

New Sodium Ion Conducting Solid Electrolytes Based Upon Mixed Glass Formers

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While Lithium batteries have gained great attention as portable energy sources for a range of applications from cell phones to plug-in and hybrid automobiles, the use of such Lithium batteries in electrical grid level energy storage for load leaving and peak shifting is coming into question due to the limited natural abundance of lithium. Sodium has long been a low cost alternative to lithium for such large scale battery systems. So far, sodium batteries have been designed to operate at elevated temperatures to resolve problems of low Na^+ ion conductivity in solid electrolyte separators. For this reason, new higher conductivity Na^+ ion conducting solid electrolytes are of great interest and in this research program, we are actively exploring new glass compositions with very high conductivities.

In ternary glasses which are comprised of one modifying salt, typically an alkali oxide, and two (or more) glass formers, the composition dependence of properties such as the alkali ion conductivity is a highly non-linear function of the ratio of the two glass formers at constant alkali oxide concentration. For example, in the ternary system $\text{Na}_2\text{O} + \text{BO}_{3/2} + \text{PO}_{5/2}$, the Na^+ ion conductivity reaches a strong maximum nearly two orders of magnitude higher than the linear interpolation between the two end member binary glass formers. Hence, in the sodium phosphate glasses, the role of added boron is to dramatically increase the Na^+ ion conductivity, whereas it is to sharply decrease the Na^+ ion conductivity in sodium silicate glasses. Hence, these ternary mixed glass former glasses provide a unique opportunity to study large and systematic changes, both positive and negative, in the Na^+ ion conductivity caused by the addition at constant Na^+ ion concentration of a single component, in this case $\text{BO}_{3/2}$ (B_2O_3).

In the related $\text{Na}_2\text{O} + \text{GeS}_2 + \text{PS}_{5/2}$ mixed glass former system, the Na^+ ion conductivity reaches a sharp minimum corresponding to a rapidly increasing conductivity activation energy. The

In this talk, the changes in both structure and properties of these two ternary glasses and their dependence concentration will be reported. ^{11}B and ^{31}P MASS NMR measurements have been combined with IR and Raman vibrational spectroscopies and x-ray and neutron scattering measurements further substantiated with Reverse Monte Carlo simulations have been used to develop detailed models of the structures of these glasses. These models have been combined with measurements of both the Na^+ ion conductivity and the physical properties to develop key understandings of the unique role of boron in these ternary glasses.