Lithium ion battery types

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Each type of lithium-ion battery has its own set of benefits and drawbacks, making them suitable for different applications. Understanding these differences can help in selecting the right battery for specific needs123.

Lithium-ion is named for its active materials; the words are either written in full or shortened by their chemical symbols. A series of letters and numbers strung together can be hard to remember and even harder to pronounce, and battery chemistries are also identified in abbreviated letters.

For example, lithium cobalt oxide, one of the most common Li-ions, has the chemical symbols $LiCoO_2$ and the abbreviation LCO. For reasons of simplicity, the short form Li-cobalt can also be used for this battery. Cobalt is the main active material that gives this battery character. Other Li-ion chemistries are given similar short-form names. This section lists six of the most common Li-ions. All readings are average estimates at time of writing.

Its high specific energy makes Li-cobalt the popular choice for mobile phones, laptops and digital cameras. The battery consists of a cobalt oxide cathode and a graphite carbon anode. The cathode has a layered structure and during discharge, lithium ions move from the anode to the cathode. The flow reverses on charge. The drawback of Li-cobalt is a relatively short life span, low thermal stability and limited load capabilities (specific power). Figure 1 illustrates the structure.

The drawback of Li-cobalt is a relatively short life span, low thermal stability and limited load capabilities (specific power). Like other cobalt-blended Li-ion, Li-cobalt has a graphite anode that limits the cycle life by a changing solid electrolyte interface (SEI), thickening on the anode and lithium plating while fast charging and charging at low temperature. Newer systems include nickel, manganese and/or aluminum to improve longevity, loading capabilities and cost.

Li-cobalt should not be charged and discharged at a current higher than its C-rating. This means that an 18650 cell with 2,400mAh can only be charged and discharged at 2,400mA. Forcing a fast charge or applying a load higher than 2,400mA causes overheating and undue stress. For optimal fast charge, the manufacturer recommends a C-rate of 0.8C or about 2,000mA. (See BU-402: What is C-rate). The mandatory battery protection circuit limits the charge and discharge rate to a safe level of about 1C for the Energy Cell.

The hexagonal spider graphic (Figure 2) summarizes the performance of Li-cobalt in terms of specific energy or capacity that relates to runtime; specific power or the ability to deliver high current; safety; performance at hot and cold temperatures; life span reflecting cycle life and longevity; and cost. Other characteristics of interest not shown in the spider webs are toxicity, fast-charge capabilities, self-discharge and shelf life. (See BU-104c: The Octagon Battery - What makes a Battery a Battery).

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The Li-cobalt is losing favor to Li-manganese, but especially NMC and NCA because of the high cost of cobalt and improved performance by blending with other active cathode materials. (See description of the NMC and NCA below.)

Li-ion with manganese spinel was first published in the Materials Research Bulletin in 1983. In 1996, Moli Energy commercialized a Li-ion cell with lithium manganese oxide as cathode material. The architecture forms a three-dimensional spinel structure that improves ion flow on the electrode, which results in lower internal resistance and improved current handling. A further advantage of spinel is high thermal stability and enhanced safety, but the cycle and calendar life are limited.

Low internal cell resistance enables fast charging and high-current discharging. In an 18650 package, Li-manganese can be discharged at currents of 20-30A with moderate heat buildup. It is also possible to apply one-second load pulses of up to 50A. A continuous high load at this current would cause heat buildup and the cell temperature cannot exceed 80?C (176?F). Li-manganese is used for power tools, medical instruments, as well as hybrid and electric vehicles.

Figure 4 illustrates the formation of a three-dimensional crystalline framework on the cathode of a Li-manganese battery. This spinel structure, which is usually composed of diamond shapes connected into a lattice, appears after initial formation.

Li-manganese has a capacity that is roughly one-third lower than Li-cobalt. Design flexibility allows engineers to maximize the battery for either optimal longevity (life span), maximum load current (specific power) or high capacity (specific energy). For example, the long-life version in the 18650 cell has a moderate capacity of only 1,100mAh; the high-capacity version is 1,500mAh.

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