Editorial

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Already 6 years! In 2014, the Institut Photovoltaïque d’Île-de-France (IPVF) was launched within the framework of a French national program aiming at the creation of institutes for energy transition (ITE, one of the “Investments for the Future” supported by the French government) and it is time to repeat our warm backing to this wonderful joint adventure, and of course to the team working at IPVF.

In this structure, the CNRS works in close collaboration with the Ecole polytechnique and major industrial players in the photovoltaic sector that are EDF, TOTAL, Air Liquide, HORIBA and RIBER. The CNRS ambition is to contribute to gather all the necessary skills to develop the fundamental research underpinning the whole ITE program, taking advantage of its upstream vision of research. We share with our partners a strong appetite for designing the ultimate devices in the PV field, taking advantage of the cutting-edge research that is run at IPVF at the frontier between chemistry engineering and physics. New solar tandem cells, efficient and stable perovskites, high conversion efficiencies and cell performance are all high on our agenda. Moreover, innovations in the promising solar-to-fuel area have recently been added to these hot topics.

Today, 10 permanent CNRS staff members work full time in the joint-laboratory, to which can be added a bunch of scientists, nationwide, committed to working on the projects of the IPVF program and reaching the Saclay site for this purpose.

Obviously, IPVF is a key-player of the national research infrastructures on PV. Being both a center for advanced research and an open technological platform, it is the beachhead of a network of labs partners of the ITE project and is strongly involved in this joint research program. Furthermore, IPVF has much more than a national ambition: in interaction with the best French and international teams, IPVF aims at becoming one of the world’s leading research, innovation and training centers in the field of photovoltaic solar energy. Useless to insist: we do strongly support this aspiration!

Last, not least, the Paris Saclay cluster and, more broadly, the Île de France Region, are delighted to host one of the world champions of the transition toward an energy mix that will contribute to limiting global warming.

In short, we wish to deeply acknowledge the superb team who has been carrying the IPVF on the baptismal font, and in particular its Chairman, Jean-François Minster, its CEO, Bruno Carlotti and its Scientific Director, Daniel Linco. Under their guidance, a fully operative research structure has arisen, based on a unique public-private model, supported by the French government research and innovation program (“Secrétariat général pour l’investissement”). We insist on expressing our greatest confidence in the current leadership: CEO Roch Drozdowski-Strehl, Scientific Director Pere Roca i Cabarrocas, and Programs Director Christophe Bonelli. We wish them the biggest successes! CNRS is extremely proud to back you as we are confident that the next breakthroughs and innovations in the PV field will be made in IPVF.

J-Y. Marzin, C-M. Pradier, J. Maddaluno
First approach to a cost model of perovskite on silicon tandem photovoltaic cells

A preliminary model in order to assess the cost of a pilot-scale production for 4-terminal tandem modules with perovskite as top layer and crystalline silicon for bottom layer was developed by Christian Moreno, in the framework of his Master 2 internship. For the bottom layer, the model uses cost values for PERC, IBC and SHJ crystalline Silicon technologies from the literature, while for the perovskite cell, the cost of the materials was estimated by using the materials that IPVF is currently working with. The processing costs for this layer will be incorporated into the model in a second phase. The model allows to compare some material alternatives, such as glass-glass vs. glass back-sheet encapsulation instead of the highlighted phrase. This bottom-up approach for a cost model is a first step to set the cost base for an essential project of IPVF towards producing a high efficiency tandem solar module at a competitive price with higher efficiency than current mainstream technologies. It can be later adapted to other tandem architectures and be used as a base for cost models of tandem modules with other emerging materials.

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1.73 eV AlGaAs/InGaP heterojunction solar cell grown by MBE reaches 18.7% efficiency

High efficiency AlGaAs solar cells have been demonstrated. InGaP and AlGaAs solar cells have first been grown by solid source molecular beam epitaxy (MBE) and compared. The material quality of the semiconductor layers and the design of the heterojunction have been investigated and optimized. The combination of a thick p-AlGaAs base and a thin InGaP emitter provides a way to increase carrier mobilities and to reduce the impact of DX-centers, and leads to significant efficiency improvements. This heterojunction design has the additional advantages of a tunable bandgap of the AlGaAs absorber, and a low consumption of In. It resulted in a certified efficiency of 18.7% at a bandgap of 1.73 eV, perfectly suited for Si-based tandem devices.

