Engineers develop advanced solid-state electrolytes for high-performance all-solid-state lithium metal batteries

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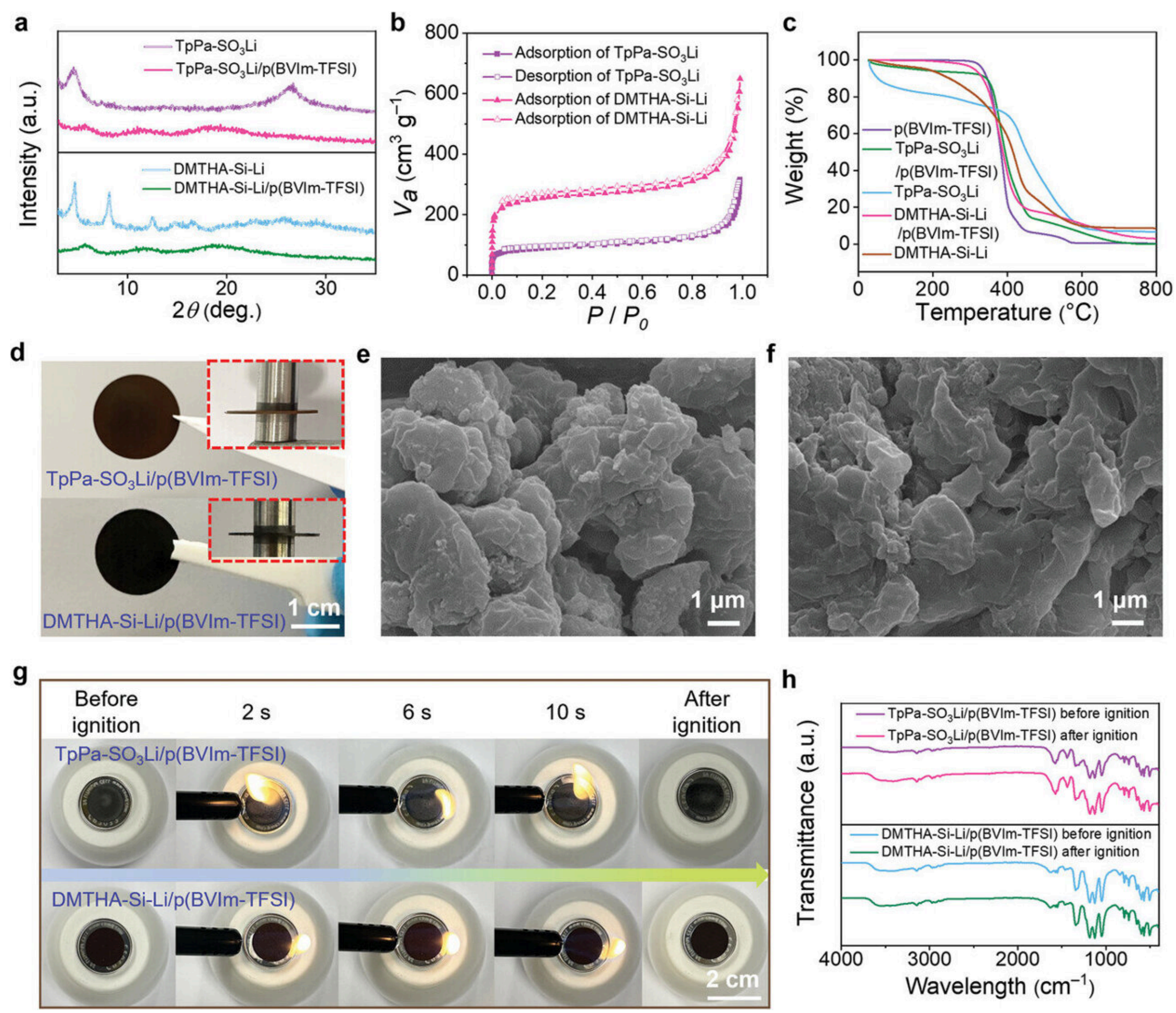

Characterization of the iCOF/PIL composites. Credit: *Advanced Energy*

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Researchers at the School of Engineering of the Hong Kong University of Science and Technology (HKUST) have recently developed a new generation of solid-state electrolytes (SSEs) for lithium-metal batteries (LMBs), that can greatly improve safety and performance. This discovery can help advance the development of energy storage technologies for battery applications like electric vehicles, portable electronics, and power grids.

Compared to traditional liquid electrolyte LMBs, all-solid-state LMBs offer enhanced safety and higher energy density by replacing the flammable organic solvent electrolytes with solid electrolytes and suppressing a harmful phenomenon called dendrite growths. They present a promising future for developing energy storage technologies. However, their wider adoption has been limited by low ionic conductivity and Li^+ transference number at room temperature.

To address this challenge, the research team led by Prof. Kim Yoonseob, Assistant Professor of the Department of Chemical and Biological Engineering at HKUST, has developed a novel strategy that combines a class of porous called ionic covalent organic frameworks (iCOFs) with a type of polymer called poly(ionic liquid) (PIL) for fabricating solvent- and plasticizer-free SSEs with high performance.

This new iCOF/PIL composite SSE achieved exceptional ionic conductivity (up to 1.50×10^{-3} S cm^{-1}) and lithium-ion transport capability (> 0.80) at room temperature. Through combined experimental and computational studies, the team revealed that the co-coordination and competitive coordination mechanisms established between the PIL, lithium bis(trifluoromethanesulfonyl)imide (LiTFSI) and iCOFs enable rapid Li^+ transport while restricting the movement of $TFSI^-$.

Using this advanced SSE, the team further fabricated a LMB full cell, made of composite SSEs and $LiFePO_4$ composite cathode, and found that it demonstrated an initial discharge capacity of 141.5 mAh g^{-1} at 1C and room temperature, with an impressive capacity retention of 87% over 800 cycles.

"Our breakthrough approach demonstrates stable cell operation and shows a high reversible capacity in all-solid-state LMBs for the first time. It unleashes great potential of iCOFs for electrochemical energy storage devices, opening up new paths forward for wider adoption of all-solid-state LMBs in a variety of applications, from electric vehicles to portable electronics and power grids," Prof. Kim said.

This study was a collaboration between researchers at HKUST, Shanghai Jiao Tong University and Zhejiang University in Mainland China and Hanyang University in South Korea.

The research paper, titled "High-Performance All-Solid-State Lithium Metal Batteries Enabled by Ionic Covalent Organic Framework Composites," was published in *Advanced Energy Materials*.

More information: Jun Huang et al, High-Performance All-Solid-State Lithium Metal Batteries Enabled by Ionic Covalent Organic Framework Composites, *Advanced Energy Materials* (2024).
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