Holding on to the electrons in artificial photosynthesis

For our future sustainable society mankind will have to make efficient use of solar energy. The conversion of sunlight to electricity is already a powerful technology, but for storage and transport we need liquid fuels, which have a much higher energy density than batteries. Researchers have now designed new clever molecules that can play a key role in Solar-to-Fuel conversion. These molecules hold on to electrons in such a way that they are not trapped quickly by oxygen and water, but can still be transported easily inside the material.

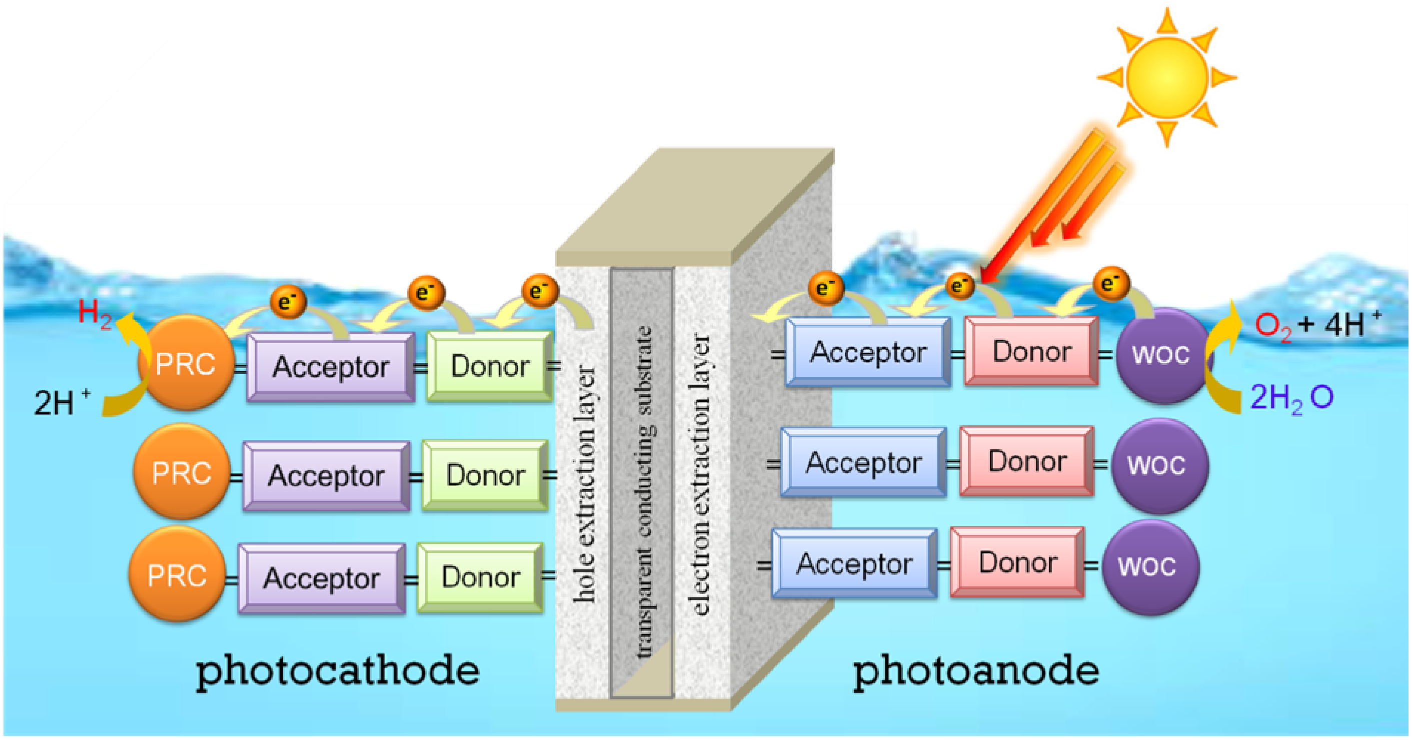

Fig. 1. Direct process of solar to hydrogen conversion by molecule based artificial photosynthesis. WOC = water oxidation catalyst, PRC = proton reduction catalyst. Electrons are taken from water and used to produce hydrogen. BPTI’s are excellent electron acceptors for use in the photoanode

Natural photosynthesis provides an inspiring blueprint for constructing an efficient artificial solar-to-fuel conversion system: an “artificial leaf”. The core of molecule-based artificial photosynthetic devices is light-induced electron transfer between donor and acceptor molecules in the photoelectrodes (Fig. 1). This generates charged intermediate species that can activate the water oxidation catalyst (WOC) and proton reduction catalyst (PRC) for oxygen and hydrogen production. These intermediate species, however, are very sensitive to reactions with water and oxygen. This is especially serious for the ones that carry the negative charge that ultimately generates the solar fuel: hydrogen. The key challenge in all fields of modern chemistry is to steer reactions in the right direction, and this was achieved here by improving the molecules that carry the electrons away after they have been taken out of water by using sunlight.

PhD student Hung-Cheng Chen at the University of Amsterdam developed a series of novel molecules (called benzo[ghi]perylenetriimides (BPTI's))

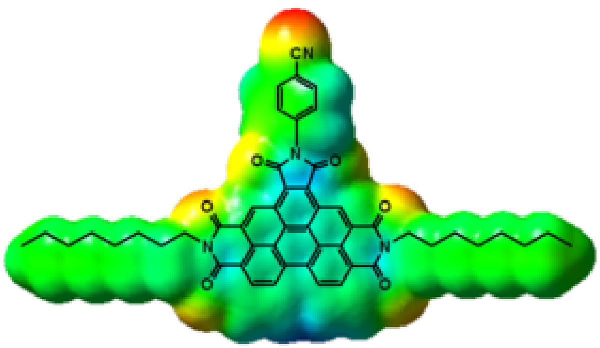

Fig. 2. Chemical structure of BPTI as electron acceptor and its electrostatic potential map

(Fig.2) that strongly absorb light in the blue-green range of the sunlight spectrum. In order to build devices with thin layers of molecules, it is important that the materials can be processed, preferably in a solution. Unfortunately, big flat molecules like BPTI's are typically very badly soluble. Chen, however, managed to prepare special BPTI's that are well soluble in organic solvents. At the same time the ability of BPTI's to take up electrons was boosted. Therefore, these BPTI molecules in a photoanode (Fig. 1) can hold on to the captured electrons in air saturated water much longer than before. Because the reactions with water and oxygen are slowed down, the electrons have more chance to go the right way and move towards the photocathode for making hydrogen. A third useful property of Chen's BPTI's is that electrons can move around rather easily in films made of layers of these molecules. They are predicted to work as well as the commonly used fullerenes in organic photovoltaic cells, but they can be much cheaper. Chen's studies show the potential of BPTI compounds as electron acceptors in devices for artificial photosynthesis aiming for water splitting and also represent very promising non-fullerene electron-transport materials for organic solar cells.

Publication

Highly Soluble Benzo[ghi]perylenetriimide Derivatives: Stable and Air-Insensitive Electron Acceptors for Artificial Photosynthesis.
Chen HC, Hsu CP, Reek JN, Williams RM, Brouwer AM
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