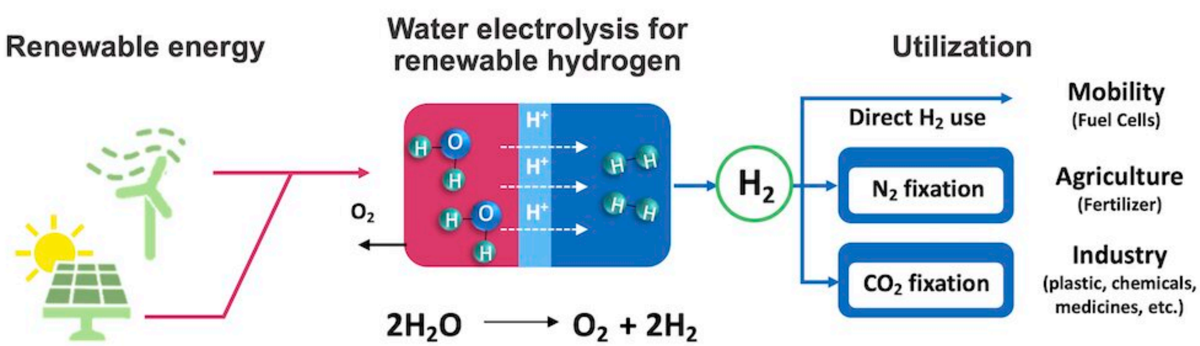
PHYS.ORG

A new, sustainable way to make hydrogen for fuel cells and fertilizers

February 14 2022



This schematic shows the concept for sustainable hydrogen production. Electricity from renewable sources (solar, wind) is used to split water into oxygen and hydrogen (electrolysis). The hydrogen can then be used for as fuel, to help make fertilizer from ammonia, and in other industries. Credit: RIKEN

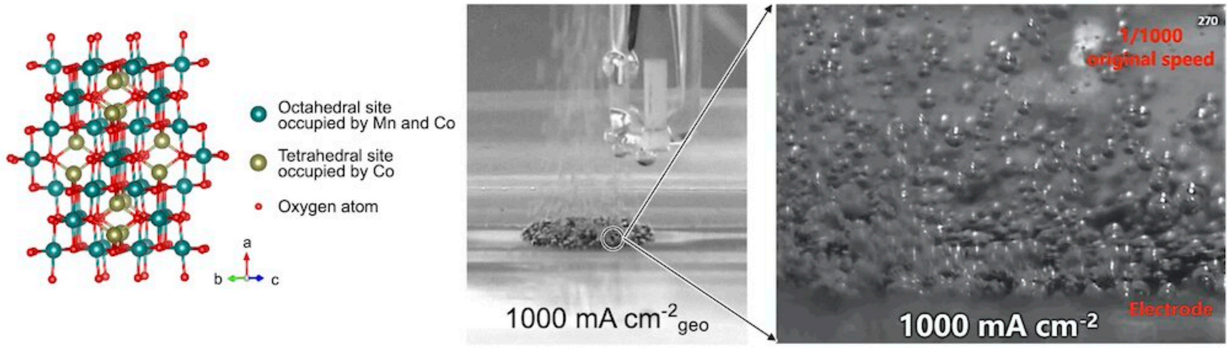
A new sustainable and practical method for producing hydrogen from water has been discovered by a team of researchers at the RIKEN Center for Sustainable Resource Science (CSRS) in Japan led by Ryuhei Nakamura. Unlike current methods, the new method does not require rare metals that are expensive or in short supply. Instead, hydrogen for fuel cells and agricultural fertilizers can now be produced using cobalt and manganese, two fairly common metals. The study was published in *Nature Catalysis*.

Unlike conventional fossil fuels that generate carbon dioxide upon combustion, hydrogen is a clean fuel that only produces water as a byproduct. If hydrogen can be extracted from water using renewable electricity, the energy grid can be made clean, renewable, and sustainable. Additionally, hydrogen is the key ingredient needed to produce ammonia, which is used in virtually all synthetic fertilizers. But instead of cleanly extracting hydrogen from water, currently, ammonia plants use fossil fuels to produce the hydrogen they need.

So why are we still using fossil fuels? One reason is that the hydrogen extraction process itself—electrolysis—is expensive and not yet sustainable.

"This is primarily due to a lack of good catalysts," says Nakamura. "In addition to being able to withstand the harsh acidic environment, the catalyst must be very active. If not, the amount of electricity needed for the reaction to produce a given amount of hydrogen soars, and with it, so does the cost."

Currently, the most active catalysts for water electrolysis are rare metals like platinum and iridium, which creates a dilemma because they are expensive and considered "endangered species" among metals. Switching the whole planet to hydrogen fuel right now would require about 800 years' worth of iridium production, an amount which might not even exist. On the other hand, abundant metals such as iron and nickel are not active enough and tend to dissolve immediately in the harsh acidic electrolysis environment.



(Left) The mixed cobalt manganese oxide, Co_2MnO_4. (Right) a frame from a video showing hydrogen being produced through electrolysis at the current density of 1000 milliamperes per square centimeter. Credit: RIKEN

In their search for a better catalyst, the researchers looked at mixed cobalt and manganese oxides. Cobalt oxides can be active for the required reaction, but corrode very quickly in the acidic environment. Manganese oxides are more stable, but are not nearly active enough. By combining them, the researchers hoped to take advantage of their complimentary properties. They also had to consider the high current density needed for practical application outside the laboratory. "For industrial scale hydrogen production, we needed to set our study's target current density to about 10 to 100 times higher than what has been used in past experiments," says co-first author Shuang Kong. "The high currents led to a number of problems such as physical decomposition of the catalyst."

Eventually, the team overcame these issues by trial and error, and discovered an active and stable catalyst by inserting manganese into the spinel lattice of Co_3O_4, producing the mixed cobalt manganese oxide Co_2MnO_4.

Testing showed that Co_2MnO_4 performed very well. Activation levels were close to those for state-of-the art iridium oxides. Additionally, the new catalyst lasted over two months at a current density of 200 milliamperes per square centimeter, which could make it effective for practical use. Compared with other non-rare metal catalysts, which typically last only days or weeks at much lower current densities, the new electrocatalyst could be a game changer.

"We have achieved what has eluded scientists for decades," says co-first author Ailong Li. "Hydrogen production using a highly active and stable catalyst made from abundant metals. In the long run, we believe that this is a huge step toward creating a sustainable hydrogen economy. Like other renewable technologies such as solar cells and wind power, we expect the cost of green hydrogen technology to plummet in the near future as more advances are made."

The next step in lab will be to find ways to extend the lifetime of the new catalyst and increase its activity levels even more. "There is always room for improvement," says Nakamura, "and we continue to strive for a non-rare metal catalyst that matches the performance of current iridium and platinum catalysts."

More information: Jianping Xiao, Enhancing the stability of cobalt spinel oxide towards sustainable oxygen evolution in acid, *Nature Catalysis* (2022). DOI: 10.1038/s41929-021-00732-9. www.nature.com/articles/s41929-021-00732-9

Provided by RIKEN

Citation: A new, sustainable way to make hydrogen for fuel cells and fertilizers (2022, February 14) retrieved 11 May 2024 from

https://phys.org/news/2022-02-sustainable-hydrogen-fuel-cells-fertilizers.html

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.