Photovoltaïque et Photobatterie : Des matériaux aux dispositifs

Luc Brohan & Mireille Richard-Plouet

Institut des Matériaux Jean Rouxel (IMN) Nantes, France

Photovoltaic, Photobattery
CESES Research Themes

11 Permanents :
3 Chercheurs CNRS,
8 Enseignants-Chercheurs

15 Non permanents :
1 Ingénieur
4 Post-Doc
10 Thésards

Objectifs : i) Réduire le coût de production du Watt-crête photovoltaïque, ii) Améliorer les rendements, iii) Convertir et stocker l'énergie solaire.

Photovoltaïque :

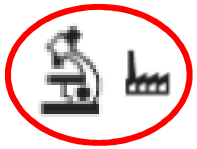
- CIGS (IMN-CESES**/44Solar/Wysips,** IMN/PCM**/Crosslux**)
- Hybrid Solar Cells (OPV) (IMN-CESES/CEA-INES/**Armor/PCAS)**
- Cellules à bandes intermédiaires (MiB)) (IMN/CESES-PMN**,** Nantes; LΦA, Angers), Nano-OxTi (IMN-CESES**/PCAS)**

Photobatterie : Nouveau dispositif permettant la **conversion et le stockage** de l'énergie solaire (IMN/CESES-ST2E/**Armor**)

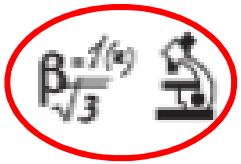
Advanced Materials, Novel Concepts and Technology Transfer

- Prototypes, Design & Processing
  - 8 => 9

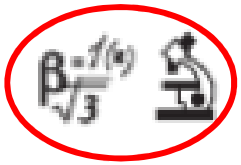
- Test, Prove and Technology Transfer
  - 6 => 7



