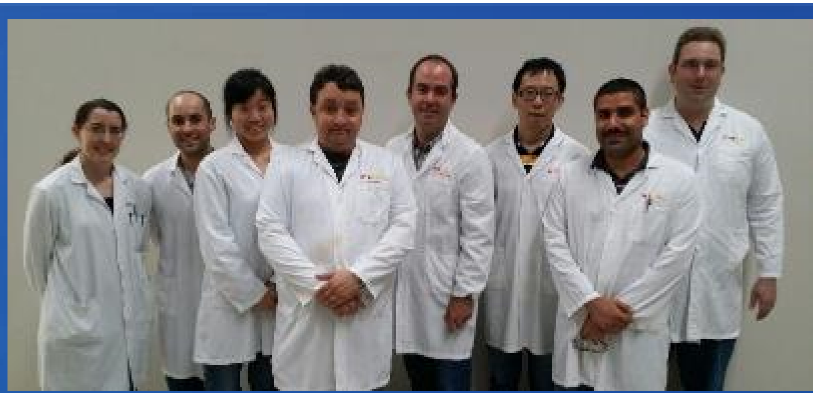
Durability and Scale-Up of Perovskite-Based Mesoscopic Solar Cells

Adriana Paracchino, Nancy Jiang, Paul Murray, Timothy Lee, Celeste Choo, Kristen Tandy, Dongchuan Fu, Francis Au, Taro Sumitomo, Hans Desilvestro, Damion Milliken

SWISSPHOTONICS WORKSHOP - 10 September 2015 – SUPSI, Lamone (CH)

Device R&D Team (AUS)



Materials R&D Team (AUS)

CSIRO

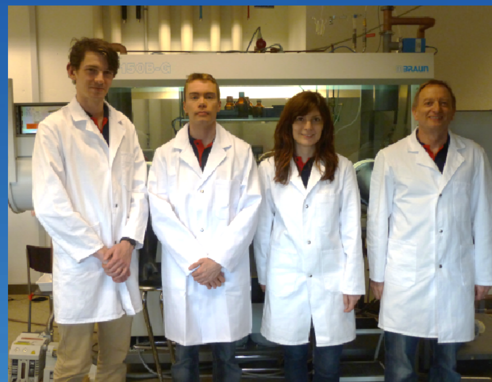
DYESOL™

GLOBAL LEADERS IN DYE SOLAR CELL TECHNOLOGY

NANYANG TECHNOLOGICAL UNIVERSITY

EPFL
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

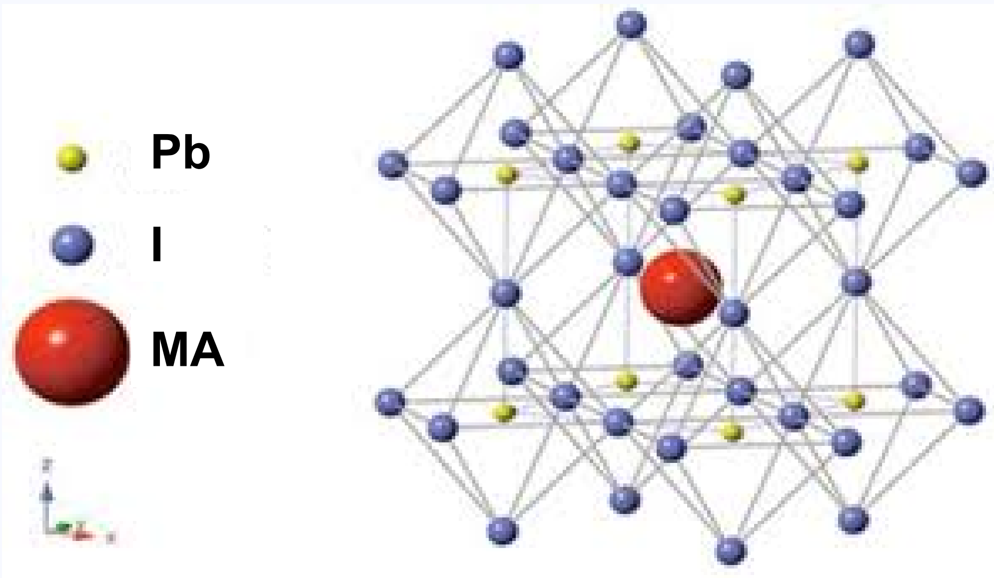
Metals R&D Team (UK)



Greatcell Solar Team (CH)

Outline

- Device architectures for $CH_3NH_3PbI_3$ (MALI) solar cells
- Effect of morphology on the stability of $CH_3NH_3PbI_3$
- Stability under light soaking for different device architectures
- Scale-up of perovskite solar cells

