Lithium-ion Battery

A lithium-ion battery (sometimes Li-ion battery or LIB) is a family of rechargeable battery types in which lithium ions move from the negative electrode to the positive electrode during discharge, and back when charging. Chemistry, performance, cost, and safety characteristics vary across LIB types. Unlike lithium primary batteries (which are disposable), lithium-ion electrochemical cells use an intercalated lithium compound as the electrode material instead of metallic lithium.

Lithium-ion batteries are common in consumer electronics. They are one of the most popular types of rechargeable battery for portable electronics, with one of the best energy densities, no memory effect, and only a slow loss of charge when not in use. Beyond consumer electronics, LIBs are also growing in popularity for military, electric vehicle, and aerospace applications.[6] Research is yielding a stream of improvements to traditional LIB technology, focusing on energy density, durability, cost, and intrinsic safety.

The three primary functional components of a lithium-ion battery are the negative electrode, positive electrode, and the electrolyte. The negative electrode of a conventional lithium-ion cell is made from carbon. The positive electrode is a metal oxide, and the electrolyte is a lithium salt in an organic solvent[] The electrochemical roles of the electrodes change between anode and cathode, depending on the direction of current flow through the cell.

The most commercially popular negative electrode material is graphite. The positive electrode is generally one of three materials: a layered oxide (such as lithium cobalt oxide), a polyanion (such as lithium iron phosphate), or a spinel (such as lithium manganese oxide).

The electrolyte is typically a mixture of organic carbonates such as ethylene carbonate or diethyl carbonate containing complexes of lithium ions.[10] These non-aqueous electrolytes generally use non-coordinating anion salts such as lithium hexafluorophosphate ($LiPF_6$), lithium hexafluoroarsenate monohydrate ($LiAsF_6$), lithium perchlorate ($LiClO_4$), lithium tetrafluoroborate ($LiBF_4$), and lithium triflate ($LiCF_3SO_3$).

Depending on materials choices, the voltage, capacity, life, and safety of a lithium-ion battery can change dramatically. Recently, novel architectures using nanotechnology have been employed to improve performance.

Pure lithium is very reactive. It reacts vigorously with water to form lithium hydroxide and hydrogen gas. Thus, a non-aqueous electrolyte is typically used, and a sealed container rigidly excludes water from the battery pack.

Lithium ion batteries are more expensive than NiCd batteries but operate over a wider temperature range with higher energy densities, while being smaller and lighter. They are fragile and so need a protective circuit to limit peak voltages.

Li-ion cells are available in various formats, which can generally be divided into four groups:[11][12]

- Small cylindrical (solid body without terminals, such as those used in laptop batteries)
- Large cylindrical (solid body with large threaded terminals)
- Pouch (soft, flat body, such as those used in cell phones)
- Prismatic (semi-hard plastic case with large threaded terminals, often used in vehicles' traction packs)

The lack of case gives pouch cells the highest energy density; however, pouch cells (and prismatic cells) require an external means of containment to prevent expansion when their state-of-charge (SOC) level is high.[13]

Positive electrodes			
Electrode material	Average potential difference	Specific capacity	Specific energy
$LiCoO_2$	3.7 V	140 mA·h/g	0.518 kW·h/kg
$LiMn_2O_4$	4.0 V	100 mA·h/g	0.400 kW·h/kg
$LiNiO_2$	3.5 V	180 mA·h/g	0.630 kW·h/kg
$LiFePO_4$	3.3 V	150 mA·h/g	0.495 kW·h/kg
Li_2FePO_4F	3.6 V	115 mA·h/g	0.414 kW·h/kg
$LiCo_{1/3}Ni_{1/3}Mn_{1/3}O_2$	3.6 V	160 mA·h/g	0.576 kW·h/kg
$Li(Li_aNi_xMn_yCo_z)O_2$	4.2 V	220 mA·h/g	0.920 kW·h/kg

Negative electrodes			
Electrode material	Average potential difference	Specific capacity	Specific energy
Graphite (LiC_6)	0.1-0.2 V	372 mA·h/g	0.0372-0.0744 kW·h/kg
Hard Carbon (LiC_6)	? V	450 mA·h/g	? kW·h/kg
Titanate ($Li_4Ti_5O_{12}$)	1-2 V	160 mA·h/g	0.16-0.32 kW·h/kg
Si ($Li_{4.4}Si$)[38]	0.5-1 V	4212 mA·h/g	2.106-4.212 kW·h/kg
Ge ($Li_{4.4}Ge$)[39]	0.7-1.2 V	1624 mA·h/g	1.137-1.949 kW·h/kg

