



## **■ An Integrated, Layered-Spinel Composite Cathode for Energy Storage Applications**

**The composite cathode can be used in rechargeable Li-ion batteries in hybrid electric vehicles, laptops, medical devices, and military vehicles.**

*John H. Glenn Research Center, Cleveland, Ohio*

At low operating temperatures, commercially available electrode materials for lithium-ion batteries do not fully meet the energy and power requirements for NASA's exploration activities. The composite cathode under development is projected to provide the required energy and power densities at low temperatures and its usage will considerably reduce the overall volume and weight of the battery pack.

The newly developed composite electrode material can provide superior electrochemical performance relative to a commercially available lithium cobalt system. One advantage of using a composite cathode is its higher energy density, which can lead to smaller and lighter battery packs. In the current program, different series of layered-spinel composite materials with at least two different systems in an integrated structure were synthesized, and the volumetric and gravimetric energy densities were evaluated. In an integrated network of a

composite electrode, the effect of the combined structures is to enhance the capacity and power capabilities of the material to levels greater than what is possible in current state-of-the-art cathode systems.

The main objective of the current program is to implement a novel cathode material that meets NASA's low temperature energy density requirements. An important feature of the composite cathode is that it has at least two components (e.g., layered and spinel) that are structurally integrated. The layered material by itself is electrochemically inactive; however, upon structural integration with a spinel material, the layered material can be electrochemically activated, thereby delivering a large amount of energy with stable cycling. A key aspect of the innovation has been the development of a scalable process to produce submicron- and micron-scale particles of these composite materials.

An additional advantage of using such a composite electrode material is its low irreversible loss ( $\approx 5\%$ ), which is primarily due to the unique activation of the composite. High columbic efficiency ( $>99\%$ ) upon cycling may indicate the formation of a stable SEI (solid-electrolyte interface) layer, which can contribute to long cycle life. The innovation in the current program, when further developed, will enable the system to maintain high energy and power densities at low temperatures, improve efficiency, and further stabilize and enhance the safety of the cell.

*This work was done by Nader Hagh and Ganesh Skandan of NEI Corporation for Glenn Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18870-1.*

## **■ Engineered Multifunctional Surfaces for Fluid Handling**

**These processes create antibacterial and hydrophilic properties on metallic and polymeric surfaces.**

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Designs incorporating variations in capillary geometry and hydrophilic and/or antibacterial surface properties have been developed that are capable of passive gas/liquid separation and passive water flow. These designs can incorporate capillary grooves and/or surfaces arranged to create linear and circumferential capillary geometry at the micro and macro scale, radial fin configurations, micro holes and patterns, and combinations of the above.

The antibacterial property of this design inhibits the growth of bacteria or

the development of biofilm. The hydrophilic property reduces the water contact angle with a treated substrate such that water spreads into a thin layer atop the treated surface.

These antibacterial and hydrophilic properties applied to a thermally conductive surface, combined with capillary geometry, create a novel heat exchanger capable of condensing water from a humid, two-phase water and gas flow onto the treated heat exchanger surfaces, and passively separating the condensed water from the gas flow in a reduced gravity application.

The overall process to generate the antibacterial and hydrophilic properties includes multiple steps to generate the two different surface properties, and can be divided into two major steps. Step 1 uses a magnetron-based sputtering technique to implant the silver atoms into the base material. A layer of silver is built up on top of the base material. Completion of this step provides the antibacterial property. Step 2 uses a cold-plasma technique to generate the hydrophilic surface property on top of the silver layer generated in Step 1. Completion of this step provides the hy-