Stanford team devises a better solar-powered water splitter (w/ video)

June 21 2011, by Andrew Myers

(PhysOrg.com) -- The process of splitting water into pure oxygen and clean-burning hydrogen fuel has long been the Holy Grail for clean-energy advocates as a method of large-scale energy storage, but the idea faces technical challenges. Stanford researchers may have solved one of the most important ones.

Solar energy is fine when the sun is shining. But what about at night or when it is cloudy? To be truly useful, sunshine must be converted to a form of energy that can be stored for use when the sun is hiding.

The notion of using sunshine to split water into oxygen and storable hydrogen fuel has been championed by clean-energy advocates for decades, but stubborn challenges have prevented adoption of an otherwise promising technology.

A team of Stanford researchers may have solved one of the most vexing scientific details blocking us from such a clean-energy future.

The team, led by materials science engineer Paul McIntyre and chemist Christopher Chidsey, has devised a robust silicon-based solar electrode that shows remarkable endurance in the highly corrosive environment inherent in the process of splitting water.

They revealed their progress in a recent paper published in the journal Nature Materials.

Conceptually, splitting water could not be simpler. Scientists have long known that applying a voltage across two electrodes submerged in water splits the water molecules into their component elements, oxygen and hydrogen.

From an environmental standpoint, the process is a dream: an electrochemical reaction whose only requirements are water and electricity and whose only byproducts are pure oxygen and hydrogen, a clean-burning fuel applicable in a promising new class of renewable energy applications. In fact, hydrogen is the cleanest burning chemical fuel known.

Practical challenges

"In theory, water splitting is a clean and efficient energy storage mechanism. Unfortunately, solving one problem creates another," said McIntyre, associate professor of materials science and engineering. "The most abundant solar electrodes we have today are made of silicon, a material that corrodes and fails almost immediately when exposed to oxygen, one of the byproducts of the reaction."

This particular problem has vexed researchers since at least the 1970s. Many had given up, but McIntyre and Chidsey have devised a clever solution. They coated their silicon electrodes with a protective, ultra-thin layer of titanium dioxide.

"Titanium dioxide is perfect for this application," explained McIntyre. "It is both transparent to light and it can be efficient for transferring electricity, all while protecting the silicon from corrosion."

Sunlight travels through the protective titanium dioxide into the photosensitive silicon, which produces a flow of electrons that travels through the electrochemical cell into the water, splitting the hydrogen from the oxygen. The hydrogen gas can be stored and then, when the sun is not shining, the process can be reversed, reuniting hydrogen and oxygen back into water to produce electricity.

Decades of dead ends

Other researchers had attempted to protect the electron-producing silicon electrodes. Some tried other materials, which failed for reasons of performance or durability. Some had even tried titanium dioxide, but those efforts also fell short. Their layers were either materially flawed, allowing oxygen to seep through and corrode the semiconductor, or too thick to be electrically conductive.

Yi Wei Chen and Jonathan Prange, the lead doctoral students on the McIntyre-Chidsey team, discovered that the key to the titanium dioxide's protectiveness is achieving a very thin, yet high quality layer of material. They found that a layer just two nanometers thick was sufficient so long as it was free of the pinholes and cracks that doomed earlier titanium dioxide experiments.

With their electrodes successfully shielded from corrosion, the researchers revealed yet one more engineering ace in the hole, adding a third layer of ultra-thin iridium, a catalyst, atop the titanium dioxide. Iridium boosts the rate of the splitting reaction and improves performance of the system.

Broader applications

In side-by-side durability experiments, the researchers put their creation to the test. Control samples without the protective layer corroded and failed in less than a half-hour, while those with the titanium dioxide lasted the full duration of the test, eight hours without apparent corrosion or loss of efficiency.

The authors pointed out that their approach is general enough to work on other semiconductor substrates and to integrate other catalysts, allowing for fine-tuning of electrodes to maximize performance. Likewise, atomic layer deposition, the technique that allowed such fine and flawless layering, is in wide application in the semiconductor industry today. It should, therefore, lend itself to application on a large scale. Lastly, the results were achieved without exploring the use of other efficiency-enhancing techniques, such as surface texturing, which could further improve performance.

"We are excited about the possibilities of this technology," said McIntyre, "as much for the electrode itself, as for the process used to create it."

Their success might just push a promising technology one step closer to practical application and the world one step closer to a clean-energy future.

Provided by Stanford University

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https://phys.org/news/2011-06-stanford-team-solar-powered-splitter-video.html