Advantages

A lithium-ion battery from a laptop computer

- Wide variety of shapes and sizes efficiently fitting the devices they power.
- Much lighter than other energy-equivalent secondary batteries.[45]
- High open circuit voltage in comparison to aqueous batteries (such as lead acid, nickel-metal hydride and nickel-cadmium).[46] This is beneficial because it increases the amount of power that can be transferred at a lower current.
- No memory effect.
- Self-discharge rate of approximately 5-10% per month, compared to over 30% per month in common nickel metal hydride batteries, approximately 1.25% per month for Low Self-Discharge NiMH batteries and 10% per month in nickel-cadmium batteries.[47] According to one manufacturer, lithium-ion cells (and, accordingly, "dumb" lithium-ion batteries) do not have any self-discharge in the usual meaning of this word.[35] What looks like a self-discharge in these batteries is a permanent loss of capacity (see Disadvantages). On the other hand, "smart" lithium-ion batteries do self-discharge, due to the drain of the built-in voltage monitoring circuit.
- Components are environmentally safe as there is no free lithium metal.[*citation needed*]

Disadvantages

Cell life

- Charging forms deposits inside the electrolyte that inhibit ion transport. Over time, the cell's capacity diminishes. The increase in internal resistance reduces the cell's ability to deliver current. This problem is more pronounced in high-current applications. The decrease means that older batteries do not charge as much as new ones (charging time required decreases proportionally).
- High charge levels and elevated temperatures (whether from charging or ambient air) hasten capacity loss.[48] Charging heat is caused by the carbon anode (typically replaced with lithium titanate which drastically reduces damage from charging, including expansion and other factors).[49]

Internal resistance

- The internal resistance of standard (Cobalt) lithium-ion batteries is high compared to both other rechargeable chemistries such as nickel-metal hydride and nickel-cadmium, and LiFePO4 and lithium-polymer cells.[50] Internal resistance increases with both cycling and age.[51][52][53] Rising internal resistance causes the voltage at the terminals to drop under load, which reduces the maximum current draw. Eventually increasing resistance means that the battery can no longer operate for an adequate period.

- To power larger devices, such as electric cars, connecting many small batteries in a parallel circuit is more effective[54] and efficient than connecting a single large battery.[55]

Safety requirements

If overheated or overcharged, Li-ion batteries may suffer thermal runaway and cell rupture.[56] In extreme cases this can lead to combustion. Deep discharge may short-circuit the cell, in which case recharging would be unsafe.[57] To reduce these risks, Lithium-ion battery packs contain fail-safe circuitry that shuts down the battery when its voltage is outside the safe range of 3–4.2 V per cell. When stored for long periods the small current draw of the protection circuitry itself may drain the battery below its shut down voltage; normal chargers are then ineffective. Many types of lithium-ion cell cannot be charged safely below 0°C.[58]

Other safety features are required in each cell:

- Shut-down separator (for overtemperature)
- Tear-away tab (for internal pressure)
- Vent (pressure relief)
- Thermal interrupt (overcurrent/overcharging)

These devices occupy useful space inside the cells, add additional points of failure and irreversibly disable the cell when activated. They are required because the anode produces heat during use, while the cathode may produce oxygen. These devices and improved electrode designs reduce/eliminate the risk of fire or explosion.

These safety features increase costs compared to nickel metal hydride batteries, which require only a hydrogen/oxygen recombination device (preventing damage due to mild overcharging) and a back-up pressure valve.[47]

Lithium-thionyl chloride (Li-$SOCl_2$)

Lithium-thionyl chloride cells have a metallic lithium anode (the lightest of all the metals) and a liquid cathode comprising a porous carbon current collector filled with thionyl chloride ($SOCl_2$). They deliver a voltage of 3.6 V and are cylindrical in shape, in 1/2AA to D format, with spiral electrodes for power applications and bobbin construction for prolonged discharge.

Lithium-thionyl chloride cells have a high energy density, partly because of their high nominal voltage of 3.6 V. Bobbin versions can reach 1220 Wh/L and 760 Wh/kg, for a capacity of 18.5 Ah at 3.6 V in D format. Because self-discharge is extremely low (less than 1% per year), this kind of cell can support long storage periods and achieve a service life of 10 to 20 years.

MAJOR APPLICATION

◆ Digital lithium batteries

◆ TPMS

◆ Computer main-board

◆ Memory card

◆ Calculator

◆ Electronic clock & watch

◆ Thief alarm

◆ Electronic dictionary

◆ Water meters

◆ Calorimeters

◆ Apparatus and instrument

◆ Various types of military electronics or communication equipments

MAJOR FEATURES

● High energy density

● Long shelf life

● Wide operating temperature

● Good sealing feature

● Steady discharge voltage

Lithium Ion Polymer Battery

Lithium-ion polymer batteries, polymer lithium ion, or more commonly lithium polymer batteries (abbreviated Li-poly, Li-Pol, LiPo, LIP, PLI or LiP) are rechargeable (secondary cell) batteries. LiPo batteries are usually composed of several identical secondary cells in parallel to increase the discharge current capability.

