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Li-ion batteries can use a number of different materials as electrodes. The most common combination is that of lithium cobalt oxide (cathode) and graphite (anode), which is used in commercial portable electronic devices such as cellphones and laptops. Other common cathode materials include lithium manganese oxide (used in hybrid electric and electric automobiles) and lithium iron phosphate. Li-ion batteries typically use ether (a class of organic compounds) as an electrolyte.

Lithium ions are stored within graphite anodes through a mechanism known as intercalation, in which the ions are physically inserted between the 2D layers of graphene that make up bulk graphite. The size of the ions relative to the layered carbon lattice means that graphite anodes are not physically warped by charging or discharging, and the strength of the carbon-carbon bonds relative to the weak interactions between the Li ions and the electrical charge of the anode make the insertion reaction highly reversible.

High energy densities and long lifespans have made Li-ion batteries the market leader in portable electronic devices and electrified transportation, including electric vehicles (EVs) like the Nissan Leaf and the Tesla Model S as well as the hybrid-electric Boeing 787. In terms of decarbonizing our economy’s energy use, Li-ion technology has its greatest potential in EVs and electrified aviation.

Not only are lithium-ion batteries widely used for consumer electronics and electric vehicles, but they also account for over 80% of the more than 190 gigawatt-hours (GWh) of battery energy storage deployed globally through 2023. However, energy storage for a 100% renewable grid brings in many new challenges that cannot be met by existing battery technologies alone.

For the U.S to store 8 hours of electricity, it would need to deploy terawatt-hours of batteries, which would cost trillions of dollars at today’s prices, while 6 weeks of seasonal heating would require petawatt-hours (thousands of TWh) of storage. Therefore, a 100% clean energy future requires not only the development of low-cost battery technologies using environmentally friendly, earth-abundant materials, but also new storage strategies using a combination of electrochemical, chemical, thermal and mechanical mechanisms.

With the UW “Hyak” supercomputer, researchers can simulate molecules and their kinetic and thermodynamic interactions to understand electrochemistry from a perspective that is not afforded to experimental techniques.

Meanwhile, chemistry professor Cody Schlenker and his group investigate the fundamental chemistry of interfaces within energy storage systems with the goal of gaining a deeper understanding of electrochemical processes. By coupling electrochemistry theory with spectroscopy, the lab can identify changes in vibrational frequencies and in the dynamics of ion transfer and link them to specific chemical phenomena at key interfaces between electrodes, separator membranes, and electrolytes.

To date, several energy storage systems, including hydroelectric power, capacitors, compressed air energy storage, flywheels, and electric batteries, have been investigated as enablers of the power grid [4,5,6,7,8].

Among various battery technologies, lithium-ion batteries (LIBs) have attracted significant interest as supporting devices in the grid because of their remarkable advantages, namely relatively high energy density (up to 200 Wh/kg), high EE (more than 95%), and long cycle life (3000 cycles at deep discharge of 80%) [11,12,13]. Thus far, 77% of electrical power storage systems in the USA that operate to stabilize the grid (e.g., primarily for regulating frequency) rely on LIBs, indicating a high-value market for LIBs [11].