EBERHARD KARLS UNIVERSITÄT TÜBINGEN

A New Plasmonic System for cost-effective Solar Hydrogen Production

Technology Description

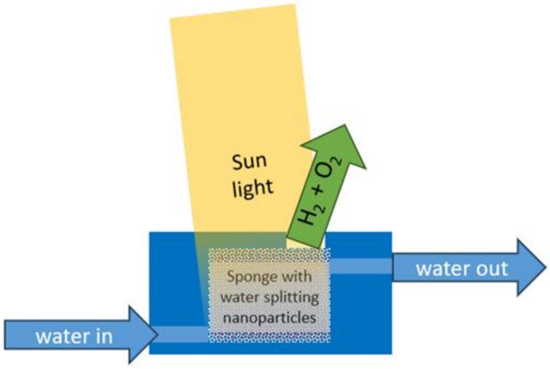

Figure 1a: *Overall design of our system for plasmonic solar hydrogen production via photon driven H_2O splitting.*

Figure 1b: *Two steps of the preparation leading to our plasmonic water splitting system. Left: uncoated PDMS sponge. Right: PDMS sponge spiked with TiO_2 and Au particles. The plasmonic nature of the Au nanostructures leads to the visible colour change of the scaffold. (corresponding to Fig. 2f).*

Plasmonic water splitting is a photon to hydrogen process where optical properties of materials on the nanoscale are used to promote the splitting of H_2O molecules into H^+ and O^- ions, followed by reforming of the ions into the gases H_2 and O_2. Thus, the energy provided by sunlight can be converted directly into hydrogen by adequately designed nanostructures.
The process is an upcoming source of green hydrogen[1,2], but still under development. The efficiency of the actually available systems is less than 5 % (photon to hydrogen). One of the reasons: The plasmonic materials so far used for H_2O-splitting were arranged on planar 2D substrates[3].

Here we present to our knowledge the first three-dimensional substrate for a plasmonic solar hydrogen production system. Our approach uses PDMS sponge-like scaffolds that are in addition coated with nanoparticles like TiO_2 and Au. The building of this transparent 3D-structures becomes possible via our newly developed construction process (please see the general description in Figure 2 on the next page).

First data point to a highly efficient H_2 generation. If 5% efficiency is reached (which is a very conservative estimate), the area covered with this system has to be ~5000 km² to cover the gross electricity consumption of Germany (546.7 TWh in 2022).

Innovation

- 3D-shaped transparent polymer sponges promise highly efficient use of solar radiation in plasmonic H_2 production from water splitting.

- Cheap and easy production process for plasmonic material with less material input, especially minimized loss of elemental gold compared to competing production systems.

IP Status/Cooperation Requested

Two Priority Applications filed on 2022-04-01, Application Numbers:
EKU-P5DE: 10 2022 107 894.9
EKU-P6DE: 10 2022 107 895.7
Subsequent PCT-applications

Looking for industrial partners with interests for licensing, collaborative further development and scaling up of production process.

Applications

- H_2 solar collector for industrial solar farms on land and water
- H_2 solar collector for private applications on house roofs

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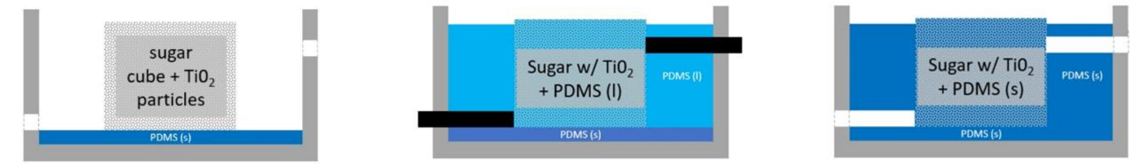
Proof of Concept