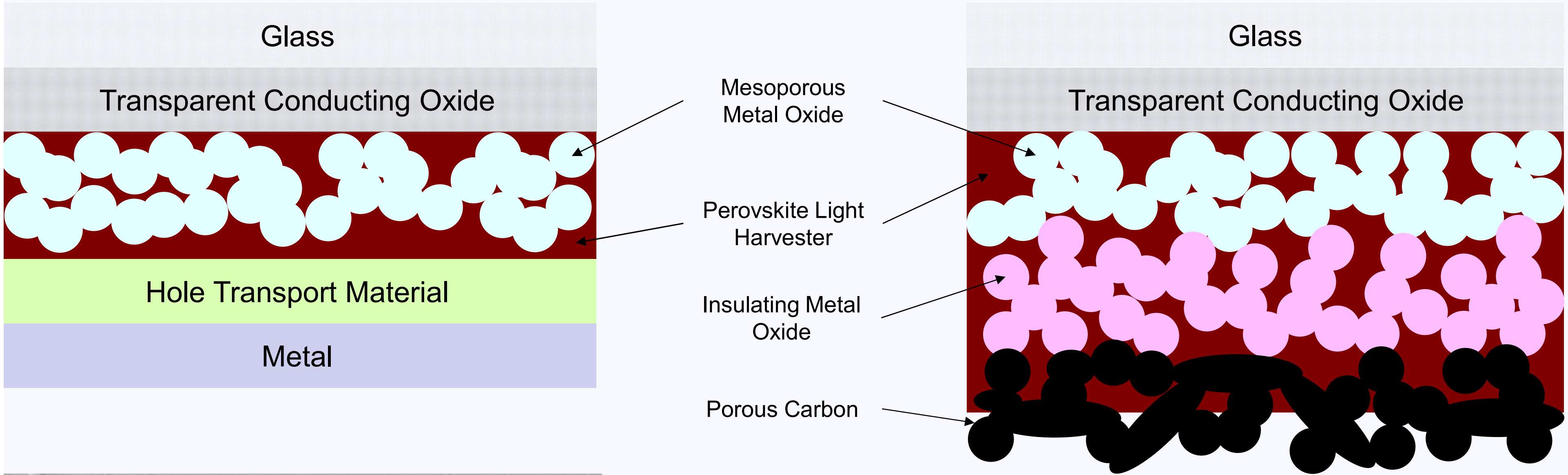


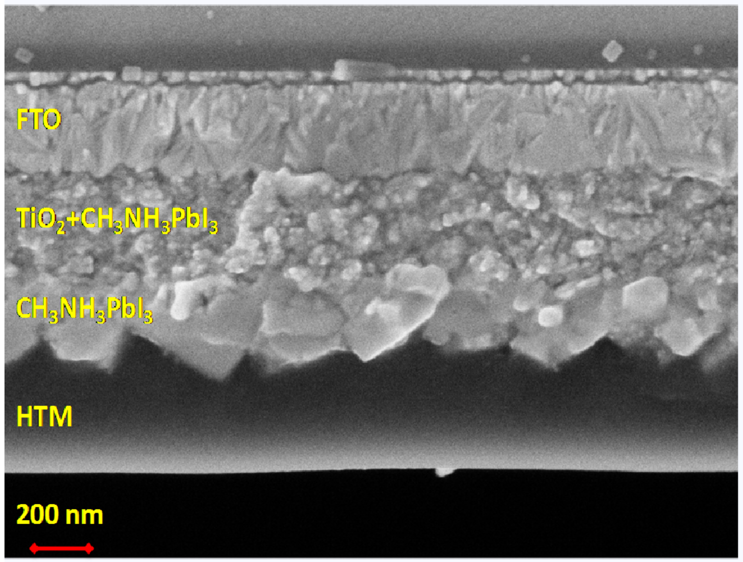
E_g=1.55 eV

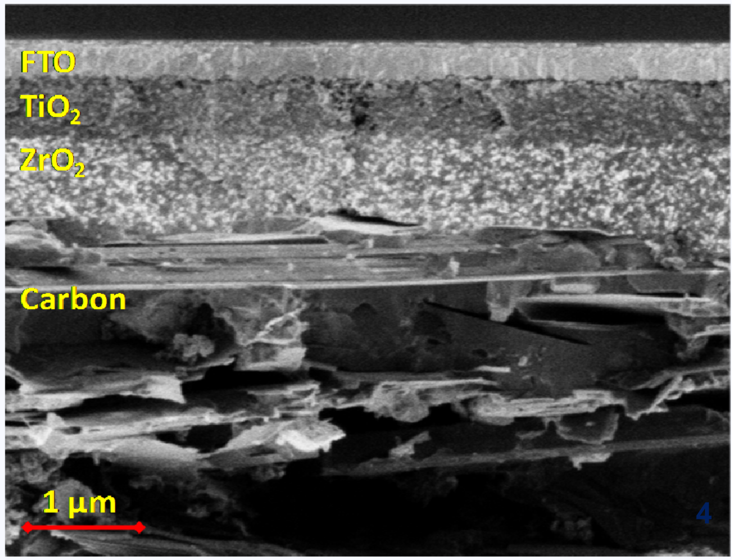
Device architectures

"Spiro cell"

"Porous Carbon cell"



