Upcycling Lead-Saturated Adsorbents for High-Performance Hybrid Supercapacitor Electrodes

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Abstract:

Lead, one of the most poisonous heavy metals, must be eliminated from the environment. Adsorption is one of the most employed techniques that generate toxic waste once the lifetime of the adsorbent has finished. This study presents a novel approach to addressing two critical global challenges—heavy metal pollution and energy storage—through the development of a sustainable and multifunctional material. A composite of sulfur-doped graphitic carbon nitride (SCN) and zeolitic imidazolate framework-8 (ZIF-8) was synthesized and employed as an efficient adsorbent for the removal of lead (Pb) from contaminated water. The composite exhibited a remarkable Pb adsorption capacity of 800 mg g^{-1} at 45 °C, achieving 95% adsorption within 40 minutes. Following adsorption, the Pb-saturated composite was subjected to heat treatment to permanently anchor Pb and transform it into a redox-active electrode material. The resultant composite, featuring Pb in the form of PbO and PbS, along-with Zn-NCN and porous carbon had increased electrochemical properties, especially as a negative electrode. As a negative electrode, the sample demonstrated a specific capacitance of 2052 F g^{-1} at 2 A g^{-1} in 3-electrode study, significantly greater than other individual components. This work highlights a sustainable strategy for converting hazardous waste into high-performance energy storage materials, paving the way for environmentally conscious innovations in water remediation and energy technologies.

Keywords:

Lead, Adsorption, Supercapacitor, Graphitic Carbon Nitride, ZIF-8.