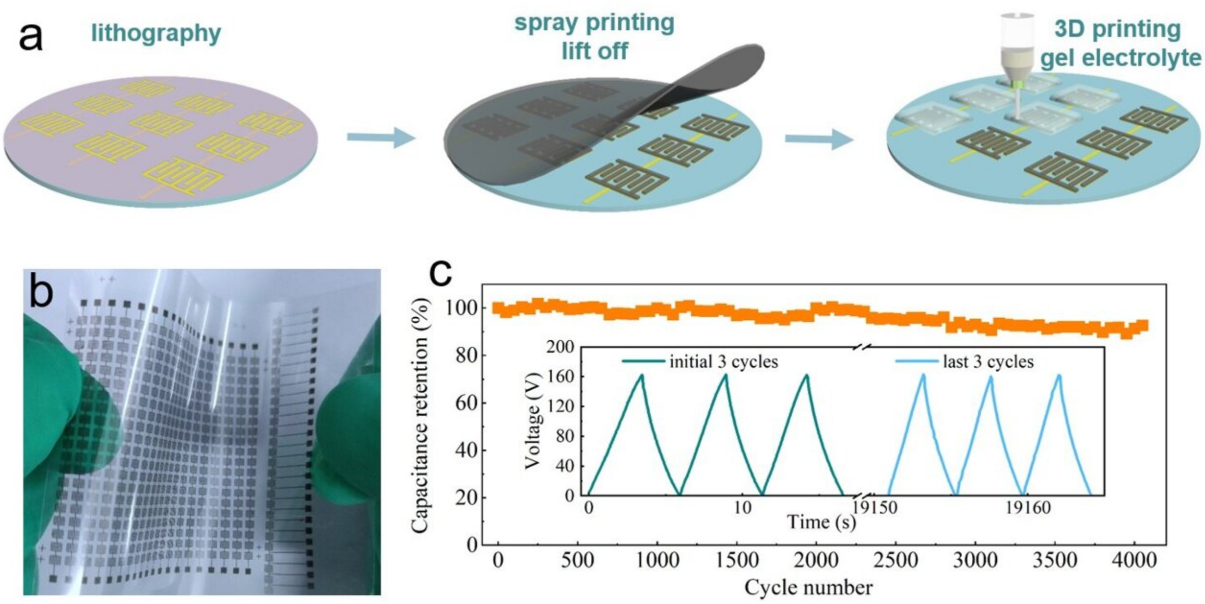
Ultrahigh areal output voltage monolithically integrated micro-supercapacitors for powering miniaturized electronics

February 28 2023



(a) Schematic of the fabrication of M-MIMSCs. (b) Flexibility of M-MIMSCs on a flexible polyethylene terephthalate substrate. (c) Cycling stability for 4000 cycles tested at 2.7 µA of 60 cells connected in series under output voltage of 162 V in PVDF-HFP-EMIMBF4 gel electrolyte. Photo credit: Dr. Sen Wang and Dr. Linmei Li. Credit: Science China Press

To realize true Internet of Things in future, compact monolithic integrated micro-supercapacitors (MIMSCs) with high systemic performance along with cell number density will become indispensable for powering miniaturized electronics, but their scalable production is still challenging. Several limitations stand as the barriers in their path.

Depositing electrolytes precisely on densely-packed micro-supercapacitors (MSCs) while ensuring electrochemical isolation is one of the most formidable challenges to overcome. In addition, electrochemical performance may be significantly sacrificed during complex microfabrication procedures, and even then, performance uniformity among numerous individual cells is difficult to achieve.

To address these critical issues, Prof. Zhong-Shuai Wu and colleagues have developed an innovative and high-throughput strategy combining multi-step lithographic patterning, spray printing of MXene microelectrodes, and three-dimensional (3D) printing of gel electrolyte, for mass production of MIMSCs, simultaneously achieving superior cell number density and high systemic performance.

The team achieved the monolithic integration of electrochemically isolated micro-supercapacitors in close proximity by leveraging high-resolution micropatterning techniques for microelectrode deposition and 3D printing for precise electrolyte deposition.

First, benefiting from the high-resolution of lithographic patterning and uniqueness of MXene nanosheets, super-dense microelectrode-arrays were fabricated, and each individual MXene-based MSC exhibits an extremely small footprint of 1.8 mm^2, high areal capacitance of 4.1 mF cm^{-2}, high volumetric capacitance of 457 F cm^{-3}, and stable performance at ultrahigh scan rate up to 500 V s^{-1}.

Second, they developed a simple, reliable and large throughput strategy for electrochemical isolation of individual units. For this a gel electrolyte ink compatible with novel 3D printing technique was designed rationally, enabling adjacent microcells to be electrochemically isolated at a close proximity of just 600 µm and provide outstanding performance uniformity.

Consequently, the researchers were able to obtain MIMSCs with a superior areal number density of 28 cells cm^{-2} (400 cells on 3.5×4.1 cm^2), a record areal output voltage of 75.6 V cm^{-2}, and an acceptable systemic volumetric energy density of 9.8 mWh cm^{-3}, far exceeding those of the previously reported integrated MSCs.

Attributed to the reliability and uniformity of each step in the microfabrication processes including lithography, spray printing, lift-off and 3D printing, the resulting MSCs showed excellent performance consistency on a larger scale, and the MIMSCs demonstrate good capacitance retention of 92% after 4000 cycles at an extremely high output voltage of 162 V (see image c below).

"This innovative microfabrication strategy marks a great advance as a new technological platform for monolithic micropower sources and will aid the applications where compact integration and high systemic performance is demanded from energy storage units," Wu says.

The paper is published in the journal *National Science Review*.

More information: Sen Wang et al, Monolithic integrated micro-supercapacitors with ultra-high systemic volumetric performance and areal output voltage, *National Science Review* (2022). DOI: 10.1093/nsr/nwac271

Provided by Science China Press