Needs and Future Prospects for Large Scale Electrochemical Energy Storage

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The ability to store electrical energy efficiently, economically, and at large scale is a critical unmet need in the drive towards energy security and reliability and a low carbon economy. As we reach the 20th anniversary of the lithium-ion battery, it is clear that the advances in battery technology that have led to rapid growth of portable device applications in its first decade, and hybrid and electric transportation in its second, have been fundamentally enabled by materials innovations. We may ask what innovations will be necessary to enable the third generation, in which the impact of electrochemical storage spreads more broadly to large-scale systems to support electricity generation and distribution and renewable energy technologies.

Research from the speaker's laboratory that aim to answer these questions will be discussed. In particular, new flow battery approaches that may meet the technical and economic metrics for large scale storage will be presented. While flow batteries have historically been based on electronically insulating redox-active solutions for which charge transfer occurs only at the interface with a stationary current collector. We explore for several electrochemical systems an alternative approach in which flow electrodes of either solution or suspension type are rendered electronically conductive through incorporation of a percolating network of nanoscale electronic conductor particles that permits distributed charge transfer throughout the flow electrode (i.e., an "infinite" current collector). Fluid electrodes exhibiting percolation at less than 3 vol% solids and reaching electronic transference number t_e up to 0.5 are demonstrated in aqueous and non-aqueous suspension electrodes and nonaqeuous solution electrodes. Electrochemical kinetics are found to be strongly dependent on specific materials and electrode microstructure. Contributions to cell impedance are characterized, and flow cell operating protocols that optimize coulombic and energy efficiency during concurrent flow and electrochemical utilization are illustrated.