Artificial Leafs Using Advanced Photoelectrosynthetic Cells – Physical boundary conditions and material science challenges

J. Schuch, P. Connor, C. Steinert, S. Tengeler, B. Kaiser, W. Jaegermann, J. P. Hofmann
Surface Science Division, Department of Materials and Earth Sciences, TU Darmstadt
V. Smirnov, F. Urbain, F. Finger, U. Rau
IEK 5, Forschungszentrum Jülich

One of the most demanding research aims for a holistic and sustainable energy economy is the integration of storage devices to solar energy converters to overcome the discontinuous supply of solar power. The direct production and use of chemical fuels such as H_2 via water splitting or CH_xO_y from CO_2 reduction mimicking natural photosynthesis would provide favourable solutions. However, the inherent challenges in the direct production of these solar fuels from solar light have not been solved in a satisfying way, yet.

Direct H_2 formation by photoelectrochemical H_2O splitting theoretically provides high light (photon) to fuel (H_2) efficiency. Advanced materials and design concepts based on the coupling of wide band gap semiconductors i.e. ZnTe, GaP, SiC, thin film Si or III-V tandem (multijunction) cells and nano-sized metal catalysts are considered as very promising options. Materials and devices with promising performance must be designed, grown, processed and characterized combining the demands of a photovoltaic converter coupled loss free to efficient electrolyser components.

From a consideration of the given thermodynamic and kinetic conditions to split H_2O we expect that only tandem (multijunction) structures with a sufficient photovoltage of the solar converter component will be able to split H_2O into H_2 (HER) and O_2 (OER). This is even more true for the light induced CO_2 reduction reaction (CO2RR). In the case of multi-electron transfer reactions new highly efficient electrocatalysts must be identified again avoiding precious metals. For device optimisation the interactions of intermediates of the electrochemical reactions with the electrocatalyst surface must be considered.