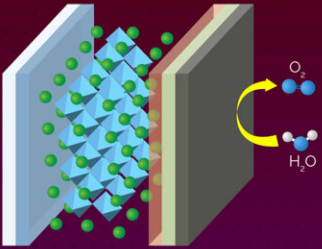


Researchers develop highly efficient organometal halide perovskite photoelectrodes for water splitting

August 9 2023

High-Efficiency Organometal Halide Perovskite-Based Photoanodes

Organometal halide perovskite (OHP)-based photoanodes are promising candidates for photoelectrochemical (PEC) water splitting

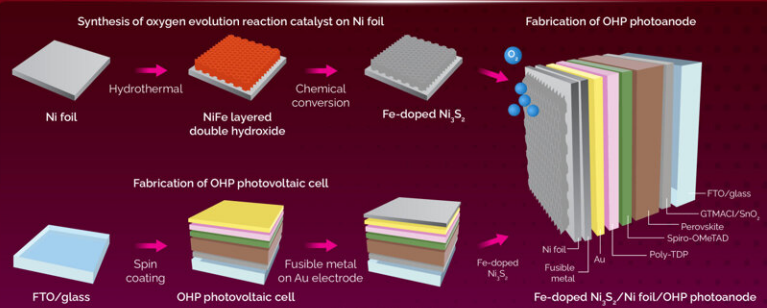


However, they suffer from:

- Non-radiative recombination of photogenerated carriers
- Slow reaction kinetics

How can we design OHP-based photoanodes that suppress these losses?

Fabricating novel high-efficiency OHP photoanodes using rational design



Synthesis of oxygen evolution reaction catalyst on Ni foil: Ni foil → Hydrothermal → NiFe layered double hydroxide → Chemical conversion → Fe-doped Ni₃S₂

Fabrication of OHP photoanode: FTO/glass → Spin coating → OHP photoanode cell → Fusible metal on Au electrode → Fe-doped Ni₃S₂ → Fe-doped Ni₃S₂/Ni foil/OHP photoanode

Fabrication of OHP photovoltaic cell: FTO/glass → Spin coating → OHP photovoltaic cell → Fusible metal on Au electrode → Fe-doped Ni₃S₂

Final OHP photoanode structure: FTO/glass, GTMACl/SnO₂, Perovskite, Spiro-OMeTAD, Ni foil, Au, Fusible metal, Fe-doped Ni₃S₂, Poly-TDP

FTO: Fluorine-doped tin oxide; GTMACl: Glycidyltrimethylammonium chloride; Spiro-OMeTAD: 2,2',7,7'-tetraakis-[N,N'-di-(4-methoxyphenyl)amino]-g-g'-spiro-bifluorene; Poly-TDP: Poly[N,N'-bis(4-bulkyphenyl)-N,N'-bis(phenyl)-benzidine]

- Cost-effective and low-temperature solution process
- Highest reported photon-to-current conversion efficiency of 12.79%
- Fe-doped Ni₃S₂ with high catalytic activity promotes PEC water oxidation kinetics
- Recombination suppressed by GTMACl-treated SnO₂ electron transport layers

The rationally designed OHP photoanodes enable highly efficient PEC water splitting by suppressing undesirable losses

Suppression of Undesired Losses in Organometal Halide Perovskite-Based Photoanodes for Efficient Photoelectrochemical Water Splitting
Choi et al. (2023)
Advanced Energy Materials | 10.1002/aeem.202300951

GIST Gwangju Institute of Science and Technology

The novel photoanodes suppress the undesirable internal and external losses associated with photoelectrochemical water splitting, resulting in an unprecedented photon-to-current conversion efficiency of 12.79%. Credit: Professor Sanghan Lee from Gwangju Institute of Science and Technology, Korea

Currently, hydrogen is mainly produced by natural gas, which,

unfortunately, also generates greenhouse gases such as carbon dioxide as by-products. Scientists argue that hydrogen produced this way, while economical, is not truly sustainable, and thus requires a more eco-friendly approach for its generation.

Photoelectrochemical (PEC) water splitting based on [solar energy](#) is one such promising approach. However, its widespread application is limited by a lack of efficient photoanodes for catalyzing the rate-limiting oxygen evolution reaction (OER), an important reaction in PEC water splitting.

Recently, organometal halide perovskites (OHPs) have emerged as a promising photoanode material on this front. Unfortunately, OHP-based photoanodes suffer from two undesired losses that limit their efficiency. One is an internal loss resulting from a recombination of photogenerated charge carriers (required for electricity generation) within the anode itself, which, in turn, hinders water splitting.

The other is external loss due to the slow reaction kinetics of water splitting, resulting in a loss of charge carriers at the interface of the anode and electrolyte.

Against this background, a team of researchers from Korea and U.S., led by Professor Sanghan Lee from Gwangju Institute of Science and Technology and including Associate Professor Jangwon Seo from Korea Advanced Institute of Science and Technology, has now developed a highly efficient OHP-based photoanode using a rational design approach, which overcomes the above limitations. Their study was published in the journal *Advanced Energy Materials*.

"The high efficiency of the photoanode for photoelectrochemical water splitting was achieved through the simultaneous suppression of internal and external losses of photogenerated carriers," highlights Prof. Lee.

In their work, the team fabricated a novel Fe-doped Ni₃S₂/Ni foil/OHP photoanode in three steps. They first synthesized the Fe-doped Ni₃S₂ catalyst for OER on Ni foil through a hydrothermal method followed by a chemical conversion. They then separately fabricated the OHP photovoltaic cell consisting of SnO₂ electron transport layers (ETLs) through spin coating. Finally, they combined the two components to obtain the photoanode.

The team found that adding glycidyltrimethylammonium chloride (GTMACl) to the anode passivated the defects at the OHP/ETL interface, effectively suppressing the undesired charge carrier recombination within the anode. Further, it enhanced the light-soaking stability of the OHP cell, a crucial factor in real-world PEC water splitting. Additionally, the high catalytic activity of Fe-doped Ni₃S₂ ensured a high OER rate at the anode, reducing the loss of photogenerated carriers within the electrolyte.

Consequently, the Fe-doped Ni₃S₂/Ni foil/OHP photoanode exhibited an unprecedented applied bias photon-to-current conversion efficiency of 12.79%, higher than that reported for OHP-based photoanodes in existing studies.

Overall, this study provides important insights into the prospects of rationally designed OHP-based photoelectrodes, as Prof. Lee highlights: "The proposed [technology](#) is expected to contribute to the vitalization of the hydrogen economy and carbon neutrality by enabling a large-scale and eco-friendly hydrogen production using solar energy without external voltage in the next 10 years. This, in turn, will help realize hydrogen as an ideal renewable source of energy in the future."

More information: Hojoong Choi et al, Suppression of Undesired Losses in Organometal Halide Perovskite-Based Photoanodes for Efficient Photoelectrochemical Water Splitting, *Advanced Energy*

Materials (2023). [DOI: 10.1002/aenm.202300951](https://doi.org/10.1002/aenm.202300951)

Provided by GIST (Gwangju Institute of Science and Technology)

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