Ion-Conducting Organic/Inorganic Polymers

Properties can be tailored through a choice of starting alkoxysilane and diamine ingredients.

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Ion-conducting polymers that are hybrids of organic and inorganic moieties and that are suitable for forming into solid-electrolyte membranes have been invented in an effort to improve upon the polymeric materials that have been used previously for such membranes. Examples of the prior materials include perfluorosulfonic acid-based formulations, polybenzimidazoles, sulfonated polyetherketone, sulfonated naphthalene polyimides, and polyethylene oxide (PEO)-based formulations. Rela
tive to the prior materials, the polymers of the present invention offer greater dimensional stability, greater ease of formation into mechanically resilient films, and acceptably high ionic conductivities over wider temperature ranges. Devices in which films made of these ion-conducting organic/inorganic polymers could be used include fuel cells, lithium batteries, chemical sensors, electrochemical capacitors, electrochromic windows and display devices, and analog memory devices.

The synthesis of a polymer of this type (see Figure 1) starts with a reaction between an epoxide-functionalized alkoxysilane and a diamine. The product of this reaction is polymerized by hydrolysis and condensation of the alkoxysilane group, producing a molecular network that contains both organic and inorganic (silica) links. The silica in the network contributes to the ionic conductivity and to the desired thermal and mechanical properties.

Examples of other diamines that have been used in the reaction sequence of Figure 1 are shown in Figure 2. One can
MoO₃ Cathodes for High-Temperature Lithium Thin-Film Cells

MoO₃ has shown promise as a cathode material that can extend the upper limit of operating temperature of rechargeable lithium thin-film electrochemical cells. Cells of this type are undergoing development for use as energy sources in cellular telephones, wireless medical sensors, and other, similarly sized portable electronic products. The LiCoO₂ and LiMn₂O₄ cathodes herefore used in these cells exhibit outstanding cycle lives (of the order of hundreds of thousands of cycles) at room temperature, but operation at higher temperatures reduces their cycle lives substantially: for example, at a temperature of 150 °C, cells containing LiCoO₂ cathodes lose half their capacities in 100 charge/discharge cycles.

The superiority of MoO₃ as a cathode material was demonstrated in experiments on lithium thin-film cells fabricated on glass slides. Each cell included a layer of Ti (for adhesion to the glass slide), a patterned layer of Pt that served as a cathode current collector, a cathode layer of MoO₃, a solid electrolyte layer of Li₃PO₄·N₂O₂₂ ("LiPON"), and an anode layer of Li. All the layers were deposited by magnetron sputtering except for the Li layer, which was deposited by thermal evaporation.

These cells, along with similar ones containing LiCoO₂ cathodes, were subjected to several tests, including measurements of specific capacity in charge/discharge cycling at a temperature of 150 °C. The results of these measurements, plotted in the figure, showed that whereas specific capacity of the cells containing LiCoO₂ cathodes faded to about half its initial value after only 100 cycles, the specific capacity of the cells containing the MoO₃ cathodes faded only slightly during the first few hundred cycles and thereafter not only recovered to its initial value but continued to increase up to at least 5,500 cycles.

This work was done by William West and Jay Whitacre of Caltech for NASA’s Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).