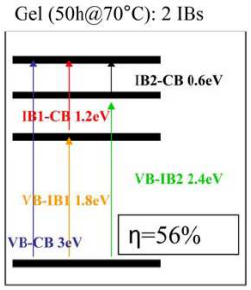
- Advanced Materials
  - 5 => 6

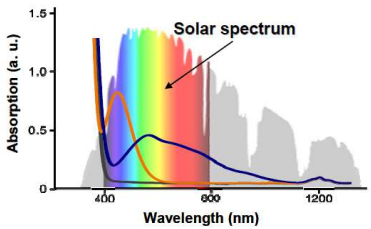


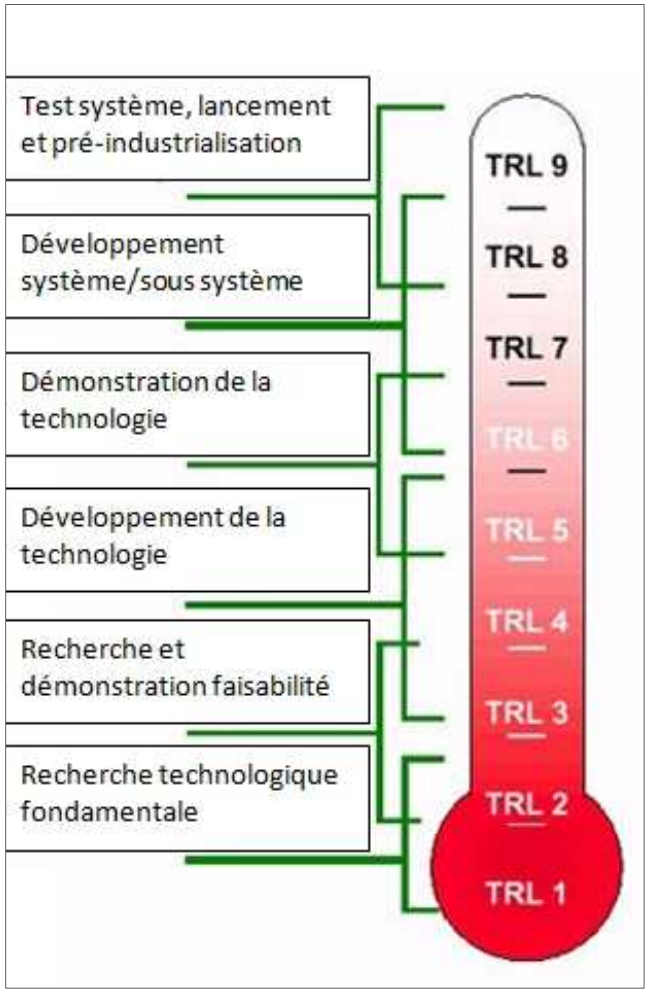
- Concept Validation
  - 3 => 4



10X10 cm^2





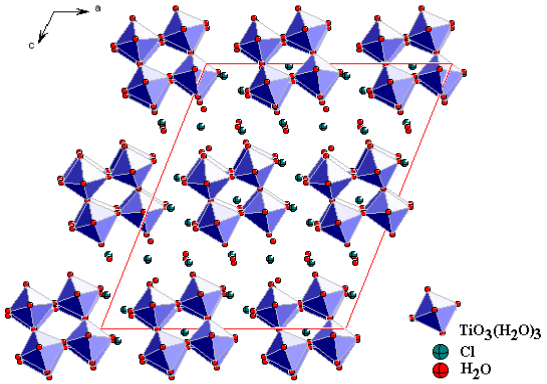


Advanced Materials

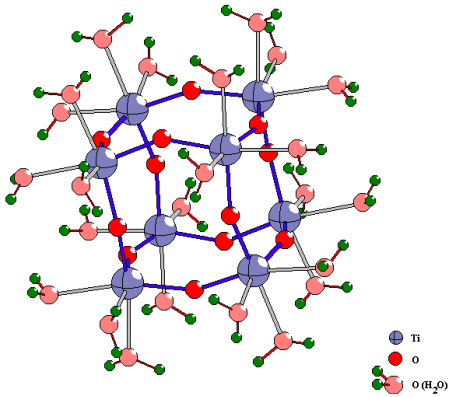
New titania precursor : [Ti8O12(H2O)24]Cl8.HCl.7H2O

8 ($TiOCl_2$, 1.4HCl 5H_2O) => $[Ti_8O_{12}(H_2O)_{24}]Cl_8.HCl.7H_2O$ + 5H_2O + 18.2HCl

$[Ti_8O_{12}(H_2O)_{24}]Cl_8.HCl.7H_2O$ Crystals (1)

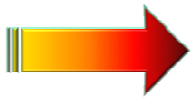


Crystalline structure in projection along [010].



Polycation-unit : $[Ti_8O_{12}(H_2O)_{24}]^{8+}$
Diam $_{long}$ ~ 1.4 nm

Scale-Up Materials (2) *(Scale Factor x 700)*



pcas more than chemistry

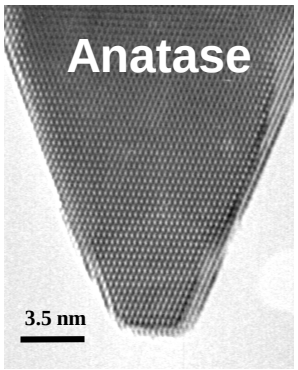
(3)

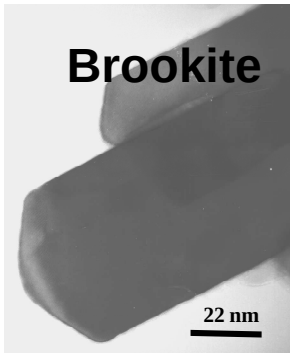
1) *Titanium aquo-oxochloride and preparation method thereof. L. Brohan, H. Sutrisno, E. Puzenat, A. Rouet, H. Terrisse. - French CNRS patent delivered N° 0305619 (07/07/2006) ; International Publication n° WO 2004/101436 A2 (25/11/2004) ; EP CNRS patent n° 04 742 604.4 (24/11/2005) ; JP CNRS patent n°2006-530327, delivered January 25, 2011 ; US CNRS patent n° 018344/0578, delivered 18/08/2010.*

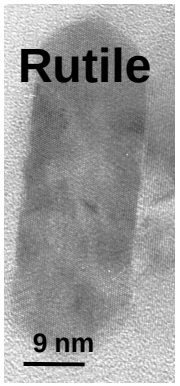
2) ANR Emergence, Nano-OxTi, (2013-2014) IMN/CESES-LIMATB, Lorient

3) ANR Progelec Tandori (2012-2014), (S. Berson, CEA/INES), Post-Doc Moustafa El Kass, 2012-2013 IMN/CESES