This work was published online on 5 February 2020: Prog. in Photovoltaics, 2019. https://doi.org/10.1002/pip.3249
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Encapsulation of flexible CIGS solar mini-modules

With the fast growing efficiency for flexible Cu(In,Ga)Se₂ (CIGS) thin film solar cells (record cell efficiency: 20.8%), it is urgent to find effective and low-cost encapsulation solutions. The European solar-era.net project DURACIS (www.duracis-solareranet.com) addresses this challenge. Atomic layer deposition (ALD) – a strong technique asset available in IPVF – serves as a robust tool to grow dense and pinhole free barrier layers with precise thickness control under relatively soft conditions (e.g. low deposition temperature) that are compatible with attributes of flexible CIGS technology. Mini-modules (up to 10×10 cm²) on both glass and polyimide substrates are encapsulated using ALD-Al₂O₃ barriers. A new methodology has been employed to directly determine the optimal thickness of the Al₂O₃ barrier layer, which reveals simultaneously the degradation mechanisms. Raman mapping has been successfully used to detect the electrical degradation of ALD-Al₂O₃ encapsulated Al:ZnO (AZO) after damp heat test (1000h in 85°C and 85% of relative humidity).

The figure shows a Raman mapping of 5×5 cm² AZO samples encapsulated by 25 nm ALD-Al₂O₃ barrier layer after the damp heat test. Data point refers to the intensity ratio of defect band (related to AZO conductivity centered at ~500 cm⁻¹) divided by the sum of defect band and A₁(LO) band (centered at ~575 cm⁻¹).

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Another way to analyze TRPL decays

Time resolved photoluminescence (TRPL) microscopy is of great importance to probe the unusual properties under light soaking or electric bias of perovskite. Drift-diffusion models have been employed to interpret and fit experimental results. This figure plots the relative weight of the different recombination and transport mechanisms that explain the TRPL decay. We first notice that the short scale rely mostly on diffusion, radiative recombination and top surface recombination whereas SRH recombination appears at longer time scale. (Parameters representative of perovskite absorber).

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News from the platform

Vacuum deposition Pole

News on sputtering equipments (1L.18)
All reactors are available. Possibility to deposit different TCO layers (ITO, AZO, ZnO, ZnMgO…); metallic layers (Mo, Ti, ...).
Please contact the sputtering team (D. Coutancier, S. Rives, F. Donsanti) for any request.

News on evaporation equipments (1L.18 and 0L.57)
• Moving MBE RIBER C21 for III-V deposition in progress (for more details please contact A. Michaud).
• Possibility to deposit anti-reflective coatings (MgF2); deposition of chalcogenide layers (CIGSe, CISE, CGSe…); deposition of metallic contacts (Au, Pt, Ag, Ni, Al, Ti, Ge, Cr, …) with different patterns. Please contact the evaporation team (V. Daniau, A. Rebai, S. Rives, F. Donsanti) for any request.
• First tests of perovskite layers by coevaporation (for more details please contact A. Pye, J. Hajhemati, F. Donsanti).

News on ALD equipments (0L.36 and 3LB06)
• All the ALD reactors are available
• Possibility to deposit oxide layers (ZnO, AZO, Al2O3, …).
• Development of oxide layers for perovskite cells on BENEQ reactor in progress
Please contact for more details the ALD team (D. Coutancier, F. Donsanti, N. Schneider, A. Zauner).

Are you ready to work in our cleanrooms? Read this!

I am pleased to announce that a new maintenance contract has just been signed in February to monitor the air quality in our cleanrooms. This operation is essential to ensure the production quality of the materials and devices, and to guarantee a reliable characterization of their performances.
A team of highly qualified engineers and technicians will be in charge of monitoring the proper functioning of the rooms. All these people have been trained to French and international standards for cleanrooms [1] [2].
A cleanroom is a room in which the concentration of airborne particles is controlled, and which is designed and used in a way to minimize the introduction, generation, and retention of particles inside the room, along with regulating other relevant parameters such as temperature, humidity, and pressure.
Several measurement campaigns are planned this year to monitor the following parameters:

Air change rate: this refers to the number of times the air is renewed within a cleanroom. It is expressed as air changes per hour (ACH). At IPVF, it represents more than 20 air changes per hour. This means that every three minutes the room air volume is replaced.

Particles concentration: this refers to the number of particles per m3. The basic metric for standard cleanroom is the micrometer (µm), which corresponds to the size of the particles to be filtered. At IPVF, the particle sizes considered are ranging from 0.1 µm to 5 µm (ISO 8/ISO 9).

