Research reveals potential for 50-fold increase in catalyst mass activity

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One of the stumbling blocks that has held back more widespread adaptation of certain forms of green energy has been the higher cost associated with first converting to them.

Research being conducted by a team of UT and US Department of Energy (DOE) national laboratories could soon change that.

Their work has led to a new understanding of how and where electrochemical reactions occur, garnering them acclaim from the American Association for the Advancement of Sciences journal Acclaim.

That research—"Discovery of true electrochemical reactions for ultrahigh catalyst mass activity in water splitting"—allows the design of hydrogen-producing cells that increase the catalyst mass activity 50 times higher than before.

This discovery is expected to lead to opportunities to maximize the use of catalysts and significantly reduce the cost of proton exchange membrane electrolyzer cells (PEMECs), which could contribute to an affordable supply of renewable hydrogen as we seek deeper decarbonization of the United States' energy supply.

"We discovered that placing the catalyst layer adjacent to good electrical conductors drastically increased the performance," said Feng-Yuan Zhang, an associate professor in UT's Mechanical, Aerospace, and

Biomedical Engineering (MABE) Department and in NanoHELP. "In doing so, we can significantly reduce the cost of such devices."

An added benefit to the great increase in hydrogen production would be better adaptation and adoption of carbon-free forms of energy.

The big change in the new approach was a move from traditional electrolysis technology to what is known as proton exchange membrane electrolyzer cells (PEMECs).

These cells have a higher response rate, a better efficiency, and are more compact than previous cells, among other advantages.

The main purpose of PEMECs is to split water into its components—hydrogen and oxygen—before filtering and collecting the hydrogen. To improve the affordability and performance of PEMECs, it is important to understand the fundamental principles and operational dynamics of the electrochemical reactions occurring in PEMECs. However, these fast and microscale reactions are often masked from observation in locations behind other components.

"The challenge is that the conventional design of PEMECs makes it hard to observe the process," said Zhang. "With reactions taking place so rapidly at the center of PEMECs and at such a small scale, it makes it that much more difficult to study."

To overcome that, Zhang and the team developed novel materials and designed a transparent PEMEC with optical access to the ultrafast reaction sites, a critical step in understanding and perfecting the process.

"The work shows a potential pathway toward significantly reduced catalyst loading and reduced cost for electrolyzers, which has been a key impediment to their widespread implementation," said Matthew Mench,

co-author and head of the department at UT.

To confirm this finding, the researchers fabricated a novel PEMEC by sputter coating catalyst on the liquid/gas diffusion layer (LGDL), rather than spraying it in a uniform layer on the membrane.

The measured PEMEC performance was similar to, though slightly lower than, that of the conventional catalyst layer. However, the new catalyst layer on the LGDL was only 1/1000th the thickness of the conventional layer, resulting in a 50-fold increase in catalyst mass activity compared with conventional catalyst-coated membranes.

"Our partners at the University of Tennessee had an idea about how to improve the performance PEMECs," said Green, now associate lab director for mechanical and thermal systems engineering at the National Renewable Energy Laboratory (NREL). "The collaboration made it possible to take it a step further, bringing together electrochemical research and advanced manufacturing expertise to improve the efficiency of producing and storing hydrogen."

More information: J. Mo et al. Discovery of true electrochemical reactions for ultrahigh catalyst mass activity in water splitting, *Science Advances* (2016). DOI: 10.1126/sciadv.1600690

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