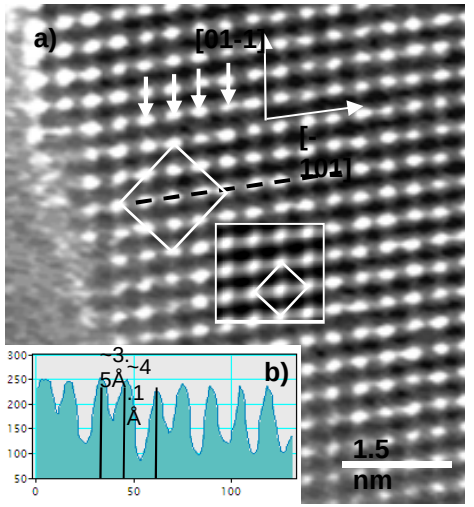
TiO_2 : Tailoring particle morphology, size and allotropic variety



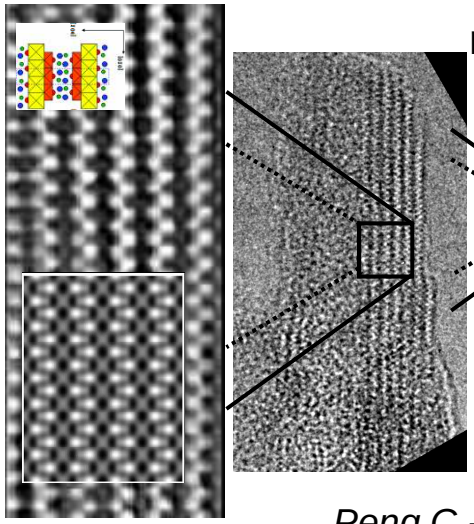




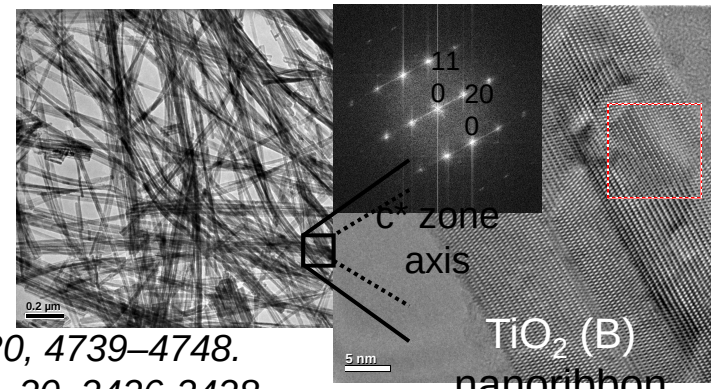
TiO_2 single crystals



L-T Anatase single crystal

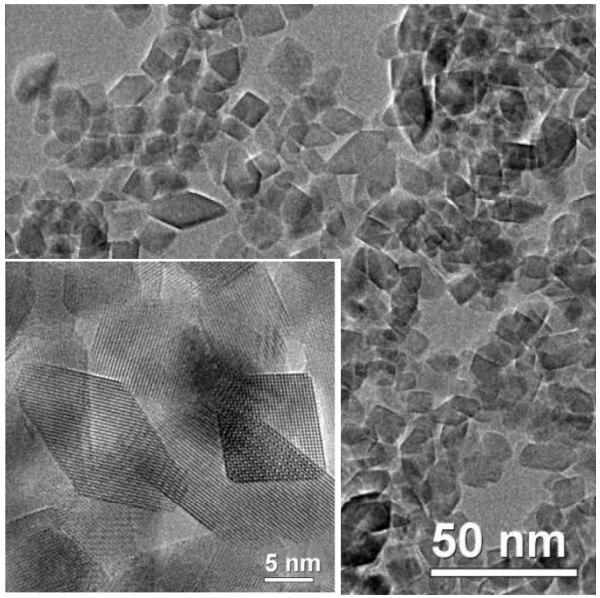


nanotube, semi-nanotube or nanoribbon

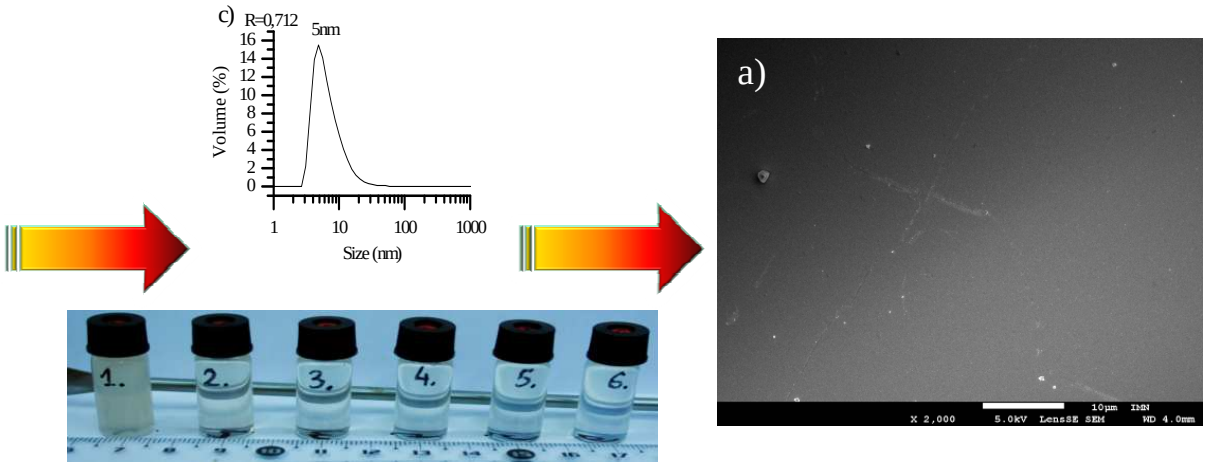


C.-E. Liu & al, Chem. Mater. 2008, 20, 4739–4748.
Peng C.-W. & al, Chem. Mater. 2008, 20, 2426-2428.
Peng C.-W. & al, Crystal Growth & Design, 2008, 8(10), 3555-3559.
Peng, C-W & al, Chem. Mater. 2008, 20(23), 7228-7236.
T. Beuvier & al, J. Phys. Chem. C 2009, 113, 13703–13706, T. Beuvier & al, J. Phys. Chem. C, 2010, 114 (17), pp 7660–7665; T. Beuvier & al. Inorg. Chem., 2010, 49, 8457–8464.

From Anatase TiO_2 single crystals to stable colloidal solutions suitable for printing technologies

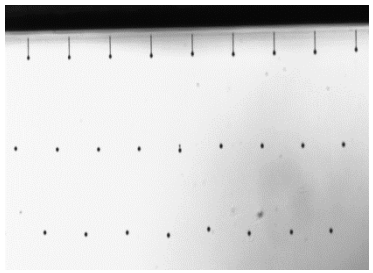


Anatase :
TiO_2 single crystals (1)



Stable colloidal solutions for Ink-jet and Roll-to-Roll printing

Thin-film deposition (20nm) magnification x 2000 (1-2)

