HARNESSING THE POTENTIAL OF TINY POWER SOURCES

At a research HUB IN HONG KONG, scientists are advancing the frontiers of renewable energy.

A drop of water released from a height of 15 cm can generate a voltage of more than 140 V, enough to power 100 small LED lights. The technology behind this phenomenon, developed at City University of Hong Kong (CityU), significantly improves the efficiency of generating power from rainwater.

This is just one example of how energy researchers at CityU are developing new devices and technologies that offer low-cost, pollution-free solutions to power the future, from capturing low-frequency kinetic energy in raindrops to converting solar power to electricity.

Driving efficient energy conversion

Scientists throughout the world are seeking clean and renewable energy sources, such as hydropower. In addition to tides and waves, kinetic energy from falling raindrops can be transformed into electricity. But technological limitations usually mean the conversion rate is low.

However, a droplet-based electricity generator designed by a collaborative team led by Zuankai Wang, a professor in CityU's Department of Mechanical Engineering, holds great promise.

Wang believes the key to improving conversion efficiency lies in increasing the number of charges generated when a droplet hits a surface. His team found that when droplets continuously hit a PTFE plastic surface, which possesses a quasi-permanent electric charge, the surface charges accumulate until they gradually reach saturation point.

Inspired by this phenomenon, the team has created design features that include an indium tin oxide (ITO) electrode with a PTFE film deposited on top. The electrode is responsible for charge generation, storage and induction. When a falling raindrop hits and spreads out on the PTFE/ITO surface, it naturally connects the PTFE/ITO electrode with the aluminium electrode, forming a closed-loop electric circuit. Similar to a field-effect transistor (FET), the specially designed structure allows for the accumulation of high-density surface charges, increasing instantaneous power density thousands of times greater than that achieved by similar devices without the benefit of the FET-like structure.

Wang expects to apply this new design and its accompanying energy conversion efficiency to different surfaces.

"We hope to facilitate meeting sustainable development goals by harvesting water energy more efficiently," he said.

A more efficient rate of conversion has also been achieved by another CityU team. This one is led by Alex Jen, CityU's provost and chair professor of chemistry and materials science, and Zonglong Zhu, assistant professor in the Department of Chemistry. These researchers have developed a novel all-inorganic inverted perovskite solar cell that has achieved a record power conversion efficiency of 16.1%.

Known for their thermal stability, all-inorganic perovskite solar cells have attracted a great deal of attention. However, increasing the cells' power conversion efficiency remains a challenge, because defects formed on the surface during the crystallisation of perovskite will 'trap' the electrons, leading to severe losses of open-circuit voltage.

For Jen and Zhu, the route to enhanced efficiency lies in the molecular passivation strategy, a method typically used to reduce the activity of the material surface of organic solar cells. The team introduced a small molecule additive to passivate the perovskite surface during production. This additive increases the grain size of the perovskite film, which reduces the defects in the grain boundaries and the voltage loss.

The solar cell also shows improved photostability and enhanced resistance to moisture, oxygen, and light, which is all enabled by passivation. These improvements allow the cell to be deployed in harsh environments, including deserts. "With room to improve the conversion efficiency, we believe the application prospects for all-inorganic perovskite solar cells are promising," said Jen.

Minimizing pollution

Researchers are also focusing on reducing emissions in energy generation. CityU's materials scientist, Jr-hau He, leads a team that has captured ocean wave energy while reducing emissions of CO_2, a major greenhouse gas.

