DegradationLab

Advanced centre for testing degradation and failures in new and emerging solar cells

Newsletter, December 2020

Project ID: INFRASTRUCTURES/1216/0043

European Union
European Regional Development Fund

Republic of Cyprus

Structural Funds
of the European Union in Cyprus

About DegradationLab

The DegradationLab is a newly developed research laboratory at the University of Cyprus (UCY), which is an integral part of the Department of Electrical Engineering and the FOSS Research Centre for Sustainable Energy. Its main scope is to contribute to **the accurate characterization of novel and promising new generation solar cells** towards addressing some of the main challenges faced by these new technologies namely regarding their performance degradation, reliability, etc. To this end, the new research unit brings together three laboratories from the University of Cyprus (the Photovoltaic Technology Laboratory, the Laboratory of Molecular Spectroscopy, and the Laboratory of Ultrafast Science) with three excellent European research organizations, namely IMEC (Belgium), the AIT Austrian Institute of Technology (Austria), and the Max Planck Institute for the Science of Light (Germany).

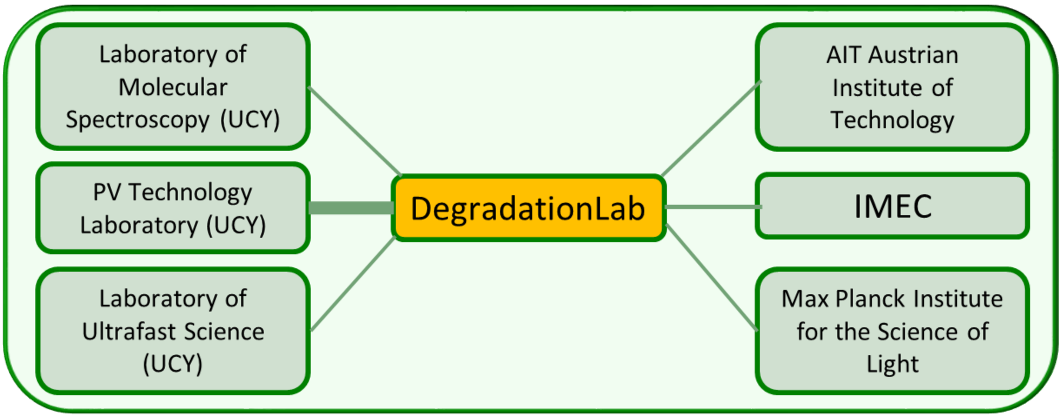
The DegradationLab is co-financed by the European Regional Development Fund (ERDF) and the Republic of Cyprus through the Research and Innovation Foundation under the programme 'New Strategic Infrastructure Units - Young Scientists'. The laboratory is currently located at two sites in Nicosia: at the main campus in Aglantzia and at Latsia campus.

Duration:
4 years

Budget:
999,460 €

6 Partner
Labs

Project Vision



Our vision is to develop a dedicated research hub in Cyprus focusing on the accurate characterization of novel solar cells and mini-modules such as perovskite devices, perovskite tandems, kesterites, chalcohalides, etc. Particular focus will be on aspects of **performance degradation, reliability, and long-term stability.**

The unit is envisaged to grow from the initial network of six (6) individual partner laboratories to an integrated network of expert laboratories offering a complete range of scientific and technical testing solutions both for the purposes of pure scientific research and for research-related services to any interested stakeholders (academia, R&D sector, industry, and society) in Cyprus and beyond. The target will be to achieve an advanced research unit that can be useful to any interested stakeholder in the ecosystem of Cyprus, MENA region and beyond.

Main Objectives

In a nutshell, the main aims of the DegradationLab initiative are:

- To gain a **fundamental understanding of failure development and evolution** in novel solar cell devices, and
- To find ways to accurately, systematically, and reproducibly study such solar cells/modules assisting in the **development of appropriate measurement protocols**.