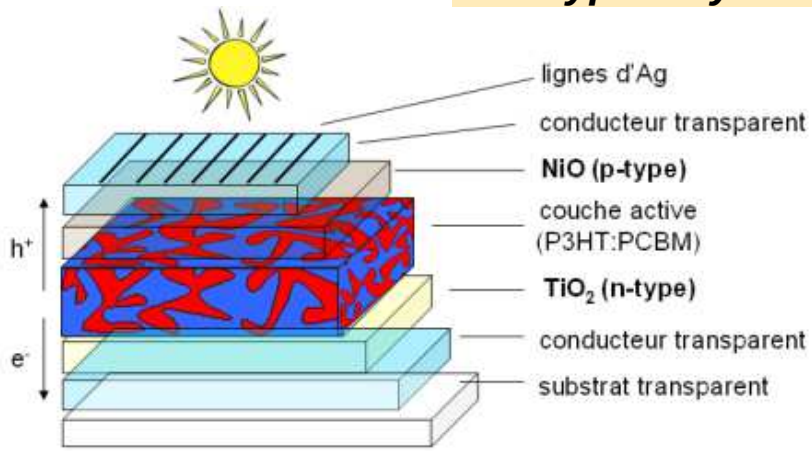


*TiO_2, Ink-jet Printing, (**ARDEJE**-Valence)*

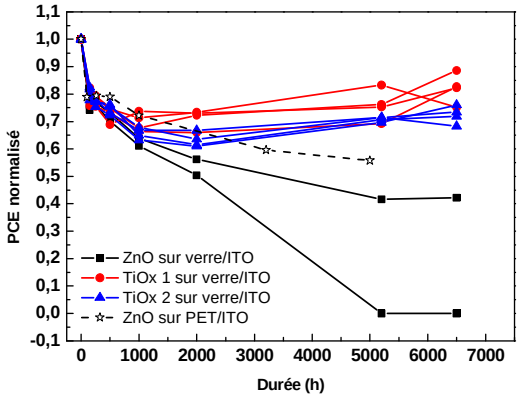
1) *Ph.D thesis, CESES/IMN Nantes, A. Karpinski (2009-2011), V. Jouenne, (2011-2013)*
2) *Brohan L., Karpinski A., Richard-Plouet M., Berson S., Guillerez S., Barret M., French CNRS-CEA, Ardège, Patent N°11 58275, (October 18, 2013), PCT|EP2012|067 N°WO 2013/050222 A1 (April 11, 2013).*

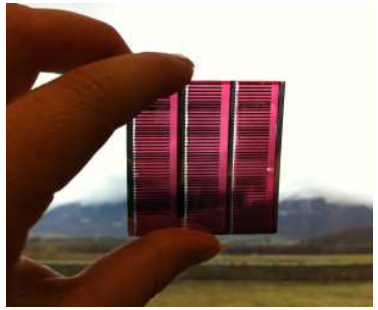
Enhancing performance

Solhypin: Hybrid Organic Solar Cells PIN (1-2)



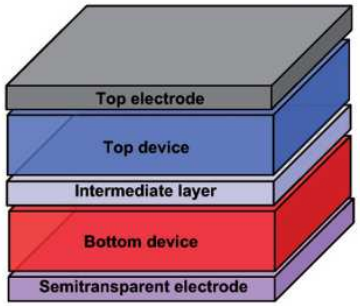
Concept of semi-transparent hybrid organic solar cell.

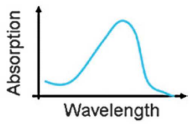




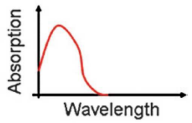
Power conversion efficiency (normalized values) of organic solar cells having TiO_2 charge transporting layer

Tandori: Tandem Organic Solar Cells (3)





LBG



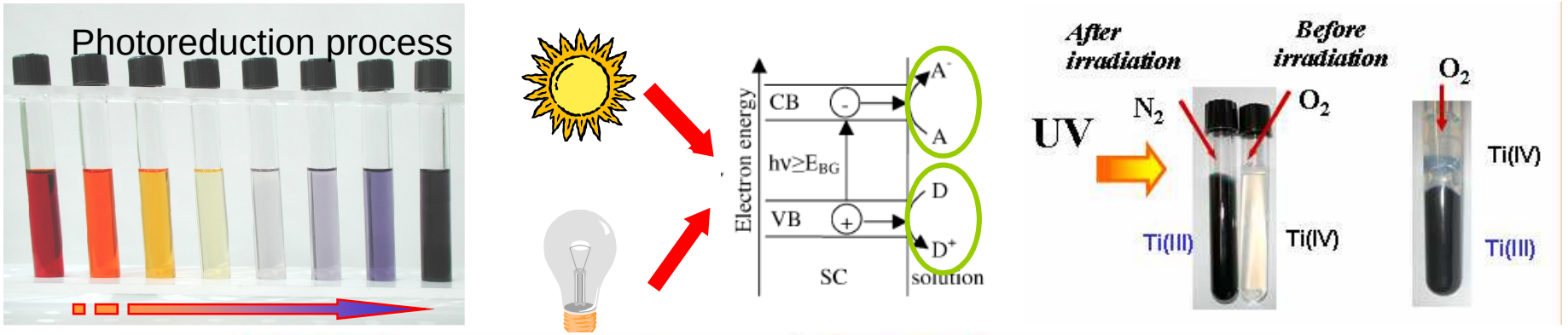
HBG

CEA INES/LMPV, Chambéry
CEA/LEMOH, Grenoble
CNRS, LIPHT, Strasbourg
IM2NP, Marseille
CNRS, IMN/CESES, Nantes
ARMOR, Nantes
PCAS, Paris

