The CHEOPS Protocol

Recommendations for performance measurement and stability testing of perovskite photovoltaic devices

June 2018

Most of the perovskite (PK)-based photovoltaic (PV) devices are subject to a hysteresis phenomenon when measuring their I-V characteristic. Together with general questions regarding device stability, these hysteresis issues can lead to dramatic overestimation of device performances, which is a challenge for the entire industry. Therefore, CHEOPS has established a measurement procedure and degradation tests with the intention to serve as a standard protocol for academic and industrial development of PK-based PV devices.

PK cell efficiencies are subject to interpretation due to a hysteresis effect appearing when scanning the I-V curve from short-circuit to open-circuit conditions and back. The reasons for this effect are not yet well understood but the effect renders the comparison of results between different materials and processes difficult. CHEOPS has therefore created a standardised protocol including a reliable measurement procedure allowing for comparison of the different results achieved in different research projects and by various actors in the academic and industrial PK community.

In addition, a set of degradation tests has been developed, assessing the device stability towards compliances with IEC norms. The CHEOPS protocol is to become the prevailing standard used by the scientific community as well as by the industry developing PK-based PV devices.

The protocol includes recommendations for the following areas:

1. Irradiation
2. Cell Performance Measurement
3. Stability Testing for encapsulated cells
4. Sample requirements
5. Measurement conditions
6. Data to be communicated

About CHEOPS

CHEOPS is a research project co-funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 653296. Based on perovskite PV technology, we aim to develop a novel type of photovoltaic cell – one that has the potential to be both low-cost and extremely efficient. The project runs from February 2016 until January 2019.
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This work is a result of the CHEOPS project, which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 653296.

THE CHEOPS PROTOCOL

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The following protocols have been agreed on within CHEOPS:

1. Irradiation

All tests requiring irradiation of the solar cell must be performed in a steady-state sun simulator with the AM1.5 spectrum.

2. Cell performance measurements

- 2.1. Dark-IV scans in reverse (from *Voc* to *Jsc*) and forward (from *Jsc* to *Voc*) direction
- 2.2. Light-IV scans at 1-sun illumination in reverse and forward direction
- 2.3. MPP tracking for 5 minutes
- 2.4. Light-IV scans at 1-sun illumination in reverse and forward direction
- 2.5. External quantum efficiency measurement

3. Stability testing for encapsulated cells

- 3.1. Test cells at 85°C in the dark in inert atmosphere or air (only encapsulated samples)
- 3.2. Thermal cycling between -40°C and 85°C for 200 cycles
- 3.3. Light soaking at 60°C for 1000 h at the MPP if a suitable setup is available
- 3.4. Damp-heat test at 85% rel. hum. and 85°C for 1000 h
- 3.5. Reverse bias cells during IV scans up to -2V

In addition, the following requirements to sample fabrication and measurement conditions were agreed on:

4. Sample requirements:

- 4.1. Sample geometry 1 cm2, defined by shadow mask, shape is chosen by the project partners
- 4.2. 1-sun illumination and, if possible, low illumination.
- 4.3. No dedicated pre-conditioning or light soaking.
- 4.4. Measurement speed is 50 mV/s.

5. Measurement conditions:

- 5.1. No UV filters: Spectrum should be as close to AM1.5g as possible
- 5.2. Temperature during MPP tracking/light soaking: room temperature

6. Data to be communicated:

- 6.1. Voc, Jsc, FF and PCE for both scan directions
- 6.2. Ratio between best scanned forward and reverse PCE and stabilised MPP efficiency
- 6.3. Results from four co-deposited substrates with 1 cm2 aperture

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