Stable Next-Generation Photovoltaics: Unravelling Degradation Mechanisms of Organic Solar Cells by Complementary Characterization Techniques
StableNextSol – MP1307

-Stability of TANDem solar cells by Impedance Spectroscopy –

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M. Guillaume SCHUCHARDT, Dr. Beatriz ROMERO HERRERO, Dr. Solenn BERSON, Dr. Gerard PERRIER

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EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

TITLE: Stability of TANDem solar cells by Impedance Spectroscopy (STANDIS)

HOST Laboratory /Country and PI: Universidad Rey Juan Carlos - Spain
GUEST Laboratory/ Country and PI: CEA Liten/LOCIE - France
ESR Name: Guillaume SCHUCHARDT
Duration: 1 Month

Objectives: The main goal is to study the degradation of tandem and single organic solar cells by means of IS

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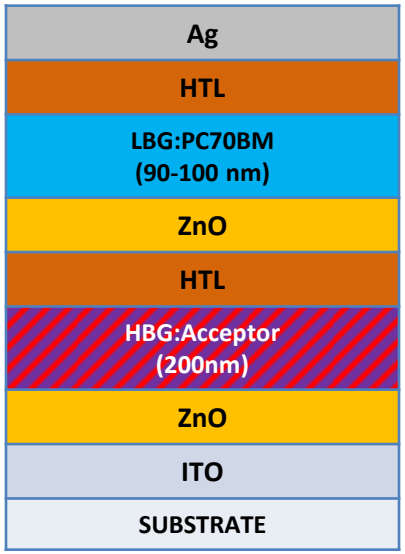
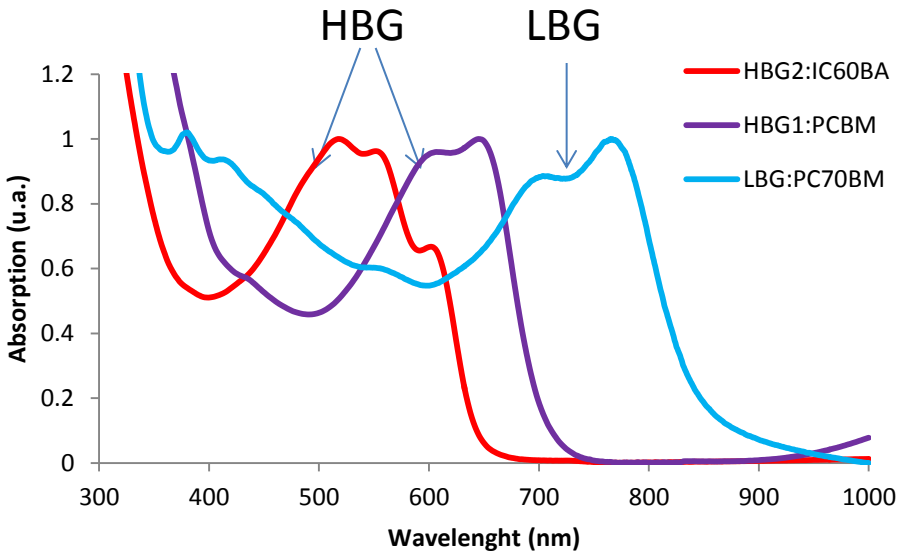
DE LA RECHERCHE À L'INDUSTRIE

