Novel composite improves performance in solid-state lithium-ion batteries

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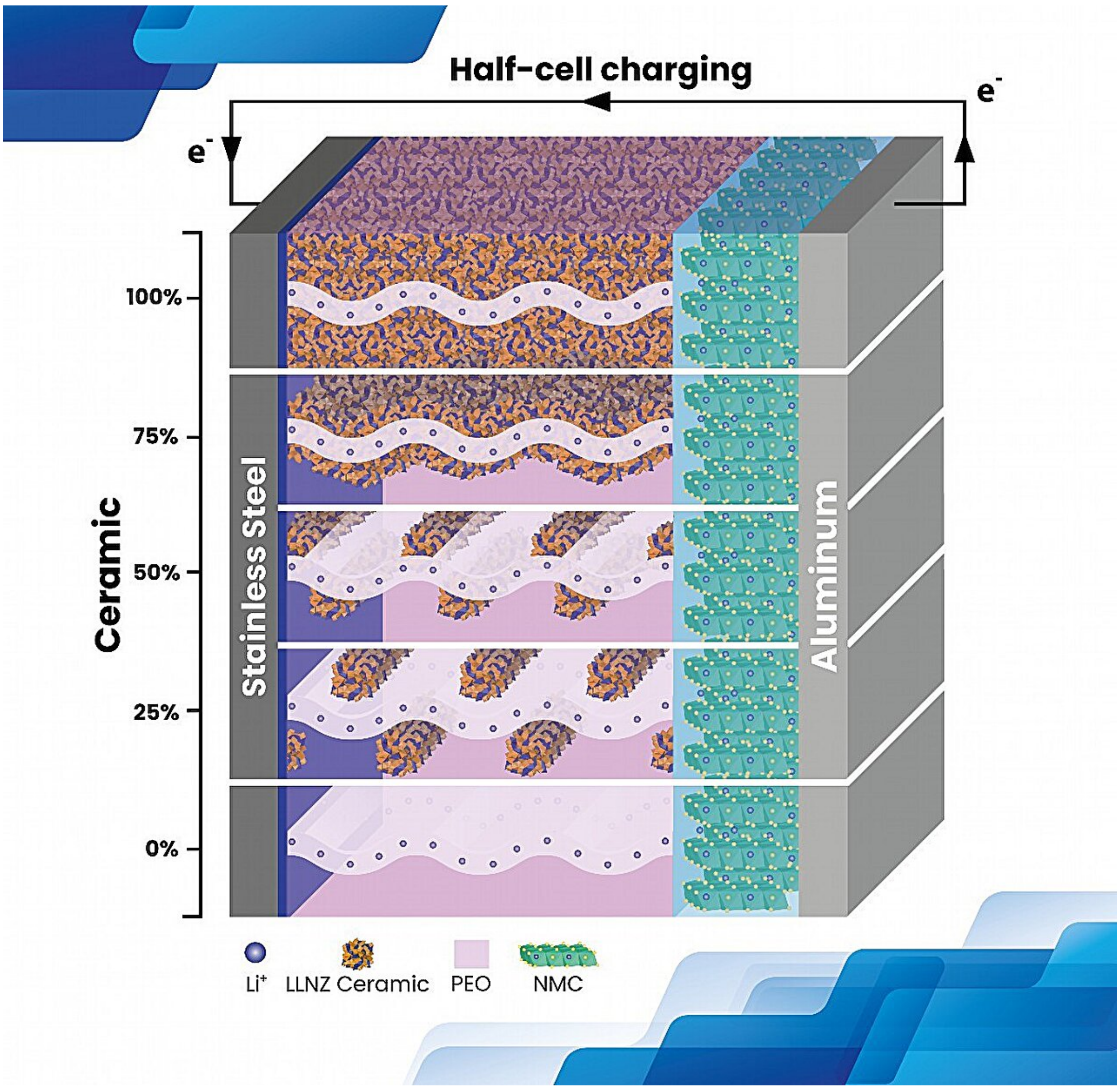

Charging a solid-state battery. Credit: Shirley Reis

Lithium-ion batteries are widely viewed as a necessity for meeting our growing energy demands while reducing our dependence on fossil fuels. So far, however, their commercial rollout has been hindered by safety issues relating to their use of liquid electrolytes: including the possibility for the harmful chemicals they contain to leak into the environment, or even explode if they become too hot.

In a recent study published in *Solid State Ionics*, Shirley Reis and colleagues at the SENAI Innovation Institute in Electrochemistry, Curitiba, Brazil, show how strong performance can be maintained and safety improved in lithium-ion batteries when liquid electrolytes are replaced with solid composites, composed of specially engineered blends of ceramic and polymer electrolytes.

These promising findings show that when the right materials are employed, solid-state batteries could become well suited for applications including electric vehicles, and storage for renewable energy.

"As part of a 5-year partnership between our Institute and the Brazilian Metallurgy and Mining Company (CBMM), the main goal of our study is to enable the use of niobium-based raw materials produced by the company for the next generation of lithium-ion batteries," says Reis.

In both solid- and liquid-state batteries, charges are carried by ions in an electrolyte, which is sandwiched between a pair of electrodes. These ions move from the anode to the cathode as the battery discharges, then back again during charging. Yet solid-state batteries offer clear advantages over their liquid-state counterparts—at least in principle.

"Since they are non-flammable and have a higher thermal stability, solid-state batteries are a highly sought-after technology, and have been widely studied as a substitute for liquid electrolytes," Reis explains. "However, more studies are needed to gain a better understanding of the technology and bring it to the commercial market."

The challenge is that solid electrolytes often come with significant limitations that make them unsuitable for use in commercial batteries. In particular, ceramic electrolytes have high ionic conductivities and are stable at high voltages, but are often very brittle. In contrast, polymer electrolytes are far more flexible, but have low ionic conductivities, and are often unstable at high voltages.

In their study, Reis' team examined the possibility of blending ceramic and polymer electrolytes into 'composite' electrolytes, which combine the unique advantages of both materials.

The composite produced by the team included a blend of zirconium-doped niobium garnet oxide and polyethylene oxide polymer. They investigated its performance when charged and discharged using a metallic lithium anode and a high-nickel NMC cathode,

They also tested out different variations in the ratio between ceramic and polymer in the composite, allowing them to precisely determine which composition was best suited to a solid-state battery. In all of the composites they tested, the electrolyte demonstrated a good flexibility, high conductivity of lithium ions, and strong stability at high voltages. It could even retain much of its original charge capacity after numerous cycles of charging and discharging.

As Reis describes, "the results are promising, and indicate the possibility of the use of high-nickel cathodes in all-solid-state batteries to increase their energy density." In demonstrating such a strong performance in a battery made from low-cost, readily available materials, the researchers are now hopeful that their results have promising implications for the future of solid-state lithium-ion batteries.

"The growth of the lithium-ion battery market all around the world opens new opportunities to develop new materials and technologies that improve batteries' properties," Reis concludes. "The results obtained in our paper are very consistent with the literature, and we hope they will help to improve our understanding of how composite electrolytes can be used for all-solid-state batteries with high-nickel cathode materials."

More information: Juliane B. Kosctiuk et al, Niobium garnet/polyethylene oxide composite as a solid electrolyte for all-solid-state batteries (ASSB) with high-nickel cathodes, *Solid State Ionics* (2024). DOI: 10.1016/j.ssi.2024.116607

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