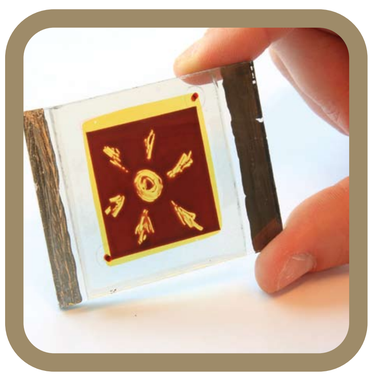
Laboratory of Photovoltaics and Optoelectronics

University *of Ljubljana*
Faculty *of Electrical Engineering*

LPVO R&D activities in Photovoltaics



Lab-scale technology for dye-sensitized SC

Characterisation of SC and PV modules

Education

Modeling and simulation of SC and PV modules

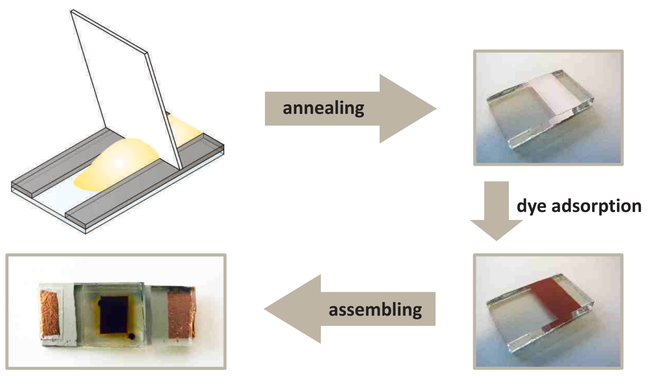
Monitoring and analysis of PV modules and systems

University of Ljubljana
Faculty of Electrical Engineering
Laboratory of Photovoltaics and Optoelectronics
Tržaška 25, SI-1000 Ljubljana, Slovenia

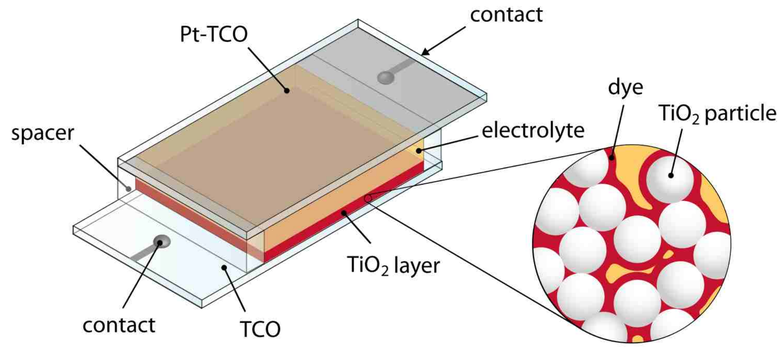
lpvo.fe.uni-lj.si

Dye-Sensitized Solar Cell Technology

Fabrication



Structure

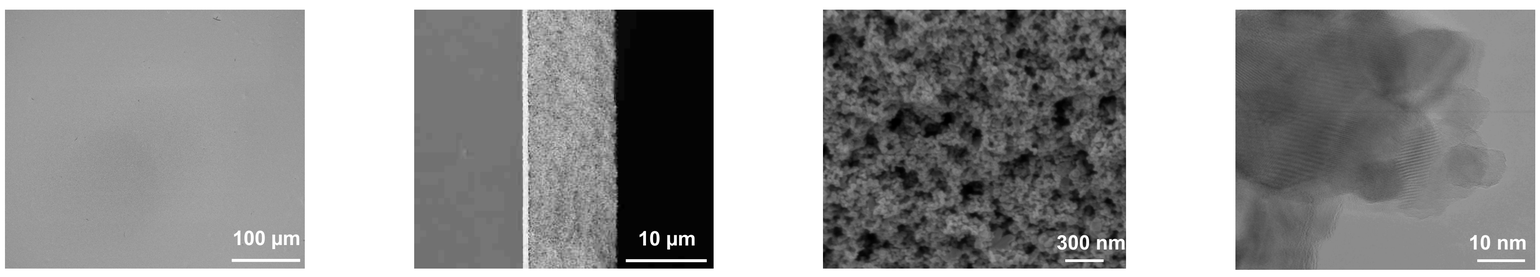


Activities

- Development of TiO_2 and other metal oxide (Wo_3, WO_3/TiO_2, SnO_2, ...) pastes and inks
- Design and fabrication of DSSCs
- Testing and optimization of electrolytes
- Testing of dyes
- Stability studies (indoor and outdoor)
- Development of advanced DSSC systems
- ...