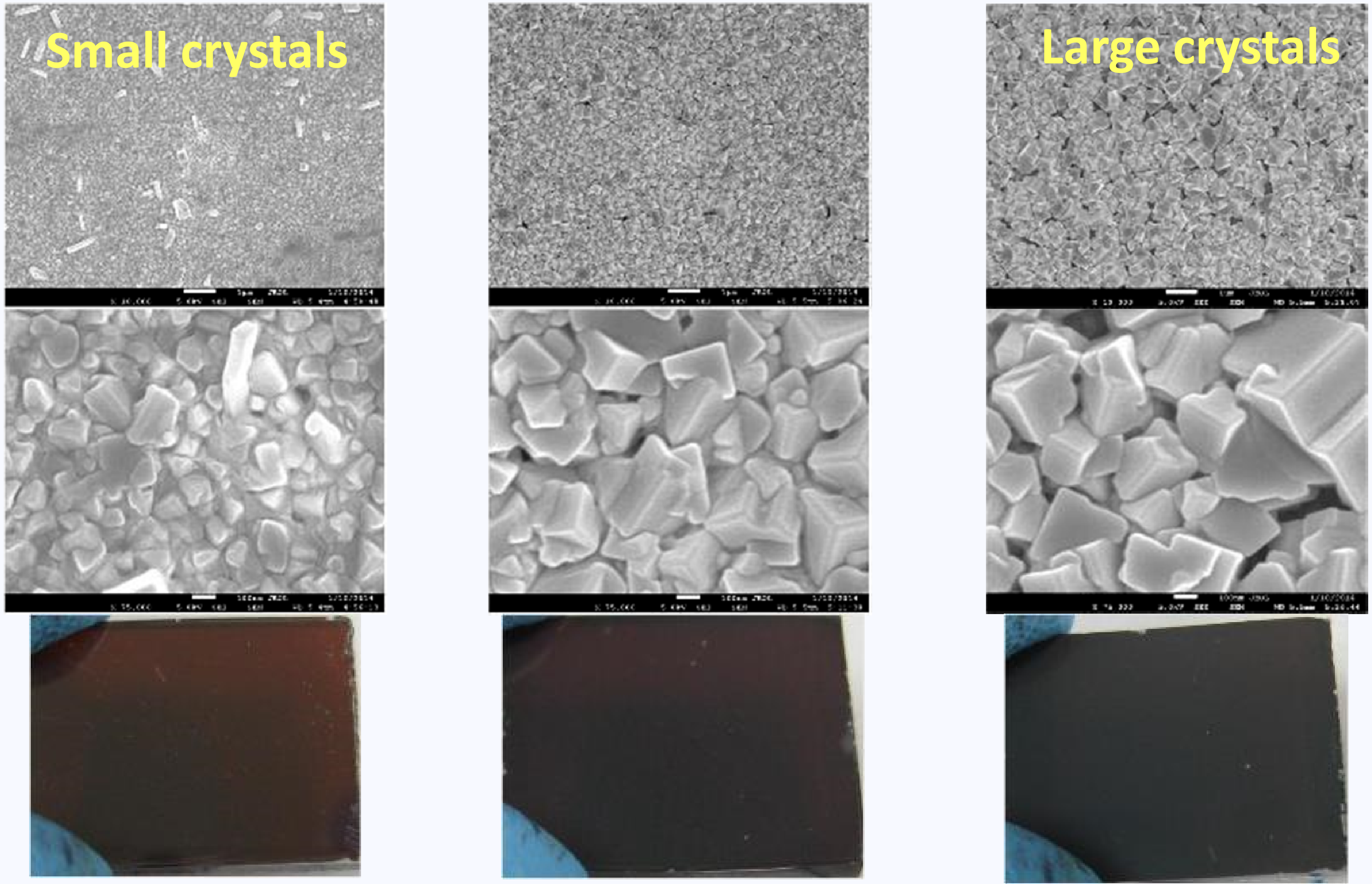




Effect of morphology on the stability of $CH_3NH_3PbI_3$ layer

Initial SEM images and sample pictures

MAI 10 mg/ml | MAI 8 mg/ml | MAI 7 mg/ml

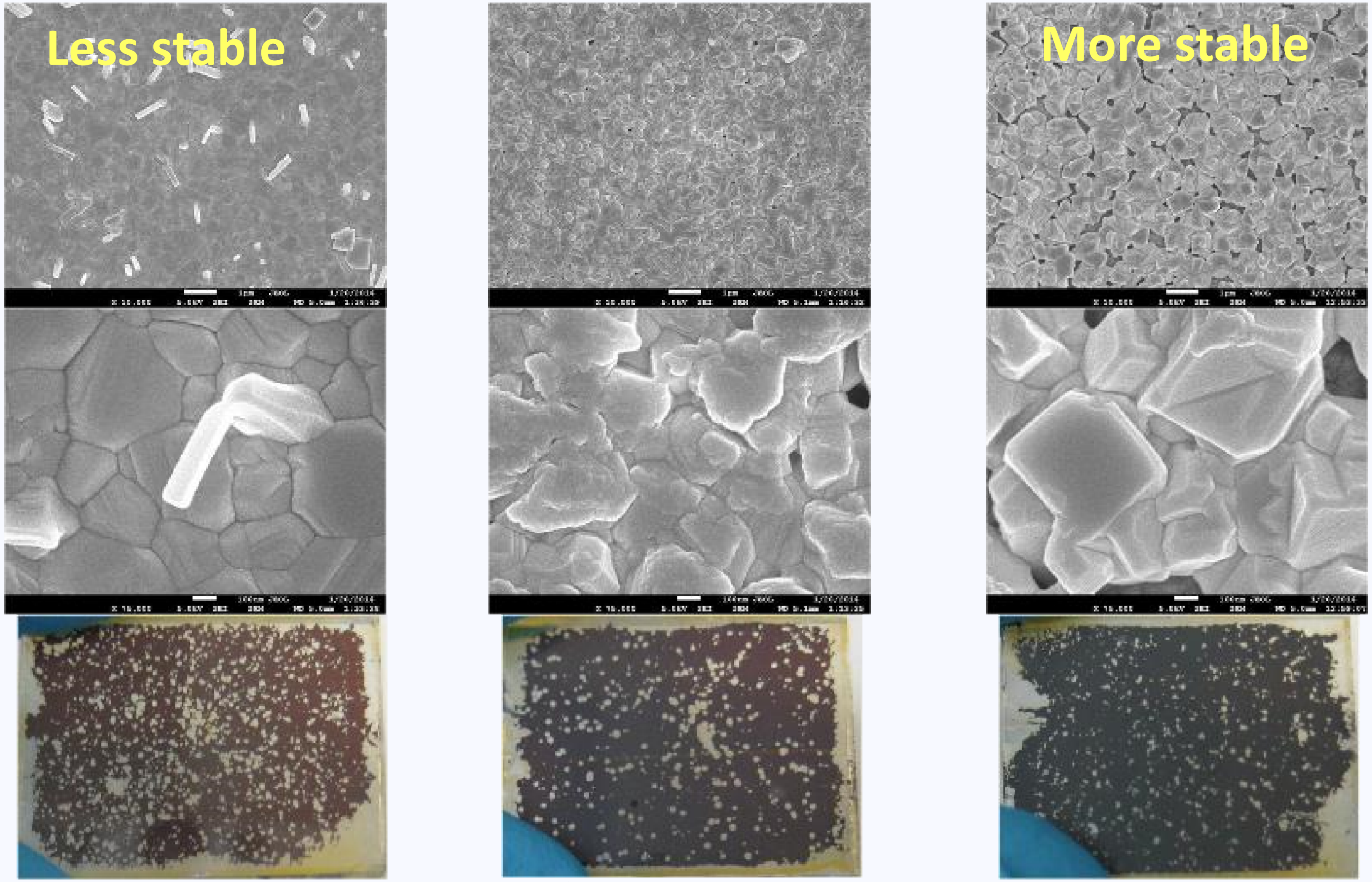


Effect of morphology on the stability of $CH_3NH_3PbI_3$ layer

GLOBAL LEADERS IN DYE SOLAR CELL TECHNOLOGY

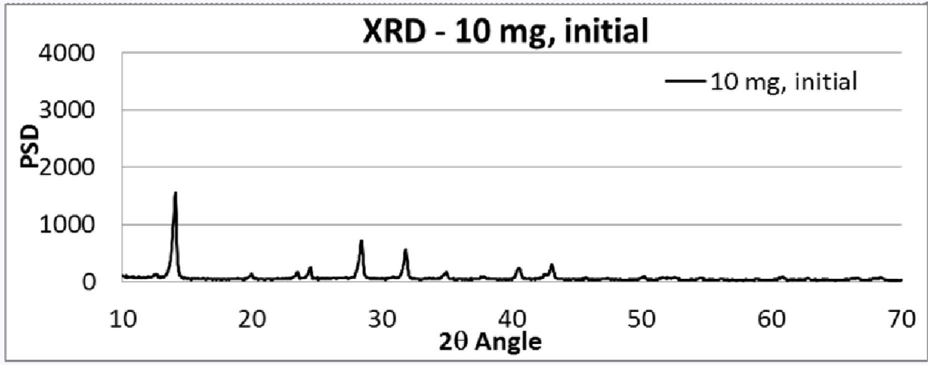
SEM images and sample pictures after 240h at RT and 70%RH

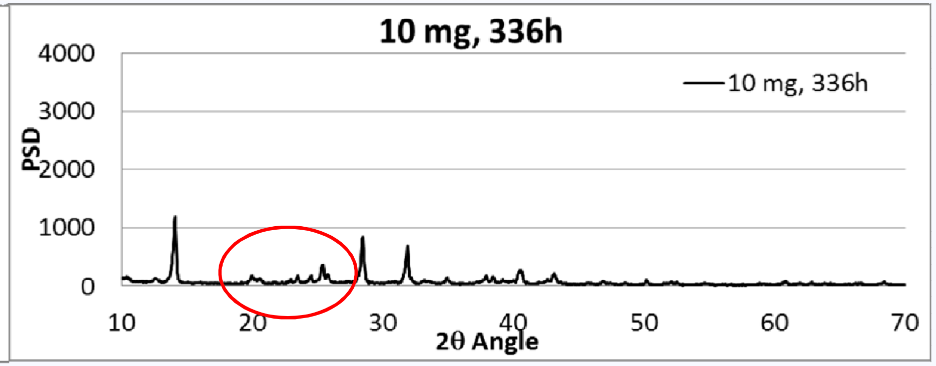
MAI 10 mg/ml | MAI 8 mg/ml | MAI 7 mg/ml

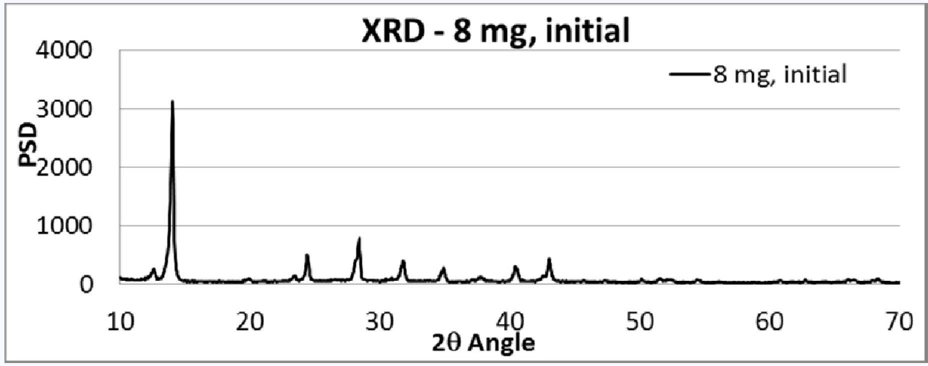


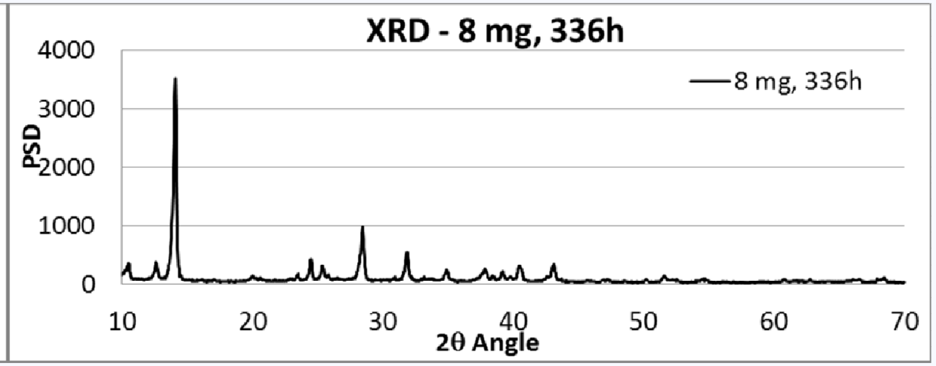
Effect of morphology on the stability of $CH_3NH_3PbI_3$ layer

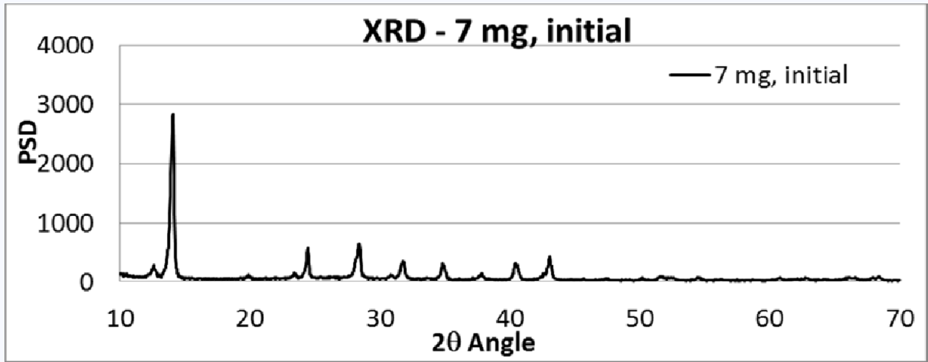
Initial XRD | **XRD after 336h at RT + 70%RH**

