StableNextSol
COST MP1307

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Stable Next-Generation Photovoltaics: Unravelling Degradation Mechanisms of Organic and Perovskite Solar Cells by Complementary Characterization Techniques.

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5th MC Meeting, 4th WG Meeting

Lindner Hotel Gallery Central, Bratislava, Slovakia
Bratislava, Slovakia April 21-22, 2016

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ESF provides the COST Office through a European Commission contract

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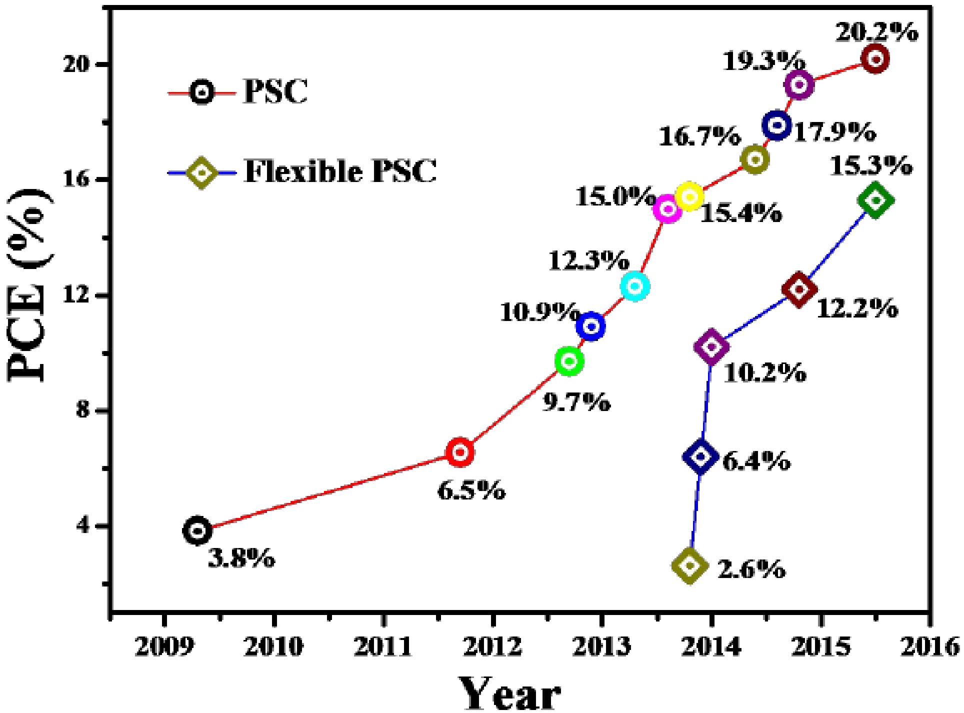
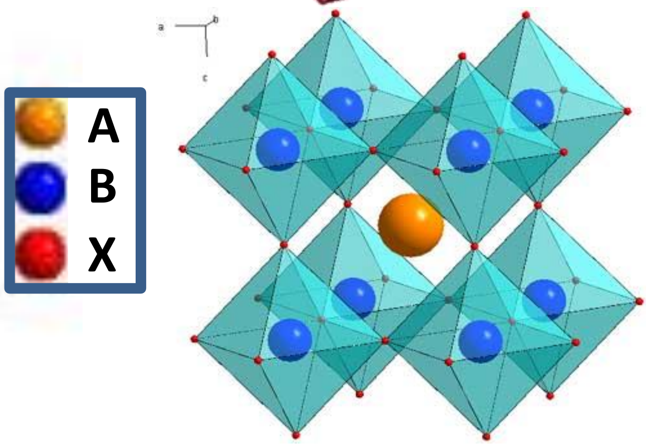
Perovskites: an intriguing emerging technology



