Three-Dimensional Hierarchical Porous Electrode Structure for Improved Performance in Battery Applications

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The demand for Lithium-ion batteries is rapidly increasing due to urgent needs for effective renewable energy storage. Particularly, attention has shifted towards thick electrodes, as they optimize the active to inactive material ratio in battery systems, increasing the energy densities of these systems; however, thick electrodes lose capacity and stability at high output rates due to their low porosity. Current research aims to solve this by utilizing nanotechnology to create porous structures in cathode materials that greatly increase ion transport rates. Cathode materials are primarily studied since they reach 20% of anode capabilities, limiting overall performance. Previous studies have created porous channels and nanopore structures within cathode materials, but these approaches fail to resolve the innate problems of thick electrodes. This project presents a uniform three-dimensional porous network in $LiCoO_2$, a commercialized Lithium-ion battery cathode, using polymer templating with poly(methyl methacrylate) (PMMA) in both micrometer and nanometer scales, a novel LiCoO2 electrode synthesis method. After mixing $LiCoO_2$ with PMMA, the mixture is heated at high temperatures to burn out PMMA and sinter the templated $LiCoO_2$ powder into a monolithic electrode. The micrometer-sized pores enhance ion conductivity by shortening ion diffusion pathways, and the nanometer-sized pores improve stability by evenly distributing the battery electrolyte. Compared with commercial standards, these electrodes had up to 200% greater specific capacities and 51.1% better capacity retention at high output rates, results that can be applied to numerous battery applications. This study furthers 3D nanostructure understanding and opens discussion about dual-scale porosity.

Awards Won:

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