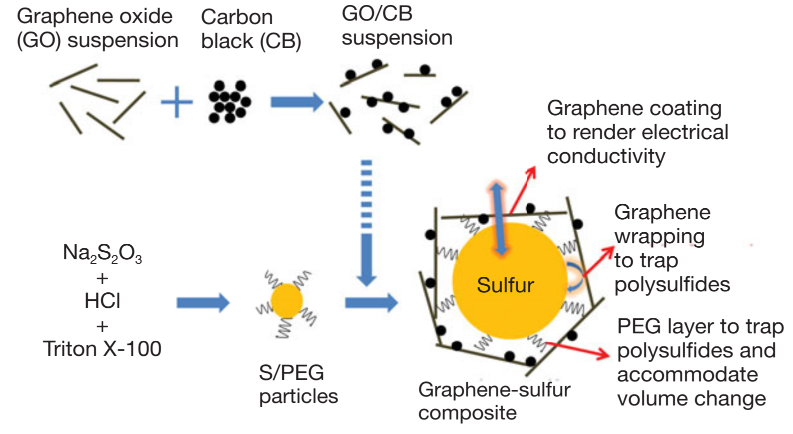
Energy Focus

Novel graphene-sulfur composite with high capacity and high stability cathode for lithium-ion batteries

One of the major limitations for automobile applications of lithium-ion batteries is their inability to power electric cars for long distances due to their low cycle life, low specific capacity, and low energy efficiency. Consequently, tremendous research efforts have been made to improve the energy and power density of rechargeable lithium batteries for possible use in electrical cars. Researchers at Stanford University, led by H. Dai and Y. Cui, have developed a new type of lithium battery by synthesizing a graphene-wrapped sulfur-based composite material that shows high and stable specific capacities of up to 600 mAh/g over more than 100 cycles. The researchers suggest that this type of material shows great promise as a high-performance cathode material for Li-S batteries.

As reported in the July 15 issue of *Nano Letters* (DOI: 10.1021/nl200658a; p. 2644), the team fabricated this material by wrapping poly(ethylene glycol) (PEG) coated submicrometer-sized sulfur particles with mildly oxidized graphene oxide sheets decorated with carbon black nanoparticles. The PEG and graphene coating layers are important for accommodating volume expansion of the coated sulfur particles during discharge, thereby trapping soluble polysulfide intermediates and rendering the sulfur particles electrically conducting. The team found that the average size of the sulfur particles was less than 1 µm and energy dispersive spectroscopy was used to confirm the structure and composition of the graphene-sulfur composite. Colorimetric titration experiments determined that the graphene-sulfur composition contained 70 wt% of sulfur (with 15% of mildly oxidized graphene sheets and 8% carbon black).



Schematic of the synthesis steps for a graphene-sulfur composite, with a proposed schematic structure of the composite. Reproduced with permission from *Nano Lett.* **11** (7) 2011 (DOI: 10.1021/nl200658a; p. 2644). © 2011 American Chemical Society.

The researchers fabricated coin cells to test the electrochemical performance of the graphene-sulfur composite material with a Li foil as the anode in an electrolyte of 1.0M lithium bis-trifluoromethane sulfonylyimide in 1,3 dioxilane and 1,2 dimethyoxyethane. The results demonstrated that the PEG-coated graphene-sulfur composite can maintain a specific capacity of ~600 mAh/g for more than 100 cycles. The capacity fading for 100 cycles was 10–15%.

Further work is now required to understand the large performance variability observed in the lithium-sulfur batteries tested in this study. For example, about 30–50% of the Li-S system for this study showed a declining cycling performance of 20–25% decay over 100 cycles.

Nevertheless, according to the researchers, the high specific capacity and good cycling stability obtained from the graphene-sulfur composite is an initial step in creating a promising potential material for future lithium-ion batteries with high energy density.

Jean Njoroge

Energy Focus

Azobenzene-functionalized CNTs predicted to be high-energy density solar thermal fuels

Economical and sustainable conversion of sunlight into other useful forms of energy that are easily transportable is currently a significant research challenge. One approach that has been explored is the use of solar thermal fuels. Upon absorption of light energy, photoactive molecules switch to a metastable, higher energy conformation. This results in the storage of energy (ΔH), which can be released when an external trigger is applied and thermal barrier E_a is overcome—see (a) in figure. The fuel can then be recharged on exposure to light and the cycle is repeated. Although solar thermal fuels have important advantages—they are potentially 100% renewable, produce no emissions, and are easily transportable—they were dismissed as unfeasible decades ago because the fuel degraded after only a few cycles of energy conversion and release. Interest in the concept was renewed, however, with the synthesis of a Ru-fulvalene compound. This constituted a new solar thermal fuel that does not degrade, although its low volumetric energy density (several orders of magnitude lower than Li-ion batteries), and the expense of Ru, makes it impractical. Recently, however, A.M. Kolpak and J.C. Grossman of the Massachusetts Institute of Technology designed a new, stable solar thermal fuel, which has a pre-

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