

Operando study of humidity on the performance of perovskite solar cell

Kun Sun¹, Julian E. Heger¹, Manuel A. Reus¹, Xinyu Jiang¹, Lukas Spanier¹, Sigrid Bernstorff², Peter Müller-Buschbaum^{1,3}

¹Technische Universität München, Physik-Department, Lehrstuhl für Funktionelle Materialien, James-Frank-Str. 1, 85748 Garching, Germany

²Elettra-Sincrotrone Trieste S.C.p.A. Strada Statale 14 km 163.5, AREA Science Park, Basovizza 34149, Italy

³Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Lichtenbergstr. 1, 85748 Garching, Germany

Perovskite solar cell

Clean Energy Demand
+ Energy crisis
+ Fossil fuel shortage
+ Climate change
+ Extreme weather

Advantage of Perovskite Solar Cell (PSCs):
+ Clean energy
+ High efficiency
+ Low cost
+ Easy to fabricate

Structure of PSCs
+ Transparent conductive oxide
+ Electron transport layer
+ Active layer
+ Hole transport layer
+ Electrode

Perovskite [1,2]:
+ Tunable bandgap
+ High electron/hole mobility
+ Strong light-absorption coefficient
+ High defect tolerance

Characterization and Experimental Setup

Beam energy: 8 kV
Sample to detector distance (SDD): 1477.5 mm
Incident angle: 0.44

Overall structure evolution and solar cell parameters were simultaneously obtained

GISAXS features [3]:
+ no scattering/absorption by substrate
+ non destructive interaction
+ enhanced intensity due to grazing incidence geometry

Motivation

Modification strategies towards enabling high-humidity processed PSCs

We use cesium iodide as additive to further enhance the moisture resistance

Sample Preparation

Perovskite precursor → Spin-coating (with CsI additive)

+ One-step spin-coating method
+ Chlorobenzene was used as anti-solvent

ITO/ETL/Perovskite/HTL/Au

Real cross-section SEM image

Results

Current density (mA·cm⁻²) vs Voltage (V) (ref, t=0)

Normalized data vs Time (min) (ref)

Normalized data vs Time (min) (with CsI additive)

Increasing operation time

Solar cell Performance
+ V_{OC} of reference and with additive decrease 15% and 11%, respectively
+ PCE of reference and with additive decrease ~40% and ~20%, respectively
+ with CsI as additive, PCE and V_{OC} show slow decay, whereas reference shows fast decay under humidity

In-operando GISAXS was performed simultaneously to study the structure change
+ relative stable crystal size in the device without significant changes

Summary & Outlook

Summary

- We simultaneously probe the structure change with grazing incidence small-angle scattering (GISAXS) and solar cell performance during the device operation
- With CsI additive, PCE and V_{OC} both show slow decay
- Relative stable crystal size in the device without significant changes

Outlook

- Further quantitative GISAXS analysis and also model fit will be performed
- Recombination kinetics will be studied by time-resolved photoluminescence