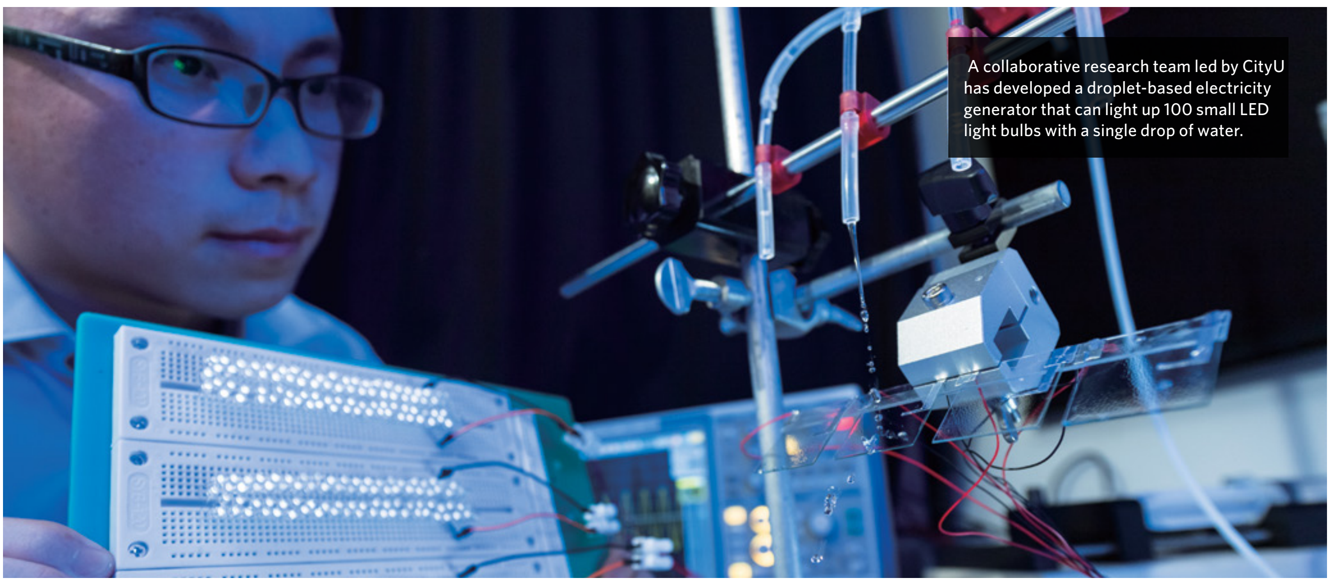
He's novel electrochemical system can convert ocean wave energy and produce formic acid, a liquid fuel that can be easily stored and transported. This system features a spherical spring-assisted triboelectric nanogenerator that converts the mechanical wave energy into electricity. The system's power management circuit temporarily stores the harvested energy and, importantly, the electrochemical setup reduces CO_2 emissions, converting them to formic acid.

The device achieves higher wave energy conversion efficiency and power output than conventional wave energy converters, and is more cost effective. "Our lightweight device can float on water and has minimal impact on marine life and the sea floor, and it can withstand storms, too," He said.

He's team has also invented an efficient and stable photoelectrochemical (PEC) system that uses sunlight and specialized semiconductors to split water into hydrogen and oxygen. While most existing PEC systems operate with a single-sided device, and are prone to instability, He adopts an epitaxial lift-off and transfer technique, which uses both sides of the device and the recycling of a substrate.

The all-inorganic inverted perovskite solar cells developed by the CityU research team have a greater power conversion efficiency than previous devices.

A field test for the spherical spring-assisted triboelectric nanogenerator is performed in the sea.



A collaborative research team led by CityU has developed a droplet-based electricity generator that can light up 100 small LED light bulbs with a single drop of water.

It increases the efficiency of solar-to-hydrogen conversion by two-fold, and maintains stability from a few minutes to more than 150 hours, at half the cost.

Also working on water splitting techniques for converting solar to clean hydrogen, CityU's energy scientist, Yun-hau Ng, is keen to develop a zero-pollution technology that tackles both energy shortage and pollution problems. "When using hydrogen to generate energy, the only by-product is water — the process causes no pollution," Ng said.

As hydrogen can be produced through artificial photosynthesis by putting a semiconductor into water under sunlight, Ng focuses on enhancing conversion efficiency by improving the semiconductor. His team uses titanium oxide, easily obtained from sand, or rusted copper and iron, to produce semiconductors, leading to an economical and environmentally friendly way to split water into hydrogen and generate renewable energy. The team's recent progress uses cuprous oxide, an economical material typically considered non-stable for photosynthesis, to produce hydrogen from water. To stabilize the material, they have developed strategies that allow for the continuous generation of hydrogen.

Ng has recently published an article in *Advanced Materials* elucidating the similarities and differences between photocatalysis and photoelectrocatalysis — powder type and thin film type reactions. This informs the research community and can serve as a tutorial for beginners in the field.

For his contribution to the field of photoelectrocatalysis, Ng was awarded the 2019 Asia-Pacific Economic Cooperation (APEC) Science Prize for Innovation, Research and Education. He expects his research will soon be commercialized for applications in fuel cells for mobile phones and vehicles. ■

CityU
香港城市大學
City University of Hong Kong

www.cityu.edu.hk
+852-3442 7654
vprt@cityu.edu.hk