TRAINING ACTIVITIES

Objectives

The ESRF workshop facilitated discussion on the collaboration between CACTUS and ESRF, exploring how advanced ESRF techniques can help address the specific problems raised by the CACTUS project in the field of photovoltaic technologies. A similar workshop was organized on the next day to obtain the sale results regarding the ILL techniques. Besides the workshop, the attendees visited the ESRF and ILL facilities.

Time and place:

- ESRF workshop + ESRF visit 12 June 2024
- ILL Workshop + ILL visit 13 June 2024

Attendees at ESRF workshop

- ESRF representatives: Zhenggang Zhang, Florian Jürries, Fabien Léonard, Simon Benichou, Rebecca Dowek, Thu Nhi Tran Caliste
- Representatives of CACTUS-PV: José Martín (EU-Solaris), Felipe Valencia (ATAMOSTEC), Ernesto Pérez (UNAL), Asier Sanz (TECNALIA), Romain Couderc (CEA-INES), Delfina Muñoz (CEA-INES), Aitor Marzo (UGR, EU-Solaris)

Attendees at ILL workshop

- ILL representatives: Mark Johnson, Thomas Saerbeck, Alessandro Tentagattini
- Representatives of CACTUS-PV: José Martín (EU-Solaris), Felipe Valencia (ATAMOSTEC), Ernesto Pérez (UNC), Asier Sanz (TECNALIA), Romain Couderc (CEA-INES), Delfina Muñoz (CEA-INES), Aitor Marzo (UGR, EU-Solaris), Alexander Astiagarraza (EURAC), Juan José Stivanello (EURAC)

ESRF-Workshop

1. Romain Couderc (CACTUS):
    - He presented an overview of the CACTUS project and the problems to be addressed in terms of measurement and sampling.
2. Thu Nhi Tran Caliste and BM05 team (ESRF):
    - They presented the types of analysis and measurement techniques available on the BM05 line. Measurement techniques include:
        - X ray Imaging: 2D - 3D
            - Bragg Diffraction Imaging,
            - Absorption,
            - Reflectivity
        - X-ray Beam Induced Current (XBIC)
            - 3D movies: visualize the structure, defects
            - High sensitivities: strain, orientation, phase
            - Electrical properties
            - Combination resolution: lateral, spatial, angular
    - Sample size: from mm to dm, from g to 5 kg

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- Tomography allows characterising the crystalline quality:
  - By revealing the distortion field associated with defects such as dislocations, inclusions, growth sectors and growth striations, twining, and general distortions (curvature)
  - In overgrown layers: revealing lattice parameters mismatch with respect to the substrate, local mosaic spread...
  - Over sub-surface damaged areas, often associated with prior surface processing (cutting, polishing...)
- Over any single crystal:
  - White beam tomography allows a qualitative (semi-quantitative) approach:
    - Overview of defect distribution
    - Global stress and strain
    - Individual dislocations or dislocation densities
    - Rapid, large area measure
  - Monochromatic Rocking Curve Imaging allows quantitative analysis:
    - 2D strain mappimg and defect location
    - Local "mosaic spread" of crystal / the local distortion
    - Effective misorientation
    - More time consuming, high resolution, selected area
  - In both Laue and Bragg cases:
    - In reflection mode: Quantitative picture of features present in a several micro-m thick subsurface layer
    - In transmission mode: Probes the whole depth-volume of the sample
  - Section of 10 micro-m wide beam: use for both techniques, slides along thickness of samples
- Tomography at BM05.

ILL workshop

Neutrons are scattered and absorbed differently from other types of radiation and therefore provide unique information, which is e.g. highly complementary to X-rays. In particular, neutrons are highly sensitive to light atoms and molecules (hydrogen and water) that are practically invisible to X-rays. In addition, neutrons are highly penetrating and can measure bulk samples but the scattered or transmitted beam is the sum of the scattering and absorption from all irradiated parts of the sample.

4 neutron techniques are used to perform structural studies over length scales ranging from sub-nm (neutron diffraction) to microns and beyond (imaging).
Given the information shared about PV cells and modules – the former being a component of the latter in effectively 2D, layered structures – two neutron techniques – neutron REFLECTOMETRY and IMAGING - are considered to do feasibility measurements in the scope of the CACTUS project.

The length scales of the cells (layer thicknesses of the order of 10-200 nm) are amenable to neutron REFLECTOMETRY – the layers on this length scale provide reflectivity curves with interference effects depending on the layer thicknesses and their scattering powers, including

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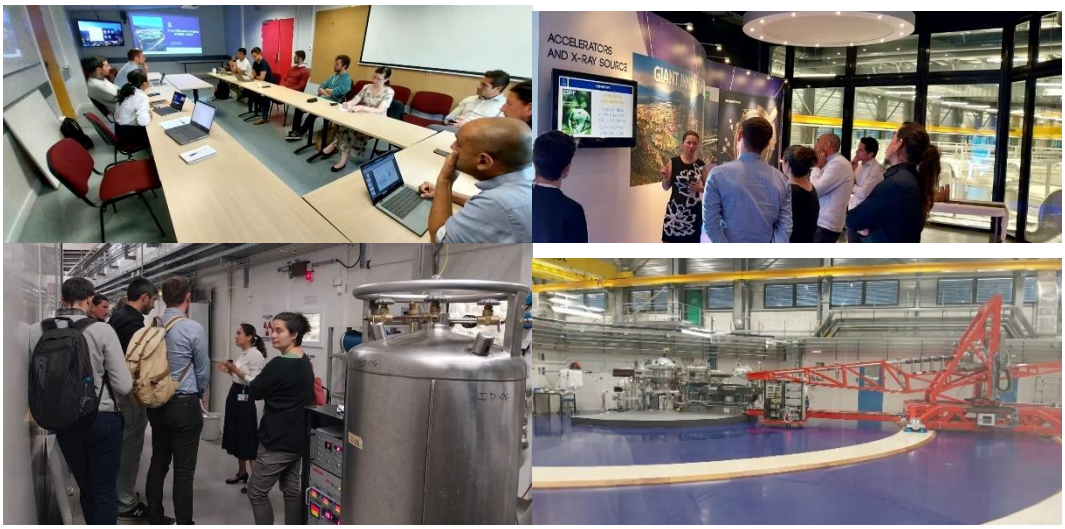
the effect of 'contamination' (e.g. water) at interfaces. However, model samples are required since rough interfaces (pyramidal texture) diffuse the beam and most often render the data unusable.

Cells could be measured as prepared (reference measurements) and following ageing in the desert if the model cells can be included in modules installed there and then removed from the modules without significantly changing the cells in this process of extraction. If cells of limited size (several cm) can be produced, they can be measured in ILL sample environments that would allow, for example, hydrogen and water penetration to be studied, possibly in real time if the penetration takes place on the seconds-minutes-hrs time scale.

Neutron IMAGING is the second technique that can potentially give useful data on hydrogen, water, sodium diffusion and penetration as well as corrosion. Imaging can produce 2D images – radiography – or 3D volumes – computed tomography – by back construction of a set of images obtained by rotating the sample.

Photos



Results

The workshops + visits allow to have a shared knowledge of the technical specifications of the technics available at ESRF and ILL for the PV actors and to identify the best ones for the PV degradation characterization.

Training Activity	Workshops + visits ESRF/ILL
Date	12/13 June 2024
Number of attendees	15
Place and country	Grenoble, France
Consortium Partners involved	ATAMOSTEC, CEA, EURAC, UNC, TECNALIA, ESRF, ILL, EU-SOLARIS
Additional Notes	

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