Technical University of Cartagena (UPCT) - Spain

University created in 1998 (formerly part of University of Murcia)

7207 students (2014); (of which 792 postgraduates)
631 teaching and research staff
396 technical and administrative staff

Focused on Engineering (mechanical, electrical and electronic, chemical, agronomical, architecture, also economical sciences). A few postgraduate programs, one of them devoted to Renewable Energy.
Technical University of Cartagena (UPCT) - Spain

10 min!
“Advanced materials for energy applications”
“Quantum Energy” R&D groups at UPCT

Staff:  
- Jose Abad (PhD experimental physics)  
- Javier Padilla (PhD electrochemistry)  
- Antonio Fernández (PhD electrochemistry)  
- Antonio Urbina (PhD experimental physics)

Postdoc researchers: Lucía Serrano (PhD now at Imperial College)

PhD students:  
Carlos Toledo  
Rodolfo López  
Soffiane Hassab

Collaboration and possible merging with UPCT group “Quantum Many Body Systems”:  
Javier Prior, Javier Molina and Enrique Castro (quantum physics, theory)

We are part of MP1307- Cost Action: Stable Next-Generation Photovoltaics: Unraveling degradation mechanisms of Organic Solar Cells by complementary characterization techniques.

Close collaboration with:  
**Imperial College London** (J. Nelson, J-S. Kim, N. Stingelin)  
**DTU Denmark** (F. Krebs)
Outline

- OSCs fabrication
- Materials and devices: indoor characterization
- Devices and modules: outdoor characterization
- Life Cycle Analysis for Energy Technologies
Organic Solar Cell fabrication

Standard and inverted organic solar cells, small modules

Spin casting

OSC sizes: from 1mm² to 2cm²

Evaporation/sputtering

Dr. Blade

Screen printing

Automated spray coating

Limitations: commercial materials, no glove box, no clean room.
Indoor testing of organic solar cells (and materials)

- Solar simulator AM1.5G, class AAB
- Precission electronics (Keithley)
- Controlled temperature (1.2K-400K)
- Controlled atmosphere
- Magnetotransport (up to 12T)
- Software developed in LabView

Degradation studies:
- Ageing (dark/light)
- Temperature cycles
- Photodegradation
- Humidity/gases

Also: UV-Vis spectroscopy, Impedance spectroscopy, AFM and access to neutron scattering and synchrotron radiation facilities (ILL, ISIS, ESRF, Diamond)
Organic Solar Cell fabrication at UPCT

Active layer:
P3HT/PCBM; 1cm²
PCE: 2-2.5% typical, some up to 3.1%

Moving towards other materials for active layers, ETL, HTL and electrodes.
Characterization of materials for organic solar cells: calorimetry, electronic transport, EQE, UV, IR and Raman spectroscopy

Calorimetry of P3HT

Quantum conductance steps in MWNT

PEDOT/Ag nanorods

Raman spectroscopy of doped CNT (in collaboration with KAIST-Korea and ICL-UK)
Neutron scattering: dynamics (INS, IQNS)

\[ S(Q, \omega) = \exp \left\{ -\frac{\langle u_{\text{vib}}^2 \rangle}{3} Q^2 \right\} \mathcal{L}(\omega, \Gamma_1) \otimes \{ A(Q) \delta(\omega) + [1 - A(Q)] \mathcal{L}(\omega, \Gamma_2) \} \]
Neutron scattering: structure (SANS, NR)

SANS

NR

Reflectivity vs. Q (Å⁻¹)

Reflectivity vs. Q (Å⁻¹)

PCBM (% vol)

Air

Thickness (nm)
Outdoor testing: solar tracker
Outdoor testing: solar tracker + electrical scheme

Measuring IV curves and feeding the grid
Relays are controlled through the Parallel Port and we can measure individually each OPV module of one string without affecting the rest of the facility:

![Diagram of electrical scheme](image-url)

