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III-V Materials and Acid-Stable Coatings for Efficient and Stable Solar-to-Chemical Conversion

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Solar-to-chemical conversion mimics nature's photosynthesis, for example, taking sunlight and splits water into H_2 and O_2. Once abundant and low-cost solar fuels of H_2 is produced as a universal energy carrier, we can use it to convert synthetic fuels, upgrade bio-fuel feedstock, improve combustion and even produce ammonia. However, achieving such an efficient artificial leaf is not trivial, particularly due to the instability of efficient semiconductor/liquid interfaces: technologically important semiconductors like Si and GaAs photocorrode in water. Because of this, protective coatings are emerging as an essential design component in the field of photoelectrochemistry (PEC) and photovoltaic energy conversion.

Achieving an efficient photocatalytic device is not trivial, particularly due to the instability of efficient semiconductor/liquid interfaces. Particularly, instability of solid/liquid interfaces during water oxidation in acid is the remaining challenge. In this work, we present the synthesis of thick (Ti, Mn)O_x ternary mixed oxide films (> 20 nm) by using atomic layer deposition (ALD) to extrinsically modify the original, "leaky" TiO_2 coatings and preserve their robust chemical, electrochemical and mechanical stability in acid. We discovered a p-type oxide of (Ti, Mn)O_x can transport holes via defect bands to high work function co-catalysts such as Ir, Pt and Au metals, Ru oxides and Ir-based molecular water-oxidation catalysts. Unprecedented stability has been observed for >100 hour water oxidation in pH = 0-1 sulfuric acid at 1–2 $mA \cdot cm^{-2}$, with no detectable surface degradation. We will show electrical, electrochemical and spectroscopic analysis of this p-type oxide in a wide composition range. Such an p-type, acid-stable surface layer promises many critical applications in oxidative photochemistry and earth-abundant photovoltaics.

Biography:

Shu Hu is an Assistant Professor of Chemical & Environmental Engineering at Yale University. He is also affiliated with the Energy Science Institute at Yale West Campus. Shu Hu graduated from Tsinghua University in 2006 and received his PhD degree of Materials Science and Engineering in 2011 from Stanford University, where he worked on nanoscale germanium-silicon crystal growth and epitaxy control. He was then a postdoctoral scholar at California Institute of Technology and Joint Center for Artificial Photosynthesis. His work spans fundamental and applied research areas in nanophotonics, nanoscale group III-V growth and solid-electrolyte interfaces for artificial photosynthesis. The experimental demonstration of protective coatings was highlighted in major media including NPR News, Scientific American, CE&N News, and Nature.