CanApple ニュース（321）

カーボン・エネルギーコントロール社会協議会 (CanApple)
事務局：民秋均
発行責任者：石谷治
編集責任者：八木政行

Turning Sunlight into Clean Hydrogen Fuel: Transparent WO_3 Film Technology

Niigata University Debraj Chandra

With growing global concerns over energy and the environmental sustainability, scientists are actively seeking clean and renewable technologies to produce carbon-neutral fuels.[1] One promising solution is photoelectrochemical (PEC) water splitting, a process that uses sunlight and a semiconductor material (used as photoanode and photocathode) to split water into oxygen (O_2) and hydrogen (H_2). Since 2010, when I began investigating solar water splitting by extending my expertise in nanomaterials development, my commitment to this filed has remained steadfast. In this newsletter, I would like to introduce the development of a new class of optically transparent and mesoporous tungsten trioxide (WO_3) photoanode for efficient PEC water oxidation and discuss their prospective utilization in tandem PEC water splitting devices.

WO_3 is a leading semiconductor material for visible-light-driven PEC water splitting,[2-3] but characteristically suffers from poor stability and low Faradaic efficiency (efficiency of electrical current drives the desired O_2 evolution; FE_{O2}, ~70%) due to the unwanted surface photo-oxidation that compete with water oxidation to O_2 evolution. However, achieving a stable WO_3 photoanode and $FE_{O2} \approx 100\%$, especially under neutral pH conditions, is essential for real-world application to solar water splitting.

Another challenge is the need for optically transparent photoanodes for PEC water splitting that can be used in next-generation tandem solar devices, where they act as the “front window”, allowing longer-wavelength light to pass through and be harvested efficiently. In these devices, the overall efficiency is enhanced by stacking multiple photoabsorbers to capture different regions of the solar spectrum. Until now, no transparent WO_3 photoanode has been able to deliver both high performance and long-term stability during PEC water splitting.

We have successfully developed a crystalline mesoporous WO_3 film with high optical transparency, delivering both high efficiency and remarkable long-term stability for PEC water oxidation.[4] Using a surfactant-template strategy combined with a unique in situ template-carbonization technique, we fabricated the WO_3 film directly on an FTO electrode while preserving its oriented crystal structure. The resulting material exhibits a mesoporous structure with high specific surface area (124 m^2 g^{-1}) for abundant active sites, ultrathin pore walls (~10 nm) for shorter hole-migration paths for surface reaction, and preferential growth of an intrinsically active crystal plane for water oxidation (Fig. 1A).[4] This unique architecture enables faster charge transport and more efficient water oxidation at the photoelectrode surface. As a result, the co-catalyst deposited WO_3 film achieved up to three times higher performance than conventional WO_3, while maintaining 98% of its activity even after 30 hours of continuous operation with an outstanding FE_{O2} of 93% (Fig. 1B), which is unprecedented among WO_3 photoanodes.[4] This innovation paves the way for the development of practical solar water-splitting systems that are capable of producing renewable hydrogen on a large scale. Transparent mesoporous WO_3 films have the potential to herald in a new era of sustainable, efficient solar fuels with the addition of further optimization and integration into tandem device architectures.

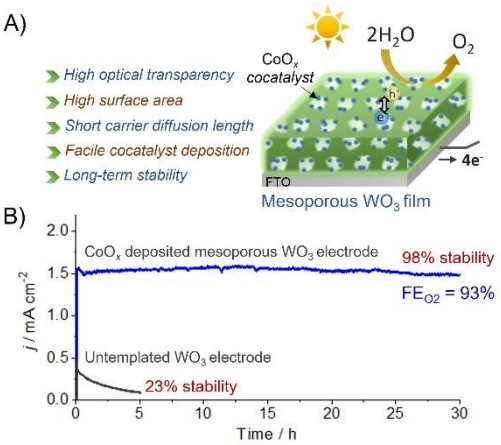

Figure 1: (A) Schematic illustration of efficient PEC water oxidation and (B) PEC performance and stability test on transparent WO_3 photoanode.

[1] *Nature* ***2012****, 488, 294*
[2] *Angew. Chem. Int. Ed.* ***2013*** 52, 12606.
[3] *ACS Appl. Mater. Interfaces* ***2023***, 15, 20885.
[4] *Appl. Catal. B* ***2026***, 380, 125733.