Title: Hyperuniform Photoelectrodes for Hydrogen Generation.

Duration: 36 months Locations: INL (ECL site, Ecully).

Scientific domaine and context: According to the Paris Agreement adopted in 2015 by 195 countries, limiting greenhouse gas emissions is a global priority to significantly reduce climate change. Solar energy is expected to become the largest source of electricity worldwide by 2050 [1]. However, even though electricity can be generated using solar cells, the generated energy must be used instantly or stored in long-term and costly batteries. Fuels made directly from sunlight can be considered an environmentally friendly way to compensate for the intermittency of solar radiation [2]. Hydrogen, the simplest solar fuel, can thus be easily stored and transported and releases only water when combined with oxygen in a fuel cell. This sector is currently limited by the low efficiencies of electrolyzers. In this context, research on new photoelectrocatalytic materials becomes one of the most important challenges in nanoscience and nanotechnology. The thesis aims to develop highly efficient photoelectrodes for H2 generation using abundant and inexpensive materials such as silicon and functional oxides [3]. By employing innovative strategies, including hyperuniformity [4] and nanostructuring [5, 6], this study aims to enhance light-matter interactions and achieve improved light absorption, thereby increasing overall efficiency.

Thesis Objectives : The main objective of the thesis is to achieve a "solar to hydrogen" efficiency greater than 10% with a durability of 10 years, thus paving the way for cost-effective and adaptable renewable energy technologies. The thesis work is divided into four sub-objectives.

- Design and synthesis of photoelectrodes using abundant materials: Silicon, protective oxides, and catalysts will be selected and optimized for their electronic, optical, and electrocatalytic properties as well as their criticality. Various fabrication techniques will be explored to produce thin films with suitable heterojunctions and compositions (especially PN junctions) for efficient H2 generation.
- Implementation of hyperuniformity for enhanced light-matter interactions: Hyperuniformity will be developed as a means to promote optimal trapping and absorption of light. This may involve hyperuniformizing the distribution of surface metallic catalysts or the morphology of the photoelectrode through etching techniques. Advanced simulation and modeling techniques of optical properties will guide the design process to achieve higher photon conversion efficiency.
- Characterization of photoelectrodes for light absorption and charge separation: Various characterization techniques, including microscopy and spectroscopy, will be used to evaluate the structural, optical, and electronic properties of fabricated photoelectrodes. The goal is to elucidate the mechanisms governing light absorption, charge carrier dynamics, and catalytic activity.
- Optimization of photoelectrode performance through materials engineering and device integration: Optimization based on experimental data will be undertaken to refine the properties of photoelectrodes and improve both conversion efficiency and durability. The integration of optimized photoelectrodes into photoelectrochemical cells will be carried out to assess system-level efficiency and stability.

Candidate Profile: The candidate must hold a master's degree or an engineering degree and must possess solid knowledge in materials physics, optics, and electrochemistry. A penchant for experimental work is essential, and modelling work will also be conducted. The candidate should have a good command of English and scientific communication.

Bibliography

[**1**] United Nations Development Program and World Energy Council, Energy and the challenge of sustainability (2000)
[**2**] International Energy Agency, Technology Roadmap, **Solar Photovoltaic Energy 2014 Edition** (2014)
[**3**] Mahesh P. Suryawanshi *et al.* **Progress in Materials Science** 134, 101073 (2023)
[**4**] Nasim Tavakoli *et al.* **ACS Photonics** 9, 1206 (2022)
[**5**] Peng Zhou *et al.* **Nature** 613, 66 (2023)
[**6**] Taylor S. Teitsworth et al. **Nature** 614, 270 (2023)

About INL

INL is a laboratory for fundamental and applied research in the field of micro and nanotechnologies. Research at INL aims to develop technologies for application domains covering major economic sectors: the semiconductor industry, information technology, life and health technologies, energy, and environment. (http://inl.cnrs.fr/)

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