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LITHIUM BATTERIES

A protective film

To increase the energy density of lithium metal batteries, and for them to reach the performance that is thought to be theoretically possible, dendrite growth on the lithium anodes must be prevented. Attempts to achieve this include the generation of a solid electrolyte interphase on the lithium anode using electrolyte additives, high concentrations of lithium salts in the electrolyte or the use of solid electrolytes. However, few approaches have resulted in long-term and stable cycling at practical current densities greater than 1 mA cm^{-2}.

Now, writing in *Nature Energy*, Linda Nazar and colleagues report the protection of lithium metal anodes by the *in situ* formation of a metal alloy film on the surface of the anode. The alloy film prevents the growth of dendrites during the electroplating process. "The method is significant because it provides a simple and inexpensive strategy to stabilize lithium metal," says Nazar. "The lithium metal fundamentally changes its electrodeposition behaviour from dendritic to non-dendritic, and opens up a promising research direction."

> Lithium metal fundamentally changes its electrodeposition behaviour from dendritic to non-dendritic

The alloy films, with thicknesses of about 10 μm, are formed rapidly by the reaction of metal chloride with lithium metal. This reaction yields the lithium-richest Li_xM alloy (where M = In, Zn, Bi or As) and LiCl, with both products providing beneficial effects. First, the Li-rich alloy enables the fast mobility of lithium ions through the films. Second, the electronically insulating nature of LiCl creates a potential gradient across the film such that lithium ions are promoted to rapidly diffuse through it. The chemically stable Li-rich films, which are directly bonded to the lithium metal, also serve to isolate the lithium from the organic electrolyte and hence slow parasitic reactions between the two components. This reduces the consumption of the electrolyte and thus enhances the performance of the cell.

"The alloy film-protected lithium anode delivers an extended cycling life of 1,400 hours of continuous plating/stripping at high practical current densities of 2 mA cm^{-2}," explains Nazar. "The improvement afforded by the alloy layer was also demonstrated in cells with lithium metal paired with a $Li_4Ti_5O_{12}$ electrode; these can undergo over 1,500 cycles with no significant degradation."

Electron and optical microscopy imaging of the process reveals that lithium plating occurs beneath the alloy film with a uniform ion flux; therefore, the tendency of dendrites to form (which is exacerbated by an inhomogeneous ion distribution) is minimized.

"We are currently developing approaches that will improve the mechanical properties of the membranes and their stability in carbonate electrolytes with the aim that these protected lithium anodes could serve for a variety of lithium batteries," concludes Nazar.

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ORIGINAL ARTICLE Liang, X. *et al.* A facile surface chemistry route to a stabilized lithium metal anode. *Nat. Energy* **6**, 17119 (2017)