In more detail, the project objectives are:

- Development of new laboratory infrastructure at the University of Cyprus for studying new generation solar cells/ modules
- The indoor and outdoor investigation of degradation mechanisms of different structure perovskites and perovskites/silicon tandems at ambient and laboratory conditions and using a combination of advanced techniques.
- Addressing the technical and scientific challenges in indoor and outdoor characterization of perovskite-based cells.
- Investigating carrier dynamics and chemical imaging of perovskite-based solar devices before and after degradation in an attempt to understand carrier losses and various decomposition products.
- The correlation between the microscopic investigations of failures with the performance degradation of perovskite-based cells.

Key Deliverables

- A new fully-operational experimental facility for novel solar cell/module characterization including a steady-state solar simulator, a Dark Lock-in Thermography/Illuminated Lock-in Thermography system, a Light Beam Induced Current system, and a spatially-resolved Electroluminescence and photoluminescence system.
- A systematic multiway indoor evaluation of novel solar cell devices using a combination of advanced optoelectronic, spectroscopic, and structural microscopy characterization techniques.
- Short- and long- term stability studies of novel cells/mini-modules in real ambient operating conditions (environmental, spectral, seasonal) and correlation of indoor and field testing findings
- Gaining an understanding of failure mechanisms and their evolution in different architecture/encapsulation novel solar cell devices
- Development of accurate indoor and outdoor measurement protocols towards 'STC' methodologies/procedures for novel perovskite-based cells and modules.

Infrastructure development

During the first phase of the project, a lot of effort has been placed on developing the new core experimental infrastructure of the DegradationLab with which detailed investigation of failure analysis in new and emerging solar cell technologies will take place. Overall, the desired specifications for this new infrastructure were:

- to be able to test small-size solar cells ($0.5x0.5cm^2$) up to mini-modules ($30x30cm^2$)
- to be suited for thin films (perovskites, organics, etc.)
- High definition cameras (for LIT/DLIT and PL/EL)
- High-spatial resolution systems
- High-precision current source (for EL)
- Different light excitation LEDs or lasers to enable mapping of different junctions in tandems

With this in mind, and after completion of a tendering process, the following equipment has been fully commissioned at our laboratory premises and is already operational.

Steady-state solar simulator

The steady-state solar simulator is being used to test performance of all types of solar cells under AM1.5 spectrum.

The Solar simulator is certified to IEC 60904-9 Edition 2 (2007), JIS C 8912, and ASTM E 927-10 standards for Spectral Match, Non-Uniformity of Irradiance, and Temporal Instability of Irradiance.

Manufacturer: Oriel, Newport
Model: Sol3A Class AAA Solar Simulator

Spectral response and External Quantum efficiency set-up

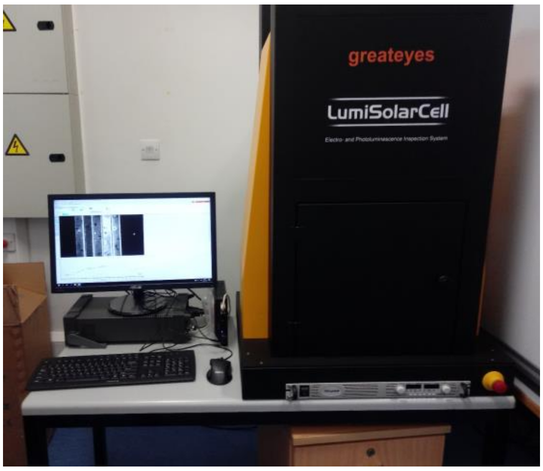
A high-resolution spectral response (SR) set-up was designed to measure small dimensions' organic and inorganic solar cells. The spectral response of a cell can be measured with or without encapsulation by using a solar simulator and measuring the short-circuit current output of a cell under different wavelengths of light.

