Nickel-foam-supported carbon-nanotube electrode offers improved performance for lightweight lithium batteries

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Lithium–oxygen batteries are innovative devices that generate power from atmospheric oxygen trapped inside porous, carbon-based electrodes. These batteries are significantly lighter than traditional lithium-ion batteries, and thus have the potential to extend the driving

range of electric and hybrid vehicles. However, many practical challenges remain for lithium–oxygen batteries, most notable of which is the buildup of insoluble lithium peroxide by-products in the carbon electrode, which can cause the battery to cease operation after only a few charge cycles.

Now, Zhaolin Liu from the A*STAR Institute of Materials Research and Engineering in Singapore, in collaboration with Aishui Yu and co-workers from Fudan University in China, has developed a carbon nanotube electrode that can alleviate recharging problems in lithium–oxygen batteries, thanks to a support made from three-dimensional nickel foam1.

In previous efforts to improve the performance of lithium–oxygen batteries, researchers investigated numerous types of permeable carbon electrodes—including high-surface-area charcoal, graphene and porous aerogels. Such approaches, however, rely on glue-like binders to hold the carbon particles together. These binders decrease oxygen diffusion rates through the electrode and can degrade and clog pore spaces.

Liu and co-workers set out to design a binder-free electrode by turning to nickel foam, an inexpensive substance with a porous three-dimensional structure that makes it both rigid and lightweight. To ensure the foam's compatibility with lithium–oxygen batteries, the team grew carbon nanotubes doped with small amounts of nitrogen directly on its surface. Nitrogen-doped carbon-nanotube electrodes have been shown to possess catalytic activity that boosts battery lifetimes, and the team anticipated that they could create improved devices by supporting these nanomaterials with nickel foam.

Using chemical vapor deposition, the researchers were able to cover the nickel foam with layers of doped carbon nanotubes arranged in typical bamboo-like structures. These nanotubes were loosely packed and

contributed to a network of large, interconnected tunnels throughout the foam. According to Liu, these tunnels facilitate oxygen diffusion and provide critical voids where lithium peroxide can be deposited without limiting battery performance.

When they measured the performance of their binder-free electrode, the team found that it could deliver twice the electrical capacity of a pure-nitrogen-doped carbon-nanotube electrode. Liu notes that the strong electrical contact between the nanotubes and the nickel support suppresses volume expansion and limits the polarization effects that hinder battery recharging. "The next step will be to apply these electrodes in real lithium–oxygen batteries," he says.

More information: Lin, X., Lu, X., Huang, T., Liu, Z. & Yu, A. "Binder-free nitrogen-doped carbon nanotubes electrodes for lithium-oxygen batteries." *Journal of Power Sources* 242, 855–859 (2013). DOI: 10.1016/j.jpowsour.2013.05.100

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