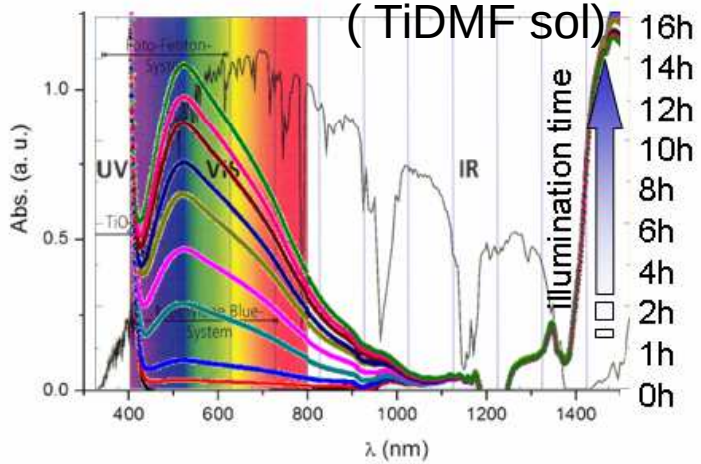
1) *ANR Habisol Solhypin (2008-2012; S. Guillerez, CEA/INES), Ph.D thesis Arkadiusz Karpinski, 2011 IMN/CESES/PCM,*
2) *Karpinski, A.; Berson, S.; Terrisse, H.; Mancini-Le Granvalet, M.; Guillerez, S.; Brohan, L.; Richard-Plouet, M., Solar Energy Materials and Solar Cells 2013, 116 (0), 27-33.*
3) ANR Progelec Tandori (2012-2014), S Berson, CEA/INES), Post-Doc Moustafa El Kass, 2012-2013 IMN/CESES,

Advanced Materials

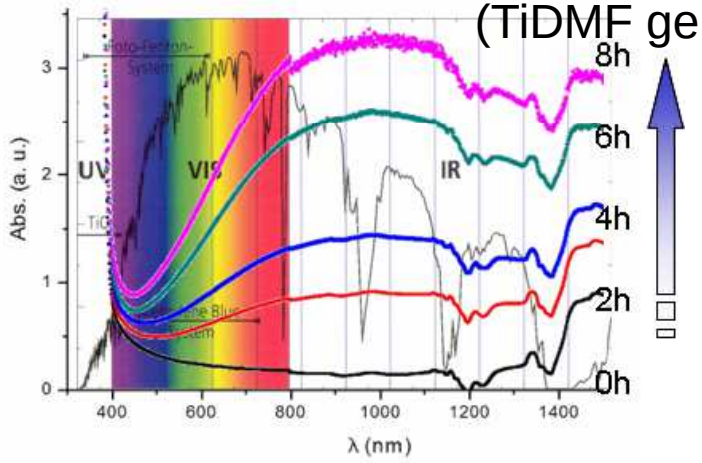
Novel photosensitive sols and gels based on titanium complexes



(1-2) (TiDMF sol)



(TiDMF gel)

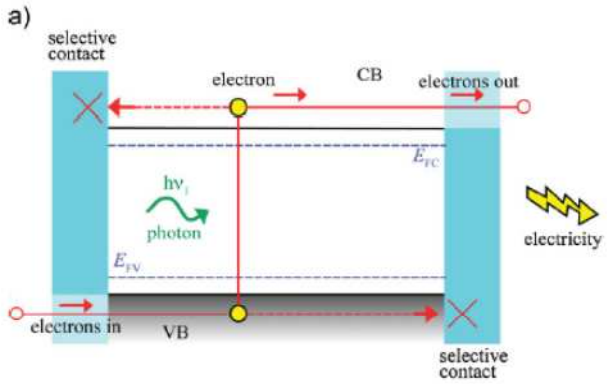


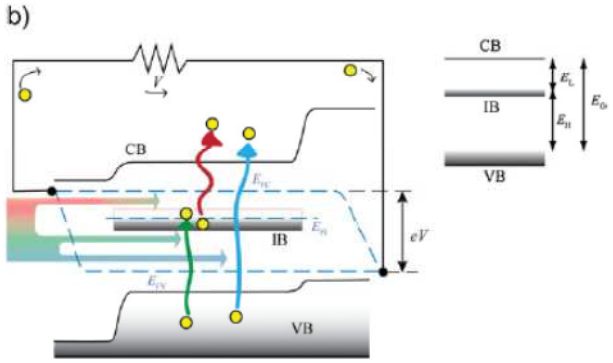
(3-4-5)

