Space Charge Region and Diffusion Length of CsPbBr₃ Solar Cells

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Background

Hybrid organic-inorganic lead halide perovskites with the generic structural formula AMX₃, (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 CsPbBr₃ as an absorber layer can work equally well as, and with better stability than devices based on CH₃NH₃[MA]PbBr₃ [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 CsPbBr₃-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

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

1 – Device structure

FTO/dense-TiO₂/porous (mp)-TiO₂/CsPbBr₃/HTL/Au

200nm

Hole Transport Layer (HTL)

Perovskite

mp-TiO₂ + Perovskite

Dense - TiO₂

FTO

3 – EBIC Under bias

SE Image

EBIC profile line

0

0.0V

0.1V

0.2V

0.3V

0.4V

0.5V

0.6V

0.7V

200 nm

0 200 400 600 800 1000 1200

Length [nm]

Intensity [a.u.]

Small decrease in hole collection

Large decrease in electron collection

Top view of the device:

Conductive glass contact

Gold contact

Absorber layer

SEM Image

60 um

4 – Hole defusion length?

Cesium-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 for the first time, EBIC under bias has been measured.

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• CsPbBr₃ device

The EBIC signal is stable throughout the whole device with is no apparent loss in charge collection efficiency when scanning multiple times, suggesting CsPbBr₃ does not degrade under the electron beam.

• MAPbBr₃ device

The EBIC signal indicates efficient charge collection at the FTO/dense-TiO₂ interface in the first scan, but a steady decrease in collection efficiency in multiple scans, suggesting there’s severe beam damage cause by local heating.

Summary

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.