Hydrogen production method opens up clean energy possibilities

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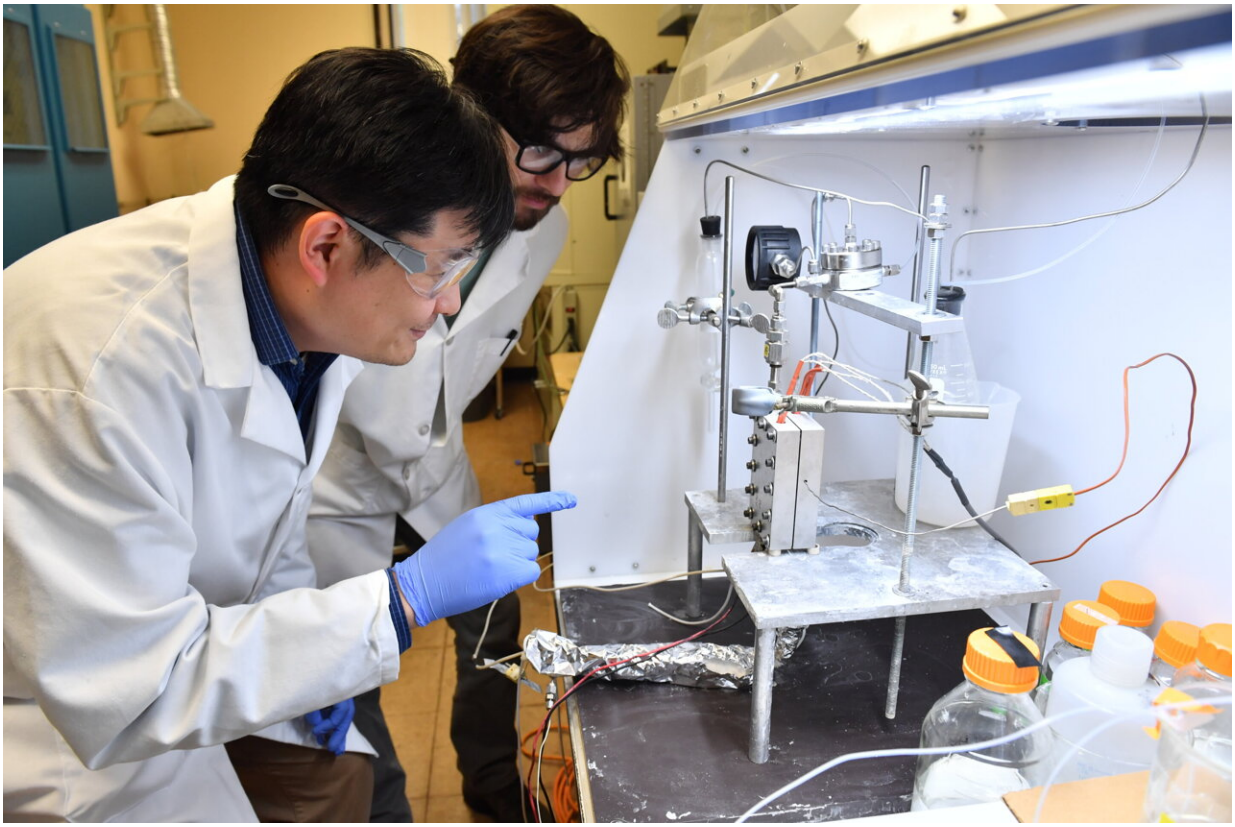

Postdoctoral researcher Jamie Kee and Professor Su Ha and the novel reactor they developed to produce pure compressed hydrogen. Credit: WSU Photo Services

A new energy-efficient way to produce hydrogen gas from ethanol and

water has the potential to make clean hydrogen fuel a more viable alternative for gasoline to power cars.

Washington State University researchers used the ethanol and water mixture and a small amount of electricity in a novel conversion system to produce pure compressed hydrogen. The innovation means that hydrogen could be made on-site at fueling stations, so only the ethanol solution would have to be transported. It is a major step in eliminating the need to transport high-pressure hydrogen gas, which has been a major stumbling block for its use as a clean energy fuel.

"This is a new way of thinking about how to produce hydrogen gas," said Su Ha, professor in the Gene and Linda Voiland School of Chemical Engineering and Bioengineering and corresponding author on the paper published in the journal, *Applied Catalysis A*. "If there are enough resources, I think it has a really good chance of making a big impact on the hydrogen economy in the near future."

Using hydrogen as a fuel for cars is a promising but unrealized clean energy. Like an electric-powered car, a hydrogen fuel-cell powered car doesn't emit any harmful carbon dioxide. Unlike an electric car, it can be filled up with hydrogen gas in minutes at hydrogen fueling stations.

Despite the promise of hydrogen technology, however, storing and transporting high-pressure hydrogen gas in fuel tanks creates significant economic and safety challenges. Because of the challenges, there is little hydrogen gas infrastructure in the U.S., and the technology's market penetration is very low.

In their work, the WSU researchers created a conversion system with an anode and a cathode. When they put a small amount of electricity into the ethanol and water mixture with a catalyst, they were able to electrochemically produce pure compressed hydrogen. Carbon dioxide

from the reaction is captured in a liquid form.

Instead of having to transport hazardous hydrogen gas, the conversion method would mean that the existing infrastructure for transporting ethanol could be used and that the compressed hydrogen gas could be easily and safely created on-demand at gas stations.

"We're already using ethanol-containing gasoline at every gas station," said Ha. "You can imagine that an ethanol water mixture can be easily delivered to a local gas station using our existing infrastructure, and then using our technology, you can produce hydrogen that is ready to pump into a hydrogen fuel cell car. We don't need to worry about hydrogen storage or transportation at all."

The electrochemical system the team developed uses less than half the electricity of pure water splitting, another method that researchers have studied for de-carbonized hydrogen production. Instead of working hard to compress the hydrogen gas later in the process, the researchers used less energy by instead compressing the liquid ethanol mixture, thereby directly producing an already compressed hydrogen gas.

"The presence of the ethanol in water changes the chemistry," said graduate student Wei-Jyun Wang, a co-lead author on the paper. "We can actually do our reaction at a much lower electrical voltage than is typically needed for pure water electrolysis."

Their system also doesn't require an expensive membrane that other water splitting methods do. The resulting hydrogen from the electrochemical reaction is then ready for use.

"A process that offers a low-electrical energy cost alternative to water electrolysis and can effectively capture carbon dioxide while producing compressed hydrogen could have a significant impact on the hydrogen

economy," said Jamie Kee, a Voiland School postdoctoral researcher and one of lead authors on the paper. "It's really exciting because there are a whole lot of aspects that play into improving the production methods of hydrogen."

The researchers are working to scale up the technology and operate it in a continuous manner. They also are working to make use of the carbon dioxide captured in the liquid.

More information: Benjamin L. Kee et al, Caustic Aqueous Phase Electrochemical Reforming (CAPER) of Ethanol for Process Intensified Compressed Hydrogen Production, *Applied Catalysis A: General* (2022). DOI: 10.1016/j.apcata.2022.118647

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