Ultrafast spectroscopy of transparent solar cells designed for the near-IR

DIRECTEUR DE THESE : STEFAN HAACKE
INSTITUT DE PHYSIQUE ET CHIMIE DES MATERIAUX DE STRASBOURG,
23, RUE DU LOESS, BP 43, 67034 STRASBOURG
TEL : 03 88 10 71 71 ; E-MAIL : STEFAN.HAACKE@IPCMS.UNISTRA.FR

New approaches to make solar cells alternative to roof-top Silicon panels include Dye-Sensitized Solar Cells (DSSCs) [1]. They use organic dyes, which under the action of light liberate electrons and inject them into the semiconductor anode, on which they are grafted (fig. 1). The electron transfer process is ultrafast, i.e. it occurs within a picosecond or less (10^{-12} s). The dyes are regenerated to their neutral form on a slower micro-second time scale through an electrolyte, and the whole solar cell is then a source for electric current.

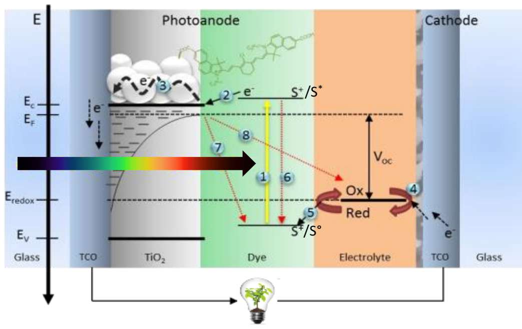

FIGURE 1: SCHEMATIC OF A DSSC, INCLUDING THE ENERGY LEVELS OF TIO_2, DYE AND ELECTROLYTE. FEMTOSECOND SPECTROSCOPY MEASURES THE PRIMARY STEP « 2 », THE INJECTION OF ELECTRONS INTO THE TIO_2 SEMICONDUCTOR. FROM PHD THESIS V. NOVELLI.

The whole power conversion efficiency (PCE) of the device is a result of many detailed molecular steps, but in many instances the first limiting step is the primary electron transfer [2] from the dye into the TiO_2. In our lab, we can measure the speed and the efficiency of the reaction via femtosecond fluorescence (FLUPS) and transient absorption spectroscopy (fs-TAS).

Our team is involved in the French national project “TRANSITION”, which develops DSSCs specifically for the near-IR portion of sun light. These devices are almost fully transparent, and could be used on large window surfaces for “building-integrated” photo-voltaics. The project partners, including the contributions from a previous PhD thesis in our team [3], have recently obtained a world-record near-IR solar cell, however with a moderate PCE of 2.1% [4]. New dyes, based on the new DPPy family recently reached higher PCE values [5]. Further improvements, which should allow to reach PCE’s in the range of 7%, concern the use of solid state electrolytes. **All these new materials call for further fs-TAS and ultrafast fluorescence experiments in order to understand their improved performances. This is the central motivation for the present PhD project.**

In this context, we search for a PhD candidate with a strong motivation in this applicative area of molecular spectroscopy. The student will be trained in making of DSSCs by the project partners at LRCI Amiens (Dr. F. Sauvage). Organic dyes, electrolytes and the semiconductors will be provided by the project partners in Amiens and Nantes. **We will address the central questions such as “do the new dyes have a higher electron injection rate ?”, “what is the optimal electrolyte composition for high injection rates” and “to which extent are molecular aggregates impairing the injection efficiency”.** Another new aspect is to investigate the effect of the excitation wavelength on the carrier injection efficiency. This can be best addressed by two-dimensional femtosecond spectroscopy, a powerful technique currently under development in our team.

[1] B. O'Regan and M. Grätzel Nature, **353**, pp. 737-740 (1991).
[2] C. Martín et al., J. of Photochemistry and Photobiology C, **26**, 1-30 (2016).
[3] I. Nikolinakos, PhD thesis University of Strasbourg; https://www.theses.fr/2022STRAE005
[4] A. Waad, V. Novelli, I. Nikolinakos, et al., JACS Au, **1,** 409-426 (2021).
[5] T. Baron, W. Naim, I. Nikolinakos et al., Angew. Chem. Int. Ed., **61,** e202207459 (2022).