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Innovative Multifunctional Materials and Nanomaterials for Energy Storage Applications: Composite Electrodes Based on Polypyrrole, Fe_2O_3, and g-C_3N_4 for Supercapacitors

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Abstract

Energy is a fundamental factor for socio-economic development, and the increasing global demand, combined with environmental concerns, makes the development of efficient energy storage systems essential [1]. Supercapacitors have emerged as promising devices due to their high power density, fast charge–discharge capability, and long cycle life, complementing batteries in applications from portable electronics to electric vehicles[2].

Conducting polymers such as polypyrrole (PPy) are widely used in supercapacitors for their good conductivity and pseudocapacitive behavior[3]. Transition metal oxides like Fe_2O_3 provide additional redox-active sites, while graphitic carbon nitride (g-C_3N_4) offers a porous structure that improves structural stability in composite electrodes[4].

In this work, two PPy-based electrodes supported on nickel foam were fabricated and compared. The first electrode was prepared by electropolymerization of PPy. The second electrode was preperd using a layer-by-layer approach in which PPy was combined with Fe_2O_3/g-C_3N_4 to form a composite architecture. Electrochemical characterization showed an areal capacitance of 0.228 F•cm^{-2} for the PPy electrode, while the composite electrode reached 0.268 F•cm^{-2} (~17.5% increase). the enhancement, although modestdemonstrates that incorporating Fe_2O_3 and g-C_3N_4 improves redox activity and structural stability, highlighting the potential of hybrid electrodes for next-generation supercapacitor applications.

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