mechanical strength in addition to improved chemical and electrochemical stability. In particular, a sulfonated tetrafluoroethylene fluoropolymer-copolymer can form dense films to coat the surface of graphene-sulfur nanocomposites, which inhibit the polysulfide from diffusing into the electrolyte from the adsorbed sulfur particles. Furthermore, since it is a cationic membrane with sulfonate ionic groups, Li ions readily diffuse through the membrane, while still suppressing polysulfide anion transport, most likely due to electrostatic repulsion.

While a number of embodiments of the present invention have been shown and described, it will be apparent to those skilled in the art that many changes and modifications may be made without departing from the invention in its broader aspects. The appended claims, therefore, are intended to cover all such changes and modifications as they fall within the true spirit and scope of the invention.

We claim:

1. A rechargeable lithium-sulfur battery comprising a cathode and an electrolyte, the cathode characterized by a nanocomposite comprising graphene layers, wherein the graphene layers have thicknesses of equal to or less than about 10 nm, and with particles comprising sulfur adsorbed to the graphene sheets, the particles having an average diameter less than approximately 50 nm.

2. The battery of claim **1**, having a reversible capacity greater than 950 mAh g^{-1} after 100 cycles.

3. The battery of claim **1**, further comprising a polymer contacting the nanocomposite to minimize diffusion of polysulfide into the electrolyte.

4. The battery of claim **3**, wherein the polymer coats the nanocomposite surfaces.

5. The battery of claim **3**, wherein the polymer, the graphene layers, and the sulfur particles compose a mixture.

6. The battery of claim **3**, wherein the polymer is a cationic membrane.

7. The battery of claim **3**, wherein the polymer comprises a sulfonated tetrafluoroethylene based fluoropolymer-copolymer.

8. The battery of claim **3**, wherein the polymer comprises polyethylene oxide (PEO).

9. The battery of claim **1**, having a discharge capacity of at least 74% of an initial capacity after 50 cycles at 0.1 C.

10. The battery of claim **1**, wherein a powder of the nanocomposite has a tap density greater than 0.92 g cm^{-3}.

11. The battery of claim **1**, having a sulfur content greater than approximately 70 wt % in the nanocomposite.

12. The battery of claim **1**, wherein the adsorbed particles are arranged in sulfur layers between graphene layers in a stack of alternating graphene layers and sulfur layers, surfaces of the alternating sulfur layers sandwiched between and substantially flush with surfaces of the graphene layers on either side.

13. The battery of claim **1**, wherein the graphene layers are arranged randomly.

14. The battery of claim **1**, wherein the graphene layers are arranged pseudo-randomly.

15. A rechargeable lithium-sulfur battery comprising a cathode and an electrolyte and having a reversible capacity greater than 950 mAh g^{-1} after 100 cycles, the cathode characterized by a nanocomposite comprising graphene layers, wherein the graphene layers have thickness of equal to or less than about 10 nm, and with particles comprising sulfur adsorbed to the graphene sheets, the particles having an average diameter less than 50 nm, wherein the sulfur content is greater than approximately 70 wt % in the nanocomposite.

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