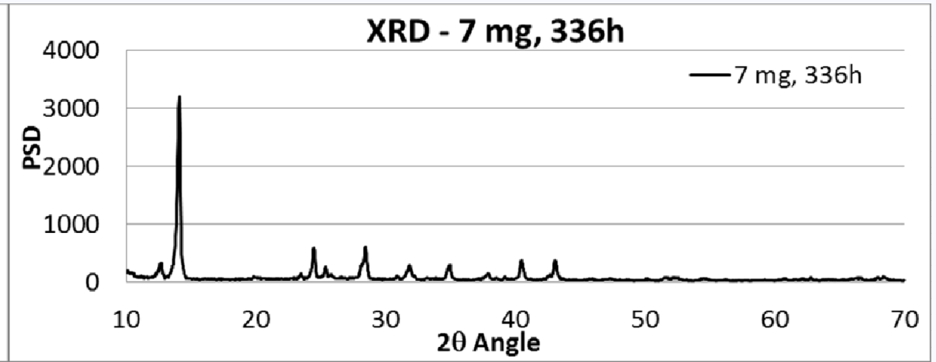




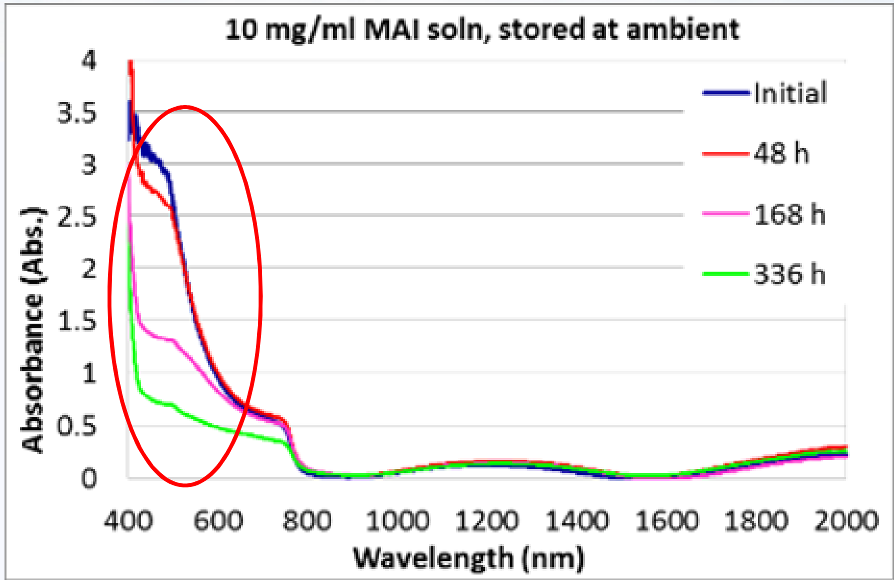


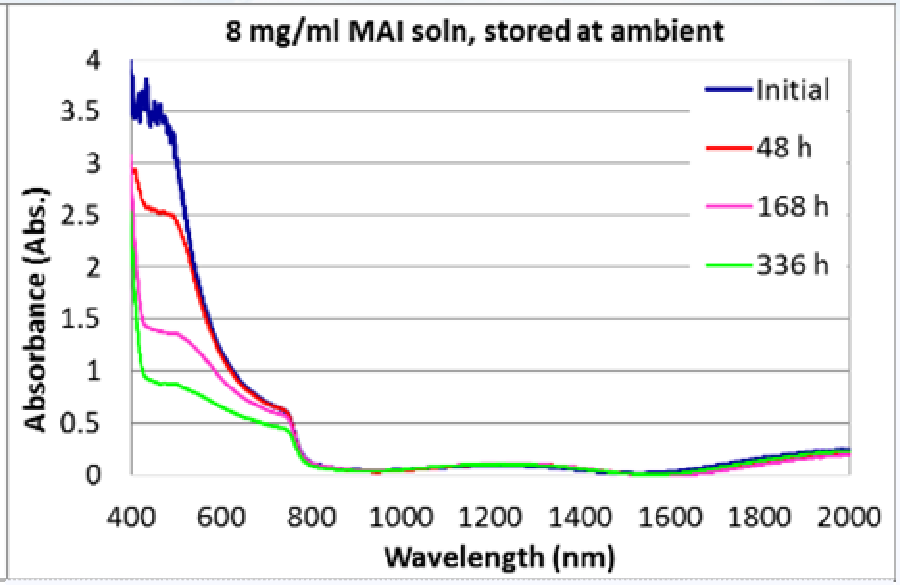


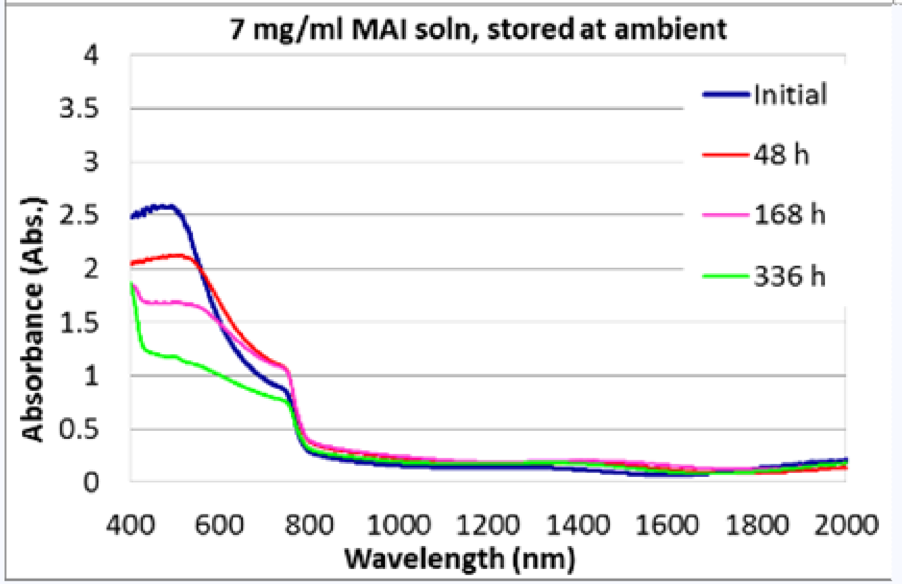




Effect of morphology on the stability of $CH_3NH_3PbI_3$ layer







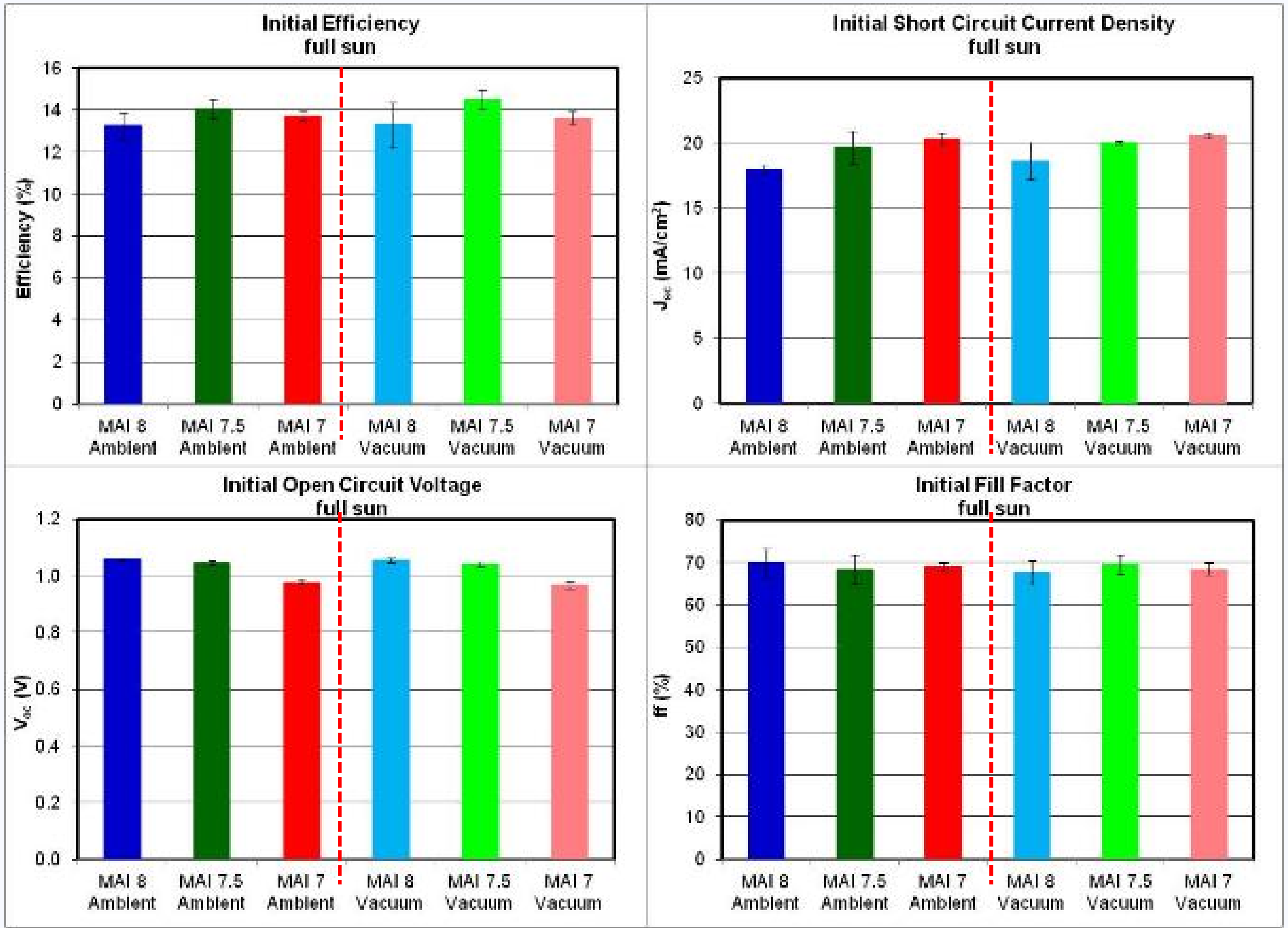
The lower the MAI concentration, the larger the MALI crystal size, and the slower the degradation rate.

Stability of devices with different MALI morphology

DYESOL
GLOBAL LEADERS IN DYE SOLAR CELL TECHNOLOGY

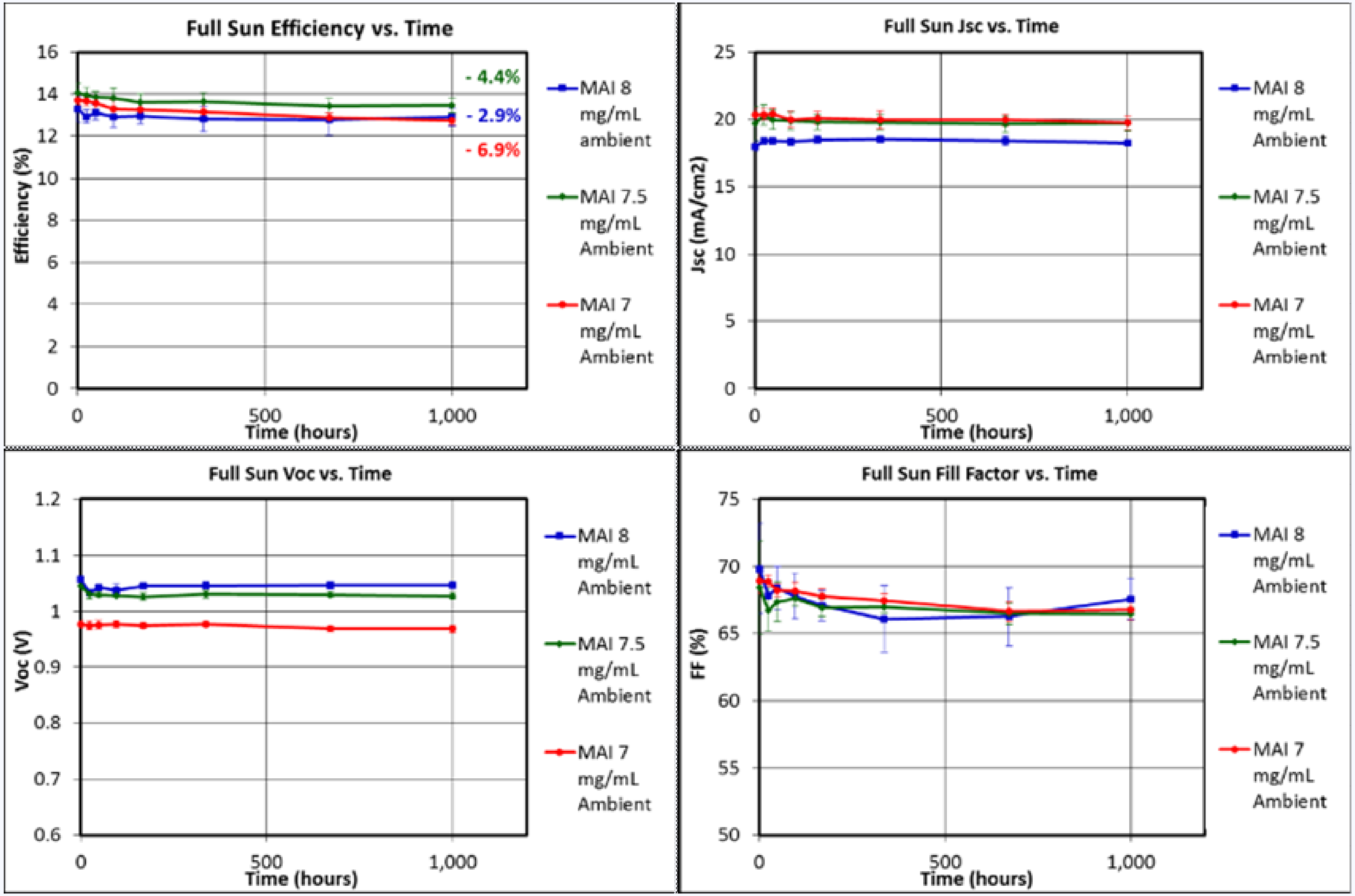
Initial IV Results vs. MALI Morphology

Storing in ambient (70%RH) vs. storing under vacuum (no encapsulation)



