interberg batteries

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atlantic power group

Electrical Vehicle Lithium (LiFePO4) Batteries

Catalogue

Edition 03-20120430

LiFePO4 Batteries

1. Electrochemical Properties

Lithium is an alkali metal with silver-white appearance, soft handle, low density (0.534 g/cm3), large specific capacity (3860 Ah/kg), high electrochemical potential, high electro-negativity, and high energy density. As an alkali metal, lithium is highly reactive, and hence it is found in nature as compounds that can be used for different applications, such as pharmacology, aerospace, construction, and energy storage.

Rechargeable lithium-ion batteries, are of importance as new generation power sources because they are lighter and have higher energy density, lower self-discharge, no memory effect, prolonged service-life, larger number of charge/discharge cycles, better environmental friendliness, and higher safety when compared to many other battery systems.

Hence, lithium-ion batteries are being widely used for portable electronics from digital cameras to notebooks and music players to cell phones. They also provide an optimal solution for large-scale applications, such as electric vehicles and storage devices for power grids.

2. Structure and Operation Principles

A standard lithium-ion battery consists of anode, cathode and electrolyte, as shown in Fig. 1. :

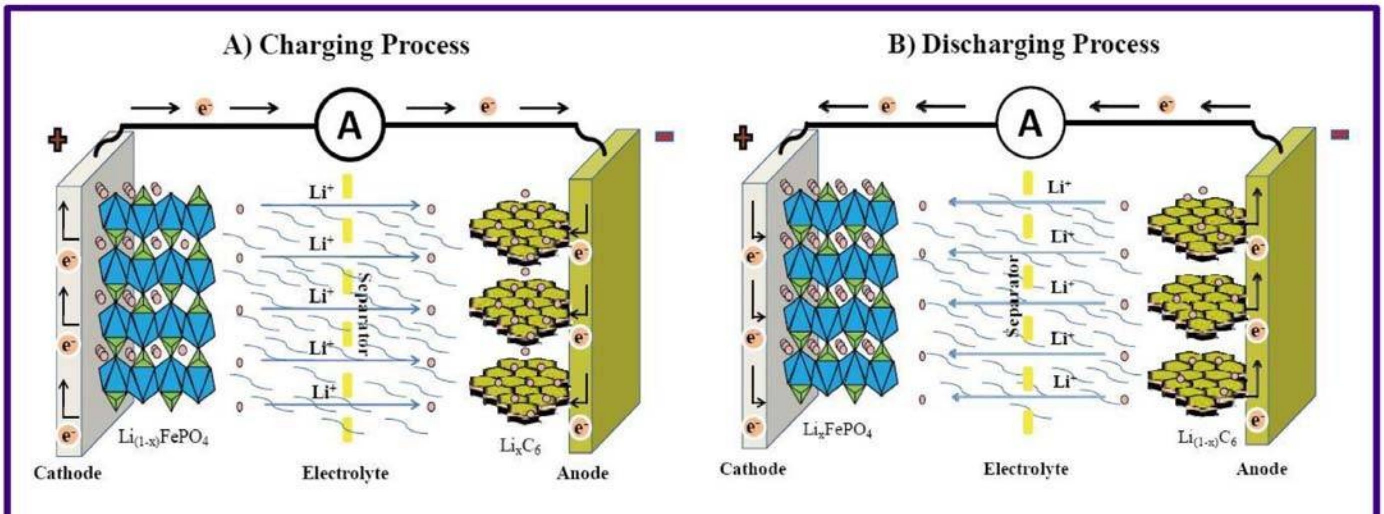

Fig.1 Charging (A) and discharging (B) processes of a typical lithium-ion battery.

When the battery is charged, lithium ions de-intercalate from the cathode and intercalate into the anode through the electrolyte; while on the discharging process, lithium ions de-intercalate from the anode and intercalate into the cathode.

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During charge/discharge cycles, electrons flow between the anode and the cathode, enabling the conversion of chemical energy and also the storage of electrochemical energy within the battery.