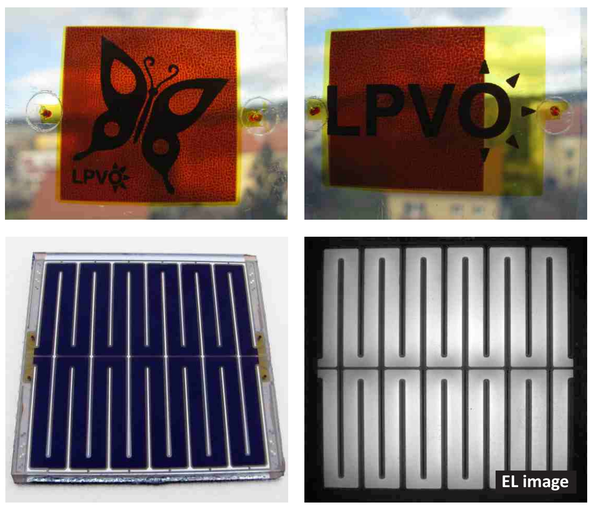
Sponge-like TiO_2 paste

- Sol-gel chemistry and TiO_2 nanopowder
- Good adhesion to TCO
- Uniform and smooth surface
- High surface area
- Well-connected TiO_2 network

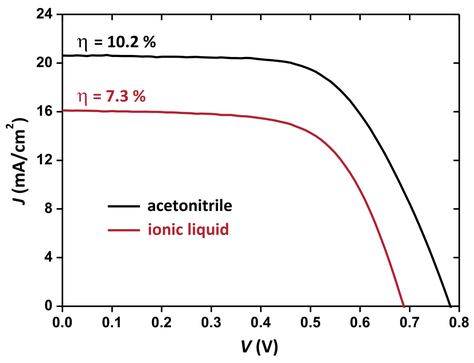


DSSCs and PV modules

Ink-jet printer Dimatix Materials 2831 (Fujifilm)



I/V characteristics

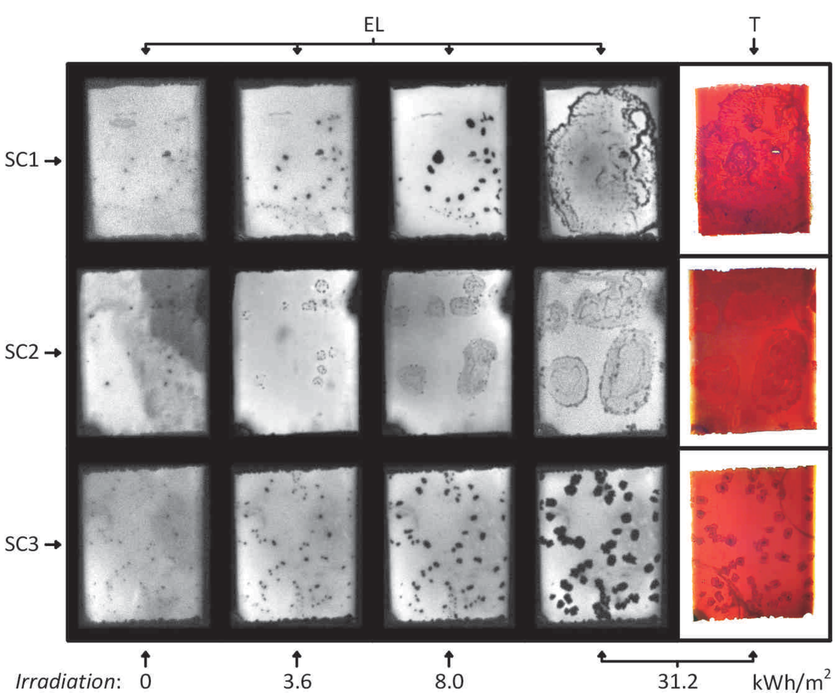


The *I/V* characteristics of the record DSSCs based on acetonitrile and ionic liquid electrolytes.

