RESEARCH NEWS

From fertilizer to energy source of the future

Ammonia: Bright Prospects

Ammonia has been traditionally known for fertilizer production. In the future, it could also play a key role in the Energy Transition as an efficient source of hydrogen and a climate-friendly substitute for fossil fuels since it can be produced from nitrogen and hydrogen with zero carbon emissions. Furthermore, ammonia offers a wealth of advantages in terms of transportation and storage. The Fraunhofer Institute for Microengineering and Microsystems IMM is working on a space-saving, efficient and, above all, decentralized ammonia cracking technology in numerous research projects.

"Ammonia has very bright prospects for the sustainable transformation of our energy system," explains Gunther Kolb, Head of the Energy Division and deputy institute director of Fraunhofer IMM in Mainz. "Producing sufficient energy without emissions isn't the only challenge involved in the Energy Transition, after all. Because large amounts of green electricity can be produced mainly in places with a lot of wind or sun, like Chile and Australia, low-loss transportation to areas with less renewable energy available is indeed an important factor." Using ammonia can bring transformative advantages in this regard.

Perfectly suited to storage and transportation of hydrogen

Green hydrogen (H_2), combines with nitrogen (N_2) in a 3:1 ratio to produce ammonia (NH_3) and energy stored and transported in this form (i.e. ammonia) undergoes lower losses in the supply chain. Moreover, ammonia has a few advantages over hydrogen for the storage of electricity. It remains liquid at atmospheric pressure and even at a pressure of just 7.5 bar or when it cools to only about -33°C. By contrast, liquefying pure hydrogen requires feeding it into a vacuum at low pressure and lowering the temperature to -253°C, which requires much energy. In addition, ammonia has a higher volumetric energy density than liquid hydrogen, so it can carry more energy per unit volume. "Generating ammonia from hydrogen and nitrogen only requires about five percent more energy than generating hydrogen from green electricity," Kolb explains. "And both producing and cracking ammonia are almost completely carbon-free." Ammonia is toxic and flammable, so it is classified as hazardous and subject to stringent regulations. Thanks to the existing high safety standards, some 25 million metric tons of ammonia are currently transported safely worldwide by ship and rail each year, chiefly for fertilizer production.

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Core hydrogen network under development

Ammonia must be reconverted into its original compounds (i.e.nitrogen and hydrogen) for use in the chemical industry or as an energy source. Equally important, this needs to be done with minimal energy losses. Ammonia in gas form is fed into a reactor at a temperature of about 600 degrees Celsius, in which it comes into contact with an inorganic nickel-based catalyst with large internal surface. "Right now, the first big electrolysis facilities are being built in locations rich in green electricity, like Australia and Chile, to produce ammonia. On the European side, one of the first major cracking facilities is under construction in Rotterdam at the same time, for example," Kolb says. The plan is to supply hydrogen to places where it is needed via pipelines. The primary issue is that many potential customers, especially SMEs, lack access to hydrogen pipelines. Germany's hydrogen infrastructure is currently being built out. Plans call for a core hydrogen network comprising about 9,000 kilometers of pipelines in total to be put in place by 2032, primarily by converting natural gas lines. However, even after that, large areas will not be connected to the hydrogen supply.

Local supply through decentralized cracking technology

"Our decentralized cracking technology can close this supply gap both efficiently and with zero emissions for required quantities of between 100 kilograms and 10 metric tons of hydrogen per day," Kolb explains. "In the AMMONPAKTOR project, which received funding from the state of Rhineland-Palatinate, we teamed up with the Fraunhofer Institute for Industrial Mathematics ITWM to develop a compact ammonia cracker that achieves an efficiency of 90 percent during the reconversion process through our innovative plate heat exchanger technology and integrated exhaust gas combustion from the pressure swing adsorption used for cleaning, in comparison to 70 percent for conventional technologies."

The energy needed to heat the reactor is generated directly in the cracking reactor with the help of the exhaust gas streams, so no additional fuel or electricity is required for cracking purposes. The AMMONPAKTOR reactor is also about 90 percent smaller than conventional technology. This is especially important for mobile and space-constrained applications. The use of exhaust gas also means the technology has a smaller carbon footprint than electrically heated reactor concepts. "Aside from the system's internal exhaust gas utilization, the innovative plate heat exchanger from Fraunhofer IMM, which is directly coated with a catalyst, makes all the difference," Kolb says. "Instead of the conventional method of generating the heat required for cracking in a pipe system heated from the outside at about 900 degrees Celsius, which requires much energy, our technology generates the heat right where it is needed, so our system has much better heat transfer. And that works out to huge energy savings."

A finished prototype at Fraunhofer IMM's location in Mainz already enables hydrogen production of about 75 kg per day, about the same as the daily output from a 50-kilowatt fuel cell. "That volume alone would be enough to supply a small hydrogen filling station, for example," Kolb notes. The next development goal, for now, is scaling up to daily production of up to 10 metric tons, including as part of the EU's five-year maritime project GAMMA and the Fraunhofer flagship project AmmonVektor, which is exploring the entire green ammonia value chain to make hydrogen available on a decentralized basis and at as low cost as possible. This three-year project, headed by the Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT, has been under way since early 2024.

Fig. 1 Fraunhofer IMM pilot plant for ammonia cracking with ammonia cracking capacity of 20 kg/h

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Fig. 2 As part of the EU's GAMMA project this freighter will be partially powered by an ammonia cracker from Fraunhofer IMM, which has an equivalent electrical output of 400 kW, together with a fuel cell.

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