Leading Tokyo's starring role in the hydrogen revolution

The Research Center for a Hydrogen Energy-Based Society (ReHES) at TOKYO METROPOLITAN UNIVERSITY has been advancing the technologies needed to make hydrogen energy a commercial reality

Billed as the 'Hydrogen Olympics', the Tokyo 2020 Olympics were to showcase Japan's advanced hydrogen technologies comprising a fleet of hydrogen-powered buses and cars, dozens of hydrogen refueling stations across the city, and hydrogen-based electricity at the athletes village. While the Olympics may have been postponed, the Tokyo Metropolitan Government is forging ahead with its plans for 80 hydrogen fueling stations and 100,000 hydrogen fuel-cell cars on the capital's roads by 2025 — enabled by the technologies developed by its main research partner, Tokyo Metropolitan University.

The Research Center for a Hydrogen Energy-Based Society (ReHES) at the university was established three years ago at the behest of the Tokyo Metropolitan Government. "We're conducting research and development on hydrogen fuel cells and the infrastructure needed to support them, such as the hydrogen refueling station network, and hydrogen production and carrier systems," says ReHES vice director Hiroyoshi Kawakami. "Our virtual research centre brings together world-leading expertise to advance comprehensive and cross-cutting research for realizing a hydrogen-energy society across a wide range of disciplines, including technologies for a low-carbon society, such as the direct capture of carbon dioxide from the air."

NEW BREAKTHROUGHS IN FUEL CELLS

The hydrogen-energy puzzle contains many pieces, and while each is advanced through focused cutting-edge research, it is by the integration of technologies that the true power of hydrogen will be harnessed. Take, for example, the hydrogen fuel cell, which converts hydrogen into electricity by an electrochemical reaction. The choice of hydrogen fuel, such as liquid hydrogen, methanol or ammonia, fundamentally not only alters the fuel-cell design, but also the way hydrogen is produced, stored and distributed. With many competing approaches advancing rapidly, technology choices now will significantly affect the design of our hydrogen future.

"Over the past few years, we've made a series of major breakthroughs in different parts of the hydrogen-fuel-cell system that make new things possible," says ReHES director, Kiyoshi Kanamura. "It started with the development of a new proton-conducting membrane that can operate at much higher temperatures than before, overcoming the main obstacle with this fuel-cell technology. This then allowed the development of a better catalyst to convert methanol to hydrogen that can also utilize the heat generated by the fuel cell to increase efficiency further. The result is a methanol-based fuel cell with close to 50% energy conversion efficiency, compared with the 30% or 40% of other technologies."

"WE'RE MAKING EXCITING PROGRESS ON NEXT-GENERATION BATTERIES"

The new fuel cell based on TMU's patented membrane and catalyst technologies runs on a methanol–water mixture — using the hydrogen contained in both — that is safe, non-flammable, stable and easy to distribute. The catalyst also requires 90% less platinum than other technologies, making it more affordable. Tetsuya Shishido, who led the design of the new catalyst, is also making important advances in the emission-free production of methanol to supply these fuel cells, as well as developing other hydrogen carriers that could be used for different purposes.

"We're now prototyping our fuel-cell technology, working with several industrial partners to refine the concept," says Kanamura. "We're aiming to have a design ready for mass production within two to five years."

BATTERIES EXPAND HYDROGEN'S UTILITY

Electric vehicles are now common on our roads, with most utilizing the energy stored in lithium-ion batteries to power their motors. Yet although this is a proven technology, there is still much to improve.

"Right now, hydrogen and batteries are very different research fields, but eventually we'll need to bring the two fields together to get the most out of both," says Kanamura. "I believe the final powertrain in many types of vehicles will include both a fuel cell for generating electricity and batteries to store and deliver electrical power. But for this to be attractive for a wide range of vehicles, we will need to double the energy density of batteries compared with today's lithium-ion technology."