Ye et al. J. Mater. Chem. A, 2016, Advance Article



Methylammonium lead halide perovskite

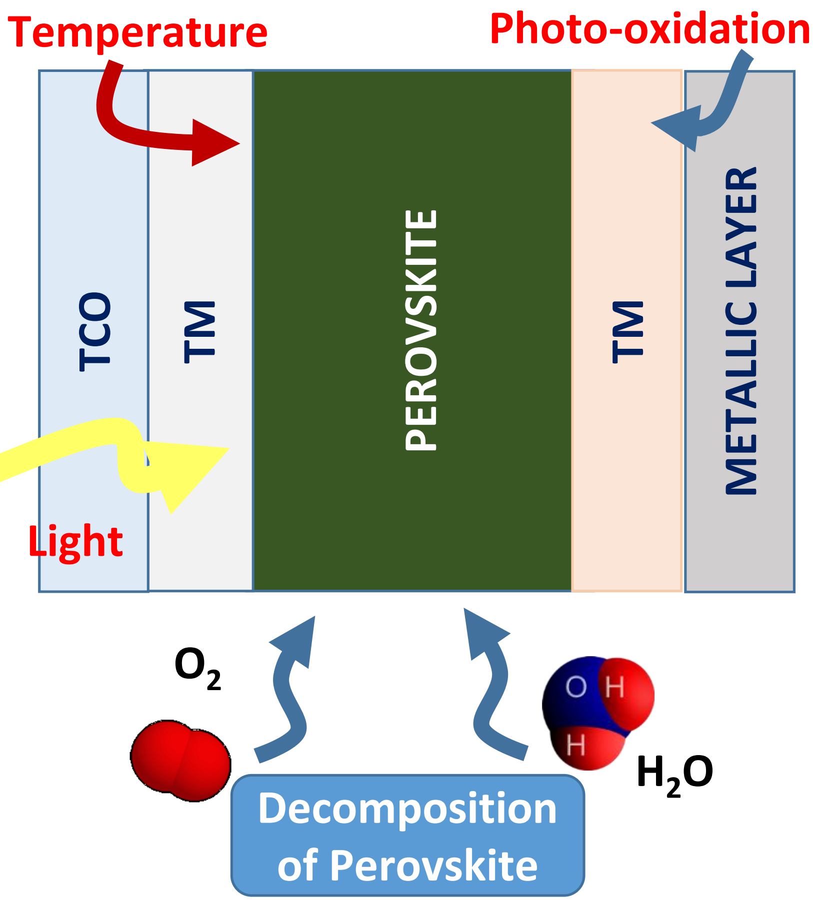
A=$CH_3NH_3^{(+)}$;B= $Pb^{(+)}$; Sn

X= $I^{(-)}$, $Cl^{(-)}$, $Br^{(-)}$

In the last years there has been a very intense activity devoted to the study of perovskites solar cells (PSC) due to their impressive photovoltaic properties, and easy device manufacturing with facile layer deposition by solution processes, suggesting the great potential for large-scale application. The long term stability of PSC is still an open issue strongly related to their commercial viability.

