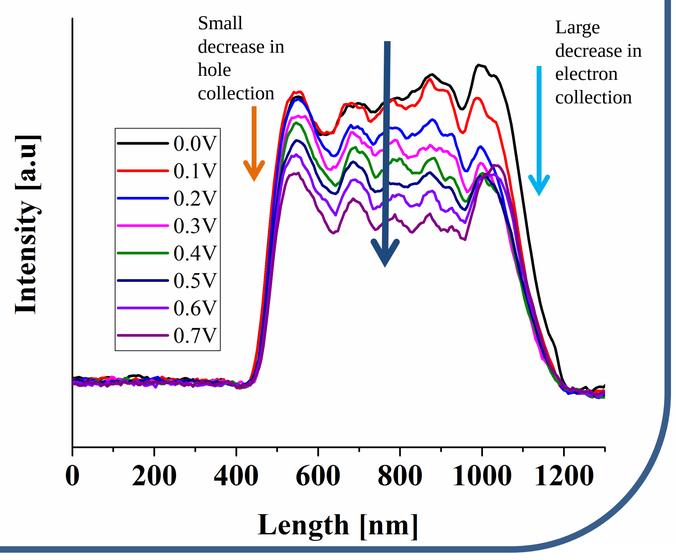
Acceleration voltage set to 3 kV



3 – EBIC Under bias



- The overall collection efficiency (main, middle arrow) decreases as bias increases.
- The bias has a bigger impact on electron collection than on hole collection effiency (make it harder for the electrons to reach the contact).

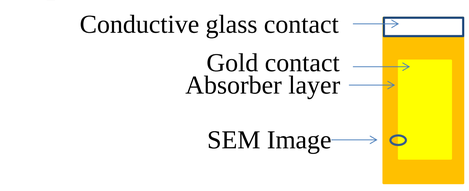


Summary

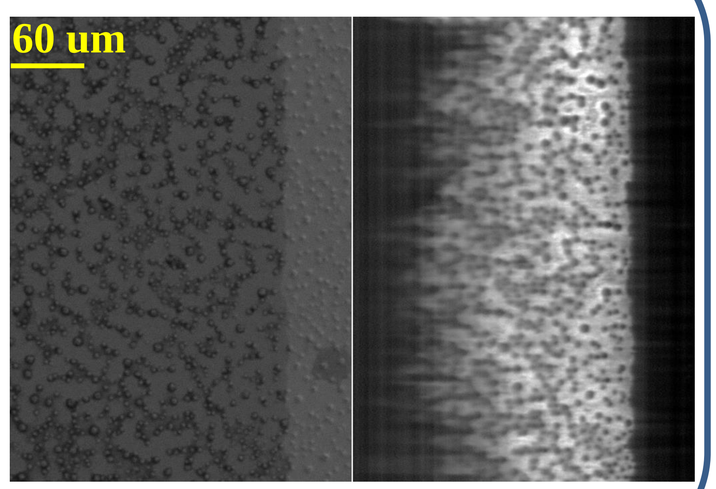
Cs-based halide perovskite solar cells were measured and characterized in the electron microscope using EBIC. The results emphasize the material is relatively stable under the electron beam and the for the first time, EBIC under bias has been measured.

4 – Hole defusion length?

Top view of the device:



We do not expect to get high collection efficiency outside the gold pad, there is still signal ***120 um*** away from it, meaning holes reach the contact.



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