The SR set-up consists of a light source, a monochromator, chopper, lenses and lock-in amplifiers. A 100 W Quartz Tungsten Halogen lamp provides the light source that is divided by the monochromator in order to produce the monochromatic light input which is then chopped at 75 Hz superimposed on the continuous bias light and measured by digital lock-in amplifiers. The monochromatic light is separated by a beam splitter and allows simultaneous measurement of a small size monitor device and a reference cell of known absolute SR. The monochromatic light is focused on the surface of the cells with a circular spot of 1.5 mm in diameter. The temperature of the cell is kept stable at 25°C. In the case of multi-junction solar cells light bias is required in order to saturate the non-measured junctions and subsequently achieve current limitation by the junction of interest.

The spectral response measurements follow the IEC standard 60904-8.

Electroluminescence and Photoluminescence setup

The Electroluminescence (EL) and Photoluminescence (PL) turn-key solution system installed at the DegradationLab can conduct spatially-resolved electroluminescence and photoluminescence measurements of single and multi-junction solar cells (encapsulated and non-encapsulated) with dimensions from 0.5 x 0.5 cm^2 up to 15 x 15 cm^2 to image micro-cracks, shunts, regions of low lifetime, inhomogeneities, hot spots and other cell failures.



Manufacturer: *Greateyes*
Model: *LumiSolarCell*

Nitrogen generator and dessicator

Adjustable shelf storage desiccator cabinets with two doors and a membrane Nitrogen Generator with 11 SCFH flow rate at 99% nitrogen purity (*Manufacturer: CLEATECH, Models: 1500-2-L and 1700-1-A).*

Lock- in Thermography (Dark and Illuminated)

A turn-key solution for the Dark Lock-In Thermography and Illuminated Lock-In Thermography spatially resolved measurements of multi-junction solar cells with dimensions from 0.5 x 0.5 cm^2 to 20 x 20 cm^2. The PV-Shunt Inspection System is able to detect shunts, defects and inhomogeneities in the solar cell devices.

The system includes a high-speed thermography camera for the detection of infrared radiation during the dark lock-in thermography and illuminated lock-in thermography of multi-junction solar cells with the abovementioned. The camera allows precise, fast and remotely controlled motorized focusing. With the indoor system, there is also a tripod for outdoor thermographic measurements using the same camera.

Manufacturer: INFRATEC
Model: PV-LIT Inspection system DLIT + ILIT (with ImageIR 8325 camera)

Light beam induced current (LBIC)

The Light Beam Induced Current (LBIC) automated system enables fast high-resolution spatial mapping of the photovoltaic response of multi-junction solar cells with dimensions from 0.5 x 0.5 cm^2 to 30 x 30 cm^2.

It is ideal for the quality control and identification of defects and shunts, poor or inactive regions. The system is a turn-key solution and can also provide External Quantum Efficiency (EQE) spatial mapping of the solar cells.

<u>Manufacturer</u>: InfinityPV
<u>Model</u>: LBIC Economy

Outdoor cell/mini-module level performance infrastructure

In addition to the development of the indoor laboratory, work took place on developing appropriate **outdoor test setups** in order to enable successful performance measurements on perovskite-based photovoltaic devices. Currently, a current-voltage (I-V) characterization system controlled by Labview software can collect and analyze the electrical characteristics of the cells under study.

Outdoor setup at UCY testing perovskite mini-modules.

A **maximum power point (MPP) system for prototype cells/modules** has been developed and introduced into an existing outdoor test bench at the PV Technology Laboratory and LabVIEW software is being used to perform automated current-voltage sweeps using a Keithley sourcemeter. The electrical parameters of the photovoltaic configuration such as short-circuit current, open circuit voltage, fill factor and efficiency are to be continuously monitored alongside the respective environmental conditions. The measurement system is composed of a number of sensors and a central data logging measurement system that can acquire data at a rate of one sample every 5 seconds or more. With this setup an array of modules can be tested sequentially for their I-V characteristics in different I-V sweep conditions i.e. varying voltage scan rates, keeping at open circuit or MPP operating conditions, performing forward or reverse bias scans and varying the scan order.

As concerns testing perovskite cells outdoors, we are in the process of developing new solutions to enable I-V measurements to be undertaken.