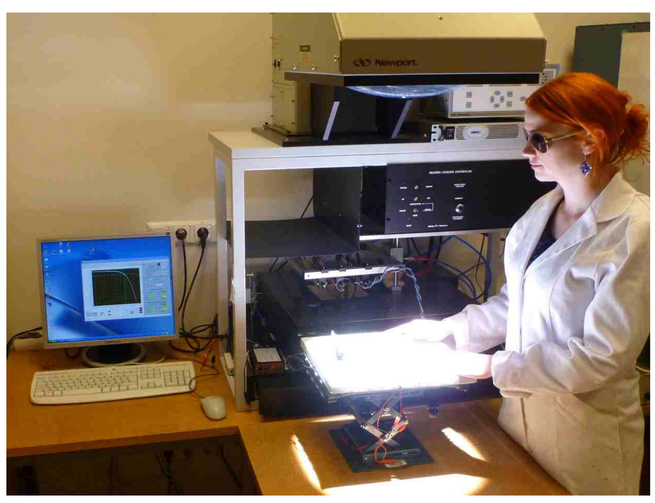
Characterization of Solar Cells and PV Modules

Measuring equipment

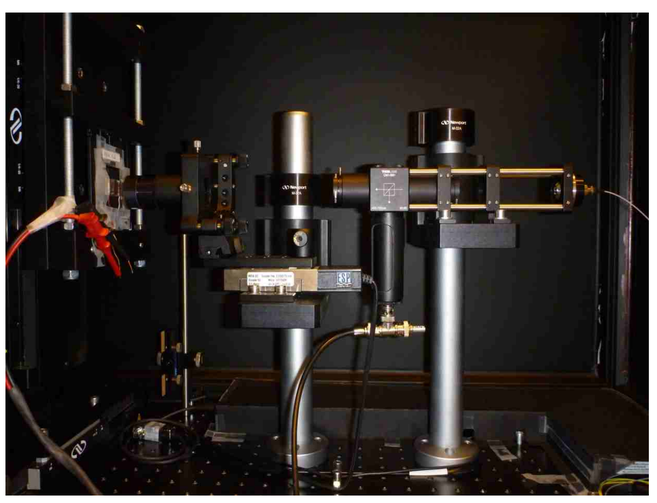
- UV-VIS-NIR spectroscopy Lambda 950 (Perkin Elmer)
- Angular resolved scattering measurement setup
- Impedance spectroscopy
- *I/V* characterization (Newport Solar simulator AM1.5 - class A)
- Spectral response measurement setup
- Light beam induced current (LBIC) setup
- Electroluminescence imaging setup
- ...



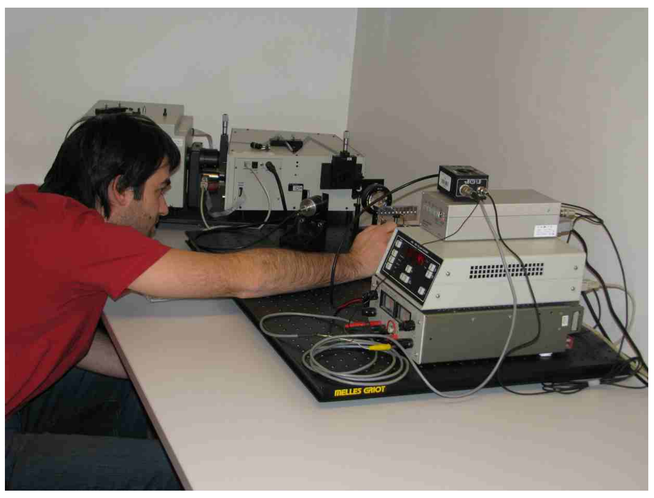
Electroluminescence (EL) and transmission (T) images of the DSSCs aged under SC mode taken at different stage of the ageing period presented with the accumulated irradiation of the solar energy.



I/V characterization setup



Light beam induced current setup



Spectral response measurement setup

Angular resolved scattering measurement setup

Modeling and Simulation of SC and PV Modules

Optical

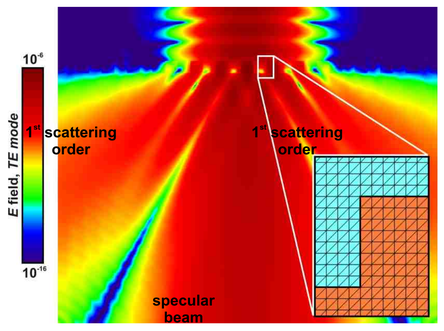
- 1D simulation of inorganic and organic TFSC with nano-textured interfaces (**Sun*Shine***).
- 2D, 3D full-wave simulation of TFSC with textured interfaces (**FEMOS, Comsol, MEEP**).
- 2D, 3D combined modelling approaches for simulation of TFSC including micro-scale interface textures (**CROWM**).

