A more than 100% quantum step toward producing hydrogen fuel

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Credit: New Jersey Institute of Technology

Efforts to reduce our dependence on fossil fuels are advancing on various significant fronts. Such initiatives include research focused on more efficient production of gaseous hydrogen fuel by using solar energy to break water down into its components of hydrogen and oxygen. Recently, in an article published in the journal *Nature Energy*, lead author Yong Yan, an assistant professor in the Department of Chemistry and Environmental Science, reported a key breakthrough in the basic science essential for progress toward this goal.

The article, "Multiple exciton generation for photoelectrochemical hydrogen evolution reactions with quantum yields exceeding 100%," reports on the investigative work that Yan carried out along with colleagues affiliated with the National Renewable Energy Laboratory, the Colorado School of Mines and San Diego State University. Essentially, they created what is known as a quantum dot photoelectrochemical cell that catalytically achieved quantum efficiency for hydrogen gas production exceeding 100%—in the case of their experiments an efficiency approaching 114%.

Quantum dots are extremely small semiconductor particles only a few nanometers in size. (A nanometer is one-billionth of a meter.) In their device, lead sulfide quantum dots replace semiconductor materials such as silicon and copper indium gallium arsenide. The advantage is that such a photoelectrochemical device can, potentially, convert a greater portion of the solar spectrum into useful energy.

The device described is able to absorb one visible solar photon and produce two, or even more, electrons through a process known as multiple exciton generation, or MEG, which are further utilized to reduce water to generate hydrogen gas. Although many scientists worldwide are engaged in efforts to achieve quantum efficiency as close as possible to 100% for solar hydrogen production, Yan's achievement in directly exceeding this threshold is a significant fundamental breakthrough. It clearly proves that the photoelectrochemical cell design he describes is much more efficient than a quantum dot solar cell with respect to quantum yield.

Yan, who joined the NJIT faculty in 2016, emphasizes that this advance is at the level of basic solar science, and that the breakthrough with respect to quantum yield does not equate to a substantial increase in the ultimate solar-to-hydrogen conversion efficiency. Nonetheless, this dramatic increase in quantum yield realized with a uniquely innovative lead sulfide quantum dot photoelectrochemical device is an important development in several ways, and as such is a product of Yan's long-standing interest in renewable sources of energy, especially in novel applications of solar energy.

For Yan, the research reported in *Nature Energy* culminated at NJIT after his previous work as a postdoc at Princeton University and at the U.S. Department of Energy's National Renewable Energy Laboratory in Colorado. The success of this leading-edge effort was made possible with funding provided, in part, by NJIT and the Department of Energy.

Yan says, "These results do present the possibility of generating more energy more efficiently with such a solar-capture device in the future. This could also lead to a fundamental change in the entire process of producing hydrogen fuel. We can now obtain hydrogen fuel from water by using electricity supplied by conventional power plants that consume fossil fuels. But by building on the basic step of achieving such high quantum efficiency for solar hydrogen generation, we could make the process of producing a 'green' fuel much greener as well."

More information: Yong Yan et al, Multiple exciton generation for photoelectrochemical hydrogen evolution reactions with quantum yields exceeding 100%, *Nature Energy* (2017). DOI: 10.1038/nenergy.2017.52

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