The DegradationLab infrastructure developed currently has the capabilities to test new and emerging photovoltaic technologies including the following perovskites and perovskite tandems, chalcopyrite solar cells, chalcogenite solar cells, and organic and dye-sensitized solar cells.

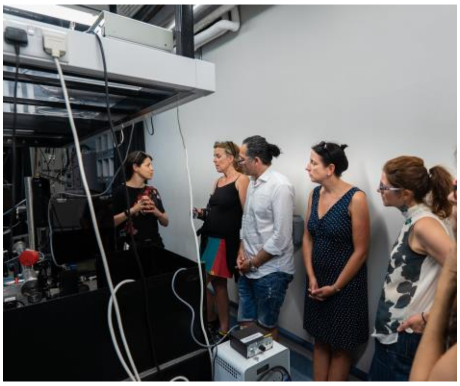
Overall a ‘portfolio’ of techniques will be utilized between the partner labs of our project to cross-investigate the degradation mechanisms in novel solar devices developed by IMEC. The main ones are the following:

- Current voltage (I-V) measurements
- External Quantum Efficiency (EQE) measurements
- Capacitance – Voltage (CV) measurements
- Light Beam Induced Current (LBIC) imaging
- Spatially-resolved Electroluminescence (EL) measurements
- Spatially-resolved Photoluminescence (PL) measurements
- Dark Lock-in Thermography (DLIT) and Illuminated Lock-in Thermography (ILIT)
- Ultrafast spectroscopy & time-resolved PL
- Resonant Raman spectroscopy
- Structural microscopy: TEM, SEM, XRD, EDX, etc.
- Field performance testing

Communication activities

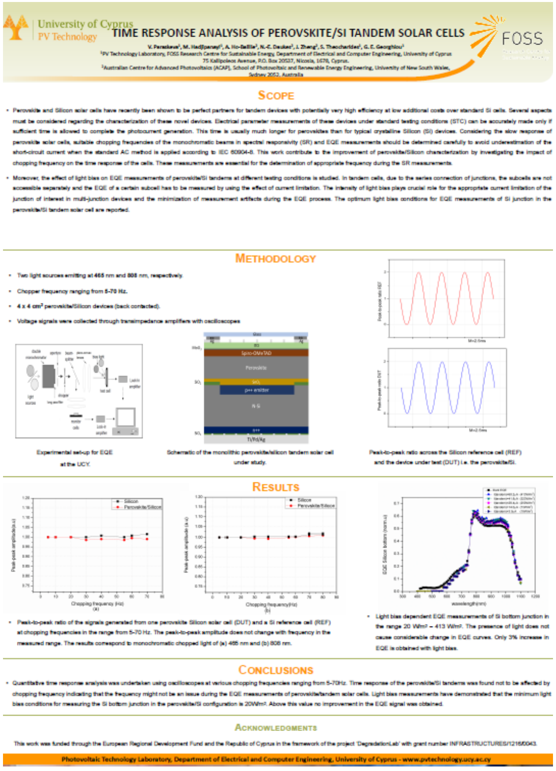
Project meetings

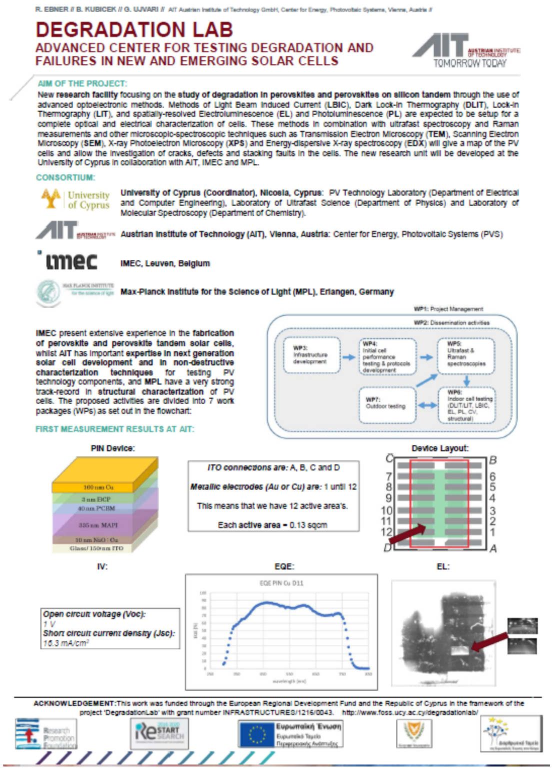
The Kick-off meeting of the project was successfully held in July 2019, in Cyprus. At the meeting the partners agreed on a common work plan and methodology in order to achieve the project objectives. A 2nd consortium meeting was held in September 2020 to discuss progress achieved and the development of the infrastructure at University of Cyprus. This meeting was online due to COVID-19 restrictions in Europe.