Pressure gradient: this refers to the different cascading levels of positive air pressure from the cleanrooms at the highest pressure down to the airlock room (gowning room). At IPVF, the gradients are more than 30/15/0 Pa.

Ambient temperature and humidity: humidity is relative – It is relative to the temperature it is at. At IPVF, the standard is Tpe = 22°C (+/-2°C) and RH = 50% (+/-10%).

Sensors: maintenance operations consist of calibrating the various temperature, humidity and pressure sensors that equip cleanrooms.

Wet Benches: the team will also be in charge of checking the correct aeraulic operation of Wet Benches (WB) and chemical bays. This is very important for monitoring laboratory air quality and operational safety.


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Conferences to come

- **Publications**

- **Visitors**
  - February 4 - Presentation of the Head of Fraunhofer Center for Silicon Photovoltaics CSP, Dr. Ralph Gottschalg: “Fraunhofer CSP – Enabling Highly Performing Systems”.
  - February 6 - Yves Brechet, Saint Gobain Scientific director and Research professor Monash University: “Ageing of materials: methods and problems”
  - February 27 - Sami Almosni, Tokyo University, RCAST, Japan: “Tools and Know-How for the fabrication of high efficiency perovskite solar cells”.

- **SPIE Contributions**

  - **Electrical scanning probe microscopy approaches to investigate solar cell junctions and devices**
    Early February José Alvarez (GeePs, IPVF) was invited to present his research activities at the “Quantum Sensing and Nano Electronics and Photonics XVII” symposium at the SPIE conference in San Francisco. He notably reviewed the capabilities of the Conductive-Probe (CP) and the Kelvin Probe (KP) –AFM to investigate amorphous/crystalline silicon heterojunctions and polysilicon/tunnelling silicon oxide passivated contacts, both being involved in highly efficient silicon solar device schemes, and radial-junction silicon nanowire solar cells. The first case study focused on silicon heterojunctions and notably hydrogenated amorphous silicon (a-Si:H)/crystalline silicon (c-Si) P/n or N/p heterostructures which band bending at the interface forms a 2D channel. This conductive channel was indeed evidenced for the first time by cross-sectional investigations by C-AFM confirming the analysis of macroscopic planar conductance measurements. A second example of nanoscale characterization concerned the passivating selective contacts based on thin silicon oxide (SiOx) layers between the c-Si and a highly doped polysilicon (polys-Si) layer. The electrical carrier transport is here not limited by the oxide layer and it is assumed that tunnelling through the oxide and/or the presence of pinholes are the main competitive mechanisms. For this specific heterostructure KPFM revealed local surface potential drops of 15-30 mV, which do not exist on samples without SiOx. These potential drops suggest the presence of pinholes that are formed during the poly-Si annealing process performed in the range of 700-900 °C. Finally, in a third case study, the electrical characterization performed on p-i-n radial junction (RJ) silicon nanowire (SiNW) devices under illumination by KPFM, in the so-called surface photovoltage (SPV) technique was illustrated. This work focused on the possibility of extracting the open-circuit voltage (VOC) on single isolated SiNW RJ by local SPV measurements using different AFM tip shapes and illumination directions in order to minimize shadowing effects. The invited paper was published in the Proceedings Volume 11288, Quantum Sensing and Nano Electronics and Photonics XVII; 112880U (2020) https://doi.org/10.1117/12.2540422

  - **Interface design for halide perovskite solar cells**
    Philip Schulz was invited to discuss the general role of interfaces in halide perovskite based solar cells. Emphasis of the talk has been on the impact of interface formation on device performance, considering effects such as chemical reactions and surface passivation on interface energetics and stability. The presentation was thus focused on the characterization of the surface properties of the perovskite absorber films and their interfaces to adjacent charge transport films by photoemission spectroscopy and complementary optical and X-ray spectroscopies, a set of techniques used to track potential degradation pathways as well as the energy level alignment at these interfaces, and to determine the impact on the optoelectronic properties of the perovskite absorber films.

  - **Jean-Baptiste Puel**: “Modeling photoluminescence decay of perovskite PV device from TR-FLIM characterization”

  - **Hamidreza Esmaielpour**: “Advanced analysis for hot-carriers photoluminescence spectrum”

- **Conferences to come**

  - **Physics of Solar Cells**: from basic principles to advanced characterization. Les Houches School of Physics, 1-6 March 2020, https://sunlit-team.eu/pv-school-2020/
  - **IPVF Spring Scientific Day**, April 23, to be held at C2N