New developments in printable three-dimensional microbatteries

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Miniature power sources are needed for a variety of applications, including implantable medical devices, remote microsensors and transmitters, "smart" cards, and IOT systems. Today's rechargeable lithium-ion batteries - with the best energy density performance and with a reasonably good power efficiency - dominate the consumer market. Reducing the size of a common LIB requires an update of the traditional manufacturing method of building electrodes and a careful evaluation of alternative electrolytes. Although 2D thin-film microbatteries (typical thickness of a few micrometers) can deliver high power, they require large (often cm^2) footprints to provide reasonable energies. Insufficient areal energy density from thin-film planar microbatteries inspires a search for three-dimensional microbatteries (3DMB) with the use of low cost and efficient micro- and nano-scale materials and techniques. The 3DMB approaches proposed so far include interdigitated-, trench-, concentric-, and sponge-type structures.

The exclusive capabilities of the 3D-printing technology enable the design of different shapes and high-surface-area structures, which no other manufacturing method can do easily. We present three types of novel quasi-solid rechargeable 3D microbatteries. The first one is assembled on a 3D-printed perforated polymer substrate. The interconnected channels formed through XYZ planes provide up to two orders of magnitude area gain of the substrate, available to the active battery materials as compared to planar batteries. We point out that the novel structure simplifies the electrochemical insertion of consecutive battery layers which, in turn, facilitates fabrication of 3D microbatteries with an aspect ratio much higher than 10. The battery occupies a footprint area of only a few mm^2, while its height may approach a few cm. Simple and inexpensive electrophoretic-deposition routes are applied for the fabrication of all the thin-film active-material layers of the microbattery. The second and the third type of the 3DMB exploit the FFF and dispensing approaches to produce batteries of spiral and interlaced shapes, in which all the active battery layers are prepared by 3D printing.

Taking advantage of thin films composed of nanosize electrode materials, like modified LFP, NCA, LTO, and original polymer-in-ceramic electrolyte, our 3D microbatteries offer high reversible specific capacity, high pulse-power capability, and intrinsic safety.

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