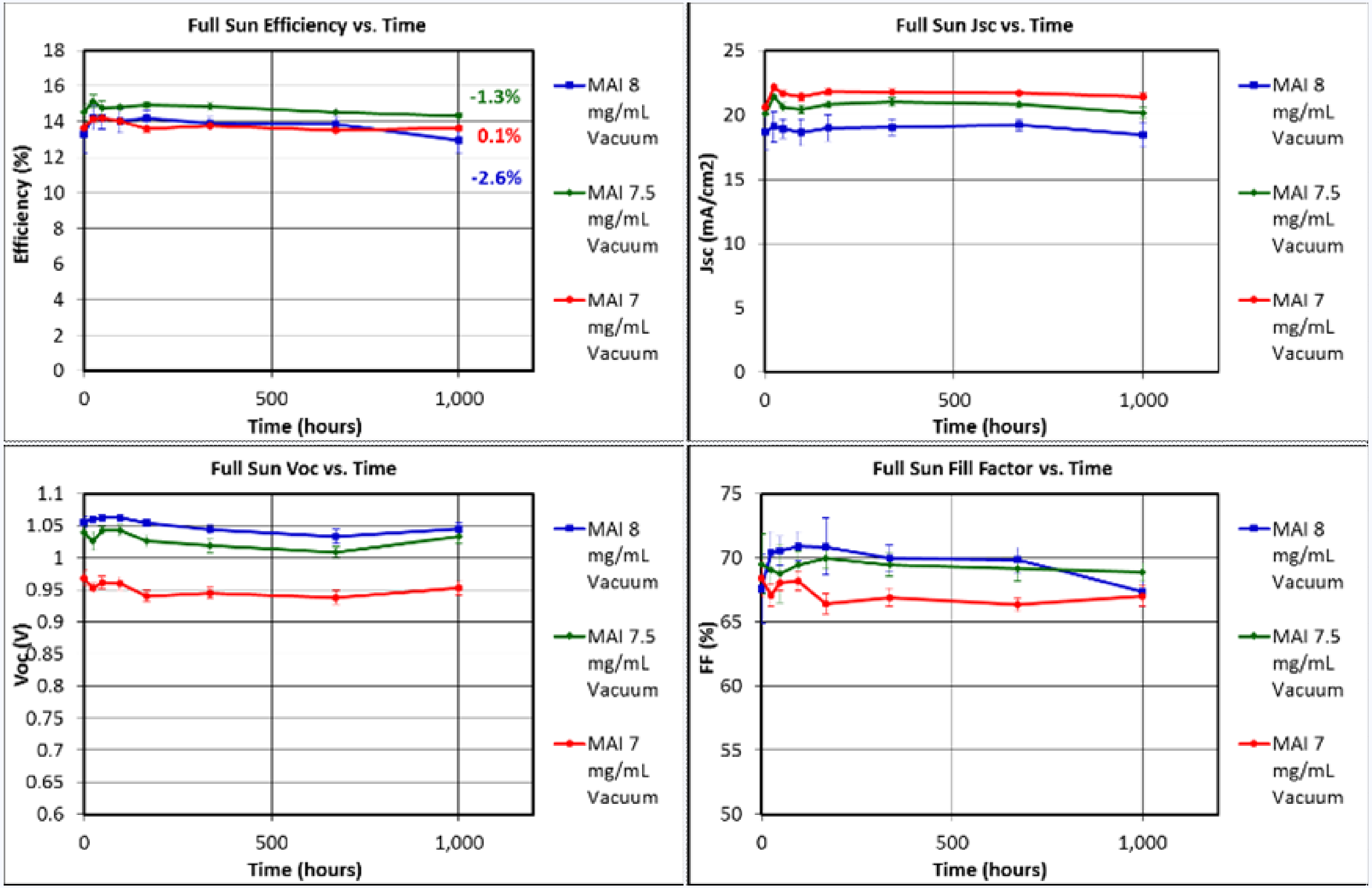
Stability of devices with different MALI morphology