The advantages of Li-ion polymer over the lithium-ion design include potentially lower cost of manufacture, adaptability to a wide variety of packaging shapes, reliability, and ruggedness. Lithium-ion polymer batteries started appearing in consumer electronics around 1995.

Cells sold today as polymer batteries are pouch cells. Unlike lithium-ion cylindrical cells, which have a rigid metal case, pouch cells have a flexible, foil-type (polymer laminate) case. In cylindrical cells, the rigid case presses the electrodes and the separator onto each other; whereas in polymer cells this external pressure is not required (or often used) because the electrode sheets and the separator sheets are laminated onto each other. Since individual pouch cells have no strong metal casing, by themselves they are over 20% lighter than equivalent cylindrical cells.

A compelling advantage of Li-poly cells is that manufacturers can shape the battery almost however they please, which can be important to mobile phone manufacturers constantly working on smaller, thinner, and lighter phones.

Li-poly batteries are also gaining favor in the world of radio-controlled aircraft as well as radio-controlled cars, where the advantages of both lower weight and greatly increased run times and power delivery can be sufficient justification for the price. Radio-controlled car batteries are often protected by durable plastic cases to prevent puncture. Specially designed electronic motor speed controls are used to prevent excessive discharge and subsequent battery damage. This is achieved using a low voltage cutoff (LVC) setting that is adjusted to maintain cell voltage greater than (typically) 3 V per cell.

Li-poly batteries are also gaining ground in PDAs and laptop computers, such as Apple's MacBook family, Amazon's Kindle, Lenovo's Thinkpad X300 and Ultrabay Batteries, the OQO series of palmtops, the HP Mini and Dell products featuring D-bay batteries. Very small GPS tracking units such as Garmin's GTU-10 rely on li-poly batteries for days or even weeks of autonomous operation between recharges. Li-poly batteries are also used in small digital music devices such as iPods, Zunes, and other MP3 players and the Apple iPhone and iPad, as well as gaming equipment like Sony's PlayStation 3 wireless controllers. They are desirable in applications where small form factors and energy density outweigh cost considerations.

These batteries may also power the next generation of battery electric vehicles. The cost of an electric car of this type is currently significantly higher than of a petrol car, but it is likely that with increased production and technological advances, the cost of Li-poly batteries will go down.

Hyundai Motor Company uses this battery type in some of its hybrid electric vehicles. On 26 October 2010, a Li-poly powered Audi A2 covered the record distance of 600 km without recharging. From April 2011 batteries of this type for output exceeding one Megawatt have been responsible for a number of world speed records in drag racing.

- All Li-Ion cells expand at high levels of state of charge (SOC); if uncontained, this may result in delamination, and reduction of reliability and cycle life; the case of cylindrical cells provides that containment, while pouch cells, by themselves, are not contained. Therefore, to achieve the rated performance, a battery composed of pouch cells must include a strong external casing to retain its shape.
- Overcharging a Li-poly battery can cause an explosion or fire.
- During discharge on load, the load has to be removed as soon as the voltage drops below approximately 3.0 V per cell (used in a series combination), or else the battery will subsequently no longer accept a full charge and may experience problems holding voltage under load. Li-poly batteries can be protected by circuitry that prevents over-charge and deep-discharge.
- Li-poly batteries typically require more than an hour for a full charge.
- Compared to the lithium-ion battery, Li-poly has a greater life cycle degradation rate.
- Lithium polymer-specific chargers are required in order to avoid fire and explosion.
- Explosions can also occur if the battery is short-circuited, as tremendous current passes through the cell in an instant. Radio-control enthusiasts take special precautions to ensure their battery leads are properly connected and insulated. Furthermore fires can occur if the cell or pack is punctured.
- As these lithium polymer batteries first emerged in the market, they were expensive.
- While charging the lithium polymer batteries, the individual cells in the pack should be charged evenly. For this purpose, the cells are to be charged with special chargers. This entails special care while charging the batteries in addition to incurring expenses on procuring the chargers specific to lithium polymer batteries.

Lithium-Ion Phosphate Battery

The lithium iron phosphate ($LiFePO_4$) battery, also called LFP battery, is a type of rechargeable battery, specifically a lithium-ion battery, which uses $LiFePO_4$ as a cathode material.

The $LiFePO_4$ battery uses a lithium-ion-derived chemistry and shares many advantages and disadvantages with other Lithium-ion battery chemistries. However, there are significant differences.