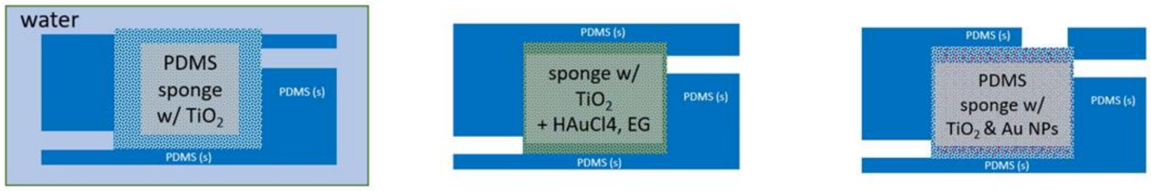
Plasmonic Solar H_2 Generation: How to Build a better Catalytic Material



a) *Curing the bottom layer and placing a sugar cube as a template for the sponge.*

b) *Adding spacers, filling the mold with PDMS until the cube is submerged.*

c) *Curing the additional PDMS and removing the spacers.*



d) *Removing the flow cell from the mold and solving the sugar in a water bath.*

e) *Adding the gold growth solution and heating the device for 2.5 h at 80°C.*

f) *Purging the sponge to remove rest of the growth solution. Cutting hole in top cover.*

Figure 2: *Schematic of the fabrication of the flow cell with the plasmonic PDMS sponge as its centerpiece. The process is entirely performed under ambient or near ambient conditions. Apart of the $HAuCl_4$ all chemicals are widely available.*

Plasmonic Hydrogen Production: High Rates under Illumination

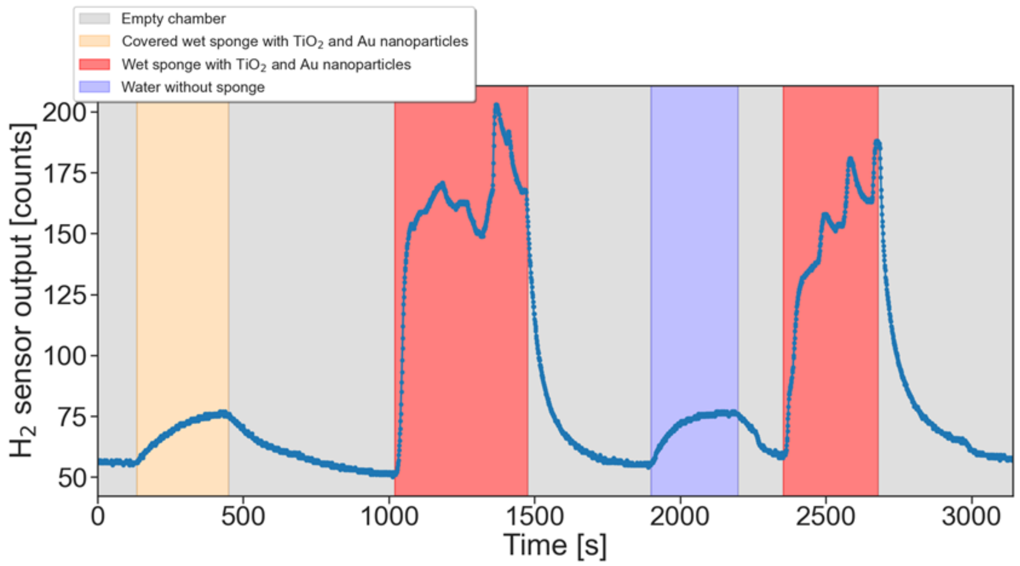


Figure 3: *Overall productive capacity of our system. We performed measurements of the hydrogen generation under different experimental conditions within one and the same setting. The system was permanently illuminated with indirect sunlight. Sections in red: our wet porous PDMS sponge spiked with TiO_2 and Au particles is placed in the chamber. Please note the huge burst in H_2 production immediately after illumination. The yellow, grey and blue areas show the results of control experiments. In the yellow section, the plasmonic sponge spiked with TiO_2 and Au particles is placed in the chamber but shielded from sunlight via a cover. Blue section: A few millilitres of water are placed in the empty chamber. The resulting weak signal of the H_2 sensor output in these both control experiments is due to a residual sensitivity of the sensor (SEN-MQ8) to gaseous H_2O. Grey section: the photonic system is taken out of the chamber. H_2 levels are falling immediately due to a complete stop of production.*

References

1 Zhang, Q.Z., et al., *Recent advancements in plasmon-enhanced visible light-driven water splitting.* Journal of Materiomics, 2017. **3**(1): p. 33-50.

2 Abed, J., et al., Recent Advances in the Design of Plasmonic Au/TiO2 Nanostructures for Enhanced Photocatalytic Water Splitting. Nanomaterials, 2020. 10(11): p. 2260.

3 Laible, F., et al., Continuous reversible tuning of the gap size and plasmonic coupling of bow tie nanoantennas on flexible substrates. Nanoscale, 2018. 10(31): p. 14915-14922.