Opal-like $CH_3NH_3PbI_3$ perovskite solar cells : effect of the 3D structuration on the conversion efficiency

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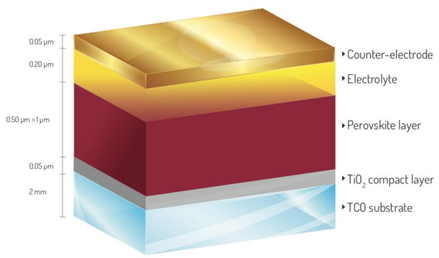
Avec le soutien de la DGO6
Département du développement Technologique
Wallonie Service public de Wallonie

Objective

Dense perovskite photoanode



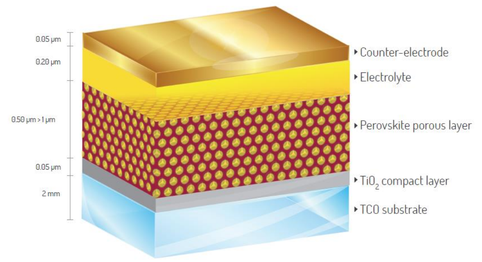
Photonic structure

Optimization of **light interaction** within the layer

Improvement of PV **efficiency** through **photonic effect**

Tuning of cell **coloration/transparency**

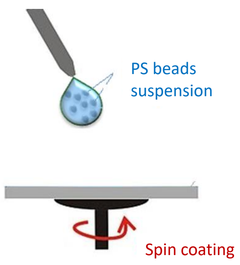
Inverse-opal perovskite photoanode



Opal-like structuration: Templating

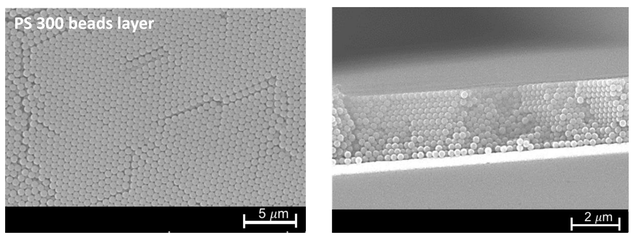
Two-steps deposition: (PS beads layer followed by perovskite precursor infiltration)

1) PS beads as structuring agent



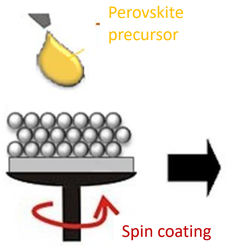
Stabilisation

Experimental settings:
- PS beads suspension: 10% vol. in H_2O/i-PrOH 50/50 vol.
- PS beads diameter: 300nm, 540 nm, 810 nm, 1000 nm, 2100 nm
- Spin-coating parameters: 1000 RPM 30 s
- Stabilisation: 70°C 30 min



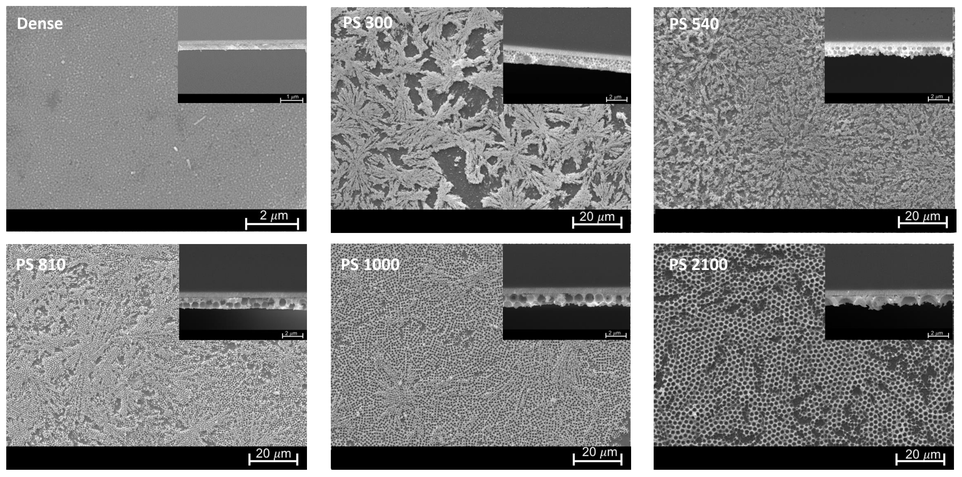
2) Precursor solution infiltration and PS beads elimination