LOCIE

Universidad Rey Juan Carlos

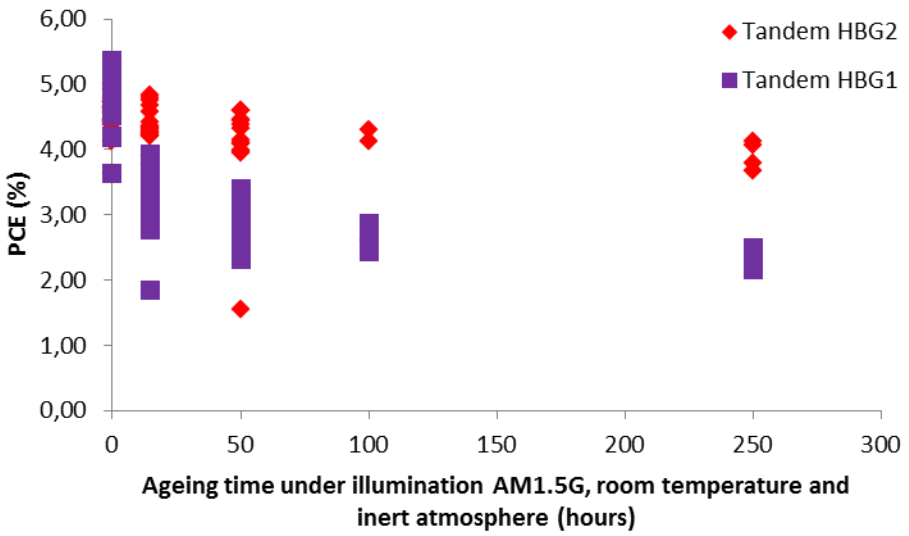
• Context





	Voc (mV)	Jsc (mA/cm²)	FF (%)	PCE (%)
HBG1:PCBM/LBG:PC70BM	1 339	7,37	52,53	5,19
HBG2:IC60BA/LBG:PC70BM	1 293	8,41	58,18	6,33

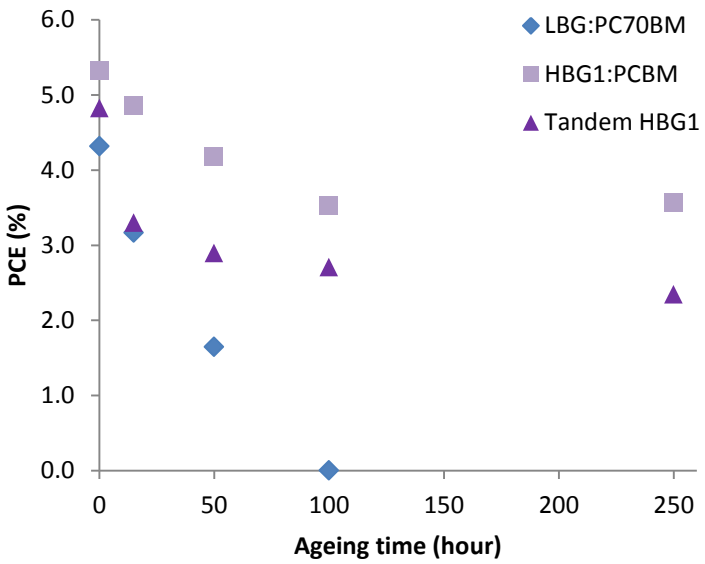
• Context

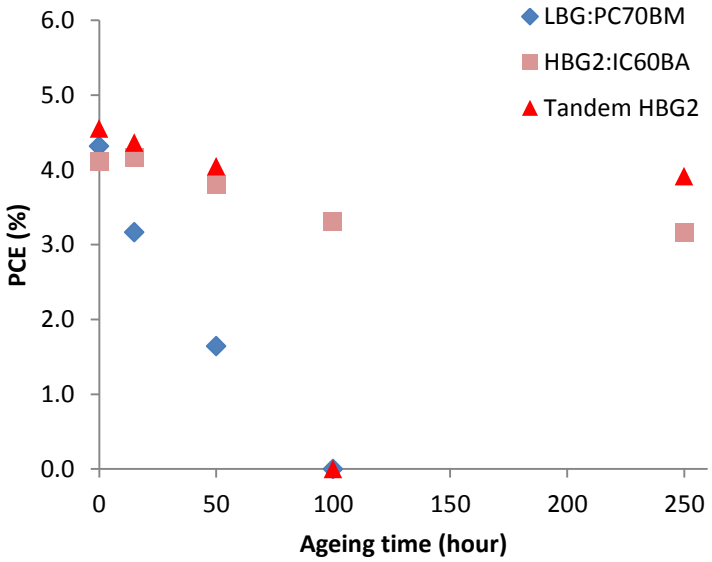


- **Two different profiles of intrinsic degradation with the same LBG material**

→ What is the influence of the HBG ?

• Context

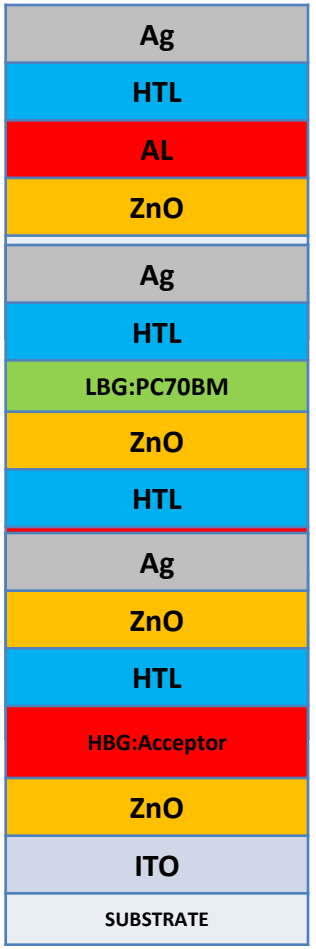




• **Tandem architecture is more stable than the combined single cell architecture (especially the LBG active material)**