Devices stored at RT + 70%RH



Stability of devices with different MALI morphology

Devices stored at RT + vacuum

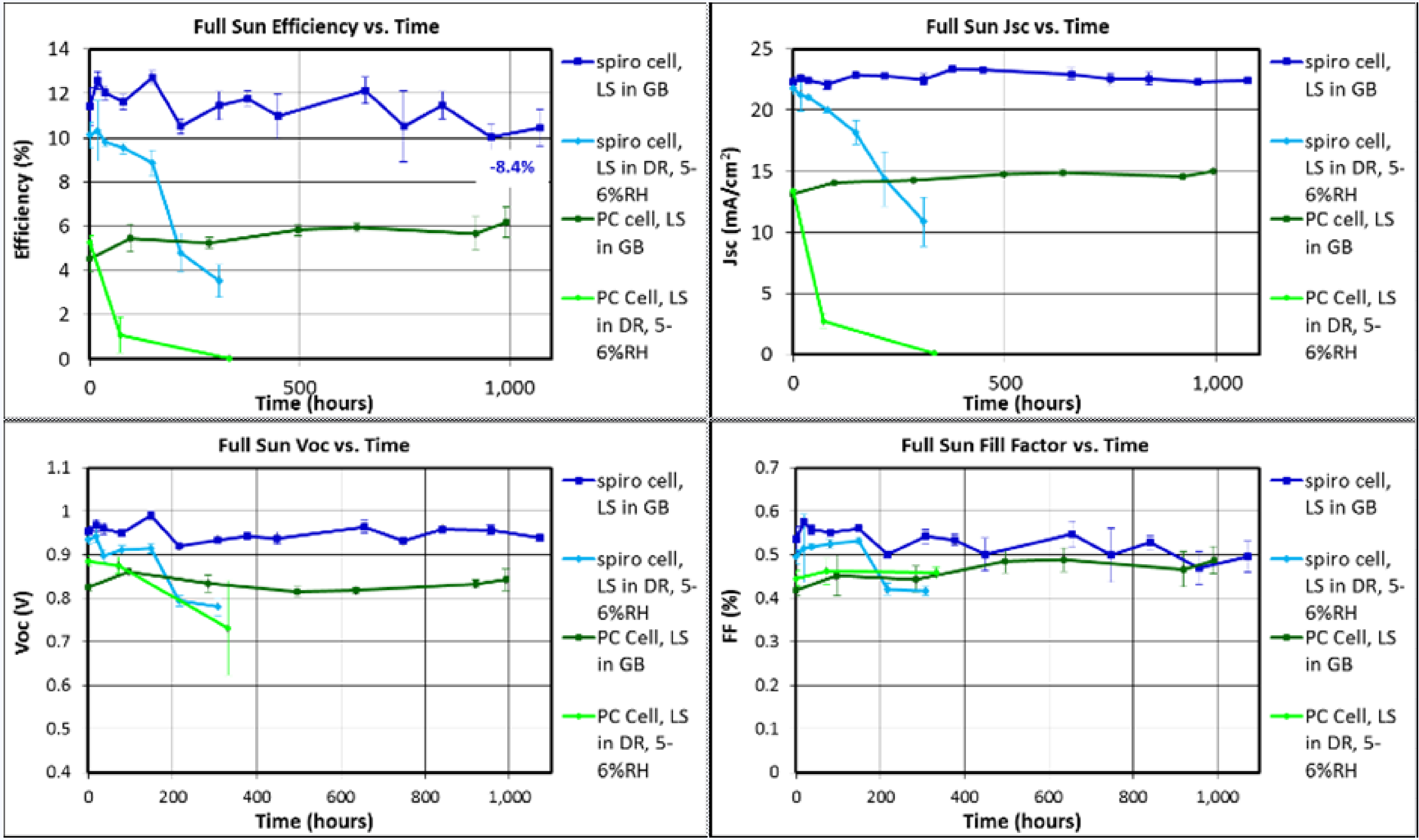


Stability of devices with different MALI morphology

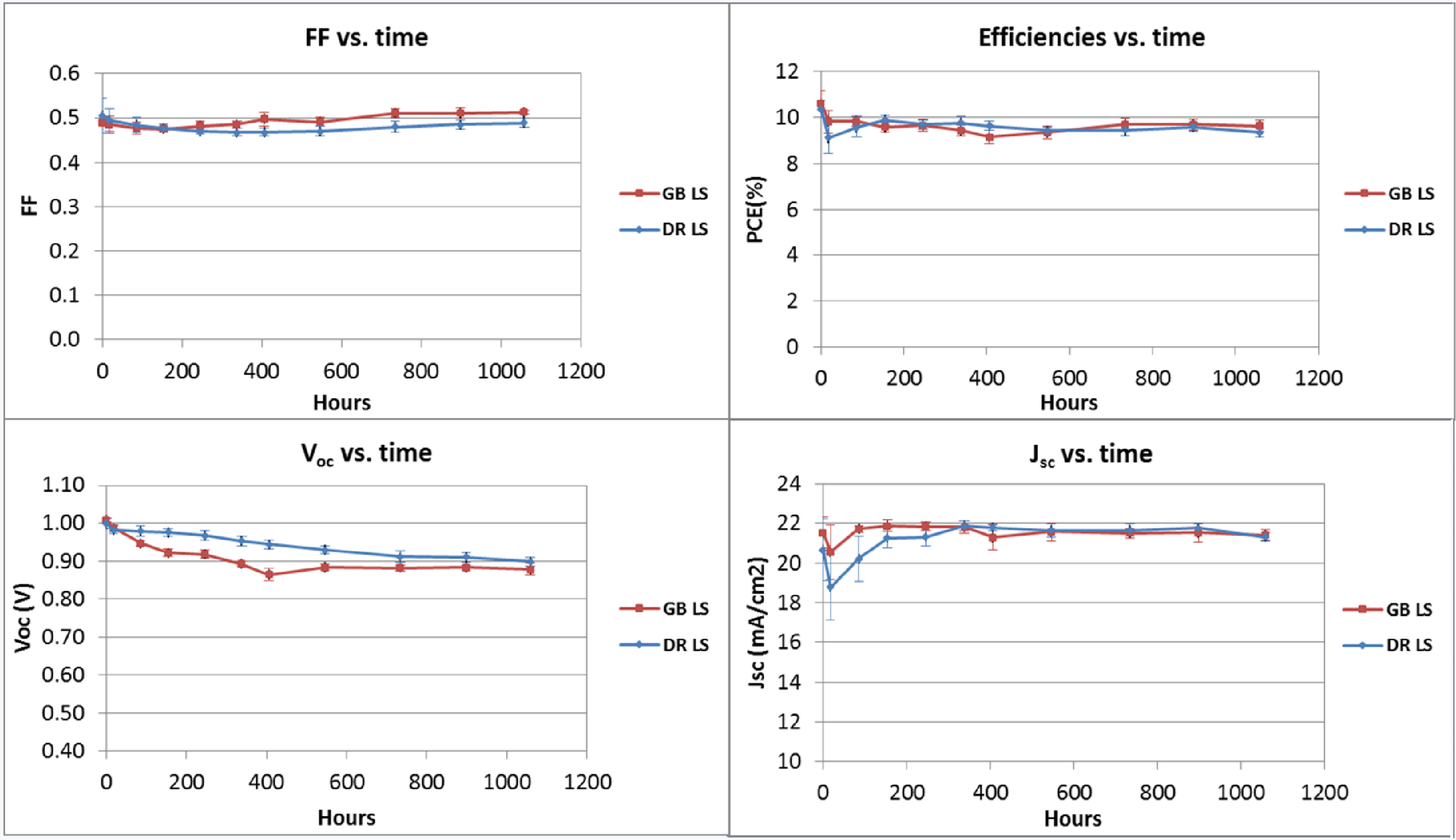
Conclusions

- Dyesol spiro cells are virtually stable at RT and in dark up to 1000 hours.
- Crystal size increases : 8 mg/ml → 7.5 mg/ml → 7 mg/ml
- J_{sc} increases with increasing crystal size
- Capping layer density and V_{oc} decrease with increasing crystal size
- In humid environment (dark), denser capping layer = higher stability.