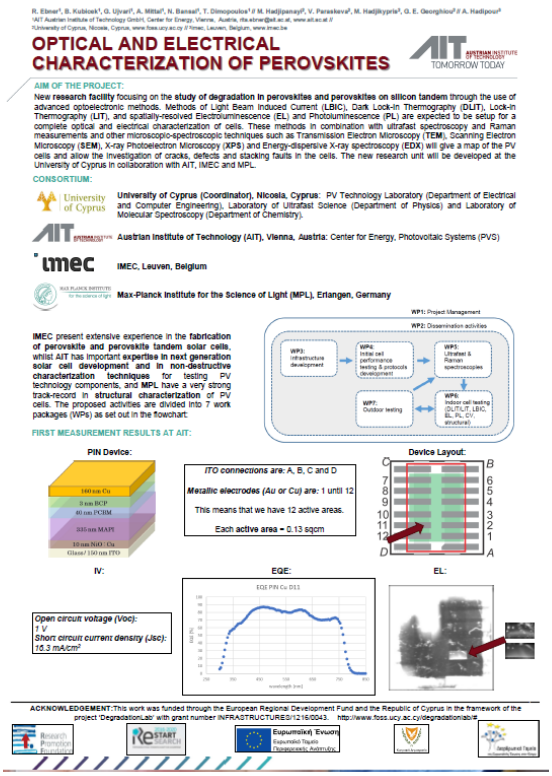


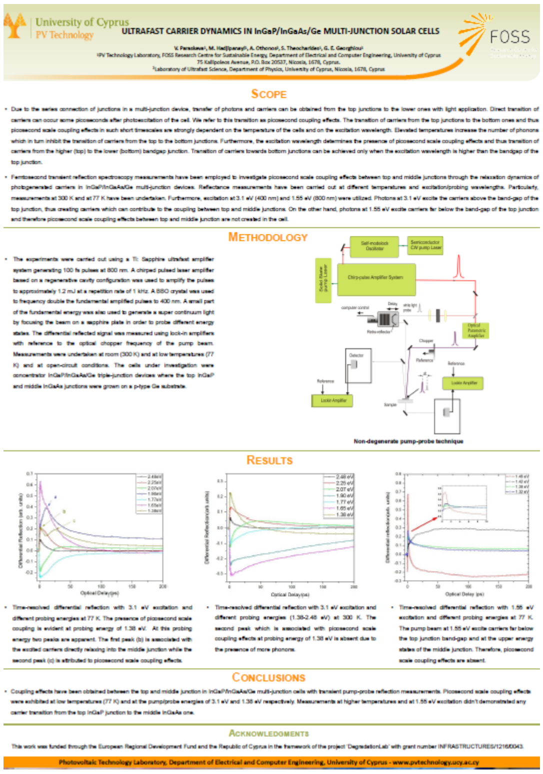
Posters

Posters regarding the project and first results were presented at events and conferences in 2019 (EUPVSEC 2019, PV event in Vienna 2019) and 2020 (EUPVSEC 2020). For more details, please check our webpage.









A local launch event for the new laboratory facilities developed at the University of Cyprus is planned for winter 2021 (its planning in Autumn 2020 was postponed due to COVID-19 situation in Cyprus). So stay tuned for more information!

