

Symmetric pseudocapacitors based on molybdenum disulfide (MoS₂)-modified carbon nanospheres: correlating physicochemistry and synergistic interaction on energy storage

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ABSTRACT:

Molybdenum disulfide-modified carbon nanospheres (MoS₂/CNS) with two different morphologies (spherical and flower-like) have been synthesized using hydrothermal techniques and investigated as symmetric pseudocapacitors in an aqueous electrolyte. The physicochemical properties of these MoS₂/CNS layered materials have been investigated using surface area analysis (BET), scanning electron microscopy (SEM), transmission electron microscopy (TEM), X-ray diffraction (XRD), Raman, Fourier transform infrared (FTIR) spectroscopy, and advanced electrochemistry, including cyclic voltammetry (CV), galvanostatic cycling with potential limitation (GCPL), long-hour voltage-holding tests, and electrochemical impedance spectroscopy (EIS). The two different MoS₂/CNS layered materials exhibit unique differences in morphology, surface area, and structural parameters, which have been correlated with their electrochemical capacitive properties. The flower-like morphology (f-MoS₂/CNS) shows lattice expansion (XRD), large surface area (BET analysis), and small-sized nanostructures (corroborated by the larger FWHM of the Raman and XRD data). In contrast to the f-MoS₂/CNS, the spherical morphology (s-MoS₂/CNS) shows lattice contraction and small surface area with relatively large-sized nanostructures. The presence of CNS on the MoS₂ structure leads to slight softening of the characteristic Raman bands (E_{12g} and A_{1g} modes) with larger FWHM. MoS₂ and its CNS-based composites have been tested in symmetric electrochemical capacitors in an aqueous 1 M Na₂SO₄ solution. CNS improves the conductivity of the MoS₂ and synergistically enhances the electrochemical capacitive properties of the materials, especially the f-MoS₂/CNS-based symmetric cells (most notably, in terms of capacitance retention). The f-MoS₂/CNS-based pseudocapacitor shows a maximum capacitance of 231 F g⁻¹, with high energy density 26 W h kg⁻¹ and power density 6443 W kg⁻¹. For the s-MoS₂/CNS-based pseudocapacitor, the equivalent values are 108 F g⁻¹, 7.4 W h kg⁻¹ and 3700 W kg⁻¹. The high-performance of the f-MoS₂/CNS is consistent with its physicochemical properties as determined by the spectroscopy and microscopy data. These findings have opened doors for further exploration of the synergistic effects between MoS₂ graphene-like sheets and CNS for energy storage.