

Sulfidation-MnO₂ Dual-Modified Cu-Co-MOFs for Flexible Supercapacitors with Hydrogel Electrolyte

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Abstract

Metal-organic frameworks (MOFs) have garnered significant attention as advanced energy storage materials owing to their exceptional specific surface area and structurally tailorable properties. Nevertheless, practical implementation faces critical limitations including intrinsic poor electrical conductivity and inadequate structural stability. To address these challenges, this study proposes an innovative dual-modification strategy integrating controlled sulfidation with conformal MnO₂ coating. Initially, bimetallic Cu-Co-MOF nanoarchitectures were hydrothermally synthesized on nickel foam substrates. Subsequent sulfidation treatment transformed the precursor into Cu-Co-S ternary compounds, effectively optimizing electronic band structures and achieving a 3.8-fold conductivity enhancement. Through rapid electrochemical deposition, ultrathin MnO₂ nanosheets were uniformly constructed on Cu-Co-S surfaces, forming hierarchical heterojunctions. This dual-engineering: (1) substantially reinforced mechanical stability via protective coating, (2) established built-in interfacial electric fields accelerating electron transfer kinetics (charge transfer resistance reduced by 67%), and (3) provided abundant electroactive sites for ion adsorption. The optimized Cu-Co-S@MnO₂ electrode delivered outstanding electrochemical performance, including a high specific capacitance of 1,842 F g⁻¹ at 1 A g⁻¹ and 91.3% capacitance retention after 10,000 cycles. When configured into a flexible asymmetric supercapacitor (FASC) employing polyvinyl alcohol (PVA)/KOH hydrogel electrolyte, the device achieved remarkable energy density of 68.4 Wh kg⁻¹ at 850 W kg⁻¹ power density, along with 88.7% capacity retention over 15,000 bending cycles. These results validate the dual-modification strategy's efficacy in developing mechanically robust, high-performance flexible energy storage systems for next-generation wearable electronics.

Key word

MOFs, Sulfidation, MnO₂ Coating, Flexible Supercapacitors