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Achievement of the world's highest performance in continuous electrolytic synthesis of ammonia proceeding at room temperature and normal pressure

Significant progress toward carbon-free ammonia production process

Idemitsu Kosan Co.,Ltd. (hereinafter referred to as "Idemitsu Kosan"), The University of Tokyo, a National University Corporation (hereinafter referred to as "The University of Tokyo"), the Graduate School of Engineering, Osaka University, a National University Corporation (hereinafter referred to as "Osaka University"), and the National Institute of Advanced Industrial Science and Technology (hereinafter referred to as "AIST") have achieved the world's highest performance in their joint research development efforts in the continuous electrolytic synthesis of ammonia[*1] proceeding at room temperature and normal pressure from nitrogen and water, substances which exist in abundance in the air.

Ammonia, which does not emit CO_2 during combustion, is attracting attention as a hydrogen carrier[*2] and a new fuel for power generation and industrial boilers, but because it is produced at high temperatures and pressures, one of the challenges is to reduce CO_2 emissions during production. The results of this research verified that ammonia can be continuously produced using nitrogen, water, and electricity (expected to be derived from renewable energy sources) at room temperature and normal pressure in laboratory scale. This innovative technology will replace the current production method (Haber-Bosch process[*3]), which has a history of more than 100 years, and will give momentum to the realization of a carbon-free ammonia production process.

In the research and development, a molybdenum catalyst[*4] developed by Professor Yoshiaki Nishibayashi et al. at the Graduate School of Engineering, The University of Tokyo, is applied. The development of an electrolytic synthesis technology suitable for this molybdenum catalyst[*5] has improved the ammonia generation rate per unit area of electrodes used in electrolytic synthesis by about 20 times compared to conventional technology, achieving the world's highest performance (Figures 1 and 2).

This research and development is being conducted as a commissioned project under the Green Innovation Fund Project[*6] of NEDO (the New Energy and Industrial Technology Development Organization), with Idemitsu Kosan as the managing entity. It will be continued to steadily develop the technology to establish a cost-competitive mass production technology and will be aimed to further develop the research results.

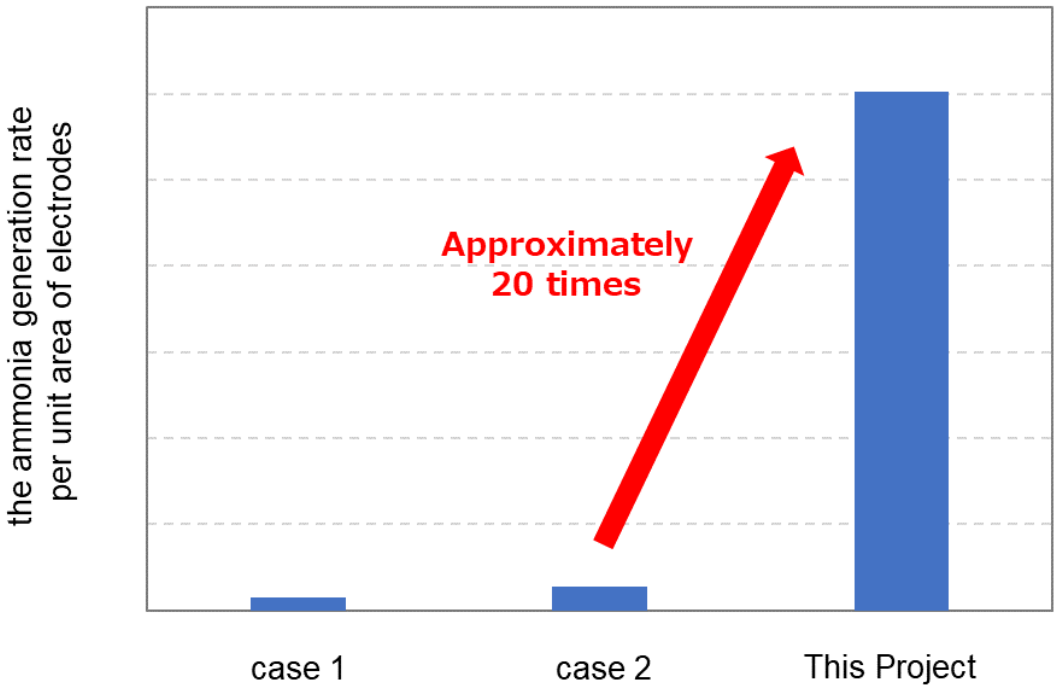

Figure 1: Comparison of performance values for ammonia electrolytic synthesis reaction using nitrogen, water, and electricity at room temperature and normal pressure.
Reported case 1: S. Zhang, H. Zhao et al., *Angew. Chem. Int. Ed.*, 59, 13423 (2020)
Reported case 2: S. Zhang, H. Zhao et al., Nat. Sustain., 6, 169 (2023)

