

“Over the years, extensive efforts have been placed on addressing the problems of poor electronic conductivity of sulfur and dissolution of intermediate polysulfides into the electrolyte. Instead, we placed special emphasis on dealing with a third challenge: the large volumetric expansion of sulfur during lithiation,” explains Zhi Wei Seh of Stanford University.

To form an actual device, the yolk-shell nanostructures are mixed with conductive carbon and a binder before coating onto Al to form a cathode. Li-S batteries constructed with the nanostructure-enabled cathode show an initial specific capacity of 1030 mA h g^{-1} at $0.5 \text{ }^\circ\text{C}$ and

Coulombic efficiency of 98.4% over 1000 cycles, with capacity decay at just 0.033% per cycle.

“[Our] new Li-S batteries have a high and stable specific capacity of about 800 to 1000 mA h g^{-1} , which is about six times that of the current Li-ion batteries (based on LiCoO_2 cathode) on the market,” says Seh.

According to the researchers, this is the best level of performance yet reported for a Li-S battery.

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Bottom-up approach promises batteries for microelectronics

Cordelia Sealy

Lithium-ion batteries are in demand for portable electronics, transport and energy storage applications but have had less impact as power sources for microelectronic devices. Now researchers believe they have come up with an elegant bottom-up solution to produce the electrodes for microbattery arrays integrated into micro/nanoelectromechanical systems (MEMS/NEMS) or biomedical devices (Y. Liu, et al., *Nano Letters* (2012), <http://dx.doi.org/10.1021/nl304104q>).

The team from the University of Maryland, the US Army Research Laboratory, and Sichuan University in China used self-assembled tobacco mosaic virus (TMV) as the template for the fabrication of three-dimensional LiFePO_4 nanoforest

electrode arrays with built-in nano-current collectors. The TMV, which is a cylindrical particle that forms a 300 nm long, 18 nm diameter nanorod (Fig. 1) is first self-assembled onto a stainless steel collector and then coated with Ni to form the current collector. Ti and LiFePO_4 sublayers are then added using radio frequency magnetron sputtering deposition and annealed at $500 \text{ }^\circ\text{C}$ for a couple of hours.

The virus is genetically modified to self assemble vertically on the current collector, maximizing power and energy densities over a minimum footprint. The heat treatment decomposes the TMV so that it only serves as a scaffold and does not impact on the eventual materials performance.

“Previously, such three-dimensional metal- LiFePO_4 core-shell nanoforest electrodes have been fabricated using sacrificed nanostructured templates through a wet impregnation process, followed by etching or template decomposition,” explains Chunsheng Wang of the University of Maryland. “However, the complexity of that practice and the associated high processing cost would limit its scalability,” he says.

The virus-templated approach, by comparison, enables the fabrication of LiFePO_4 nanorods with central metal cores simply and easily.

“The genetically-modified TMV proves to be a template that is not only stable but also amenable toward magnetron deposition processes, hence allowing architecturing of sophisticated multilayer energy storage mechanisms,” says Wang.

While further effort is need to integrate anodes, which the team have reported previously, and cathodes into a full lithium-ion battery, the researchers are confident their results demonstrate that it is possible to use nano-templates to engineer structures with layers of different functions. Wang says the next step will be to fabricate three-dimensional Si/LiPON/ LiFePO_4 nanoforest fuel cells.

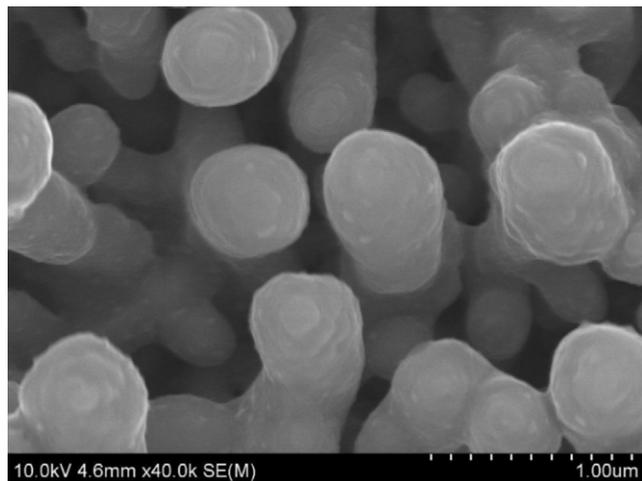


Fig. 1 TMV-enabled $\text{LiFePO}_4/\text{Ti}/\text{Ni}$ nanoforest anode. (Credit: Chunsheng Wang, University of Maryland.)

“(This work) paves the way to nanobatteries that power nano-devices,” he told Nano Energy.



Cordelia Sealy has many years' experience as a scientific journalist and editor in areas spanning nanotechnology, energy, materials science and engineering, physics, chemistry and the environment. She is currently a freelance science writer for her own company, Oxford Science Writing, and serves as News and Opinions Editor of Nano Energy and Nano Today. She also writes on energy policy and business issues. In the past,

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