- AC/DC converter
- Microinverter for Grid connection
  - SINEO 250W
  - MPPT and PLL
  - Vdc=14-80V
  - Idc nom < 5A
- Keithley 2401
  - Vdc source 5uV-21V
  - Idc measure 10pA-1.05A
- IV measuring on OPV module #3
- Up to 71 parallel strings
- <70mA
- <76.8 V (12.8x6)
Outdoor testing: home made, flexible and reliable

DC relays, regulator, MPP and transformer

DC/AC microinverter

Environmental sensors

Communications and datalogger
Outdoor testing: solar tracker parameters

• Electrical:
  o $V_{oc}$, $I_{sc}$, $V_{mp}$, $I_{mp}$, FF (individual or group of modules)
  o I-V curves (individual or group of modules)
  o Input DC current & voltage to the DC/AC (LEM)
  o Output AC current to the grid (LEM).

• Environmental
  o Global Radiation (CMP3 Kipp& Zonnen)
  o Global & Diffuse Radiation (BF5 Delta-T)
  o Cell & Ambient Temp. (EL001 PT 100, PicoTech)
  o Relative Humidity (EL026, PicoTech)
  o Wind speed and direction.
Brief description of other monitorized PV facilities

**Si-SAPV:**
Stand alone multicrystalline Silicon (4.2kWp)

**CdTe:**
Grid-connected Thin film CdTe (222kWp)

Possibility of access to additional 1.2MWp grid connected Si systems
Si-SAPV: Stand alone multicrystalline Silicon (4.2kWp)

40 modules **ISOFOTON 106/24MC**, total installed 4.2kWp (35m2)

PV generator (40 modules)

4 parallel lines of 2 series x 5 parallel modules

Charge regulator

DC Battery Voltage

Inverter

**ISOVERTER 3000**

AC 220V Voltage

AC Load

24 Series connected Batteries Bank

ISOTEL 40 SD

(* For clarity only one terminal wiring is shown

**ISOFOTON 2AT2300**

Lead-acid (open)
CdTe: Grid-connected CdTe (222kWp)

- 30 groups connected to 30 inverters: SUNNY MINI CENTRAL 7000HV
- 10 “supragroups”: with inverters working coordinately to feed electricity into triphasic grid.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Module connection</th>
<th>Module (First Solar)</th>
<th>Surface (m²)</th>
<th>Peak power (kWp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>8/13 (8 parallel stripes each of them composed of 13 modules connected in series)</td>
<td>FS-270 (70Wp)</td>
<td>1123.20</td>
<td>109.20</td>
</tr>
<tr>
<td>3</td>
<td>8/14</td>
<td>FS-267 (67.5Wp)</td>
<td>291.92</td>
<td>22.68</td>
</tr>
<tr>
<td>12</td>
<td>8/13</td>
<td>FS-272 (72Wp)</td>
<td>898.56</td>
<td>90.48</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>2263.68</td>
<td>222.36</td>
</tr>
</tbody>
</table>

Sunny-Sensor box: calibrated a-Si photodiode for global irradiation sensor, ambient and module temperature, anemometer
CdTe: Grid-connected CdTe (222kWp)

CdTe First Solar FS series

Inverters

Sensor “box”
Data acquisition: common structure for both PV systems

• Each inverter (30) (CdTe) and the regulator (Si-SAPV) provides “internal” parameters
• Additional parameters from external sensors.
• MySQL database with remote access enabled.
Life Cycle Analysis of OSC technology

ISO 14044 (advanced standardization process)
Access to EcoInvent Database (and others)
Also economic analysis
Life Cycle Analysis of OSC technology

**MODULES ITO–FREE**

Embedded energy in the sputtering process (402 MJ EPE)

**MODULES ITO-BASED**

Embedded energy in ITO sputtering process (268 MJ EPE)

**System Costs**

Cost per MWh (€/kWh)

