First 3D-printed proton-conductive membrane paves way for tailored energy storage devices

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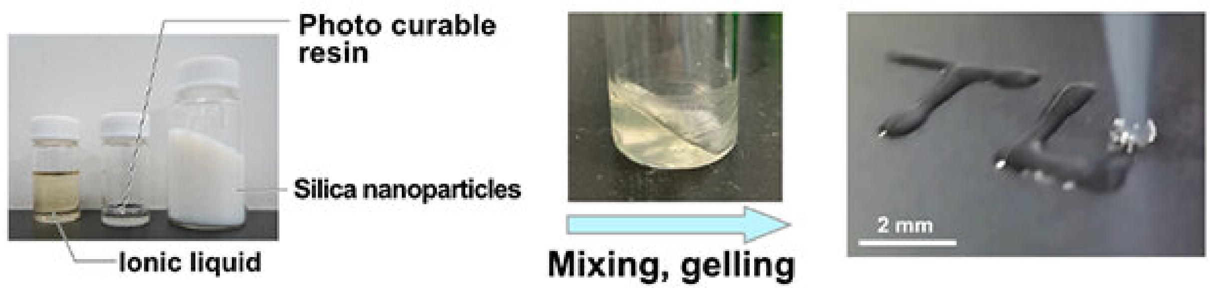


The main components for the synthesis of functionalized nanoink including printing. Credit: Tohoku University

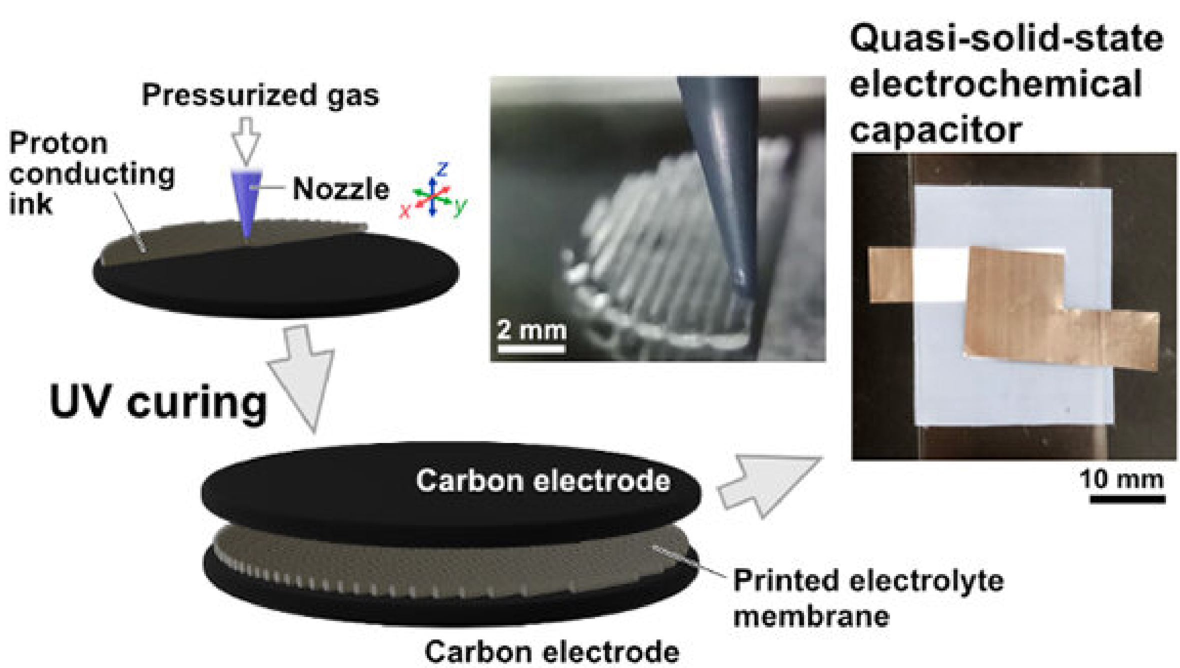
The advent and increased availability of 3D printing is leading to more customizable parts at lower costs across a spectrum of applications, from wearable smart devices to autonomous vehicles. Now, a research team based at Tohoku University has 3D printed the first proton exchange membrane, a critical component of batteries, electrochemical capacitors and fuel cells. The achievement also brings the possibility of custom solid-state energy devices closer to reality, according to the researchers.

The results were published in *ACS Applied Energy Materials*, a journal of the American Chemical Society.

"Energy storage devices whose shapes can be tailored enable entirely new possibilities for applications related, for example, to smart wearable, electronic medical devices, and electronic appliances such as drones," said Kazuyuki Iwase, paper author and assistant professor in professor Itaru Honma's group at the Institute of Multidisciplinary Research for Advanced Materials at Tohoku University. "3D printing is a technology that enables the realization of such on-demand structures."

