“Hydrogen farm” strategy for scalable solar hydrogen production via water splitting

With the support by the National Natural Science Foundation of China and the Chinese Academy of Sciences, the research team led by Prof. Li Can (李灿) at the State Key Laboratory of Catalysis, Dalian Institute of Chemical Physics (CAS) proposed and demonstrated a practically feasible approach for scalable solar hydrogen production via water splitting, named “Hydrogen Farm Project” (HFP). This approach realized a world record solar-to-hydrogen efficiency exceeding 1.8%, which was published in *Angew Chem Int Ed* (2020, DOI: 10.1002/anie.202001438)

Harvesting and converting solar energy into the form of chemical fuels is a promising solution for solar energy storage and utilization. Among the solutions for solar-to-chemical energy conversion, photocatalytic overall water splitting using particulate photocatalysts is regarded as an economical approach for hydrogen production. However, the method suffers from extremely low solar-to-hydrogen conversion efficiency due to the poor charge separation efficiency and the possible reverse reaction between H_2 and O_2, greatly challenging the large scale process.

Inspired by the natural photosynthesis in the agricultural process, Prof. Li's group proposed a practically feasible solar energy storage approach via a redox shuttle ion loop comprising two sub-systems: one is highly efficient photocatalytic water oxidation for solar energy storage and protons production, and the other is to utilize protons and the electrons stored in the redox shuttle to produce H_2. As such approach is principally analogue to the agricultural farm process, namely planting crops in a large scale and then concentrating to harvest once crops are ripe, it is named “Hydrogen Farm” Project (HFP). In the HFP, water oxidation and proton reduction reactions are spatially separated, consequently resolving the H_2/O_2 gas separation problem.

To fulfill the HFP approach, highly active photocatalysts are required for efficient photocatalytic water oxidation in the presence of shuttle ions, and the reverse reaction between shuttle ions must be completely suppressed. Based on the fundamental findings that the photogenerated electrons and holes can be spontaneously separated between different facets of a semiconductor photocatalyst, this work demonstrated experimentally that $BiVO_4$ crystals exposing both {010} and {110} facets exhibited an extremely high efficiency for water oxidation, resulting in an AQE up to 71%, and more importantly, the reverse reaction of Fe^{2+} shuttle ions could be completely blocked. With this ideal photocatalyst, a solar-to-hydrogen efficiency exceeding 1.8% was achieved, which is the world record efficiency for photocatalytic water splitting systems so far. Meanwhile, a scalable photocatalyst panel for solar energy storage via HFP was demonstrated under sunlight irradiation outdoors. This work offers a promising and practical strategy for solar energy harvesting and solar hydrogen production on a large scale by using particulate photocatalysts.

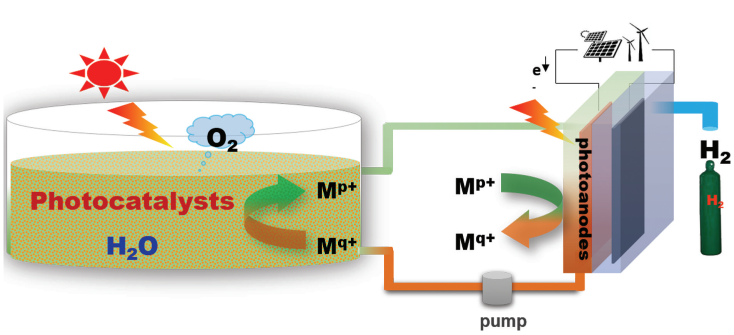

Figure Scheme of hydrogen farm project for scalable solar hydrogen production.