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Graphene/Fe_2O_3/SnO_2/ Ternary Nanocomposite as A High-Performance Anode for Lithium Ion Batteries

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Electrochemical energy storage devices with high energy and power densities are highly desirable for electric vehicle (EV) applications. It is generally believed that lithium ion battery (LIB) anodes constructed with layered graphite materials are capable of storing ions in the material's bulk, but suffer from low overall energy and power density. Graphite anodes can only intercalate one Li atom per six carbon atoms (LiC_6) with a theoretical capacity of 372 $mAhg^{-1}$ [1]. Strategies for developing new materials with fast electron transport, large capacity, and efficient lithium ion diffusion will lead to high-power and high-rate LIBs for transportation applications [2-5]. Thus, interest in anode materials has shifted from traditional graphite to more advanced materials that attempt to increase the number of lithiation sites in an effort to gain high energy and power density [6-9].

Graphene sheets, which possess a high electron conductivity, a large specific surface area (up to 2600 m^2 g^{-1}), and a broad window of electrochemical stability, hold much promise as an advanced anode material for LIB technology. The specific capacity of graphene for Li can be substantially improved over graphite, as it can adsorb lithium on both sides of the graphene sheet and the single layer allows for efficient diffusion of lithium ions, Despite these advantages, graphene anodes experience a significant irreversible capacity loss during charge/discharge cycling, mainly due to the re-stacking of the graphene layers. This problem can be at least partially alleviated by incorporating solid nanoparticles in between the sheets to reduce the overall degree of re-stacking.

An alternate anode material, Fe_2O_3, has attracted greater attention due to its high capacity (1005 $mAhg^{-1}$), low toxicity, and cost effectiveness. The lithium storage mechanism of Fe_2O_3 is associated with the reversible formation/decomposition of Li_2O catalyzed by Fe nanograins. In this so-called displacive redox reaction, the Li-ion insertion/extraction cycling leads to significant volume expansion/shrinkage. These expansion and contraction cycles can generate accumulated stresses in the Fe_2O_3 materials, resulting in particle fracture and battery capacity loss. Recent studies have suggested that the enormous strains could be relieved by preparing nano-sized materials or integrating effective structural buffers.

In this work, we propose a novel approach to designing and synthesizing a graphene nanocomposite with highly active Fe_2O_3 and SnO_2 particles, in which each component plays a different, but complementary role. Graphene serves as a matrix enabling both lithium ions and electrons to migrate to active sites, thereby fully maximizing the energy density offered by both graphene and Fe_2O_3. The graphene also is an effective elastic buffer to relieve the strain accumulated in the integrated Fe_2O_3 particles during Li uptake/release. In turn, the dispersion of Fe_2O_3 particles on the graphene prevents the restacking of graphene sheets, maintaining a high storage capacity during cycling. It is worth noting that the graphene used in this work is prepared via reduction of graphene oxide (GO) with a nontoxic reducing agent $SnCl_2$. This reducing agent leads to SnO_2, which is expected to serve as an inert matrix for Fe_2O_3 particles and keep them from agglomerating. The complimentary nature of these materials leads to high performance in these graphene nanocomposite andoes during discharg-charge cycling (**Fig. 2**).

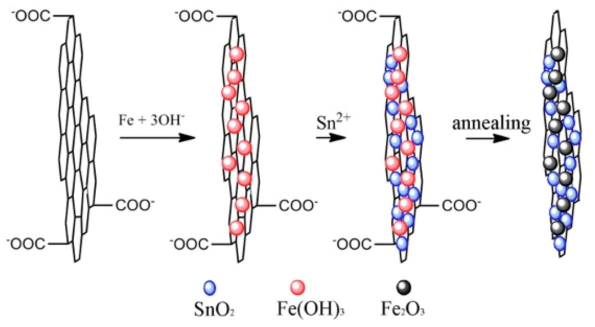

Fig. 1 Scheme of preparation of ternary rGO/Fe_2O_3/SnO_2 nanocompoiste.

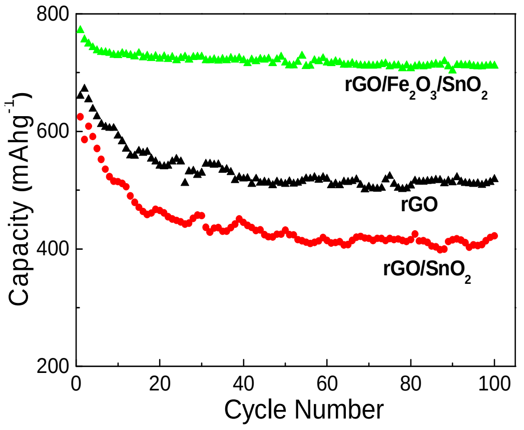

Fig. 2. A comparison of discharge-charge capacity measured with rGO, rGO/SnO_2 and rGO/Fe_2O_3/SnO_2 anodes up to 100 cycles.

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