Perovskite solar cells and stability

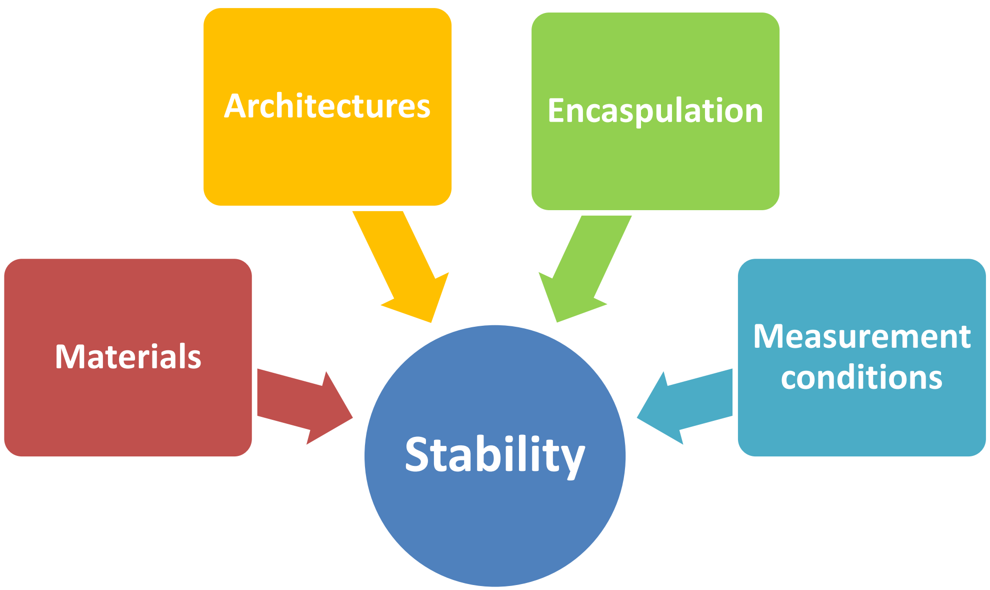
There are 3 main different architectures for perovskite solar cells, namely the planar (regular TiO2 based) and mesoporous structures, where the TCO is the anode, inverted (PEDOT:PSS based), where the TCO is the cathode.



- Electron Transporting Material (ETM)
  - Traps states in TiO2 based devices
  - UV degradation for TiO2 based devices
  - Degradation due to water and oxygen absorption in PCBM based devices
  - Electrode diffusion into PCBM layer which then reacts with perovskite
- Perovskite layer
  - Sensible to water, oxygen and temperature
- Hole transporting material (HTM)
  - PEDOT:PSS: damages ITO electrode and activates the decomposition of active layer for its acidic and hygroscopic nature
  - The Spyro is doped with hygroscopic ions which degrade the active layer and induce the oxidation of the HTM
  - Pinholes in Spyro for the direct structure
- Electrode corrosion

Stability studies on perovskites

To date, the degradation mechanism of PSC when subjected to environmental stresses such as moisture and heating cycles is not clearly understood.



Cell Configuration	J_{SC} (mA/cm^2)[a]	V_{OC} (V)[b]	FF[c]	Initial PCE (%)[d]	Stability Test Condition		Degradation Percentage (%)	Ref
FTO/bl-TiO_2/mp-TiO_2/$MAPbI_3$/Al_2O_3/Spiro-OMeTAD/Au	11.11	0.86	0.46	4.60	18 h, air, sunlight, humidity (H) ~60%, 35 °C, without sealing		52	[136]
FTO/bl-TiO_2/Al_2O_3/$MAPbI_3$/Spiro-OMeTAD/Al_2O_3/Ag	20.35	1.05	0.71	15.2	576 h, air, H ~50%, RT, without sealing		10	[137]
FTO/bl-TiO_2/$MAPbI_{3-x}Cl_x$/Spiro-OMeTAD/Al_2O_3/Au	20.62	1.03	0.62	13.07	350 h, AM1.5G illumination, with sealing		5	[138]
FTO/bl-TiO_2/mp-TiO_2/$MAPbI_3$/PDPPDBTE/Au	14.4	0.855	0.749	9.2	1000 h, air, H ~20%, room temperature (RT), without sealing		9	[131]
ITO/Cu: NiO_x/$MAPbI_3$/PCBM/Ag	19.01	1.11	0.73	15.40	240 h, air, without sealing		10	[141]
ITO/NiO_x/$MAPbI_3$/ZnO/Al	21.0	1.01	0.76	16.1	1440 h, air, H: 30-50%, 25 °C, without sealing		10	[146]
FTO/bl-TiO_2/mp-TiO_2/$MAPbI_3$/spiro-OMeTAD/Au	19.87	0.89	0.721	12.75	250 h, air, RT, one sun illumination, without sealing		10	[132]
FTO/bl-TiO_2/mp-TiO_2/$MAPbI_3$/TTF-1/Ag	19.9	0.86	0.644	11.03	500 h, air, H ~40%, RT, without sealing		27	[133]
ITO/SnO_2/$MAPbI_3$/spiro-OMeTAD/Ag	19.5	1.08	0.616	13.0	720 h, air, without sealing		10	[107]
ITO/ZnO/$MAPbI_3$/spiro-OMeTAD/Ag	19.9	1.07	0.65	13.9	480 h, air, without sealing		8	[143]
FTO/ZnO NRs/$MAPbI_3$/spiro-OMeTAD/Ag	12.7	0.68	0.58	5.0	500 h, air, RT, without sealing		13	[97]
FTO/NiMgLiO/$MAPbI_3$/PCBM/Ti(Nb)O_x/Ag	20.62	1.072	0.748	16.2 (area = 1.02 cm^2)	168 h, air, H < 20%, dark, without sealing		3	[56]
					1000 h, air, H < 20%, 45-50 °C, with sealing	dark	3	
						AM 1.5, 100 mW cm^{-2}	10	
FTO/bl-TiO_2/mp-TiO_2/$MAPbI_3$/TSHBC/graphene/Au	21.91	0.97	0.66	14.02	240 h, air, H ~45%, AM 1.5G illumination, without sealing		10	[134]
FTO/bl-TiO_2/mp-TiO_2/ZrO_2/$MAPbI_3$/Carbon	22.8	0.858	0.66	12.8	1008 h, air, AM1.5G illumination, without sealing		~5%	[62]

