Ammonia decomposition for hydrogen economy, improvement in hydrogen extraction efficiency

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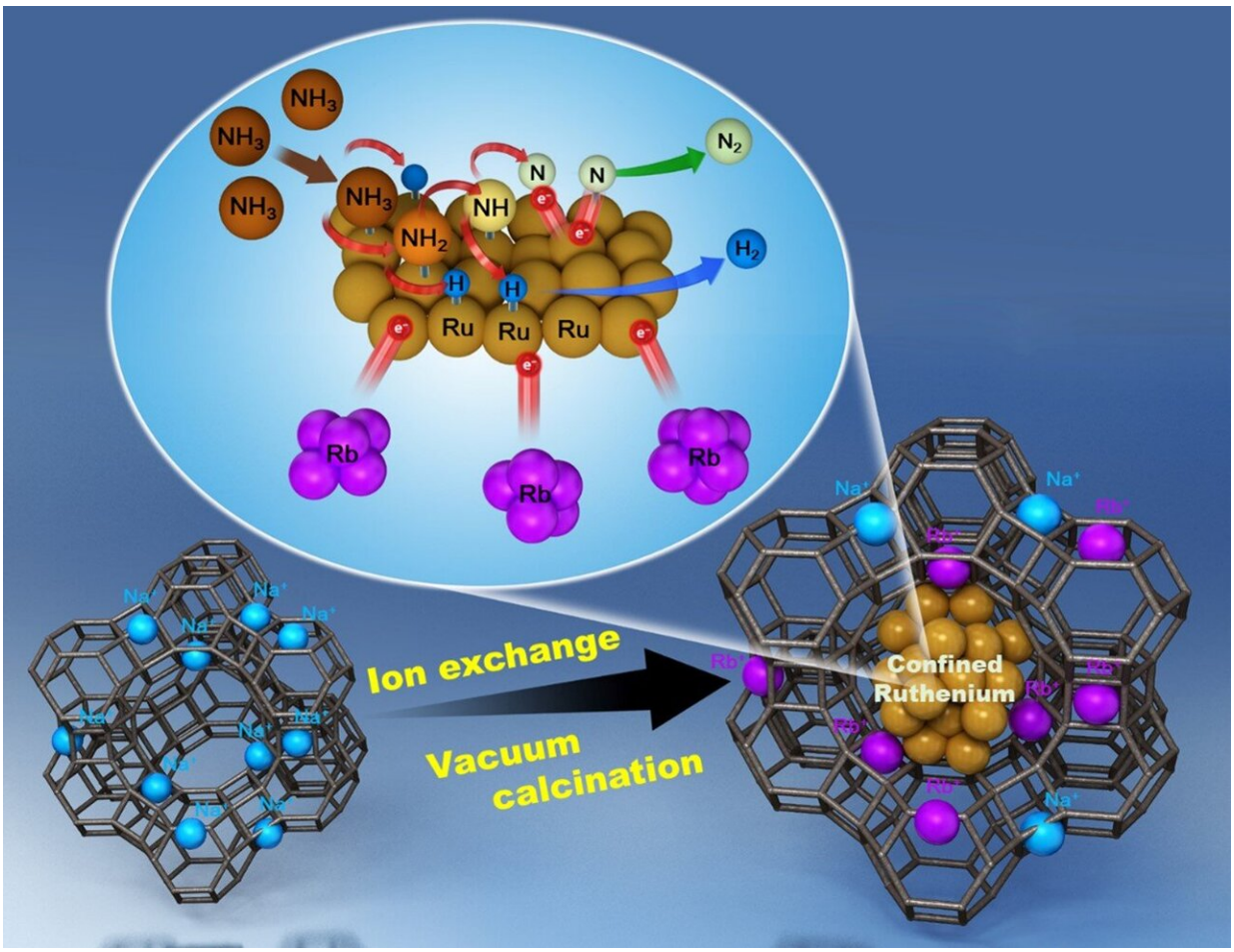

A schematic diagram of the catalytic structure for ammonia decomposition developed by KIST researchers. Credit: Korea Institute of Science and Technology (KIST)

For the implementation of an effective hydrogen economy in the forthcoming years, hydrogen produced from sources like coal and petroleum must be transported from its production sites to the end user, often over long distances and to achieve successful hydrogen trade between countries. Drs. Hyuntae Sohn and Changwon Yoon and their team at the Center for Hydrogen-fuel Cell Research of the Korea Institute of Science and Technology (KIST) have announced a novel nanometal catalyst, constituting 60% less ruthenium (Ru), an expensive precious metal used to extract hydrogen via ammonia decomposition.

Ammonia has recently emerged as a liquid storage and transport medium that has shown promising stability for long-distance hydrogen transport. At 108 kg H_2/m^3, liquefied ammonia (NH_3) can store 50% more hydrogen than liquid hydrogen. When ammonia is decomposed at high temperatures, only hydrogen and nitrogen gases are produced, with minimal carbon dioxide emissions. Because over 200 million tons of ammonia is currently produced annually for industrial use around the globe, the infrastructure for its mass storage and long-distance transport already exists and can simply be re-purposed for hydrogen transport.

The need for large amounts of heat has been a pressing issue thwarting the widespread adoption of ammonia for use in hydrogen transport and storage, however. The decomposition reaction through which hydrogen is extracted from ammonia can only proceed at high temperatures which requires high energy input. A catalyst in the form of a solid powder can be added during the decomposition reaction to lower the reaction temperature; however, existing ruthenium-metal-based catalysts are very expensive and have low stability, thus requiring regular replacement.

The KIST research team has developed a catalyst for hydrogen production from ammonia decomposition in which ruthenium metal particles and zeolite are strongly bound by calcination under vacuum, which results in the containment of sub-nanometer and nanometer (one

billionth of a meter) ruthenium metal particles in each pore of the zeolite support. This novel catalyst exhibits 2.5-times higher ammonia decomposition performance than conventional commercial catalysts and achieves this efficiency while using only 40% of ruthenium metal. Because nanometer-sized (or smaller) ruthenium metal particles are present and maintain their stability during the ammonia decomposition process even at high reaction temperatures, the use of the proposed catalyst can overcome the problem of low stability, which has been significantly limiting the commercialization of existing catalysts.

"The developed catalyst has an advantageous structure in that the nanometer-sized ruthenium metal particles are uniformly spread over zeolite, a crystalline mineral. Thus, this catalyst has shown higher performance and stability than previously reported catalysts and is expected to facilitate the commercialization of the process for high-purity hydrogen production from ammonia," said Dr. Hyuntae Sohn, KIST.

"The importance of large-capacity hydrogen transport based on ammonia is rapidly increasing, with fierce competition among advanced countries over the development and acquisition of related technologies. The application of the proposed catalyst for large-capacity hydrogen production via ammonia decomposition, which is currently under research and development, will ultimately help the commercialization of ammonia-derived hydrogen and high-capacity hydrogen transportation between countries," said Dr. Changwon Yoon.

More information: Junyoung Cha et al, Highly monodisperse sub-nanometer and nanometer Ru particles confined in alkali-exchanged zeolite Y for ammonia decomposition, *Applied Catalysis B: Environmental* (2020). DOI: 10.1016/j.apcatb.2020.119627