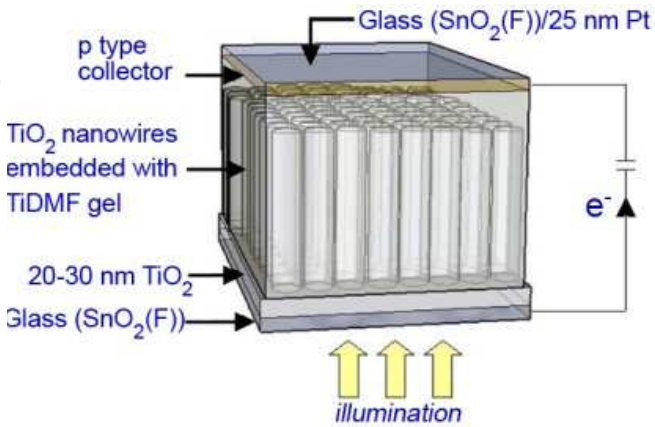
1) *L. Brohan, H. Sutrisno, O. Joubert, M. T. Caldes Rouillon, E. Puzenat, A. Rouet, Y. Piffard, CNRS patents: FR2835246 (9/03/2004); EP1470078 (21/05/2008); JP 4583758 (17/11/2010); US7524482 (14/01/2010) and US7723610 (25/05/2010)*
2) *ANR Habisol, OxTi-MiB-Photobatterie (2006-2009; L. Brohan IMN/CESES)*
3) *T. Cottineau & al. Chem. Mater. 2008, 20, 1421-1430 ; Advanced Functional Materials, 2008, 18, 1-9; Journal of Physical Chemistry C 2011, Volume: 115 Issue: 25 Pages: 12269-12274.*
4) *H. Terrisse & al.; Journal of Sol-Gel Science and Technology DOI 10.1007/s10971-013-3078-6, 2013*
5) *PhD Thesis (IMN/CESES), N. Rousseau (16/10/2013)*

Novel concepts : Intermediate Band Solar Cells (IBSC)

(2)

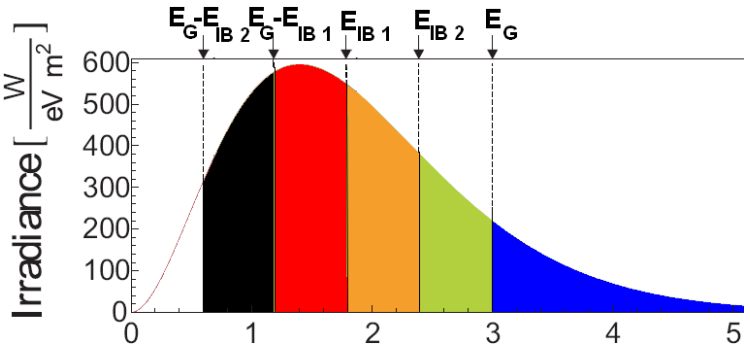




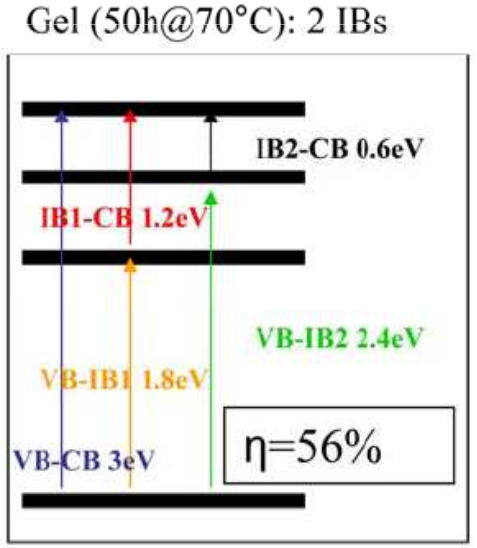


Current efficiency limitation of monogap systems : therotical conversion limit of **32%**

Photon absorption process in an IB solar cell : ultra-high conversion efficiency **>50%**

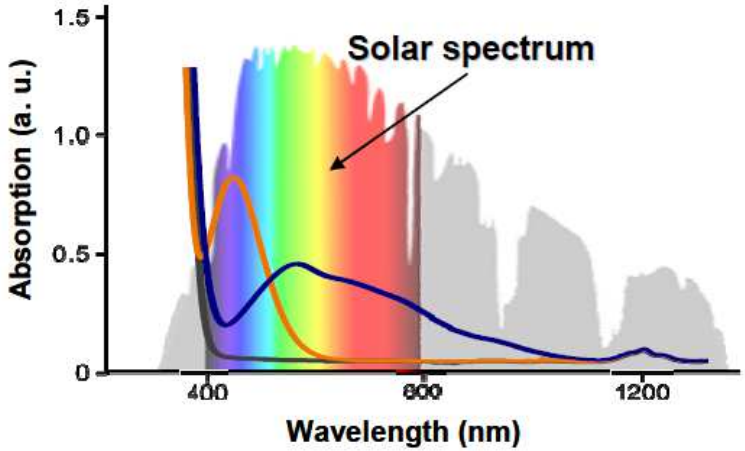


Efficiency Simulation (1)

