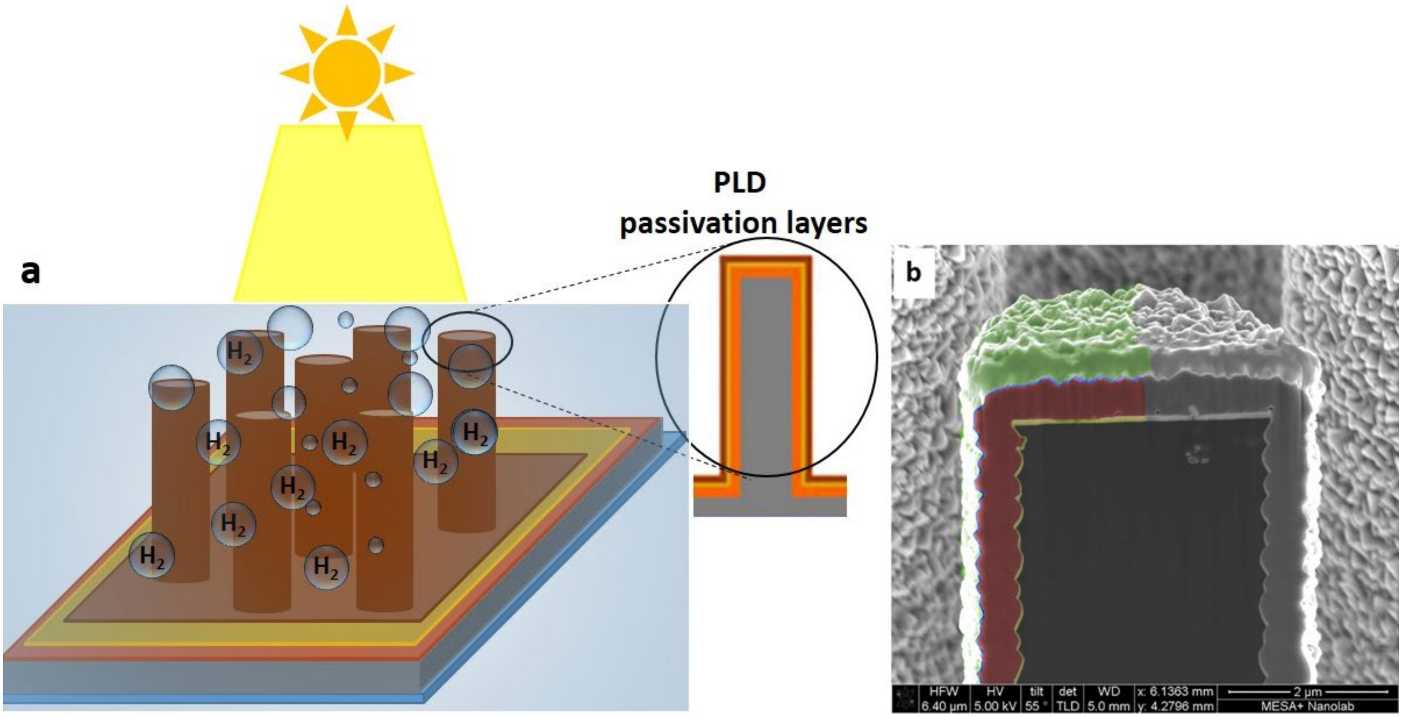
Artificial leaf: to capture and store solar energy

Solar cells have disadvantages, for instance when it comes to the coordination between supply and demand. One of the proposed solutions is a so-called solar-to-fuel device: (S2F). With this concept, solar energy is converted into a fuel that can be stored. Pramod Patil Kunturu (University of Twente) investigated S2F's resulting in the thesis 'Tandem Cu_2O-covered silicon micropillar photocathodes for solar-to-fuel devices'.

Solar technology implementation has been broadly focused on electricity generation. Despite recent progress in solar electrical energy generation, important issues remain unsolved, such as the continued need for high-power energy demand for transport, central heating, and industrial processes, and the intermittency problem, such as caused by the alternation of summer and winter periods. One of the proposed solutions is to construct a solar-to-fuel (S2F) device, which describes the concept of turning solar energy into storable fuel. To fabricate a fully inte-



(a) Schematic diagram of sunlight driven hydrogen generation using photocathodes, (b) HR-SEM cross-section images of PLD-coated ZnO (20 nm) and TiO_2 (100 nm) on top of the Si/ITO-Au/Cu_2O micropillar devices. False-colored on figure indicates conformal layers (ITO/Au layer - yellow, Cu_2O film - light red, n-ZnO- blue, and TiO_2 - green)

grated, efficient S2F device based on photo-electricity, a single or set of semiconductors must be combined with a proper electrocatalyst. In this thesis, we show various geometries and materials combinations for a S2F device, primarily based on copper-based photocatalysts with structured silicon as a base material, employing device structuring and modification.

Copper oxides

In summary, the findings presented in this thesis focus primarily on copper oxides (Cu_2O & CuO) in photocathodes. Because of its band gap of 2.0 eV, Cu_2O could theoretically provide a solar to hydrogen conversion efficiency of 18 % for a single junction Cu_2O photocathode under established working conditions for water splitting. However, the major limiting factors are the material stability and the mismatch between the optimal thickness for light absorption and the charge carrier diffusion length. As shown in this thesis, micro/nanostructuring is favourable for enhancing the efficiency, and can provide devices that deliver higher performance compared to planar architectures.

To improve the performance of photocathodes based on Cu_2O, composite materials have been used, heterojunctions have been developed, and the surface has been passivated with stable oxide materials with improved optical absorption and charge extraction properties. The tandem PEC configuration is shown to be superior, concerning aspects of high efficiency, stability, and the use of earth abundant materials. These improvements may lead to design strategies for fabricating efficient photocathodes and push the boundary of solar water splitting, possibly beyond the target of 10% solar-to-hydrogen efficiency.

The PhD research work of Pramod Patil Kunturu was carried out in the department of Molecular Nanofabrication. His supervisor is prof.dr.ir. J. Huskens from the faculty Science and Technology at University of Twente. He successfully defended his PhD thesis on the 5th of July 2019. The title of his dissertation is ‘Tandem Cu_2O-covered silicon micropillar photocathodes for solar-to-fuel devices’.

The thesis is online (PDF)>