

Influence of surface structure geometry on the performance of electrodes for photoactivated hydrogen generation

M. Schieda[a], A. Rzeszutek[a], I. Herrmann-Geppert[a],
A. C. Bronneberg[b], D. L. Olynick[b], T. Klassen[a]

[a] Helmholtz-Zentrum Geesthacht, Institute of Materials
Research
Max-Planck-Str. 1, 21502 Geesthacht, Germany

[b] Molecular Foundry, Lawrence Berkeley National
Laboratory
One Cyclotron Road, Berkeley, CA 94720, USA

Solar fuel generation in photoelectrochemical cells is a key technology for the utilization of renewable energy. However, in order to achieve cost effective performance, it will be necessary to develop efficient photoelectrode interfaces.

The use of nanostructuring in order to increase the specific surface area of photocatalysts has attracted increasing interest in recent years [1], as structured electrodes consistently show higher photocurrents than planar electrodes [2]. Furthermore, the influence of the nanostructure geometry has been experimentally demonstrated, for example, in the case of nanorod catalysts, which show optimal H₂ production rates for light incident along the nanorod axis [3]. Despite this, there are no extensive systematic studies of the influence of the surface structure geometry on photoelectrochemical performance in the water splitting reaction.

Besides having higher specific surface area and showing enhanced light capture, photoelectrodes for practical hydrogen generation devices must adequately manage the gaseous reaction products of the water splitting reaction. Nevertheless, most research is focused on structured flat electrodes, which also suffer from photovoltage loss due to the adsorbed gas bubbles on the electrode. Therefore further structuring is required for an efficient gas management.

We here report on our ongoing efforts to understand the relationship between photoelectrode surface structure geometry and the various parameters affecting photoelectrocatalytic performance in water splitting processes.

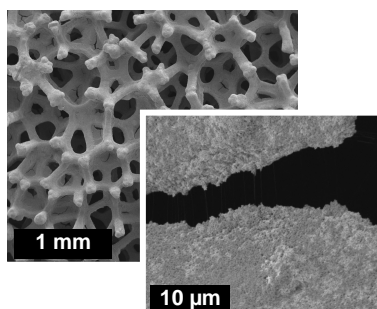


Fig 1 Nickel foam substrate, coated with porous TiO₂/PANI composite.

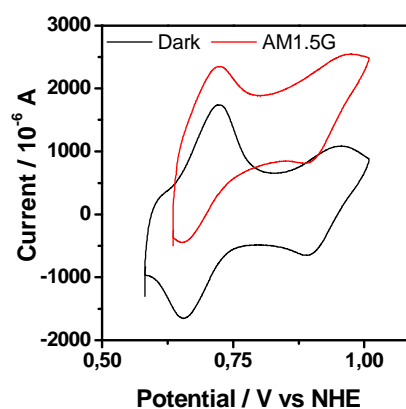


Fig 2. WO₃ coating generated in-situ over a PANI film: cyclic voltammetry in acid electrolyte (H₂SO₄ 0.5 M), at a scan rate of 25 mV s⁻¹ (A = 1 cm²), in dark conditions and under illumination (AM1.5G).

As model catalysts for our systematic study we have chosen TiO₂, WO₃, as these have been extensively studied in recent years. Starting with both porous and patterned substrates, we further increase the surface area by depositing structured photocatalysts. The resulting hierarchically structured electrodes are extensively characterized physicochemically (HRSEM, XPS, XRD, Raman, specific surface area, catalyst layer thickness). Fig. 1 shows an example of a porous nickel foam coated with a macroporous polyaniline/TiO₂ composite. The polyaniline (PANI) acts as binder and current collector. An example of PANI supporting the photoelectrocatalytic properties of the WO₃ can be seen in Fig. 2.

In this here presented contribution, the photoelectrochemical performance under simulated sunlight is correlated to the surface structure geometry and to the resulting physicochemical properties, and compared to that of planar photoelectrodes.

References

1. Barreca, D. et al. *Adv. Funct. Mater.* **21**, 2611-2623 (2011).
2. Hwang, Y.J. et al. *Nano Lett.* **9**, 410-415 (2008).
3. Wang, Y. et al. *ACS Nano* **2**, 1492-1496 (2008).