Sulfide solid state electrolytes for all-solid-state lithium-sulfur batteries

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Traditional lithium-sulfur batteries with organic liquid electrolyte are always facing two major challenges, *i.e.* safety problems and the polysulfide shuttle reaction, which seriously hampered their practical applications. Using inorganic solid electrolytes instead of combustible liquid electrolytes is considered as the ultimate solution to address the above issues.[1] Compared with oxide electrolytes, sulfide electrolytes are considered to be promising ion conductors due to their high ioinc conductivities and favorable interface compatibility with sulfide or sufur-based electrodes.

A series sulfide solid electrolytes with room temperature ionic conductivity in range of 10^{-3} ~ 10^{-2} S/cm were successfully synthesized. Meanwhile, a new battery construction containning a solid electrolyte bilayer, *i.e.* $Li_{10}GeP_2S_{12}$ and $70\%Li_2S$-$29\%P_2S_5$-$1\%P_2O_5$, have been designed, well addressing the compatibility between electrolyte and metallic lithium.[2] Besides, the intimate contact interface can be realized by coating sulfide electrolyte particles evenly on the surface of active materials, which enables the battery to withstand the large stresses/strains during repeated charging/discharging, leading to significant improvements in energy density and cycle life. For example, the all-solid-state lithium batteries employing ~10 nm $Li_7P_3S_{11}$ electrolyte particles evenly anchored on cobalt sulfide sheets exhibit reversible discharge capacity of 421 mAh g^{-1} at 1.27 mA cm^{-2} after 1000 cycles and 360 Wh kg^{-1}, 3823 W kg^{-1} (based on cathode) at current densities of 0.13, 12.73 mA cm^{-2}, respectively.[3]

Furthermore, a reduced graphene oxide coated with ~2 nm sulfur composites were employed in all-solid-sate lithium-sulfur battery, which significantly reduced the interface resistance and stress/strain of sulfur cathodes. At 60 °C, the all-solid-state lithium-sulfur cell demonstrates a similar electrochemical performance as in liquid organic electrolyte, showing high rate capacities of 1525.6, 1384.5, 1336.3, 903.2, 502.6, and 204.7 mA h g^{-1} at 0.05, 0.1, 0.5, 1.0, 2.0, and 5.0 C, respectively. Besides, it can maintain a high and reversible capacity of 830 mA h g^{-1} at 1.0 C for 750 cycles. The uniform distribution of the rGO@S nanocomposite in the $Li_{10}GeP_2S_{12}$-AB matrix generates uniform volume changes during lithiation/delithiation, significantly reducing the stress/strain, thus extending the cycle life. Minimization of the stress/strain of solid cells is the key for a long cycle life of all-solid-state lithium-sulfur batteries.[4]

References:

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