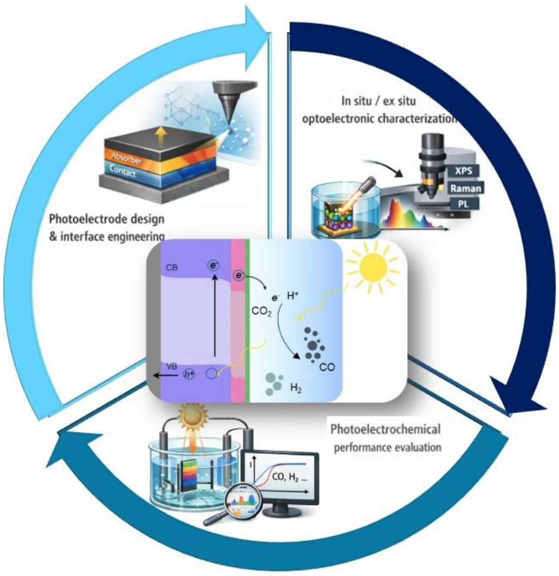
Harnessing Surface Defects in Chalcogenide Photoelectrodes for Scalable Solar Fuel Systems (SUN2FUEL)

Objectives and Scientific Context

Solar-driven conversion of CO_2 into chemical fuels is a promising strategy for sustainable energy storage and carbon valorization. Photoelectrochemical (PEC) systems enable the direct coupling of solar energy harvesting with electrochemical reactions to drive light-induced chemical transformations. Semiconductor absorbers originally developed for photovoltaic devices are particularly attractive candidates for PEC photoelectrodes due to their excellent light-harvesting capabilities and favorable optoelectronic properties. However, when operated in electrochemical environments, these materials often suffer from limited long-term stability, as corrosion and degradation processes can significantly affect device performance and durability. Understanding and overcoming these stability limitations is therefore a key challenge for the development of efficient PEC systems.



The objective of this project is to design defect-engineered chalcogenide-based photoelectrodes capable of delivering high photovoltages and photocurrent densities while maintaining long-term stability under operating conditions. The approach relies on exploiting intrinsic surface states as catalytic active sites to promote selective solar-driven chemical transformations.

The research will combine advanced materials and interface engineering with operando spectroscopic and photoelectrochemical characterization to uncover the relationships between composition, surface chemistry, electronic structure, and catalytic performance. By establishing these structure–function correlations, the project will systematically investigate how composition, bandgap, and reaction environment influence device performance and product selectivity. Ultimately, this work aims to guide the design of durable and efficient photoelectrodes for solar-driven CO_2 conversion into CO and other value-added chemicals, thereby advancing sustainable solar-fuel technologies.

Research Environment

The postdoctoral researcher will work within a collaborative project involving two leading research laboratories in materials science applied to photovoltaic and electrochemistry.

Institut Photovoltaïque d'Île-de-France (IPVF)

IPVF is a world-class research institute dedicated to the development of next-generation photovoltaic and solar energy conversion technologies. Located on the Plateau de Saclay, IPVF brings together academic and industrial partners to advance innovative materials and devices for solar energy applications.

Within IPVF, the project will benefit from state-of-the-art facilities for thin-film semiconductor fabrication and advanced characterization. In particular, the candidate will have access to a variation of characterisation techniques including Raman spectroscopy, photoluminescence measurements, enabling detailed investigation of structural and electronic changes in photoelectrodes under operating conditions.

Laboratoire de Chimie Moléculaire (LCM), École Polytechnique

The Laboratoire de Chimie Moléculaire (LCM) at École Polytechnique is internationally recognized for its expertise in molecular catalysis, electrochemistry, and analytical chemistry. The laboratory hosts advanced platforms for electrochemical characterization and product analysis.

Within this project, LCM will provide expertise in electrochemical and photoelectrochemical measurements, as well as in the identification and quantification of reaction products generated during CO_2 reduction using state-of-the-art analytical techniques.

The collaboration between IPVF and LCM will provide a highly interdisciplinary environment combining materials science, spectroscopy, electrochemistry, and catalysis.

Main Responsibilities

The postdoctoral researcher will play a key role in the experimental development of the project. The main responsibilities will include:

- Development and optimization of chalcogenide-based photoelectrodes through compositional and interfacial engineering.
- Investigation of photoelectrochemical properties under simulated solar illumination.
- Electrochemical and photoelectrochemical characterization of photoelectrodes under different operating conditions (inert and CO_2 atmospheres, varying electrolyte compositions and pH).
- Analysis of reaction products from CO_2 reduction using GC, GC-MS, IC, and NMR.
- Participation in operando spectroscopic studies to understand structure–property relationships.
- Data analysis and development of mechanistic insights linking material composition, electronic properties, and catalytic activity.
- Contribution to scientific publications and presentations at international conferences.

Candidate Profile

Applicants should hold a **PhD in materials science, physical chemistry, electrochemistry, or a related field**.

The ideal candidate will have experience in one or more of the following areas:

- photoelectrochemistry or electrochemistry
- semiconductor materials and thin-film devices
- catalysis or CO_2 reduction
- spectroscopic characterization techniques
- solar energy conversion technologies

Additional desired skills include:

- experience with PEC or electrochemical measurements
- knowledge of semiconductor interfaces
- strong experimental skills and data analysis capabilities
- ability to work in an interdisciplinary research environment
- good communication and scientific writing skills in English