Cost per MWh (€/kWh)

**LEC (€/kWh)**

- Max
- Min

- OPV

ITO Electrode
- HC-PEDOT:PSS Electrode

2% Tech Dev model
- 5.6%, 10 year life

2% Tech Dev model
- 5.6%, 10 year life

Mature PV on rooftop
- Mature PV

Wind
- Hydro
Some references about LCA and economics

**Life cycle analysis of organic photovoltaic technologies**

**Economic assessment of solar electricity production from organic-based photovoltaic modules in a domestic environment**

**A life cycle analysis of polymer solar cell modules prepared using roll-to-roll methods under ambient conditions**

**Environmental and economic assessment of ITO-free electrodes for organic solar cells**

**Life cycle assessment of ITO-free flexible polymer solar cells prepared by roll-to-roll coating and printing**
Espinosa, N.; Garcia-Valverde, R.; Urbina, A.; et ál.. SOLAR ENERGY MATERIALS AND SOLAR CELLS, 97, 3-13 (2012)

**Solar electricity in a changing environment: The case of Spain**
Urbina, A., RENEWABLE ENERGY, 68, 264-269 (2014)

**Environmental benefits of parking-integrated photovoltaics: a 222 kWp experience**

**Life cycle assessment study of a 4.2 kW(p) stand-alone photovoltaic system**
Some references about materials and devices characterization

**Work function engineering of ZnO electrodes by using p-type and n-type doped carbon nanotubes**
Urbina, Antonio; Park, Ji Sun; Lee, Ju Min; et ál.. NANOTECHNOLOGY, 24, 484013 (2013)

**Molecular dynamics of solutions of poly-3-octyl-thiophene and functionalized single wall carbon nanotubes studied by neutron scattering**

**Molecular structure of poly(3-alkyl-thiophenes) investigated by calorimetry and grazing incidence X-ray scattering**

**Synthesis and electro-optical characterization of new conducting PEDOT/Au-nanorods nanocomposites**
Salsamendi, M.; Abad, J.; Marcilla, R.; et ál.. POLYMERS FOR ADVANCED TECHNOLOGIES Volumen, 22, 1665-1672 (2011)

**Isolated rigid rod behavior of functionalized single-wall carbon nanotubes in solution determined via small-angle neutron scattering**

**Dynamics of functionalized single wall carbon nanotubes in solution studied by incoherent neutron scattering experiments**
Some references about degradation studies

**Kelvin probe microscopy and current images of the degradation process of layered poly-3-octyl-thiophene structures**

**Consensus stability testing protocols for organic photovoltaic materials and devices**
Reese, M. O.; Gevorgyan, S. A.; Jorgensen, M.; et ál..
SOLAR ENERGY MATERIALS AND SOLAR CELLS, 95, 1253-1267 (2011)

**Influence of UV radiation and ozone exposure on the electro-optical properties and nanoscale structure of P3OT films**
Abad, J.; Urbina, A.; Colchero, J. ORGANIC ELECTRONICS, 12, 1389-1398 (2011)

**The influence of UV radiation and ozone exposure on the electronic properties of poly-3-octyl-thiophene thin films**
Abad, J.; Espinosa, N.; Garcia-Valverde, R.; et ál..
SOLAR ENERGY MATERIALS AND SOLAR CELLS, 95, 1326-1332 (2011)
Within the framework of “NanoSOL”
UPCT is Subproject 5,

leading WG5 (LCA) and participating in WG2, 3, 4

Objectives – SUBP5:

○ Perform LCA of the organic solar cells and modules, including material inventory and environmental impact of materials and processes. (WP5)

○ Calculate economic cost of organic solar modules and LCOE (including BOS costs). (WP5)

○ Fabrication and characterization of organic solar cells by pilot printing technologies in air, including stability studies. One deliverable will include printed battery on the back of the module. (WP 2, 3, 4)
Thank you for your attention!!