



## Nanostructured MnO<sub>2</sub>-Based Cathodes for Li-Ion/Polymer Cells

Experiments show promise for increasing energy densities.

Lyndon B. Johnson Space Center, Houston, Texas

Nanostructured MnO<sub>2</sub>-based cathodes for Li-ion/polymer electrochemical cells have been investigated in a continuing effort to develop safe, high-energy-density, reliable, low-toxicity, rechargeable batteries for a variety of applications in NASA programs and in mass-produced commercial electronic equipment. Whereas the energy densities of state-of-the-art lithium-ion/polymer batteries range from 150 to 175

W-h/kg, the goal of this effort is to increase the typical energy density to about 250 W-h/kg. It is also expected that an incidental benefit of this effort will be increases in power densities because the distances over which Li ions must diffuse through nanostructured cathode materials are smaller than those through solid bulk cathode materials.

The developmental MnO<sub>2</sub>-based cathode nanostructures are, more specifically,

layered structures that have compositions of Li<sub>x</sub>Mn<sub>1-y</sub>M<sub>y</sub>O<sub>2</sub> (where  $x \geq 0$ ,  $0 \leq y \leq 1$ , and M denotes a dopant metal other than Mn or Li). The average size of crystallites in cathodes made from nanolayered Li<sub>x</sub>Mn<sub>1-y</sub>M<sub>y</sub>O<sub>2</sub> was observed to be about 50 nm. The energy densities of these cathodes were found to be approximately 440 W-h/kg. The charge/discharge curves of these cathodes were observed to lie in the potential range of 4.2 to 2 V and to be continuous. The

nanostructures were found to be stable and the charge/discharge capacities of the cathodes were found not to fade after multiple charge/discharge cycles (see figure).

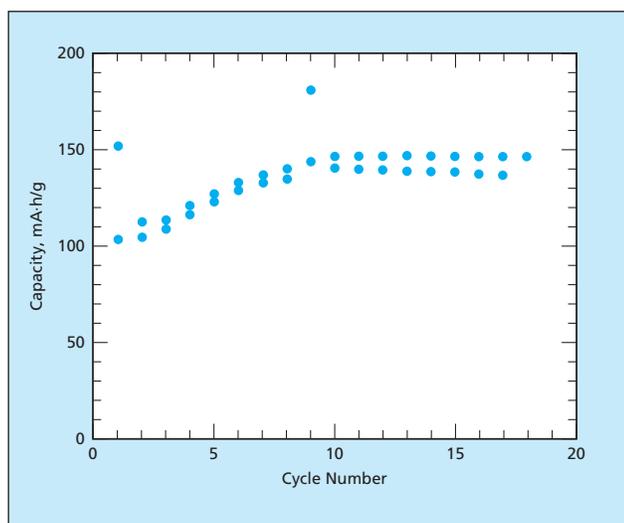
The experiments performed thus far have involved small laboratory cells. Further research will be needed to demonstrate practical cells. The tailoring of nanostructures and compositions is likely to be an important topic of research because the electrochemical properties of Li<sub>x</sub>Mn<sub>1-y</sub>M<sub>y</sub>O<sub>2</sub> from which the cathodes are made depend on the sizes of the crystallites, and the type and the amounts of dopants.

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The Charge/Discharge Capacities of Li<sub>x</sub>Mn<sub>1-y</sub>M<sub>y</sub>O<sub>2</sub> cathode materials were observed not to decrease below initial values after 20 charge/discharge cycles.

## Multi-Layer Laminated Thin Films for Inflatable Structures

Laminates offer advantages over equal-thickness monolayer sheets.

NASA's Jet Propulsion Laboratory, Pasadena, California

Special-purpose balloons and other inflatable structures would be constructed as flexible laminates of multiple thin polymeric films interspersed with layers of adhesive, according to a proposal. In the original intended application, the laminate would serve as the envelope of the Titan Aerobot — a proposed robotic airship for exploring Titan (one of the moons of Saturn). Potential terrestrial applications for such flexible laminates could include blimps and sails.

In the original application, the multi-layered laminate would contain six layers of 0.14-mil (0.0036-mm)-thick Mylar®, (or equivalent) polyethylene terephthalate film with a layer of adhesive between each layer of Mylar®. The overall thickness and areal density of this laminate would be nearly the same as those of 1-mil (0.0254-mm)-thick monolayer polyethylene terephthalate sheet. However, the laminate would offer several advantages over the monolayer sheet, especially with respect to interrelated

considerations of flexing properties, formation of pinholes, and difficulty or ease of handling, as discussed next.

Most of the damage during flexing of the laminate would be localized in the outermost layers, where the radii of bending in a given bend would be the largest and, hence, the bending stress would be the greatest. The adverse effects of formation of pinholes would be nearly completely mitigated in the laminate because a pinhole in a given layer