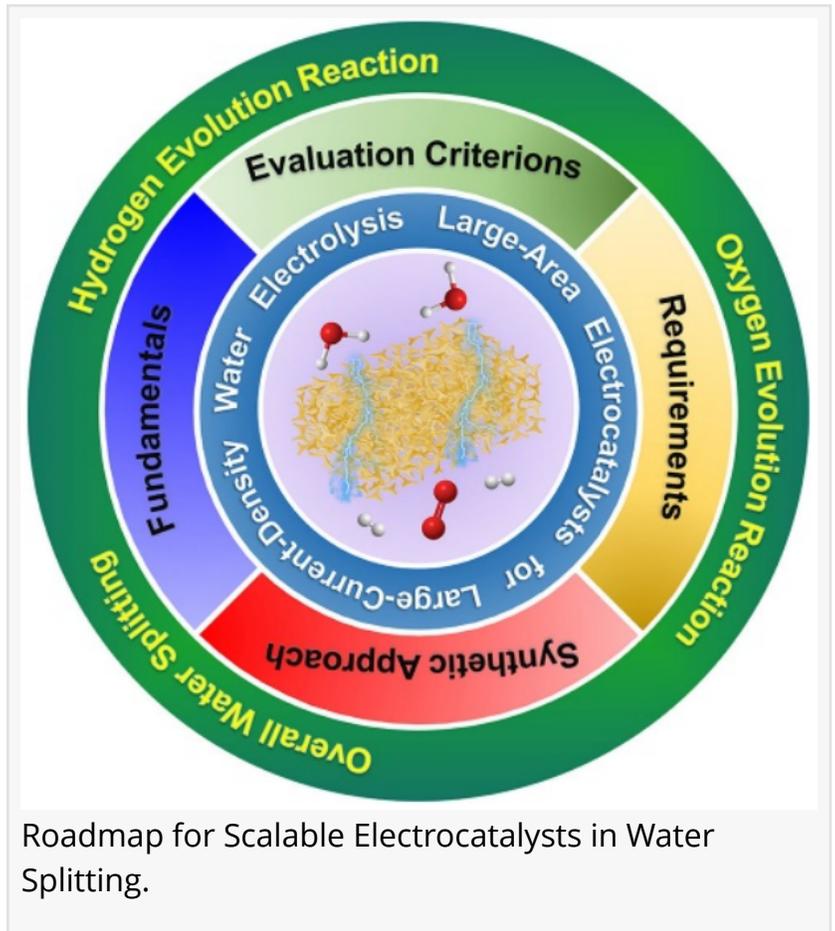


Toward gigawatt hydrogen: advances in large-scale electrocatalyst design

FAYETTEVILLE, GA, UNITED STATES, October 22, 2025 /EINPresswire.com/ -- [Electrochemical water](#) splitting holds promise for producing clean hydrogen at industrial scales, but current technologies often falter under large current densities. Recent advances in catalyst design and scalable synthesis strategies are bridging this gap, offering materials that maintain high efficiency, stability, and durability under harsh operational conditions. This review synthesizes progress in scalable electrocatalyst production, from electrodeposition and corrosion engineering to thermal treatment approaches, and further to their combinations. By addressing the key challenges of performance degradation, bubble management, and cost limitations, the study highlights emerging solutions that can accelerate the industrial adoption of green hydrogen production technologies.



Fossil fuel overuse has fueled global concerns about climate change, energy security, and environmental degradation. Hydrogen, with its high energy density and zero-carbon emissions, is viewed as a cornerstone of the clean energy transition. Yet, the majority of hydrogen production still comes from carbon-intensive methods such as steam methane reforming. Water electrolysis powered by renewable electricity is a viable pathway to green hydrogen, but it requires electrocatalysts that can withstand large current densities without losing efficiency. Based on these challenges, there is an urgent need to develop scalable, high-performance catalysts that can drive electrochemical water splitting at industrial levels.

Researchers from the Dalian Institute of Chemical Physics, Chinese Academy of Sciences, have

published a comprehensive review (DOI: [10.1016/j.esci.2024.100334](https://doi.org/10.1016/j.esci.2024.100334)) in *eScience* (available online July, 2025) summarizing progress in electrocatalyst design for high-current-density water electrolysis. The study outlines advances in scalable synthesis approaches and identifies the critical requirements for catalysts that can withstand industrial operating conditions. By providing guidelines for achieving both performance and large-scale manufacturability, the review offers a roadmap for accelerating the transition from laboratory breakthroughs to real-world hydrogen production systems.

The review highlights three major strategies for developing large-sized electrocatalysts: electrodeposition, corrosion engineering, and thermal treatment, as well as their combinations. Electrodeposition enables precise control over catalyst composition and morphology, yielding nanostructured surfaces that boost hydrogen and oxygen evolution reactions. Corrosion engineering, involving self-induced surface modifications, creates layered hydroxide structures with abundant active sites and demonstrated long-term stability at ampere-level current densities. Thermal treatment methods, including ultrafast heating, hydrothermal synthesis, and combustion, allow rapid large-scale fabrication of robust catalysts with enhanced conductivity and durability.

Key performance indicators discussed include overpotential, Tafel slope, turnover frequency, Faradaic efficiency, and mechanical stability under harsh electrolyzer conditions. Particular emphasis is placed on hydrophilicity and aerophobicity, which ensure efficient gas bubble detachment and sustained active site exposure at high current densities. Moreover, the review addresses the importance of membrane electrode assembly (MEA) testing to bridge laboratory research with practical device performance. Collectively, these insights form a framework for scaling catalyst synthesis from centimeter-sized lab samples to square-meter industrial electrodes while minimizing reliance on scarce noble metals.

“Achieving industrial-scale hydrogen production requires catalysts that not only perform well under high current densities but can also be manufactured reliably at large scales,” said co-author Zhong-Shuai Wu. “This review provides both a snapshot of recent progress and a practical guide for future developments. By aligning material design with scalable production techniques, we are one step closer to making green hydrogen economically viable and technologically robust. The next frontier is integrating these catalysts into commercial electrolyzer systems that can operate efficiently for thousands of hours.”

The insights outlined in this review carry broad implications for the green hydrogen economy. Scalable production of high-performance electrocatalysts can reduce the cost and footprint of electrolyzer systems, enabling gigawatt-scale hydrogen generation to meet projected global demand. Practical advances in bubble management, stability, and non-noble-metal utilization can improve device lifetimes and affordability, making water electrolysis more competitive with fossil fuel-based hydrogen. Beyond energy, these strategies also provide transferable knowledge for other electrochemical processes, including carbon dioxide reduction and ammonia synthesis, thereby supporting a broader portfolio of sustainable chemical manufacturing technologies.

References

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Lucy Wang

BioDesign Research

[email us here](#)

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