M. Ye, X. Hong and X. Liu, *J. Mater. Chem. A*, 2016, DOI:10.1039/C5TA09661H.

COST Action for perovskites

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The COST action can benefit of the large number of partners both from the realization and from the characterization side to try to:

1. Investigate the aging phenomena using already established aging protocols (ISOS)
2. Asses, if necessary, a possible protocol for device characterization
3. Investigate in detail some specific aging phenomena tanks to the interaction between the cost partners

EXPERIMENT 1 Organization

Participant scouting
25^{th} April-6^{th} May 2016

→

Experimental session
June 2016-July 2016

→

Outcomes
Meeting in Crete
October 2016

EXPERIMENT Description

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Main experiment description: Top down

Device realization
- Different architectures
- Same time

→

Characterization
- Non-destructive
- Destructive

→

Outcomes
Meeting in Crete
October 2016

Secondary experiments: Bottom up

Suggestion from the COST partners to study a specific characteristic

→

Device/materials realization and characterization

→

Outcomes
Meeting in Crete
October 2016

EXPERIMENT Description

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What did we learn from previous experiments?

- Timing is critical! It was difficult to have devices prepared at the same time
- Spread in the characteristics of the realized devices (different efficiencies,lifetime…)
- Characterizion was quite time consuming for OPV for perovskites could be even longer!
- Data analysis requires a big effort (large number of data)

What could we do?

- Use a doodle to agree on one day of fabrication and delivery.
- Select producer that can deliver reproducible (as much as possible!) devices
- Define a common way to ship samples
- Agree on a measurement protocol to characterize the devices
- Use programs which allows the efficient data analysis

Call for production and characterization partners

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Production partners

- Type of device
- How many devices can I produce?
- What parameter for the aging I want to investigate?
- Request of possible characterization technique

Characterization partners

- Type of technique available
- Which parameter can be investigated?
- How many samples can I analyze?
- Request of possible devices/layers

EXPERIMENT outcomes

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Outcomes from the main experiment

- Are the PSCs stable? Under which conditions?
- Taking into account of the conditioning step required for measurement which is a reliable parameter to evaluate the stability of the device (efficiency vs time, Maximum power vs time other?)
- How to measure hysteresis?
- How to measure these parameter? → Protocol

Additional outcomes (more on the basic physics..)

- How is the stability influenced by device parameters i.e. interfaces, Crystallization kinetics, Chemical composition, Transporting layer, Encapsulant etc?
- Role of encapsulants
- Other additional infos related to device and material proposed characterizations

Thank you!

francesca.brunetti@uniroma2.it

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