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Conductive polymers for long cycle-life lithium and beyond lithium ion batteries

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Polymers of high electronic or ionic conductivity have become an indispensable part of rechargeable batteries. Electron conductive polymers are mostly used as the stabilizing/encapsulating materials in the cathode, e.g., polymer encapsulated sulfur nano-composites and the anode, e.g., nano-encapsulation of graphite-based anodes, where the highest electronic conductivity is favorable. Unlike electron conductive polymers, polymers of pure ionic conductivity are used as separators/electrolytes in lithium batteries to allow the fast transfer of lithium ions through the separating layer since an electronic conduction through the electrolyte creates an internal short-circuit current between the two electrodes. Here a recent study of the application of an electron conductive polymer composite for long cycle-life lithium-sulfur batteries and a mechanically robust dendrite-blocking lithium ion conductive polymer electrolyte for long cycle-life lithium ion battery will be presented. It will be shown that by simply encapsulating the sulfur nano-particles with a high electron conductive polymer a significant improvement in the performance of the battery can be observed. The improvement is due to the successful entrapment of soluble polysulfides during charge and discharge process (minimization in shuttling effect) along with the enhancement in the electronic conductivity among sulfur nano-particles. It also will be shown that by using a polymer-composite of high ionic conductivity and high mechanical stability, the internal short-circuit, due to the formation and growth of lithium dendrite can be prevented.

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Functional partially fluorinated polymers via post-polymerization modification

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Post-polymerization modification (PPM) strategies have been creatively utilized to prepare functional perfluorocyclobutyl (PFCB) aryl ether polymers and partially fluorinated arylene vinylene ether (FAVE) polymers. To apply PPM via ketene chemistry, a new Meldrum's acid functionalized aromatic trifluorovinyl ether (TFVE) monomer was designed, synthesized, and successfully utilized to prepare Meldrum's acid-functionalized PFCB aryl ether polymer precursors via traditional thermal cyclopolymerization. Functional PFCB aryl ether polymers can be prepared by heating Meldrum's acid functionalized polymer precursor with functional nucleophiles at a certain temperature via ketene chemistry, which was demonstrated by the preparation of a Disperse Red 1-functionalized PFCB aryl ether polymer. To apply PPM in FAVE polymers, a novel ester-functionalized FAVE polymer precursor was designed and synthesized, which was used to prepare three reactive FAVE polymers containing carboxylic acid groups, alcohol groups, and acid chloride groups. Post-polymerization modifications of the FAVE polymer's carboxylic acid groups (via a DCC coupling procedure with the desired alcohol), alcohol groups (via DCC coupling or an acid chloride esterification procedure with the desired carboxylic acid or acid chloride), and acid chloride groups (via an optimized nucleophilic substitution reaction with the desired alcohol or amine) were successfully performed. No degradation of the FAVE polymer matrix occurs after multistep post-polymerization modification reactions. A variety of functional fluorinated polymers can be prepared via the PPM strategies we developed.

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