- Under vacuum (dark), larger crystals = better stability.

Device stability under light soaking. Non encapsulated cells, spiro vs PC



Device stability under light soaking. Encapsulated Porous Carbon cells

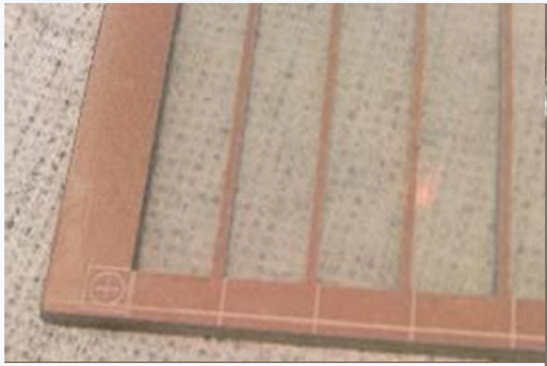
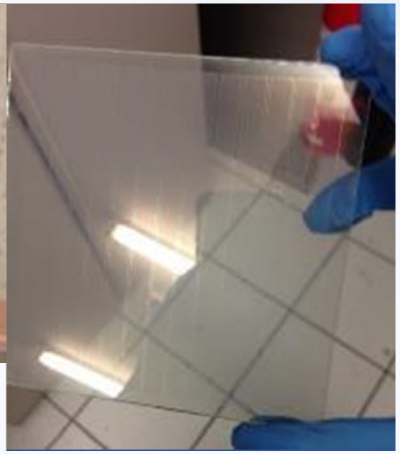
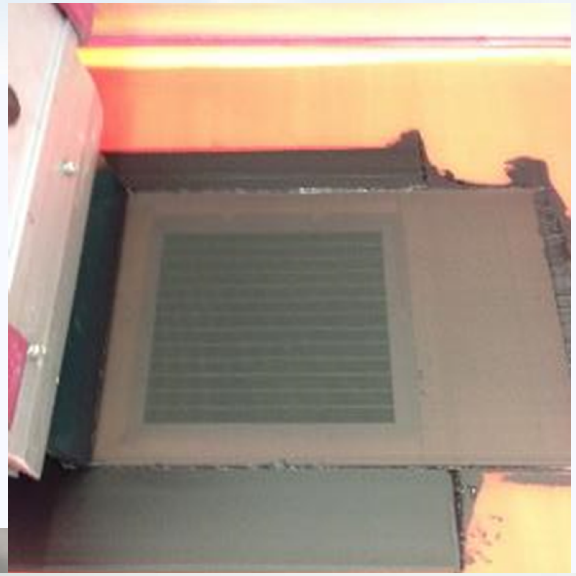
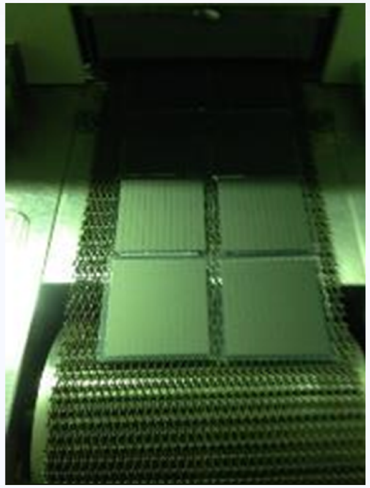
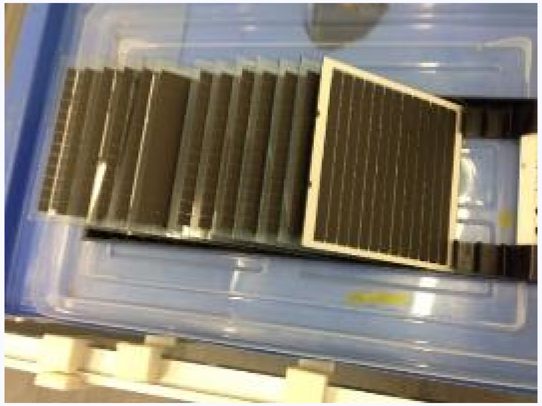
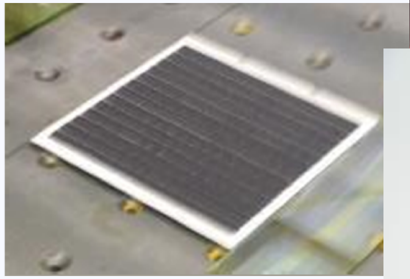
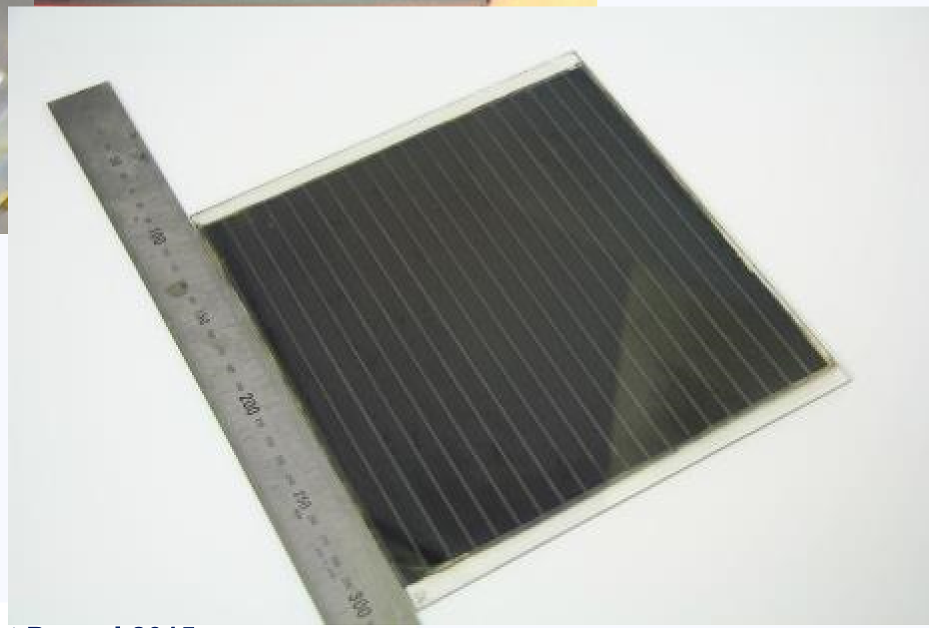
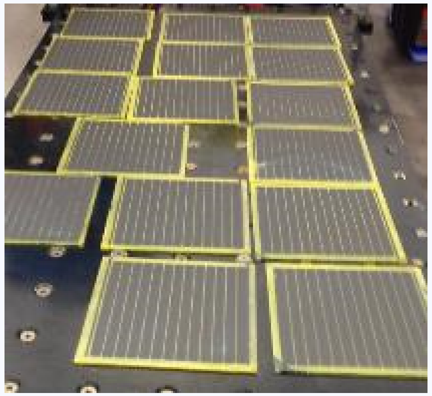
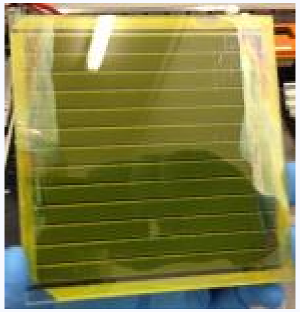