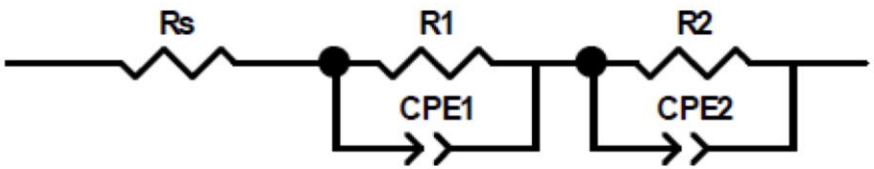
• Experiments

- **Evolution of :**
  - Single cells
    - HBG2:IC60BA
    - HBG1:PCBM
    - LBG:PC70BM
  - Tandem cells
    - HBG2:IC60BA/LBG:PC70BM
    - HBG1:PCBM/LBG:PC70BM
  - Semi-tandems
    - HBG2:IC60BA
    - HBG1:PCBM
- **Ageing conditions :**
  - Under illumination AM1.5G in inert atmosphere (in bag) and at room temperature



• Experiments

- **Measurements :**
  - Different DC potentials were applied for each architecture:
    - Two negative voltages, -1V and -0.5V, in order to check the geometrical capacitance
  - Several positive voltages: from 0V to 0.9V for the single and the special architectures, and from 0V to 1.5V for tandem architecture with an increment of 0.1V for each of all.
- **An AC voltage, with amplitude of 50mV, was applied with a range of frequency comprised between 1 Hz and 10^6 Hz with an increment of 5 points per decade.**



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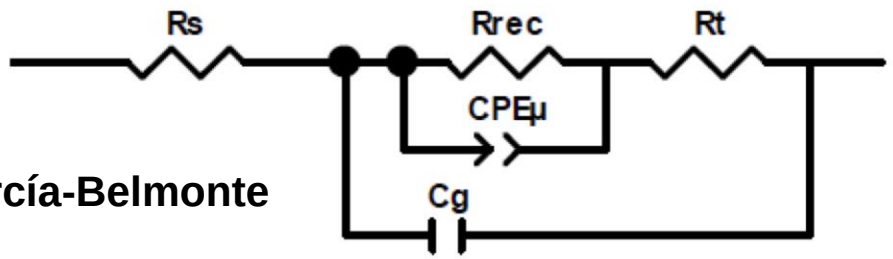
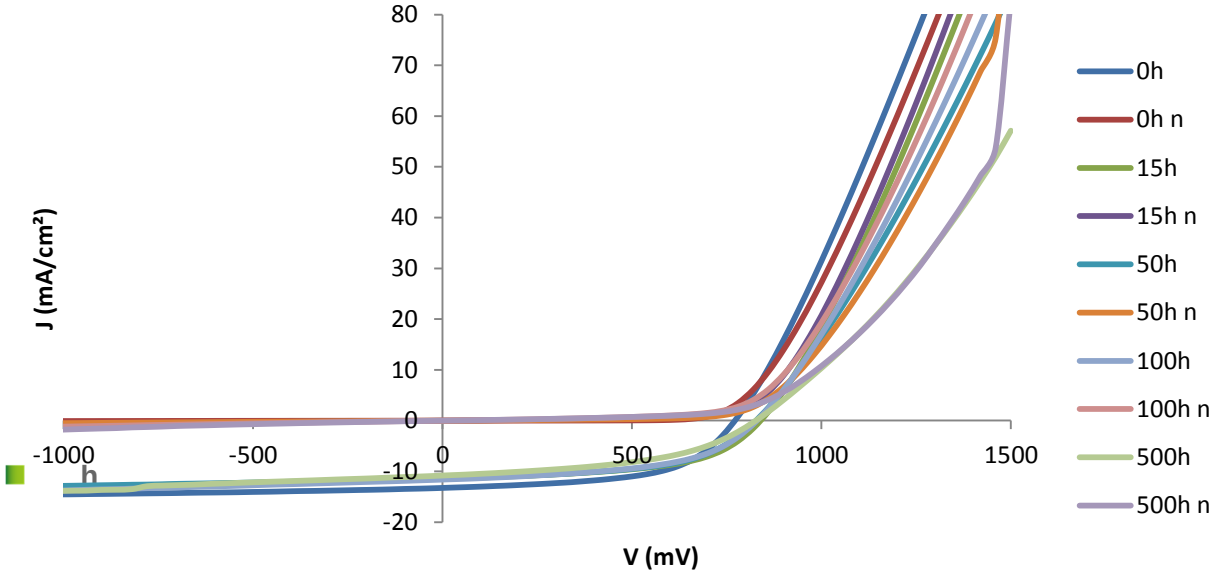
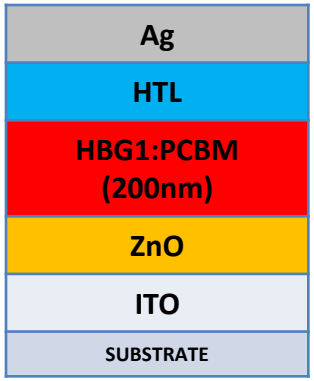


