# Weak Solvation Electrolyte Engineering for High-Rate Phosphorus Anodes in Lithium-Ion Batteries

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## Abstract

Phosphorus-based anodes offer extremely high theoretical capacities for lithium-ion batteries, but their practical implementation is limited by severe volume variation and the dissolution of lithium polyphosphide intermediates. Here a weak-solvation electrolyte strategy is introduced to regulate the lithium-ion coordination structure and stabilize the electrode interface. By incorporating a fluorinated co-solvent, the $Li^+$ solvation environment becomes less coordinated, suppressing parasitic reactions and improving charge-transfer kinetics. With this electrolyte, a phosphorus-based anode achieves a remarkable capacity of 2615.2 mAh $g^{-1}$ at 1C, maintaining 91.7% capacity retention over 1000 cycles. Even at a high rate of 4C, it delivers 2210.7 mAh $g^{-1}$ with an exceptional retention of 96.7% after 1500 cycles. Furthermore, at 0 oC, the anode sustains a capacity of 2016.7 mAh $g^{-1}$, with 97% retention after 300 cycles at 1C. This study provides a novel electrolyte design strategy to regulate the solvation sheath, paving the way for high-rate, long-cycle phosphorus-based anodes suitable for fast-charging applications. These findings highlight electrolyte-structure engineering as an effective route toward fast-charging lithium-ion batteries.

## Keywords

Weakly solvated electrolyte, interfacial stability, phosphorus-based anode, fast charging.