➔ Inverse-opal perovskite porous layer



Crystallisation + Beads elimination

Experimental settings:
- $CH_3NH_3PbI_3$ precursor: PbI_2 + MAI 0.7 M in DMSO
- $CH_3NH_3PbI_{3-x}Cl_x$ precursor: $PbCl_2$ + MAI 1 M in DMSO
- Spin-coating parameters: 2000 RPM 30 s
- Stabilisation: 100°C 1h
- Beads elimination: Toluene 1 min

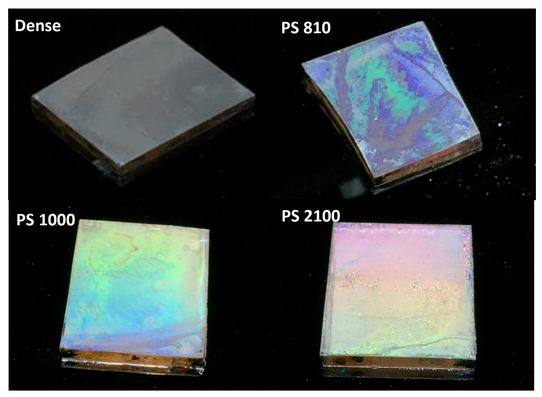


Optoelectronic properties

	$CH_3NH_3PbI_3$				$CH_3NH_3PbI_{3-x}Cl_x$			
Porosity	V_{OC} (V)	J_{sc} (mA/cm²)	FF	PCE (%)	V_{OC} (V)	J_{sc} (mA/cm²)	FF	PCE (%)
Dense	0.316 ± 0.011	2.3 ± 1.2	26 ± 5	0.4 ± 0.4	0.727 ± 0.067	13.7 ± 0.8	51 ± 5	8.0 ± 1.1
PS 300	0.557 ± 0.086	3.0 ± 0.9	37 ± 6	1.0 ± 0.5	0.465 ± 0.093	3.4 ± 3.3	47 ± 8	1.1 ± 1.0
PS 540	0.618 ± 0.065	2.6 ± 0.3	41 ± 3	1.1 ± 0.3	0.461 ± 0.175	3.6 ± 0.6	53 ± 14	1.6 ± 1.1
PS 810	0.721 ± 0.003	3.7 ± 0.2	47 ± 4	1.9 ± 0.3	0.551 ± 0.092	5.2 ± 0.7	47 ± 2	2.2 ± 0.7
PS 1000	0.571 ± 0.020	1.8 ± 0.3	49 ± 8	0.8 ± 0.2	0.514 ± 0.105	7.6 ± 1.7	46 ± 6	3.0 ± 1.2
PS 2100	0.669 ± 0.100	3.8 ± 0.8	54 ± 12	2.3 ± 1.2	0.444 ± 0.178	7.5 ± 2.3	47 ± 8	2.5 ± 1.3

3D structuration ➔ PCE ↗

3D structuration ➔ PCE ↘



Coloration under illumination on silicon substrates

Summary

- Efficiency improvement due to 3D structuration for $CH_3NH_3PbI_3$ samples
  ➔ electron-hole extraction enhancement at the perovskite/Spiro interface
- Efficiency improvement with increasing PS bead size
- Doping effect not obvious for inverse-opal samples

- Tuning of the layer coloration through photonic effect

Acknowledgment

The research was funded through the SOLIDYE_1 Project, Complement FEDER, Grant agreement 1510607 financed by the Walloon Region and supported by the French Community of Belgium (ARC grant for Concerted Research Actions).