

cell contains a Li metal foil and a separator film of Celgard 2400 saturated with 1M LiPF₆ in ethylene carbonate and dimethyl carbonate (1:1 by volume), as shown in FIG. 7(c). The voltage-capacity profiles of the SnO₂-graphene nanocomposite electrode at different current density are shown in FIG. 7(d). SnO₂ is converted into metallic Sn in the first charge/discharge cycle, as confirmed from differential charge/discharge curves of SnO₂-graphene nanocomposite electrode. In the subsequent charge/discharge cycles, Li ions were reversibly inserted into Sn as Li/Sn alloys (LiSn or Li₄Sn) as shown in FIG. 9. Pure graphene tested within the same voltage range at current density of 0.004 A/g has a steady capacity of 120 mAh/g. At 40 wt % graphene in the nanocomposites, the capacity from graphene is less than 10% of the total capacity in the SnO₂-graphene electrode. The overall capacity of the electrode is mostly from the SnO₂ active phase.

The specific capacity of the SnO₂ in the nanocomposite paper as a function of cycle number is shown in FIG. 7(e). The discharge capacity drop in 1st cycle is attributed to irreversible conversion of SnO₂ to Sn and Li₂O upon lithiation. The increase in specific capacity during the initial 10 cycles is attributed to improvement in electrolyte wetting of dense SnO₂-graphene nanocomposite electrode and the conversion of SnO₂ to Sn occurring upon initial lithiation. As the electrode is well wetted by the electrolyte, a steady specific capacity of 625 mAh/g is obtained at a current density of 0.02 A/g (as shown in FIG. 7(e), top). Significantly, the SnO₂-graphene nanocomposite electrode shows excellent capacity retention over the charge-discharge cycles in contrast to the rapid degradation of the control SnO₂-Super P electrode, SnO₂-graphene powder electrode as shown in FIG. 10, and typical SnO₂ electrode materials. A steady specific capacity of 760 mAh/g for the nanocomposite paper can be obtained at a current density of 0.008 A/g (shown in FIG. 7(e), bottom), close to the theoretical capacity (780 mAh/g). The specific capacities of 225 mAh/g and 550 mAh/g are obtained at a current density of 0.08 A/g and 0.02 A/g (shown in FIG. 7(e), bottom), respectively. At all the charge rates, the specific capacity in nanocomposite papers is well retained during cycling at different rates. The higher capacity and better stability in the nanocomposite electrodes are attributed to good contact between the nanocrystalline SnO₂ and sandwiched graphene even after conversion and volume change upon lithiation.

High surface area conductive materials with tailored porosity are useful in other energy storage devices such as electrical double layer supercapacitors. These experiments performed a preliminary study on the electrochemical capacitance of the mesoporous SiO₂-graphene nanocomposite powder. FIG. 7(f) shows cyclic voltammograms (CV) using a three-electrode configuration for pure graphene and a mesoporous SiO₂-graphene nanocomposite. Both graphene and the SiO₂-graphene nanocomposite display a capacitive charging current with a rectangular shape across the potential range between -1.0 and 0 V (vs. the saturated Ag/AgCl reference electrode). However, surprisingly the CV response for the nanocomposite with the "inert" silica is significantly enhanced, resulting in a much higher single electrode capacitance of 120 F/g. This value is better than the best result reported in the literature for graphene (about 100 F/g), but the actual specific capacitance for graphene in the nanocomposite is higher (170 F/g) if accounting for the 30 wt % of inert silica. These preliminary studies suggest the improved electrochemical response in the nanocomposites is likely attributed to the open mesoporous network, which prevents aggregation of the graphene sheets on the electrode.

Graphene sheets used in this study were prepared through the thermal expansion of graphite oxide. X-ray photoemission spectroscopy (XPS) of the graphene sheets shows a sharp C1s peak indicating good sp₂ conjugation.

While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character. Only certain embodiments have been shown and described, and all changes, equivalents, and modifications that come within the spirit of the invention described herein are desired to be protected. Any experiments, experimental examples, or experimental results provided herein are intended to be illustrative of the present invention and should not be considered limiting or restrictive with regard to the invention scope. Further, any theory, mechanism of operation, proof, or finding stated herein is meant to further enhance understanding of the present invention and is not intended to limit the present invention in any way to such theory, mechanism of operation, proof, or finding.

Thus, the specifics of this description and the attached drawings should not be interpreted to limit the scope of this invention to the specifics thereof. Rather, the scope of this invention should be evaluated with reference to the claims appended hereto. In reading the claims it is intended that when words such as "a", "an", "at least one", and "at least a portion" are used there is no intention to limit the claims to only one item unless specifically stated to the contrary in the claims. Further, when the language "at least a portion" and/or "a portion" is used, the claims may include a portion and/or the entire items unless specifically stated to the contrary. Likewise, where the term "input" or "output" is used in connection with an electric device or fluid processing unit, it should be understood to comprehend singular or plural and one or more signal channels or fluid lines as appropriate in the context. Finally, all publications, patents, and patent applications cited in this specification are herein incorporated by reference to the extent not inconsistent with the present disclosure as if each were specifically and individually indicated to be incorporated by reference and set forth in its entirety herein.

The invention claimed is:

1. A method comprising:

- forming an ordered nanocomposite material by providing graphene layers having a first surface and a second surface, the graphene layers having thicknesses of 0.5 to 50 nm;
- dispersing the graphene layers with a surfactant in a suspension;
- adding a metal oxide precursor;
- precipitating metal oxide in a manner to form a self-assembled nanocomposite material having a plurality of ordered layers, at least two of the ordered layers consisting essentially of a metal oxide layer directly bonded to a first surface of a graphene layer, wherein the at least two ordered layers are bonded to one another such that the metal oxide layers and graphene layers are alternatingly positioned in the ordered layers.
2. The method of claim 1 wherein the graphene layers consist essentially of functionalized graphene sheets.
3. The method of claim 1 wherein the graphene layers consist essentially of 9 to 59 graphene sheets.
4. The method of claim 1, wherein the step of precipitating is maintained for about one to about 24 hours.
5. The method of claim 1 wherein the graphene and surfactant suspension further comprises water.