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Graphene-based materials for hybrid electrochemical energy storage devices

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Increasing environmental concerns and depletion of fossil fuels have greatly stimulated development of reliable energy storage devices able to fulfill ever-increasing energy and power needs. Supercapacitors generally store charge as electric double layer capacitance (EDLC) providing high power densities while batteries store energy through reversible Faradaic redox reactions achieving high energies. Recently, combining these two energy storage mechanisms within a hybrid material has attracted great attention, offering a promising strategy to construct devices with merits of both batteries and supercapacitors.[1,2] Among different types of carbon, graphene is of exceptional interest in energy storage applications due to its excellent conductivity and high specific surface area. However, its practical capacitance/capacity is not yet satisfactory (typically 130-260 $F.g^{-1}$/36-72 $mA.h.g^{-1}$) mainly due to restacking of the layers. Hence, graphene can be best exploited in hybridization with battery-type materials such as metal oxides to achieve materials with improved properties, and this is the main motivation and goal of the present research.[3]

Accordingly, various compositions of single and mixed metal oxides (e.g. Fe_3O_4, $NiCoMnO_4$, etc.) with graphene are synthesized through chemical or electrochemical routes. The prepared samples are carefully characterized via different techniques including X-ray diffraction, Raman, X-ray photoelectron spectroscopy, electron microscopies and gas adsorption/desorption. The electrochemical properties of the samples are investigated through different techniques such as cyclic voltammetry, chronopotentiometry and electrochemical impedance spectroscopy. Moreover, samples are employed as electrode materials (negative or positive) in full devices and their energy storage properties in terms of capacity, rate capability and cycling stability are examined and compared with the previously reported materials.

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