Electrical

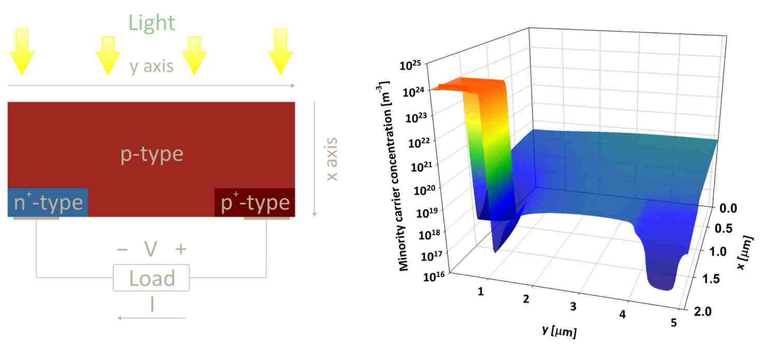
- 1D and 2D simulation of SC: drift-diffusion model enhanced with models of thermionic emission and quantum tunneling (**ASPIN2**).
- Simulation of amorphous silicon, micro- and poly-crystalline silicon and chalcopyrite SC exhibiting local inhomogeneities (e.g. CIGS), and dye-sensitized solar cells (DSSC).

PV modules

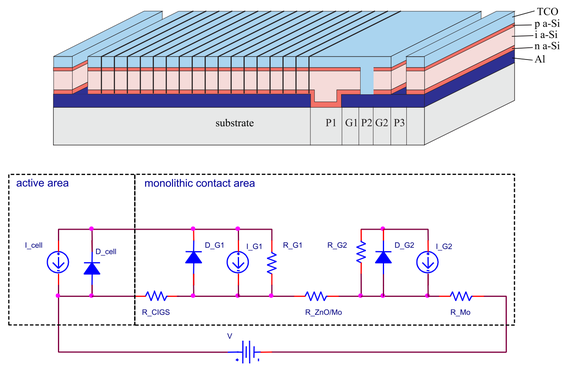
- 1D and 2D simulation of thin-film and conventional PV modules (**SPICE**).
- Simulation of electrical losses in monolithic contacts.
- 2D electrical simulation of the local defects (shunts) in thin-film solar cells.



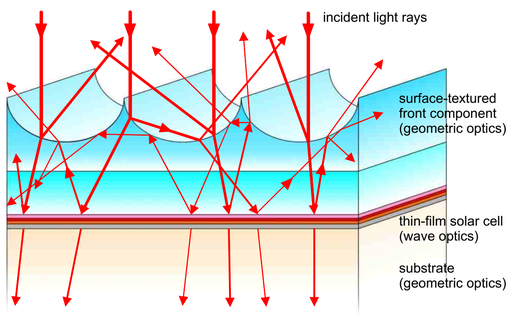
Rigorous FEM simulation (**FEMOS**) of light scattering by means of a one-dimensional rectangular periodic grating.



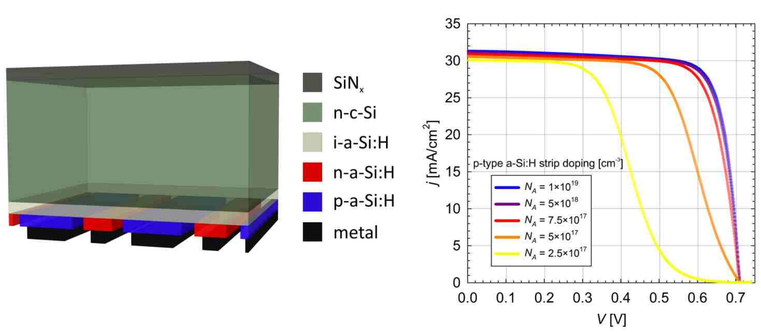
Simulation (**ASPIN2**) of the minority carrier density profile (electrons in this case) in a back-contacted silicon SC.



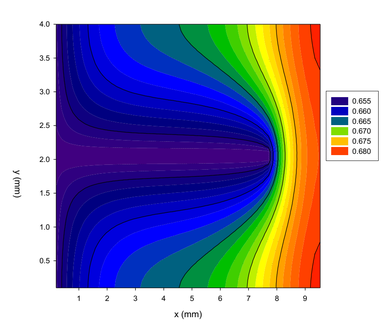
A cross-sectional schematic view of a typical thin-film module with active area 1D discretization and equivalent electrical circuit of an individual solar cell.



Combined geometric optics / wave optics simulation (**CROWM**) of a TFSC with a thick surface-textured front component.



Simulation (**ASPIN2**) of an interdigitated back-contacted silicon heterojunction SC with different doping levels of the *p*-type hydrogenated amorphous silicon.