Project website & Social networking

Stay informed on the DegradationLab project progress and news via our subsequent electronic newsletters and other press releases and news to be disseminated in our social media portfolio. More information below:

Webpage: http://www.foss.ucy.ac.cy/degradationlab/

Research Gate page (under construction): https://www.researchgate.net/project/DegradationLab

FOSS Facebook page: https://www.facebook.com/FOSSUCY/

DegradationLab Consortium

The PV Technology Laboratory of the FOSS Research Centre for Sustainable Energy has an excellent track record in research in the field of solar energy. Its main priority is the development of a research and innovation portfolio in renewable energy technology, PV performance, degradation and failure analysis, forecasting and energy yield modelling, grid integration, and integrated sustainable solutions. The Laboratory, through external competitive funding, has developed advanced infrastructure and capacity in the last 10 years. For the purposes of our project, the PV Technology Laboratory brings on board its extensive expertise in the research fields of performance loss analysis, failure detection, long-term degradation of PV, and testing of novel solar devices (quantum wells, multi-junctions, etc.) as well as making available its on-site state-of-the-art outdoor and indoor facilities used for the characterization, evaluation and monitoring of different PV technologies.

The Laboratory of Ultrafast Science is hosted in the UCY Department of Physics and its main objective is to utilize photonics to investigate the physics of interactions in novel materials using various continuous-wave and transient spectroscopic techniques. To this end, the Laboratory has developed over the years a number of state-of-the art experimental ultrafast laser setups. In our project, it brings on board its accumulated long experience in ultrafast spectroscopy and time-resolved photoluminescence towards studying charge carrier dynamics in perovskite-based solar cells before and after aging in real ambient conditions.

The Laboratory of Molecular Spectroscopy is hosted in the UCY Department of Chemistry, and is fully equipped for the spectroscopic characterization of thin films. In particular, the laboratory is equipped with a state-of-the-art UV and visible Resonance Raman system which will be made available for the purposes of the project to investigate chemical composition variations and degradation evolution in perovskite and perovskite on silicon tandem cells due to outdoor exposure.

IMEC is one of the largest independent R&D centers worldwide in the field of nano-electronics. The Thin Film PV group has a track records of over 15 years in the field of organic solar cells and since 2014 has extended its activities on hybrid, perovskite-based thin film solar cells. IMEC's Thin Film PV group acts in this project as device integrator for cells and modules based on perovskite active layers. For the purposes of this project, the Thin-Film PV group makes available its processing facilities labs for the fabrication and initial characterization of perovskite single-junction and tandem solar cells as well as perovskite mini-modules.

The Austrian Institute of Technology GmbH (AIT) is Austria's largest non-university research organization that works closely with related industry and public bodies in order to create benefits through innovation and new technologies. AIT's Center for Energy offers scientific support in R&D, as well as certified standard testing to PV and PV-related manufacturers all over the world. Moreover, AIT Energy is specialized in the experimental research of reliability, aging, and failure analysis of PV modules, the characterization and modelling of crystalline, thin-film and new PV technologies. For the purposes of the project, AIT is supporting the development of the indoor infrastructure of the new DegradationLab (tender procedure, result initial validation, calibration and training of UCY staff) as well as conducting initial cell performance tests, involvement in round-robin measurement procedures for the development of accurate protocols for novel cells, etc.

The Max-Planck Institute for the Science of Light (MPL) performs basic research in optical metrology, optical communication, new optical materials, plasmonics and nanophotonics and optical applications in biology and medicine. It is part of the Max Planck Society and was founded in 2009 in Erlangen, Germany. The Institute has a strong partnership with the Friedrich-Alexander University of Erlangen-Nuremberg (FAU), with shared resources and equipment for synthesis, modelling, and a large variety of characterization including nano-probe and correlative microscopy equipment. In particular, the extensive structural characterization facilities of the MPL/FAU lab will be made available for the purposes of the project in terms of analysing degradation in perovskite devices tested outdoors in Cyprus.

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