Alofi lithium-ion batteries

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The 2019 Nobel Prize in Chemistry has been awarded to John B. Goodenough, M. Stanley Whittingham and Akira Yoshino for their contributions in the development of lithium-ion batteries, a technology that has revolutionized our way of life. Here we look back at the milestone discoveries that have shaped the modern lithium-ion batteries for inspirational insights to guide future breakthroughs.

The development of (a) anode materials including lithium metal, petroleum coke and graphite, (b) electrolytes with the solvent propylene carbonate (PC), a mixture of ethylene carbonate (EC) and at least one linear carbonate selected from dimethyl carbonate (DMC), diethyl carbonate (DEC), ethyl methyl carbonate (EMC) and many additives, (c) cathode materials including conversion-type materials, intercalation materials titanium disulfide (TiS2) and lithium cobalt oxide (LiCoO2).

To cater to the high capacity of lithium metal, conversion-type cathodes including metal fluorides, sulfides or oxides (Fig. 1c) were considered at first. During battery operation, these materials react to form phases with different structures and new compositions6. Consequently, conversion electrodes do not allow for many cycles since bond breaking and reforming occur during each cycle.

The working window of an electrolyte is determined by its LUMO and highest occupied molecular orbital (HOMO), which should be higher than the electrochemical potential of anode (ma) and lower than the electrochemical potential of cathode (mc), respectively (LUMO > ma, HOMO < mc). Alternatively, a stable passivating SEI layer should be created on the anode or cathode in the case of LUMO < ma or HOMO > mc, respectively1.

The impact of lithium-ion batteries is poised to go beyond portable electronics to domains that matter to the sustainability of the society. To meet the ever-growing demand for electrified transportation and large-scale energy storage solutions, continued materials discoveries and game-changing chemistry hold the key to unleashing the full potential of lithium-ion batteries toward seriously enhanced cost efficiency, power and energy densities, and safety.

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