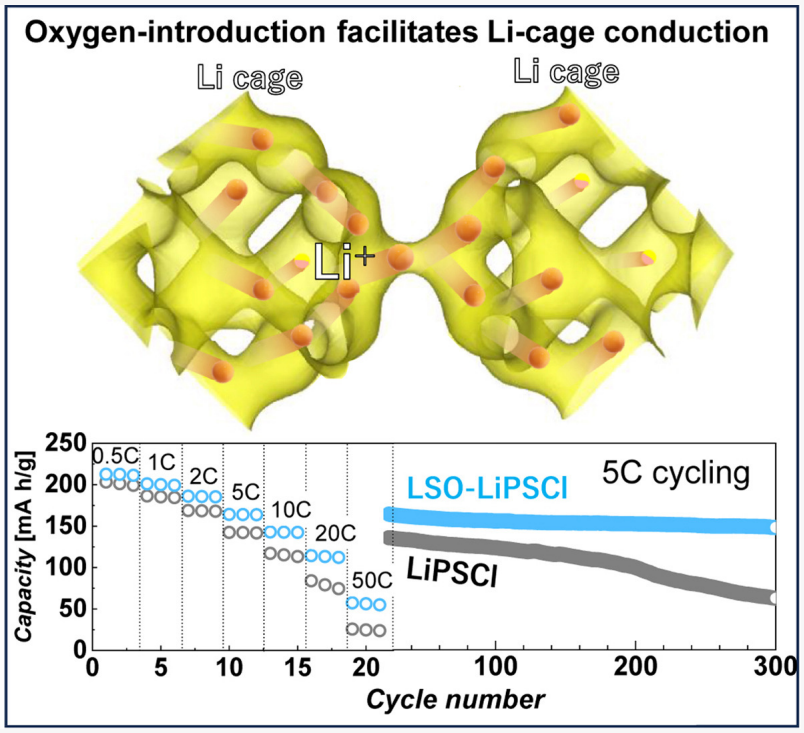
Oxygen opens new paths for solid-state batteries

GA, UNITED STATES, June 26, 2026 /EINPresswire.com/ -- All-solid-state batteries (ASSBs) are widely viewed as a safer and more powerful alternative to conventional lithium-ion batteries, but their promise is often limited by unstable interfaces inside the cell. A new study shows that carefully introducing oxygen into a sulfide-based solid electrolyte (SE) can stabilize this vulnerable interface while keeping lithium ions moving rapidly. Using lithium sulfate (Li□SO□) as an oxygen source, the researchers reshaped the internal lithium pathways of an argyrodite electrolyte and activated cage-to-cage ion conduction. The result is a solid electrolyte that supports high capacity, fast charging and discharging, and long cycling stability, offering a practical strategy for next-generation batteries.



Oxygen-driven lithium pathways boost solid-state battery performance.

All-solid-state batteries (ASSBs) replace flammable liquid electrolytes with solid materials, giving them strong safety advantages and making them attractive for electric vehicles, grid storage, and compact high-power devices. Among candidate materials, sulfide-based solid electrolytes (SEs) such as lithium phosphorus sulfur chloride (Li□PS□Cl, LiPSCl) stand out because of their high ionic conductivity and favorable processability. However, when these materials contact high-capacity oxide cathodes, side reactions can increase interfacial resistance and accelerate capacity loss. Previous coating and doping approaches have improved stability, but they often reduce lithium-ion transport or create unwanted secondary phases. Due to these challenges, it is necessary to conduct in-depth research on oxygen-modified sulfide electrolytes that can combine fast ion conduction with long-term interfacial stability.

A research team from the Research Institute of Industrial Technology and Science (RIST), Korea

Institute of Science and Technology, POSCO Holdings, Dongguk University-Seoul, Korea National University of Transportation, University of Wollongong, and Hanyang University reported the findings in eScience. The research paper was available online on March 2026, and presents an oxygen-incorporation strategy for improving sulfide-based ASSBs.

The team incorporated oxygen into LiPSCl by using Li□SO□ and found that oxygen selectively substituted sulfur at Wyckoff 16e sites within PS□ units. This substitution did not simply stabilize the crystal framework; it also redistributed lithium ions and changed how they moved through the electrolyte. Although oxygen is usually expected to reduce ion mobility because of its lower polarizability, the modified structure shortened the LiT2–LiT2 distance from 1.77 Å to 1.65 Å, opening inter-cage lithium conduction pathways that helped preserve high conductivity. The mechanism was confirmed through neutron diffraction (ND) Rietveld refinement, magic angle spinning nuclear magnetic resonance (MAS-NMR), X-ray absorption spectroscopy (XAS), X-ray photoelectron spectroscopy (XPS), and molecular dynamics (MD) simulations. Electrochemical tests further showed that lithium sulfate–oxygen-modified LiPSCl (LSO-LiPSCl) delivered an initial discharge capacity of about 230 mAh g□¹, sustained operation at 9 A g□¹, corresponding to a 50 C rate, and retained approximately 75% of its capacity after 1000 cycles at 2 C. In a practical pouch cell using a LiNi□.□Co□.□Mn□.□O□ (NCM811) cathode, SE layer, and graphite anode, the system operated stably for more than 500 cycles at an energy density of 400 Wh L□¹.

The authors said the study shows that oxygen can do more than protect sulfide electrolytes from degradation. When placed at the right structural site, oxygen can guide lithium redistribution and create new ion-conduction routes across neighboring cages. They said this dual effect—stabilizing the interface while maintaining rapid lithium transport—is especially important for solid-state batteries that must operate under high current and long cycling conditions.

The findings provide a scalable design strategy for high-performance ASSBs. Rather than relying only on surface coatings or complicated processing, the approach modifies the electrolyte framework itself, improving both structural stability and electrochemical durability. This could help battery developers pair sulfide electrolytes with high-energy cathodes while reducing resistance growth during cycling. More broadly, the work opens opportunities to combine oxygen-containing precursors with other dopants to fine-tune lithium pathways, suppress side reactions, and develop safer, faster-charging, longer-lasting solid-state batteries for electric mobility, renewable energy storage, and next-generation portable electronics.

References
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