Device stability under light soaking

Conclusions

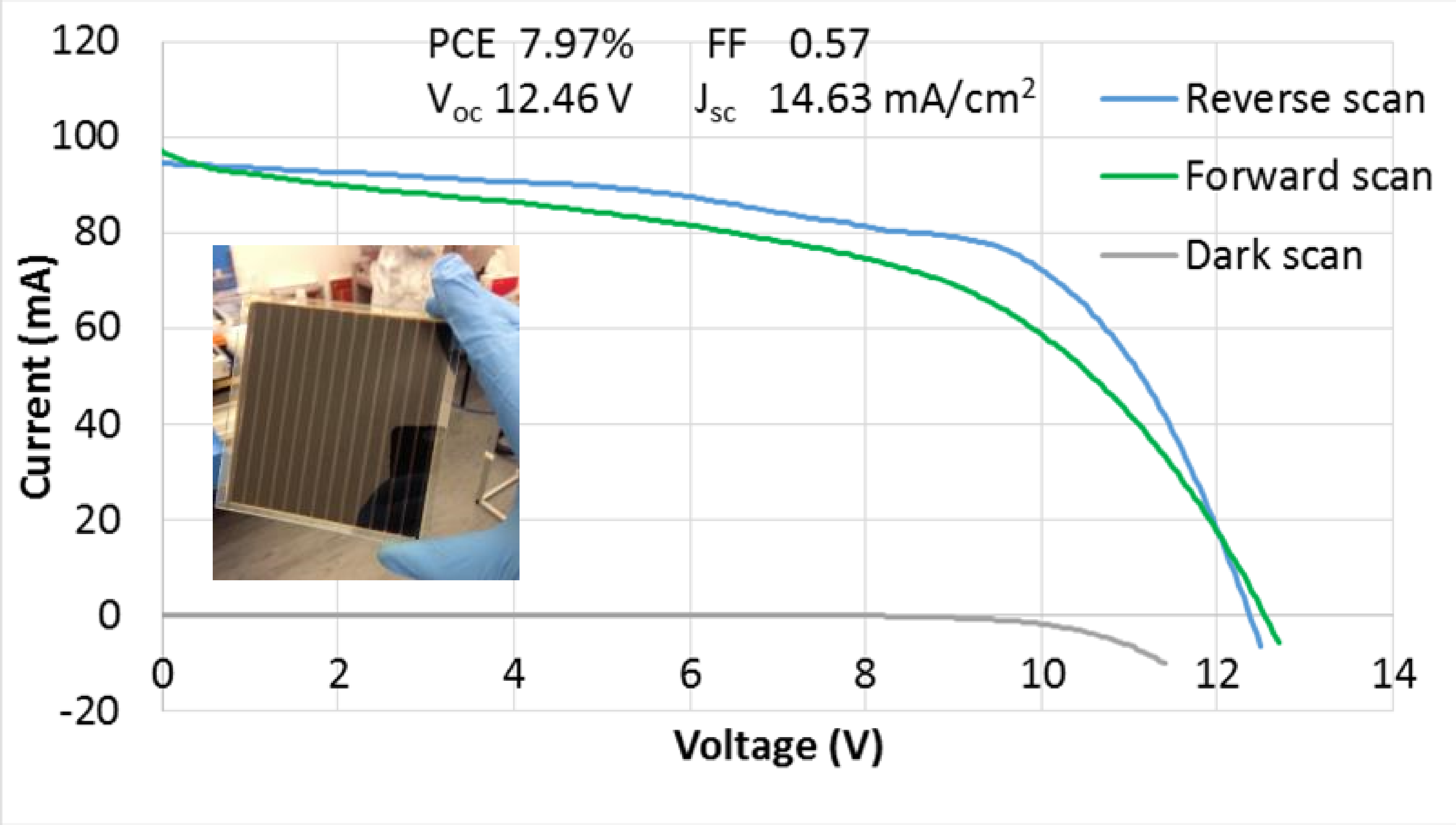
- Both unencapsulated spiro cells and unencapsulated porous carbon cells showed very good light soaking stability under inert atmosphere.
- Unencapsulated cells degraded much faster under light soaking with humidity of 5 – 6% RH → light soaking accelerates the reaction of MALI with O_2 and H_2O.
- **Encapsulated porous carbon cells showed very promising stability under light soaking:** after 1000+ h light soaking, less than 10% relative performance degradation in glovebox and in dry room.

Scale-up of processes and modules

Scale-up of processes and modules

Module of porous carbon cells



Final conclusions

- 2-step MALI enables control over morphology via concentration of the MAI solution
- **Morphology** determines both initial performance and stability of perovskite solar cells: better performing cells are also more stable.
- At Dyesol efficiencies on small scale (1 cm^2) are 13-14% for spiro cells and 11-12% for porous carbon cells. Porous carbon modules are around 7-8%.
- **Storage stability**: for certain morphologies loss in performance after 1000 hours <3% for storage in air and <1% for storage in vacuum
- **Stability under light soaking**: after 1000+ hours illumination, encapsulated devices have a <10% loss in performance .


THANK YOU for your attention