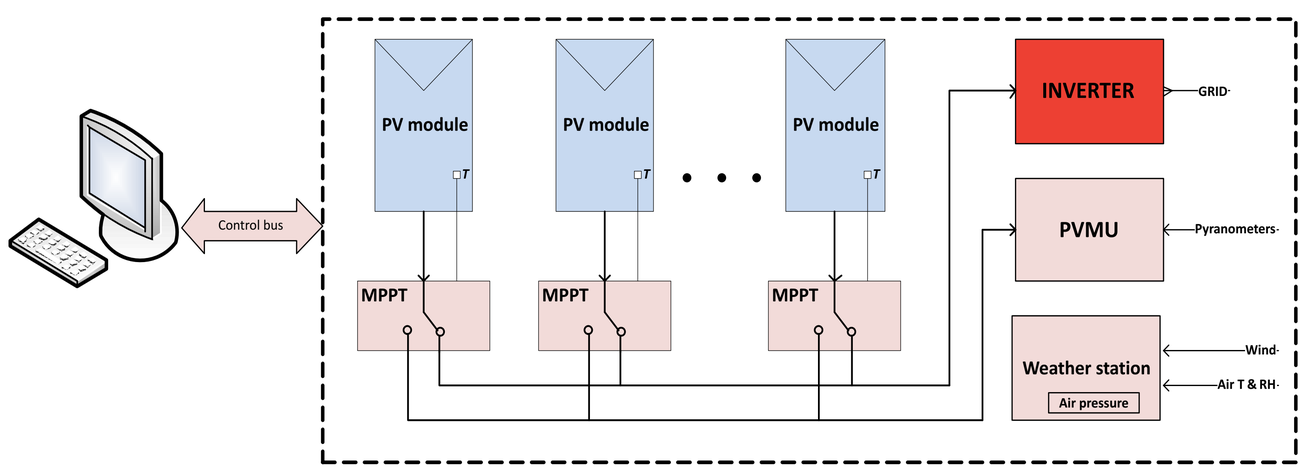


Electrical potential on the surface of a thin-film solar cell with metal grid fingers.

Monitoring and Analysis of PV Modules

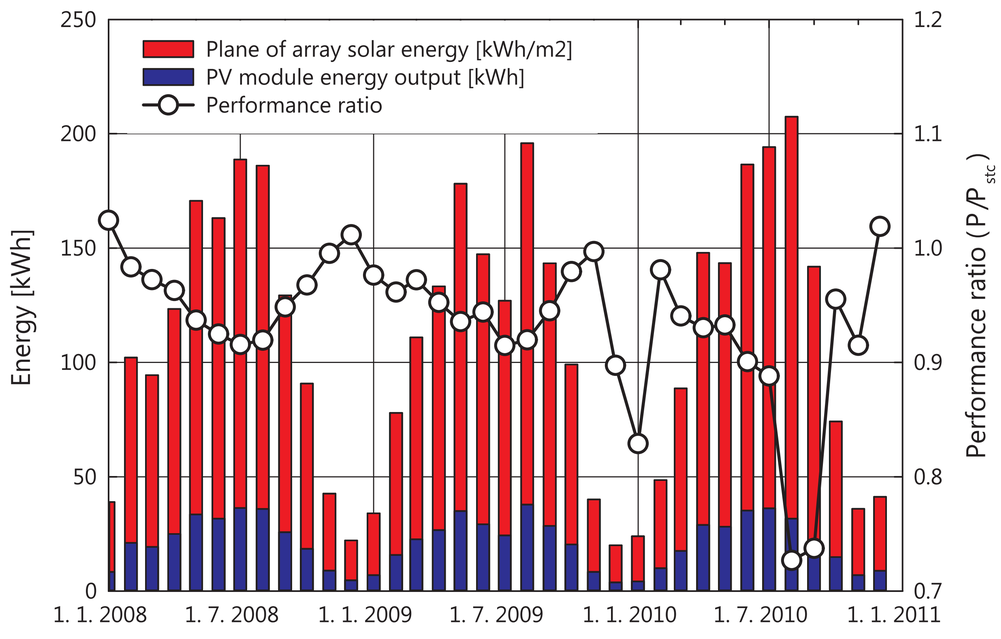
Characteristics

- Four-wire connection of each PV module to IV scanner
- IV scan accuracy (voltage 0.1 %, current 0.2 %)
- Class A pyranometers and spectraly matched reference cells
- 24 PV modules in standard configuration - easily expandable
- Open/Short circuit or MPP load conditions
- PV module max. ratings: 200 V / 10 A / 400 W
- Up to 32 temperatures monitored on each PV module (± 1 °C)
- No energy is wasted - a grid connected system
- Procedures comply to EN60891 & 60904



Each PV module is equipped with MPPT

>20 PV modules are countinously monitored



mc-Si PV module results