Therefore, the performance of rechargeable lithium-ion batteries strongly depends on the active materials employed in both anodes and cathodes for lithium storage. The common materials for anodes are carbon, lithium-alloying metals, graphite varieties (such as modified natural graphite or kish graphite), and carbon nanotubes/nanofibres. The most used cathode material is $LiCoO_2$, which is currently being used in commercial lithium-ion batteries found in portable electronic devices such as laptops and cell phones. However, the high cost, poor thermal stability at elevated temperatures and high toxicity of $LiCoO_2$ make it an unsuitable material for larger-scale applications. Consequently, battery manufacturers have turned to find other alternative materials to replace $LiCoO_2$, and examples of such materials include layered lithium nickel oxide ($LiNiO_2$), lithium manganese spinels ($LiMn_2O_4$), vanadium oxides (LiV_3O_8), and olivines.

$LiFePO_4$ has an ordered olivine structure with a Pnma space group, in which P atoms (PO_4) reside within tetrahedral 4c sites, and Fe and Li cations (FeO_6 and LiO_6) reside within octahedral 4c and 4a sites, respectively, as shown in Fig. 2 below.

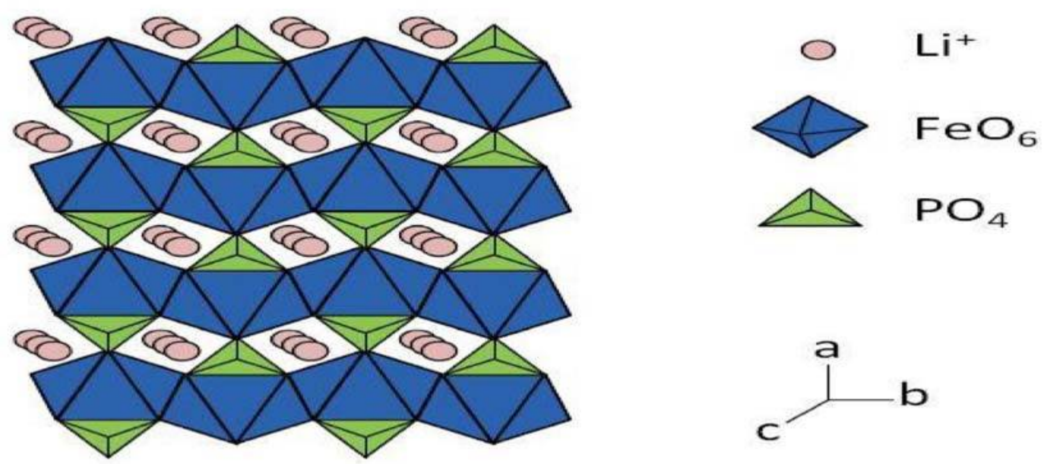

Fig. 2 Crystal structure of $LiFePO_4$.

Oxygen atoms show slightly distorted hexagonal close packed arrangement. FeO_6 is a corner shared octahedron and PO_4 is an edge-shared tetrahedron, and they form the zigzag skeleton by sharing oxygen and Li ions located in the octahedral channels.

The FeO_6 octahedra are connected through the corners in the bc plane and LiO_6 grows as a linear chain along the b axis and a PO_4 tetrahedral shares the edges with one FeO_6 and two LiO_6. The PO_4 tetrahedral structure is the reason for the good phase stability during lithium deintercalation.

3. Advantages of LiFePo4 Batteries

1) **Super Long Life Cycle:** A lead acid cell usually has a life cycle of 300 times, or 500 times at most, while a LiFePO4 cell can be discharged for 2000 times at 1C with a capacity retention rate of over 80%. That is five times the life cycle of lead acid cells, four times that of nickel-metal hydride cells and LiCoO cells, and four-five times that of Lithium-manganite cells.

2) **High Safety Level**: The chemical bond of phosphate is more stable than the traditional structure of transition metal oxides, and less prone to oxygen release. $LiFePO_4$ cells boast a stability grade of more than 400 at a high temperature, thus ensuring internal safety. They are not likely to explode or set on fire due to excessive charging, high temperature, and short circuit or collision.

