# Ionic liquid electrolytes and ionogel composites that enable safe, high capacity lithium and sodium batteries

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Traditional electrolytes currently used for Li-ion and Na-ion devices are not compatible with higher energy-density anodes required for next generation devices, such as Li metal and Na metal anodes. In addition, there is now a recognition that operation at elevated temperatures is desirable for some applications. Therefore, new electrolyte materials are currently actively being investigated for beyond Li-ion technologies. It has recently been shown that, by using an ultra-high concentration of lithium or sodium salt in an ionic liquid (or indeed some organic solvents), it is possible to achieve stable cycling of Li metal and Na metal anodes, often at high rates and current densities, and even in the presence of water. These electrolytes indicate a decoupling of the alkali metal ion dynamics from the bulk with $t_{Li+}$ or $t_{Na+}$ transport numbers approaching or even exceeding 0.5. We will discuss the structure and transport in these superconcentrated IL systems and their behaviour in lithium and sodium battery applications.

It has also been demonstrated that polymerized ionic liquids, such as poly(diallyldimethylammonium) (PDADMA), with either TFSI or FSI counterions, are capable of dissolving even higher concentrations of lithium salt leading to highly conductive solid electrolytes. These materials have high $t_{Li+}$ and improved mechanical properties and also enable stable Li metal cycling, thus offering exciting opportunities for all solid state lithium batteries. These materials will also be discussed in terms of their phase behavior, conductivity and electrochemical behavior.