LFP chemistry offers a longer cycle life than other lithium-ion approaches.[6]

The use of phosphates avoids cobalt's cost and environmental concerns, particularly concerns about cobalt entering the environment through improper disposal.[6]

$LiFePO_4$ has higher current or peak-power ratings than $LiCoO_2$.[7]

The energy density (energy/volume) of a new LFP battery is some 14% lower than that of a new $LiCoO_2$ battery.[8] Also, many brands of LFPs have a lower discharge rate than lead-acid or $LiCoO_2$. Since discharge rate is a percentage of battery capacity a higher rate can be achieved by using a larger battery (more ampère-hours).

$LiFePO_4$ cells experience a slower rate of capacity loss (aka greater calendar-life) than lithium-ion battery chemistries such as $LiCoO_2$ *cobalt* or $LiMn_2O_4$ *manganese spinel* lithium-ion polymer batteries or lithium-ion batteries.[9][10] After one year on the shelf, a $LiFePO_4$ cell typically has approximately the same energy density as a $LiCoO_2$ Li-ion cell, because of LFP's slower decline of energy density. Thereafter, $LiFePO_4$ likely has a higher density.

Solar Powered Path Lights

LPF cells are now used in high end solar powered path lights instead of NiCd. Their higher working voltage allows a single cell to drive an LED without needing a step-up circuit. That, along with their higher energy density, enables them to outperform their NiCd counterparts. Indeed, there are models that claim to be 24x brighter than baseline path lights.

One Laptop per Child

This type of battery technology is used on the One Laptop per Child (OLPC) project.[13] The batteries are manufactured by BYD Company of Shenzhen, China, the world's largest producer of Li-ion batteries.

OLPC uses LFP batteries in its XO laptops because they contain no toxic heavy metals in compliance with the European Union's Restriction of Hazardous Substances Directive.[14]

Vehicles

LFP batteries were featured on the November 5, 2008 episode of *Prototype This!*. They were used as the power source for a hexapod (walking) vehicle.[*citation needed*]

This battery is used in the electric cars made by Aptera[15] and QUICC.[16]

Killacycle, the worlds fastest electric motorcycle, uses lithium iron phosphate batteries.[17]

Roehr Motorcycle Company, uses a 5.8 kW·h capacity LFP battery pack to power its supersport electric motorcycle.[*citation needed*]

LFP batteries are used by electric vehicles manufacturer Smith Electric Vehicles to power its products.[*citation needed*]

Minneapolis Electric Bike and Chicago Electric Bicycles use LFP batteries.[*citation needed*]

BYD, also a car manufacturer, plans to use its lithium iron phosphate batteries to power its PHEV, the F3DM and F6DM (Dual Mode), which will be the first commercial dual-mode electric car in the world. It plans to mass produce the cars in 2009.[18]

In May 2007 Lithium Technology Corp. announced a Lithium Iron Phosphate battery with cells large enough for use in hybrid cars, claiming they are "the largest cells of their kind in the world.".[19]

Some electronic cigarettes use these types of batteries.[*citation needed*]

Shorai Inc. makes lithium-iron batteries for a variety of powersport vehicles (motorcycles, ATVs, etc...)

Li-Ion Disulphide (Li-FeS2)

Features：

- The world’s longest lasting AA/AA primary battery;
- 6 times service than normal alkaline battery;
- Weigh 1/3 less than standard alkaline batteries;

• Extreme working temperatures from -40°F to 140°F;
• Developed first in China, second in world;
• Can provide mass production (only 2 companies in China);
• Holding independent Intellectual Property Rights;
• Good price;
• Direct compatibility with other primary 1.5V battery types;
• 10-year Shelf Life;
• Approved by UL, UN38.3..

Application：
Lithium batteries deliver long-lasting power to keep up with today's high-tech, power hungry devices like digital cameras, MP3, MP4, Flashlight, Electric Torch, CD, MD, Toy, hand-held games. etc., which could replace for Alkaline battery, and other ordinary 1.5V primary batteries.

Li-Manganese Dioxide

Characteristics
● High energy density
● Very stable discharging Voltage
● Over 10 year shelf life
● Excellent seal feature
● Wide operating temperature: -40℃~60℃

Applications
● AV Products: Digital camera, flashlight, camcorder.
● Security Devices: Thief alarm, Smoke alarm.
● Lights and Lamps: LED lamp, Mini flashlights, fishing pole tip lights, shoe flashlights and so on.
● Electronic Devices: Electronic dictionary, electronic watch, electronic scale, calculator.
● Information Devices: Computer main-board, memory card, card reader, remote control.
● Others: Electric tools, electric toys, mini meters, medical apparatus & instruments, home electric mini-appliances.

Suppliers

http://www.truepower-tech.com/products.asp

http://www.greatpower.net/en/products_list_sub.asp?keywords_p=ishot

http://www.pkcell.net/pro-li-polymer2.html

http://www.srbattery.com.cn/home/pro_list4.php