Direct Imprinting of Microelectrodes for High-Performance Miniature Power Sources

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Microbatteries with form factors comparable to MEMS *e.g*., microsensors and actuators, offer exciting opportunities to achieve self-powered, all-on-one-chip devices. Despite significant advances of the 3D microbattery theories, scalable fabrication of microelectrodes with complicated 3D architectures and the assembly of miniature components into a well-functioning battery remain elusive. Here we utilize soft imprint lithography and functional nanoparticle inks, including $LiMn_2O_4$ (LMO), $Li_4Ti_5O_{12}$ (LTO) and TiO_2, to fabricate high aspect ratio microelectrodes. The nanoparticles, either commercial or home-synthesized, bear sub-20 nm diameters, rendering fine and stable dispersions for imprinting and offering significant advantages for easy mass and ionic diffusion in the electrochemical processes.[1-3] The low viscosity of imprinting inks facilitates the capillary-driven mold filling. By modulating the elastomer stamp dimensions, we create LMO microelectrodes with aspect ratios of 0.7, 1.7 and 3.8 (Figure 1a to 1c). To further improve the aspect ratio, we apply multilayer imprinting strategy to create woodpile-like 3D TiO_2 microelectrodes, achieving user-defined aspect ratios (Figure 1d-1e). The imprinted woodpile electrodes demonstrate specific capacity of 250.9 $mAhg^{-1}$ and stable cycling in a lithium-ion battery. Post-cycling SEM imaging (Figure 1f) shows that the imprinted feature maintain good structural integrity.

Aside from imprinted electrodes, polymer electrolytes that enable solution deposition on electrodes are developed to facilitate microbattery full cell fabrication. The resultant microbattery based on LMO/LTO electrochemical pair demonstrates superior fast charge-discharge capabilities (40% capacity retention at 300 C) and high volumetric power density of 855 $\mu Wcm^{-2}\mu m^{-1}$ (Figure 2), which is attributed to the small critical dimension and high surface-to-volume ratio of the imprinted features. In the last part, we will briefly mention about our work of using initiated chemical vapor deposition to optimize the polymer electrolyte coating quality;[4] much better uniformity and conformality can be achieved.

Reference:

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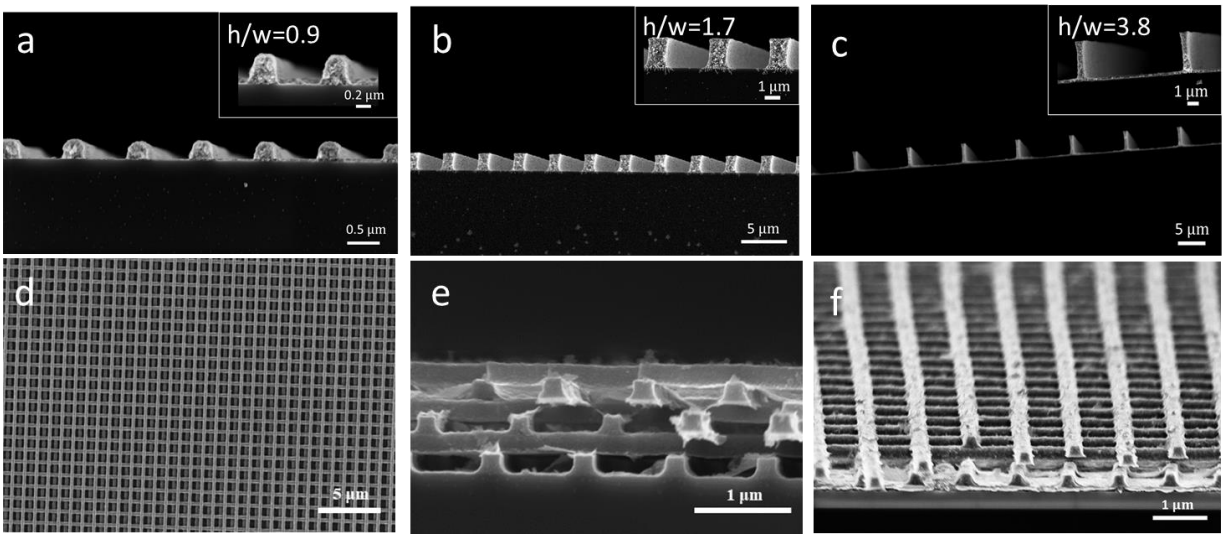

Figure 1. (a)-(c) imprinted LMO electrodes with aspect ratios of 0.9, 1.7 and 3.8. (d) and (e) top-down and cross-sectional views of TiO_2 woodpile electrodes. (f) post-cycling imaging of TiO_2 woodpile electrode.

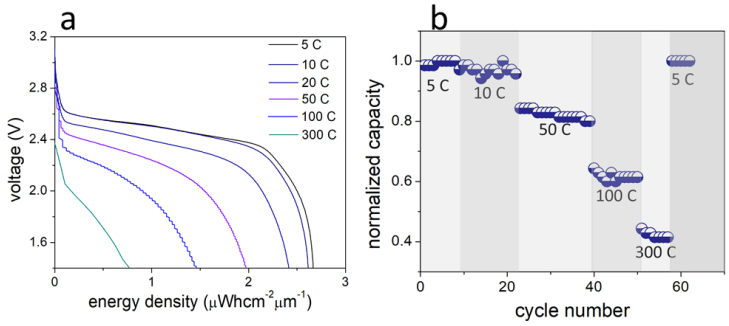

Figure 2. (a) discharging profiles of LMO/LTO microbatteries at different C rates. (b) Normalized capacity of micorbattery as a function of C rates and cycle numbers.