3) **Environment friendly with no demand for rare metals**: No heavy or rare metal (except for lithium) is used in making $LiFePO_4$ cells. They are non-toxic and pollution-free.

4) **Quick charging, little self-discharge and no memory effects**: $LiFePO_4$ cells can be charged or discharged quickly at a maximum current of 2C. It takes only 30 minutes to charge 95% of a battery at 2C with a special recharger. The starting current can reach 2C, which lead-acid cells cannot attain.

5) **Small and light**: $LiFePO_4$ cells are about 2/3 the size and 1/3 the weight of lead-acid cells with the same capacity. They are also smaller than nickel-metal hydride cells, with a weight about 2/3 of the latter with the same capacity.

6) **High single cell voltage and stable discharging platform**: At 3.2V and with few series connections, LiFePO4 cells are highly reliable. They can be charged and discharged at a huge current and high rate, capable of discharging 96% of the capacity at 10C with a capacity retention rate of 90%.

In a word, $LiFePO_4$ cells have obvious advantages over traditional batteries and other Lithium cells. A comparison is drawn up among them in Table 1 and Table 2 below.

Table 1 Comparison between $LiFePO_4$ Cells and Traditional Batteries

Technical Indicators	Nickel Cadmium Cell	Nickel-metal Hydride Cell	Lead-acid Cell	$LiFePO_4$ Cell
Working Voltage (V)	1.2	1.2	2.1	3.2
Weight/Power (Wh/kg)	30-50	50-80	40	120
Size/Power (Wh/L)	150	200	70	210
Life Cycle	500	500	400	2000
Unit Price (RMB/Wh)	3	6	1.0-1.5	3-5
Unit Price/Life Cycle (1000)	6	12	2.5-3.75	1.5-2.5
Environmental Protection	Toxic	Lightly Pollutant	Toxic	Non-toxic
Safety	Outstanding	Good	Sound	Outstanding

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Table 2 Comparison of Cell Performance

	$LiCoO_2$	$LiNiCoMnO_2$	$LiMn_2O_4$	$LiFePO_4$
Tap Intensity (g/cm^3)	2.8-3.0	2.0-2.3	2.2-2.4	1.0-1.4
Specific Surface Area (m^2/g)	0.4-0.6	0.2-0.4	0.4-0.8	12-20
Specific Capacity (mAh/g)	135-140	155-165	100-115	130-140
Volt-based Platform(V)	3.6	3.5	3.7	3.2
Cyclic Performance	≥300 times	≥800 times	≥500 times	≥2000 times
Transit Metal	Poor	Poor	Rich	Very rich
Raw Material Cost	Very high	High	Low	Low
Environmental Protection	Cobalt	Nickel and Cobalt	Non-toxic	Non-toxic
Safety Performance	Poor	Good	Sound	Outstanding
Application Fields	Small battery	Small battery/Small power battery	Power battery	Power battery/Mega-capacity power supply

4. Application Examples

EV Application Examples:

Motorbikes / Scooters / electric bicycles

- **Electric bus**
- **Electric cars**
- **Light traction/neighborhood vehicle**
- **Light trucks and vans**
- **Motorbikes, scooters, electric bycicles**

Electric Cars & Buses

INTERBERG lithium iron phosphate battery is widely used on electric car, such as battery electrical vehicle (BEV), plug-in hybrid electrical vehicle (PHEV) and hybrid electric vehicle (HEV). Vehicles such as pure EVs, mini cars, light trucks and vans, neighborhood vehicles, golf carts, touristic and sightseeing trolleys, etc. which formerly used lead acid batteries, are now driving with INTERBERG LiFePO4 batteries.

Light Traction

Light traction vehicles, like electric bikes, scooters, motorcycles, and some other similar light vehicles, are the huge market for LiFePO4 battery application, definitely will flourish in the following years.

Energy Storage Application Examples:

- Wind and Solar systems
- UPS
- Emergency power
- Backup power supply
- Telecoms / Remote stations

INTERBERG has developed ES (Energy Storage) LifePO4 batteries, specially conceived and designed for energy storage applications where lead acid batteries of diverse technologies are still being used.

