3D PHOTOVOLTAICS

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The 3DPV group focuses on the manipulation of light and matter at the nanoscale with nanophotonic and nanoelectrochemistry concepts, and vice versa. With these, we develop new energy conversion concepts with higher efficiency with less quantity and more cost-effective materials. We generate strategies for the rational designing of photonic structures that maximize light absorption in ultra-thin PV architectures. In parallel, we exploit nanoelectrochemical methods to control where and when reactions take place. We exploit this control to introduce new synthesis pathways for PV materials (IIII-V, perovskites and metals) in line with circular chemistry, as well as to underpin the key physico-chemical properties of solid-liquid interfaces that rule charge transport, transfer and conversion from electrical to chemical energy.

Highlights

- Demonstrated the highest light absorption in ultra-thin Si films from rationally-designed nanopatterns with hyperuniform disorder [1]
- Developed a methodology for imaging and understanding light extinction in 3D along dielectric nanowires [2]
- Demonstrated the manipulation of charge transfer at liquid-electrode interface with controlled nanoscale resolution using scanning probes [3]
- Built new combinatorial scanning probe microscopy tools for in-situ photo-electro-chemical and photo-conductivity characterization [4]

Plans

Building on our high degree of spatio-temporal control over light and ions in solution, we will now explore their synergistic interplay, enabling new types of light-controlled material growth and chemistry at the nanoscale, for more efficient PV and electro-catalysis. We will further develop distinctive in-situ/operando scanning probe microscopes and use them for the investigation of both light-driven (electro)chemical phenomena at photonic/plasmonic nanoparticles, as well as charge transport through interfaces in solar cell devices.

Key research items

1. N. Tavakoli, R. Spalding, A. Lambertz, P. Koppejan, G. Gkantzounis, C. Wan, R. Röhrich, E. Kontoleta, A. F. Koenderink, R. Sapienza, M. Florescu, E. Alarcon-Llado, *Over 65% sunlight absorption in a 1 μm Si slab with hyperuniform texture*, ACS Photonics 9, 1206 (2022)

2. R.S. Federiksen, F. Matteini, H. Potts, G. Tutuncuoglu, K. Martinez, A. Fontcuberta i Morral, E. Alarcon-Llado, *Visual understanding of light absorption and waveguiding in standing nanowires with 3D fluorescence confocal microscopy*, ACS Photonics 4, 2235 (2017)

3. M. Aarts thesis, *Interphase: On Nanofabrication and Electrical Double Layer Dynamics with Electrochemical Scanning Probes*, University of Amsterdam, January 2021

4. F. Podjaski, D. Weber, S. Zhang, L. Diehl, R. Eger, V. Duppel, E. Alarcon-Llado, G. Richter, F. Haase, A. Fontcuberta i Morral, C. Scheu, B.V. Lotsch, *Rational strain engineering in layered oxides for highly efficient hydrogen evolution catalysis in acidic media*, Nature Catalysis 3, 55 (2019)

5. L.S.D. Antony, G. Grimaldi, A. Van der Weijden, I. Schuringa, J. Borchert, B. Ehrler, W.L. Noorduin, E. Alarcon-Llado, *The role of Pb oxidation state of the precursor in the formation of 2D perovskite microplates*, Nanoscale 15, 6285 (2023)

Artist impression on probe-driven nanoscale electrochemical deposition (credits: Laura Canil).