García-Belmonte

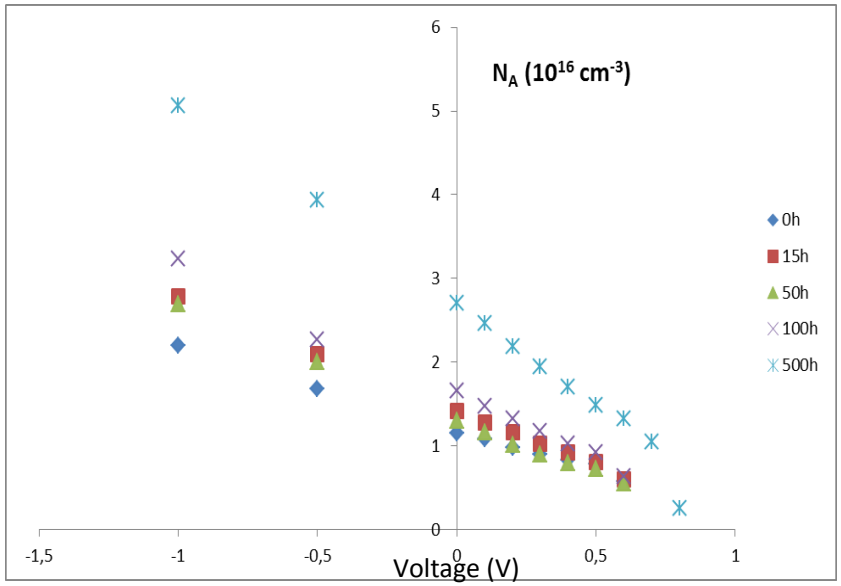
- **First results with single cell HBG1:PCBM**





Ageing time (hour)	Voc (mV)	Jsc (mA/cm²)	FF (%)	PCE (%)
0	771	13.2	56	5.7
15	837	11.4	55	5.3
50	825	11.3	54	5.1
100	827	11.6	52	5.0
500	825	10.8	47	4.2

• Experiments



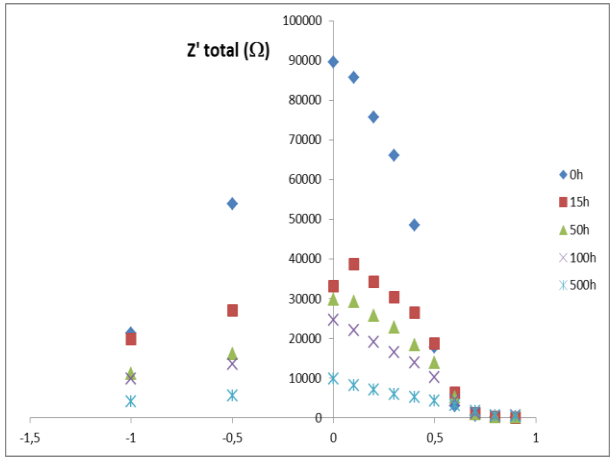
Ageing time (h)	0	15	50	100	250
Vbi (V)	0,67	0,68	0,68	0,67	0,82

$$\frac{1}{C^2} = \frac{2(V_{bi} - V)}{A^2 e \varepsilon \varepsilon_0 N_A}$$

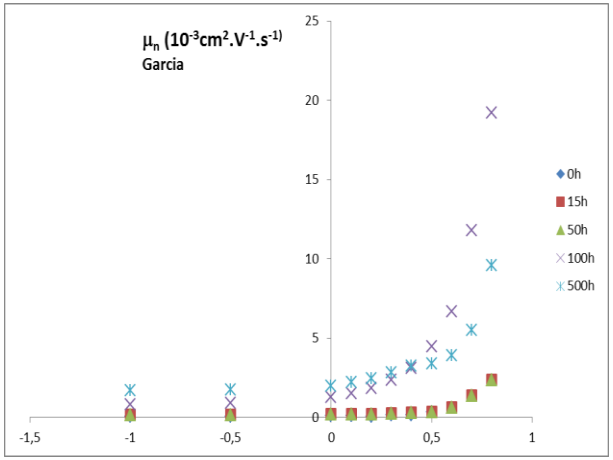
- *V* being the applied bias voltage
- *A* the active area
- e the elementary charge
- ε the relative dielectric constant of the medium
- ε_0 the permittivity of vacuum