This kind of battery is characterized by : it is cost-effective, offers a long life cycle, a large charging current acceptance (compared with lead acid), as well as a high and low temperature resistance. INTERBERG ES series LifePO4 batteries can be widely used in UPS, solar & wind system, telecoms and in many other energy storage fields.

The Electrical Vehicle Battery

The outstanding performance characteristics described below make the INTERBERG LiFePO4 battery the best and more reliable and effective option for electrical vehicle application:

INTERBERG LiFePO4 batteries offer: high continuous/peak power, providing a high performance in starting, accelerating and climbing, as well as a higher speed than electrical cars equipped with lead-acid battery of an equivalent capacity.

INTERBERG LiFePO4 battery presents an optimum weight-size proportion. Light weight means energy saving due to huge total vehicle weight reduction; weight reduction also means long driving distance.

INTERBERG LiFePO4 battery accept fast charging like 1C continuous rate, These batteries can also accept large charging current as energy regeneration by EV braking or reducing speed.
INTERBERG LiFePO4 battery for electric vehicles are mainly manufactured as large individual prismatic cells that are connected to each other and placed inside battery trays similarly as conventional lead acid traction batteries. Prismatic cells are easy to connect, easy to carry and easy to replace.

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LiFePO4 EV-Battery Prismatic Cell Program

Specifications	LF-0320200	LF-0320300	LF-0320400	LF-0320500	LF-0320600
Cell Voltage	3.20 V	3.20 V	3.20 V	3.20 V	3.20 V
Nominal Capacity	20 Ah	30 Ah	40 Ah	50 Ah	60 Ah
Dimensions (mm); LxWxH, incl. cell terminals	103 x 41 x 168	103 x 58 x 168	113 x 66 x 168	152 x 50 x 190	114 x 61 x 203
Weight	0.83 Kg	1.15 Kg	1.51 Kg	1.89 Kg	2.04 Kg
Energy Density	90.2 W/h/l	95.7 Wh/l	102.2 Wh/l	110.8 Wh/l	133.7 Wh/l
Specific Energy	77.1 Wh/Kg	83.5 Wh/Kg	84.8 Wh/Kg	84.6 Wh/Kg	94.1 Wh/Kg
Specific Power (23ºC)	386 W/Kg/@15 sec	417 W/Kg/@15 sec	424 W/Kg/@15 sec	424 W/Kg/@15 sec	471 W/Kg/@15 sec
Discharge (23ºC)					
Max. Cont. Current	60 A	90 A	120 A	150 A	180 A
Peak @ 60 sec	100 A	150 A	200 A	250 A	300 A
Cut-Off Voltage	2.50 V	2.50 V	2.50 V	2.50 V	2.50 V
Charge Method	CC/CV (3.65v)	CC/CV (3.65v)	CC/CV (3.65v)	CC/CV (3.65v)	CC/CV (3.65v)
Max. Cont. Current	20 A	30 A	40 A	50 A	60 A
Cut-Off Voltage	3.85 V	3.85 V	3.85 V	3.85 V	3.85 V

Specifications	LF-0321000	LF-0321600	LF-0321800	LF-0322000
Cell Voltage	3.20 V	3.20 V	3.20 V	3.20 V
Nominal Capacity	100 Ah	160 Ah	180 Ah	200 Ah
Dimensions (mm); LxWxH, incl. cell terminals	163 x 51 x 278	169 x 85 x 247	183 x 72 x 286	255 x 70 x 247
Weight	3.40 Kg	5.23 Kg	5.77 Kg	6.40 Kg
Energy Density	138.4 W/h/l	151.0 Wh/l	152.9 Wh/l	145.2 Wh/l
Specific Energy	94.1 Wh/Kg	87.9 Wh/Kg	99.8 Wh/Kg	100.0 Wh/Kg
Specific Power (23ºC)	471 W/Kg/@15 sec	489 W/Kg/@15 sec	499 W/Kg/@15 sec	500 W/Kg/@15 sec
Discharge (23ºC)				
Max. Cont. Current	300 A	480 A	540 A	600 A
Peak @ 60 sec	500 A	800 A	900 A	1000 A
Cut-Off Voltage	2.50 V	2.50 V	2.50 V	2.50 V
Charge Method	CC/CV (3.65v)	CC/CV (3.65v)	CC/CV (3.65v)	CC/CV (3.65v)
Max. Cont. Current	100 A	160 A	180 A	200 A
Cut-Off Voltage	3.85 V	3.85 V	3.85 V	3.85 V