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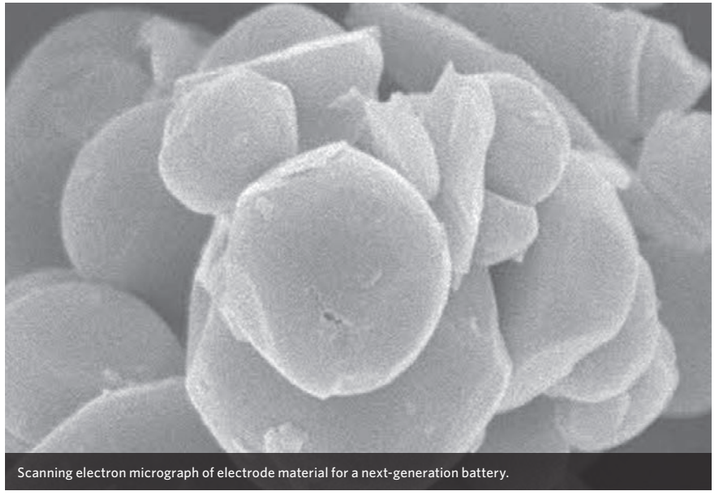

Scanning electron micrograph of electrode material for a next-generation battery.

The Tokyo Metropolitan Goverment plans to open 80 hydrogen fuel stations in Tokyo by 2025.

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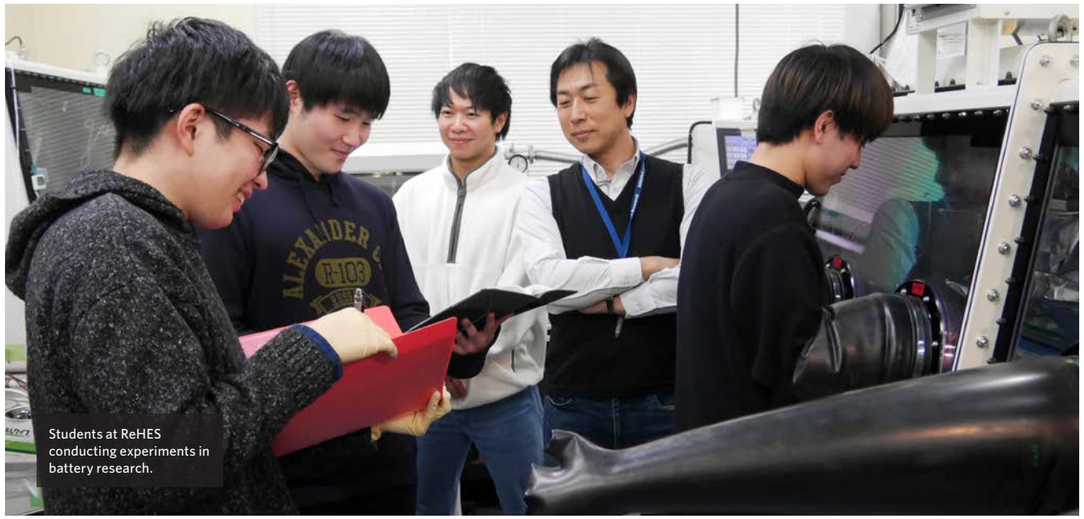

Students at ReHES conducting experiments in battery research.

This relatively low energy density is one of the main drawbacks of today's lithium-ion batteries, making them heavy and limiting the distance range of vehicles in which they are used, particularly for aircraft and ships. They are also susceptible to fire or explosion due to the flammable liquid electrolyte they contain.

"We're experimenting with a range of new battery technologies and are making some promising discoveries," says Kanamura. "A particularly exciting line of research is an all-solid-state lithium sulfide electrolyte as a next-generation battery technology. It is safe, never explodes, can be recharged thousands of times, and is capable of high-energy output while achieving that needed doubling of energy density."

Many technical challenges remain, but ReHES is at the forefront of the global research efforts in battery technology and has attracted intense interest from both research and industry, particularly in Europe and the USA.

"Japan invented the lithium-ion battery, which is now used all over the world," says Kanamura. "At ReHES, we're making exciting progress on next-generation batteries, and soon hope to reveal new advances that will continue Japan's global leadership in this critical technology." ■

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