electronic conductivity of the graphene layers and the reduced polysulfide dissolution/migration provided by the NAFION® coating. The applied polymer coating appears to provide improved 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 method of preparing a graphene-sulfur nanocomposite for a cathode in a rechargeable lithium-sulfur battery, the graphene-sulfur 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 layers, the method comprising:

thermally expanding graphite oxide to yield graphene layers;

mixing the graphene layers with a first solution comprising sulfur and carbon disulfide;

evaporating the carbon disulfide to yield a solid nanocomposite; and

grinding the solid nanocomposite to yield the graphene-sulfur nanocomposite having sulfur particles with an average diameter less than approximately 50 nm.

2. The method of claim **1**, further comprising mixing the graphene-sulfur nanocomposite with a second solution comprising a polymer and a solvent, and then removing the solvent.

3. The method of claim **2**, wherein the polymer is a cationic membrane.

4. The method of claim **2**, wherein the polymer comprises a sulfonated tetrafluoroethylene based fluoropolymercopolymer.

5. The method of claim **2**, wherein the polymer comprises PEO.

6. The method of claim **1**, wherein the battery has a discharge capacity of at least 74% of an initial capacity after 50 cycles at 0.1 C.

7. The method of claim **1**, wherein a powder of the graphene-sulfur nanocomposite has a tap density greater than 0.82 g cm^{-3}.

8. The method of claim **1**, further comprising forming a stack of alternating graphene and sulfur layers, the sulfur layers comprising adsorbed particles between graphene layers.

9. The method of claim **1**, wherein the rechargeable lithium-sulfur battery has a reversible capacity greater than 950 mAh g^{-1}.

10. The method of claim **1**, wherein the graphene-sulfur nanocomposite has a sulfur loading that is greater than 70 wt %.

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