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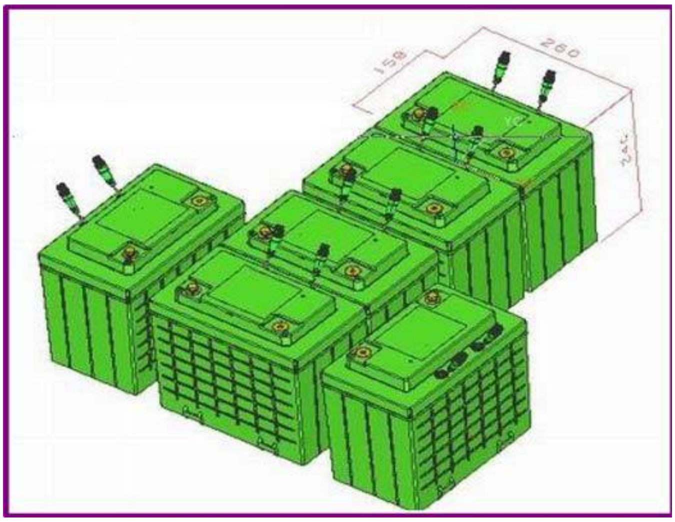
200V LiFePO4 EV-Battery in 4 pcs of 16-cell Module-Trays

24V LiFePO4 EV-Battery in an 8-Cell Steel Battery-Tray

INTERBERG does also produce mono-block type LiFePO4 batteries in the typical traditional SLI (starting automotive) battery shapes and in dimensions close or similar to those of conventional car batteries, for best physical fitting in smaller vehicles requiring a smaller footprint requirement for the battery allocation inside the vehicle.

72V LiFePO4 EV-Battery consisting of 6 pcs of 12V-Mono-blocks



Example of Mono-block style LiFePo4 EV-Battery

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The BMS (Battery Management System)

The BMS (Battery Management Systems and the Battery Charger are further fundamental elements of the propulsion side of an electrical vehicle, that is completed with the battery itself

A battery management system (BMS) is any electronic system that manages a rechargeable battery such as by monitoring its state, calculating secondary data, reporting that data, protecting the battery, controlling its environment, and / balancing it.

The basic purpose of BMS system is to optimally use the energy stored in the battery, and to minimize the risk of damage inflicted upon the battery. This is achieved by proper monitoring and controlling the charge and discharge processes of the battery. These are the key functions of the BMS that ensures a correct operation of the electrical vehicle :

- Under voltage protection;
- Over voltage protection;
- Short-circuit protection (maximum current limitation);
- Thermal protection;
- State-of-Charge (SoC) prediction and monitoring
- State of Health (SoH) and
- Cell balancing (equalization).

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The Battery Charger

There are three classes of LiFePO4 charging methods: Level 1 (“standard” charge), Level 2 (“overnight” charge) and Level 3 (“fast” charge).

The charging times will depend on the charging class chosen.

Level 1 Charging (‘Standard’ Charging)

- Portable plug standard outlet
- Delivers power from the wall to the Vehicle’s on board charger.
- Time required to achieve a full charge from fully depleted) : 16-18 h.

Level 2 Charging (‘Overnight’ Charging)

- Fixed Charging Facility Installation
- Delivers AC power from the wall to the on-board charger.
- Time required to achieve a full charge from fully discharged) : 16-18 h.

Level 3 Charging (‘Fast’ Charging)

- High powered fast charge station (like a traditional gasoline station.
- Delivers DC energy, by-passing the on-board charger in the vehicle.
- Time required to achieve a full charge from fully depleted) : about 30 minutes.

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