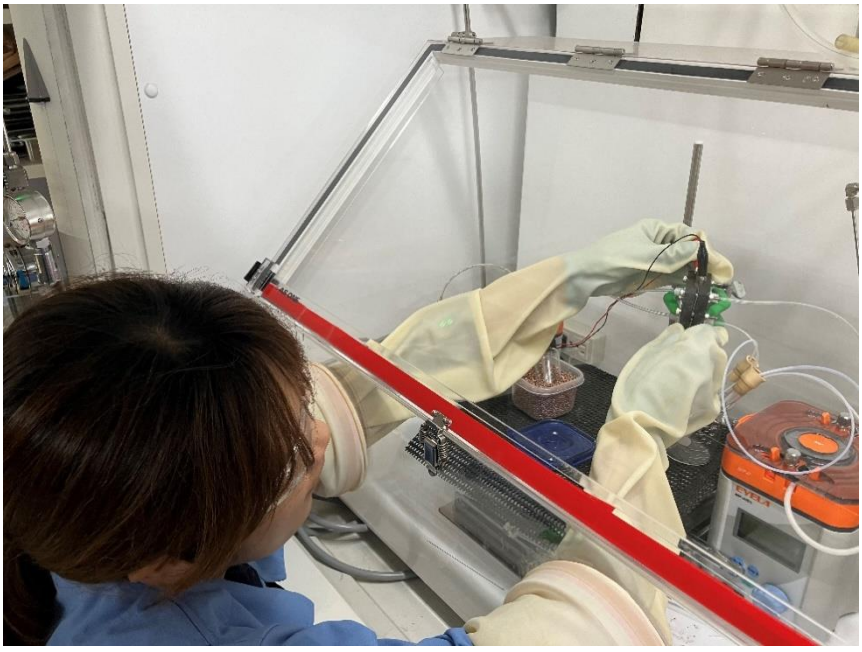

Figure 2: Ammonia electrolytic synthesis reaction test

*1 Continuous electrolytic synthesis of ammonia: Continuous synthesis of ammonia from nitrogen and water in the presence of a catalyst by energizing a device called an electrolytic cell, which consists of positive and negative electrodes and a membrane separating them. Use of solar, wind power and other renewable types of electricity enables realization of a carbon-free ammonia production process.

*2: Hydrogen carrier: A method of converting hydrogen into a liquid or hydrogen-containing compound for transport and storage. Ammonia is one of the promising hydrogen carriers.

*3: Harbor-Bosch process: Technology to produce ammonia through a reaction between hydrogen and nitrogen under high temperature and high pressure. CO_2 emissions during production are unavoidable, and since the raw material hydrogen is extracted from fossil fuels such as petroleum, coal, and natural gas, CO_2 emissions from the raw material are also an issue.

*4: Molybdenum catalyst: A catalyst consisting of molybdenum atoms surrounded by molecules and other elements called ligands. Ammonia synthesis is possible at room temperature and normal pressure in the presence of nitrogen, water, and samarium iodide (reducing agent). (Reference paper: Nature 568, 536-540 (2019))

*5: Improvement of molybdenum catalyst (Supervised by The University of Tokyo), optimization of electrolytic synthesis reaction field (Supervised by AIST and Idemitsu Kosan), and development of reducing agent to promote electrolytic synthesis reaction (Supervised by Osaka University) were conducted at each supervisory organization.

*6: The following is an overview of the implementation of the Green Innovation Fund project.

- Project name: Development of green ammonia production technology at room temperature and normal pressure
- Organization: Idemitsu Kosan Co.,Ltd. as the managing entity, The University of Tokyo, Tokyo Institute of Technology (National University Corporation), Osaka University, Kyoto University (National University Corporation)
- Subcontractor/Joint Implementation Partner: National Institute of Advanced Industrial Science and Technology, Nissan Chemical Corporation, and Toshiba Corporation, Tsukuba University (National University Corporation)
- Duration: FY2021 - FY2028 (Provisional)
- URL：https://green-innovation.nedo.go.jp/project/building-fuel-ammonia-supply-chain/scheme/

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