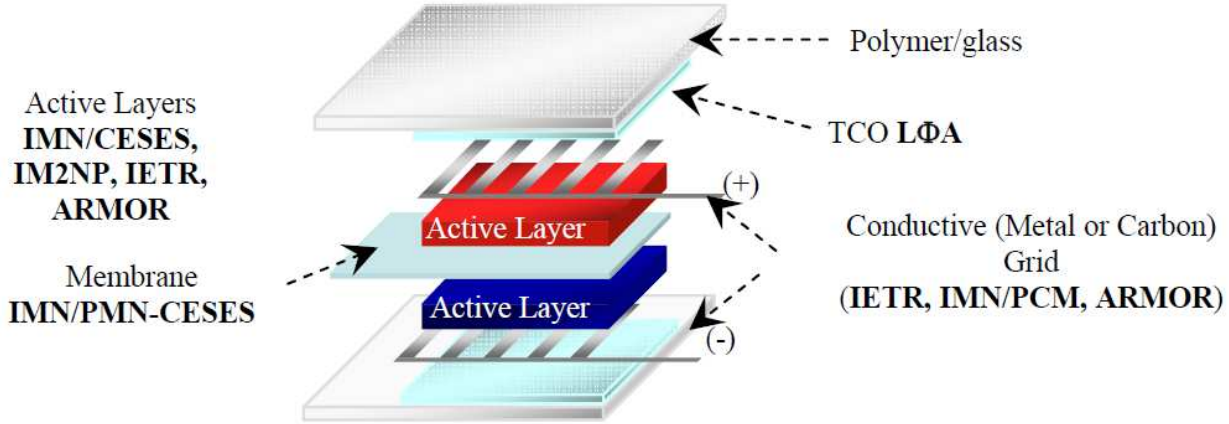


1) *PhD Thesis (IMN/CESES), Zulfiqar Ali Umrani, (5/07/2013), N. Rousseau (16/10/2013)*
2) *Solen Bechu, PhD Thesis (2013-2016) IMN-CESES, LΦA, Angers.*

Novel concepts : Photobattery



Spectral complementarities and adequate matching with the solar emission

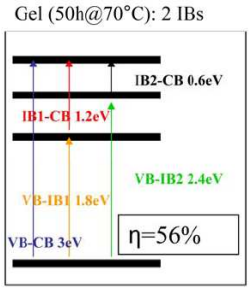


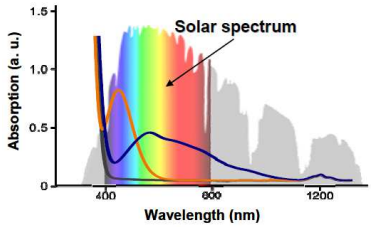
(1 & 2)

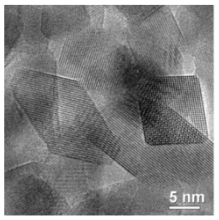
Schematic architecture of the photobattery

1) PhD Thesis (IMN/CESES), Gildas Guignard (07/2014),
2) Green-Photobat Project : Proof of concept (2013)

Know-how in metal-oxide nanomaterials : Advanced Materials, Novel Concepts and Technology Transfer







➢Concept Validation

➢Toward the development of Next Generation **High Efficiency Photovoltaics** and **Photobattery**

> Advanced Materials

Tailoring particle morphology size and allotropic variety

Novel photosensitive sols and gels based on titanium complexes

➢ Test, Prove and Technology Transfer

➢**Scale-Up Materials** (IMN/CESES, LIMATB, FIST-CNRS)

➢**Stable colloidal solutions for Ink-jet and Roll-to-Roll printing**

10X10 cm^2

➢ Prototypes, Design & Processing

➢**Hybrid solar cells** (OPV) (CEA-INES, **ARMOR**, **PCAS**…)