Microphase Separated Cation Conducting Polymers

Design, Synthesis, and Properties

Popular Scientific Summary

In step with the electrification of society, new and better methods are needed to store and convert energy. Two attractive options for achieving this are lithium-ion batteries and fuel cells. However, some problems remain with these technologies, such as that the amount of energy that can be stored is not sufficient for future needs. Both batteries and fuel cells work by performing chemical reactions in two separate "chambers", that are commonly called electrodes. The two electrodes must be kept separate in order for the reactions to take place in a controlled way to be able to obtain any electricity. Beyond this, certain chemical compounds need to be transported between the two electrodes, while others must be kept isolated. This is done by a so-called electrolyte that may consist of various chemical compounds. My research work has been about to develop electrolytes consisting of polymers, that are very large molecules composed of several smaller molecules commonly called monomers.

Using polymers as electrolytes in lithium-ion batteries has many benefits. For example, polymers are much less flammable than the liquid-based electrolytes commonly used in these batteries, which has been a contributing cause of fires in, for example, electric cars and mobile phones. Polymers can also be a more stable component which could enable the use of even more reactive chemical compounds at the electrodes and thus contribute to more energy being stored in the battery.

In fuel cells, polymers are already used as electrolytes, but there are some disadvantages of these. The necessary transport of protons is not high enough, while the polymers transport chemical compounds which should be kept isolated. In addition to this, the current polymers are very expensive.

In my research, I have tried to develop new polymers that could potentially be used as electrolytes for either new batteries or fuel cells. The research has had a very fundamental focus. Instead of studying minor improvements to existing systems, the research focus has been on developing new concepts.

Each research project has started with a certain concept being conceived as a possible polymer electrolyte. Then, the polymer has been manufactured chemically by first making monomers from commercially available chemicals. Once the monomer preparation has been completed, and that it has been confirmed through various analysis methods that the correct structures have been prepared, the monomers have been used to prepare polymers. Different polymer properties, such as their structure and transport properties have then been characterized.

Overall, the polymer structures have been tailored so that they can be phase separated into different, immiscible, phases evenly distributed throughout the material. One can compare that to oil and (*e.g.*) vinegar that are not miscible, but a (good) vinaigrette contains both components evenly distributed throughout the sauce. The different polymer phases were prepared so that one phase would be hard and contribute to mechanical strength, while another phase contributed to the transport properties of the polymer. To ensure that the phases were evenly distributed along the entire material, the phases were bound together molecular level. A total of five different polymer systems have in this thesis prepared and studied, of which three were focused on lithium batteries and two on fuel cells. Different kinds of chemistry have been used to make these polymer systems. Desired structures have usually been achieved but their transport properties have often not been good enough for practical applications. More research and development is required before similar polymer systems can be used in batteries and fuel cells.