Current 3D printing fabrication focuses on structural parts contributing to a final product's function, rather than imbuing parts with their own function.

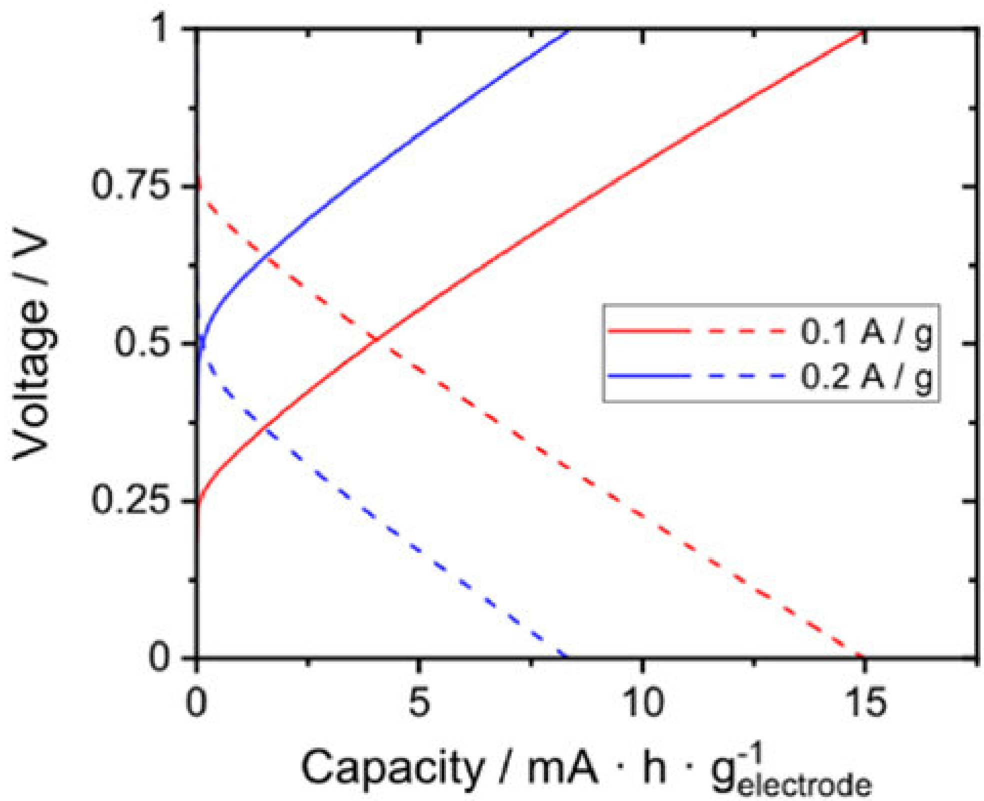
"However, 3D printing of energy storage devices requires specialized, functional inks," Iwase said. "We developed a fabrication process and synthesized functionalized nano inks that enables the realization of quasi-solid-state energy storage devices based on 3D printing."



An overview of fabrication process and a photograph of quasi-solid-state electrochemical capacitor. Credit: Tohoku University

The team mixed inorganic silica nanoparticles with photo-curable resins and liquid capable of conducting protons, with rapt attention paid to the viscosity of the resulting ink. Previous studies, the researchers said, resulted in inks that could not be 3D printed. By mixing the ratios of the ingredients, the researchers developed inks that could be employed in a dispensing 3D printer and still retain their properties even after cured with ultraviolet irradiation. To test the properties, the researchers assembled a printed membrane between two carbon electron electrodes to make an operational quasi-solid-state electrochemical capacitor—a key component needed to facilitate energy storage and discharge in electronic devices.

"As we can freely choose the inorganic materials or resins for curing, we hypothesize that this technique can be applied to various types of quasi-solid-state energy conversion devices," Iwase said.



An example of charge-discharge behavior of capacitor. Credit: Tohoku University

"Compared to conventional fabrication techniques, the ability to 3D print such devices opens up new possibilities for proton-conducting devices, such as shapes that can be adjusted to fit to the devices they power or that can be adapted to the personal needs of a patient wearing a smart medical device," Iwase said.

The team plans to improve the ink formulas with the goal of fully 3D printing energy storage devices with more complex shapes and look for industrial partners who might be interested in applying this technique or other possibilities to commercialize it.

More information: Kazuyuki Iwase et al. Direct Printable Proton-Conducting Nanocomposite Inks for All-Quasi-Solid-State Electrochemical Capacitors, *ACS Applied Energy Materials* (2021). DOI: 10.1021/acsaem.1c00076

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