- The plot of the whole capacitance at a 10kHz versus bias allows the building of the Mott-Schottky diagram, giving the built-in potential V_{bi} and therefore the concentration of acceptor impurities N_A

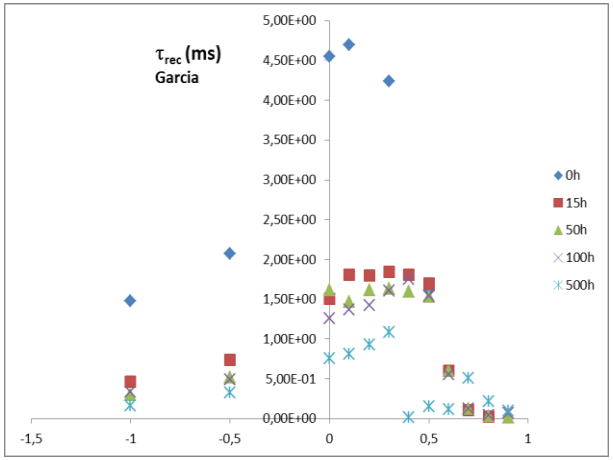
• Experiments



Voltage (V)



Voltage (V)



Voltage (V)

- The whole cell resistance is unsurprisingly at her higher value for 0 bias, when no charge is injected from outer source. Resistance is seen to highly decrease with ageing
- <u>Mobilities</u> are in the range of 0.04 - 0.6 $10^{-3}cm^2V^{-1}s^{-1}$ for 0 bias and for ageing time up to 50h. These values are slightly lower as compared to classical P3HT:PCBM cells
- Effective lifetime of charge carriers is around 4.5ms for the initial cell at 0v in the dark, decreasing down to 1ms with ageing.

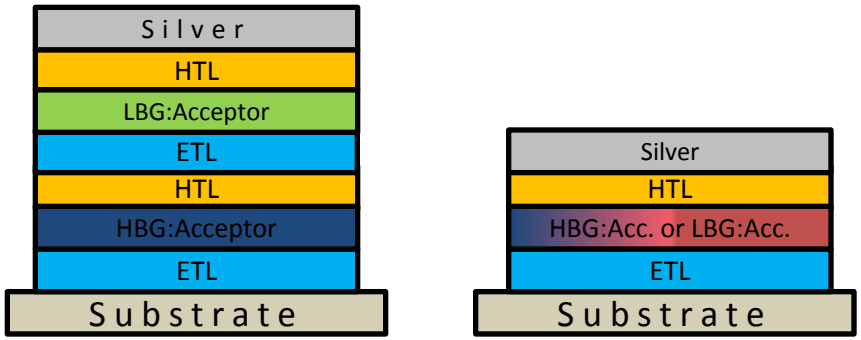
• Perspectives

- **Better understanding of the ageing degradation.**
- **Fitting of all the architectures to isolate each layers**
- **Characterization at different times stored in the dark and under illumination AM1.5G in inert atmosphere of :**

Material investigation :

- Work function : **SKP**
- Measurement of the diffusion length of minority carriers : **SSPG**

Complete device investigation :



- Performance : **JV Curves**
- Quantum efficiency : **EQE,IQE**
- Charge transport and recombination : **CELIV**

• FUTURE WORK AND COMMENTS

- Possible publications focused on degradation process of single and tandem cells.
- The experiments brought a lot of useful information about the electrical properties of the cells and would allow us to understand the degradation mechanisms.

→ Need to procces the measurements for all the architectures

SUMMARY AND CONCLUSIONS

- Single, tandem and semi-tandem cells, at different degradation levels, have been characterised by means of IS.
- Impedance spectroscopy is a very useful technique to obtain parameters involved in dynamical processes.
- Preliminary results indicate that in single cells:
  - Leakage current increases with degradation.
  - Recombination increases with degradation

- This STSM was a very useful and fruitful experience