Silicon Photovoltaics for Hydrogen Production

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The SHINE Nano-Tera.ch project aims at the realization of a fully integrated solar-to-hydrogen system using thin-film silicon solar cells. Compared to a standard approach with discrete elements – with separate solar panels and electrolyzer – an improved efficiency might be expected thanks to the recycling of the dissipated heat from the solar cell using the same components.

Due to the intermittent nature of renewable energy technologies such as wind and solar, their large-scale implementation requires solving current challenges related to energy storage.

A possible solution to elegantly store energy from sunlight in chemical bonds is the direct production of hydrogen using solar cells and water. Hydrogen can for instance be compressed, transported and stored; alternatively it can be injected in the gas distribution system as it is done, e.g., in a demonstration project in Germany.

The multidisciplinary Nano-Tera.ch project SHINE involves several research groups within the fields of optics for solar energy, optics and fluidics, semiconductor solar cells, electrochemical materials and system simulation [1]. CSEM is in charge of developing the photovoltaic components of the system.

Thin-film silicon-based triple-junction devices have been developed to be integrated with electrolysis units. Such cells consist of a stack of two amorphous silicon subcells and one microcrystalline silicon subcell, and are optimized to achieve a sufficient voltage for water splitting when coupled to an electrolyzer.

At one sun illumination, an open-circuit voltage of 2.14 V and a power density produced at the maximum power point of 11.3 mW/cm^2 have been obtained, leading to a potential water splitting efficiency of 8.1% [2]. This device has been successfully integrated in laboratory hydrogen production setups, so far leading to a stable solar-to-hydrogen conversion efficiency above 6% for over 20 hours.

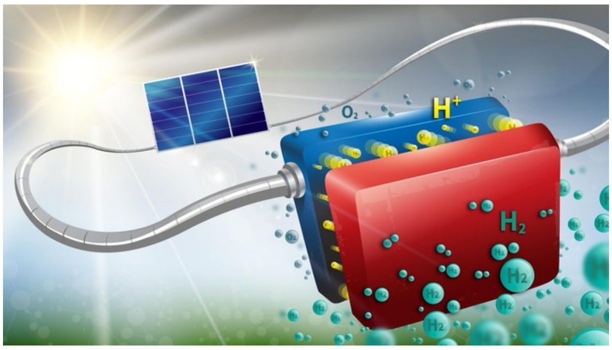

Figure 1: Artistic impression of our record solar-driven water splitting system [3].

More straightforward solutions using silicon solar cells have also been studied, such as a serial interconnection of silicon heterojunction solar cells (see Figure 1). With this approach, we have obtained a stable (>100 h) solar-to-hydrogen conversion efficiency of 14.2% without DC/DC conversion, fully relying silicon-based solar cells and earth-abundant electrocatalysts [4]. This value currently represents the highest reported efficiency worldwide for solar-driven water splitting based on silicon photovoltaics [3-5].

The solar cells that have been applied in this study are of the same type and manufacturing procedure as the ones used in the façade covering the south side of the CSEM building in Neuchâtel (see Figure 2). Moreover, contrary to many other approaches presented in the literature, this solution provides an excellent stability. Efficiencies slightly above 16% should be practically possible on the short term following this approach.

Figure 2: Solar façade on the CSEM building in Neuchâtel.

As the components in the presented system are commercially viable, easily scalable and have long lifetimes, these devices have the potential to open a fast avenue towards the industrialization and deployment of cost effective solar-fuel production systems. As an example, a 12-14 m^2 system installed in Switzerland would allow the generation and storage of enough hydrogen to power a fuel cell car over 10'000 km every year.

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[1] http://www.nano-tera.ch/projects/367.php

[2] D. Dominé, *et al.*, Proc. of WC PEC 6, Kyoto, Japan (2014).

[3] https://actu.epfl.ch/news/an-effective-and-low-cost-solution-for-storing-sol/

[4] J.-W. Schüttauf, M.A. Modestino, E. Chinello, D. Lambelet, A. Delfino, D. Dominé, A. Faes, M. Despeisse, J. Bailat, D. Psaltis, C. Moser and C. Ballif, J. Electrochem. Soc. 163, F1177 (2016).

[5] J. W. Ager, M. Shaner, K. Walczak, I. D. Sharp, S. Ardo, Energy Environ. Sci. 8, 2811 (2015).