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THE PULSE OF PROGRESS

INTRODUCTION TO LITHIUM IRON PHOSPHATE BATTERY TECHNOLOGY

JAUCH DEVELOPS

WHITEPAPER

INHALT

1. HISTORY OF THE LITHIUM IRON PHOSPHATE BATTERY

The lithium iron phosphate battery ($LiFePO_4$) has developed into an important technology in stationary and mobile energy storage over the last few decades. Its foundations date back to the 19th century: As early as 1834, the German mineralogist Johann Nepomuk von Fuchs discovered the mineral triphylite, which contains lithium, iron and phosphate.

Image: Triphylite Source: mineralienatlas.de

However, the deliberate use of this compound as a cathode material began much later. Between 1996 and 1997, researchers at the Goodenough Institute in Texas succeeded in synthesizing lithium iron phosphate and analyzing its electrochemical properties. The resulting work by John B. Goodenough and Michel Armand formed the starting point for the subsequent industrial application. John B. Goodenough was awarded the Nobel Prize in Chemistry in 2019 for his pioneering contributions to the development of modern lithium-ion batteries.

Initially, the low electrical conductivity of $LiFePO_4$ limited the battery's performance. Targeted advancements, including carbon coating, doping and the use of nanoparticles, significantly improved its efficiency. These optimization measures led to lithium iron phosphate becoming commercially viable as a cathode material.

In the early 2000s, companies such as A123 Systems and Phostech Lithium began to industrialize this technology. Phostech was acquired by Süd-Chemie in 2005, which was later integrated into the Clariant Group. These players contributed significantly to the spread and standardization of $LiFePO_4$ in industrial applications.
In the context of the energy transition, lithium iron phosphate battery technology is playing an increasingly important role due to its cell properties.

2. FEATURES AND FUNCTIONALITY OF LITHIUM IRON PHOSPHATE TECHNOLOGY

Lithium iron phosphate batteries possess a range of technical characteristics that make them particularly well-suited to various applications:

High thermal and chemical stability

A key feature is their high thermal and chemical stability, which enables particularly safe operation even under demanding conditions. The high thermal stability ensures that the material remains structurally stable even at high temperatures, while the chemical stability ensures that it does not react with other substances or decompose - even during prolonged use under demanding environmental conditions.

In contrast to lithium cobalt oxide or lead-acid systems, $LiFePO_4$ only has a low risk of "thermal runaway". This term refers to a process in which a battery continues to heat itself up through an uncontrolled chain reaction. The temperature rises to such an extent that it can lead to a technical failure of the cell - with consequences such as gas formation, fire or even explosion. Thermal runaway is usually triggered by overcharging, external heat, or mechanical damage and is particularly dangerous for batteries with unstable cell chemistry. Lithium iron phosphate cells are considered very safe as they have a low risk of such processes. Their crystalline structure is particularly stable and oxygen is not released as easily as with other cathode materials.

Long service life

Another advantage is their long service life:. $LiFePO_4$ cells typically exceed 2,000 charging cycles and can remain in operation for over ten years when used appropriately. Thanks to their low self-discharge and high charging/discharging efficiency, the batteries remain stable and reliable even when the charge level is low.

Environmentally friendly

By avoiding the use of critical or particularly pollutant-rich materials, this technology is significantly more environmentally friendly than conventional systems. No toxic heavy metals such as lead or cadmium are used, which improves recyclability and simplifies disposal.

High performance

The performance of $LiFePO_4$ cells is particularly evident in the stable voltage level during discharge, the ability to handle high charging and discharging currents, and the long service life - even with frequent charging cycles and varying environmental conditions. These properties help to ensure that the energy output remains stable over the entire operating period, minimizing performance losses. In addition, as previously mentioned, the robust cell chemistry enables a high load capacity with low heat generation, which further increases efficiency and safety during operation.

3. COMPARISON WITH LEAD-ACID BATTERIES: DIFFERENCES AND ADVANTAGES

In direct comparison with classic lead-acid batteries, the advantages of $LiFePO_4$ are evident across several key areas:

CATEGORY	$LIFEPO_4$	LEAD-ACID
LIFETIME	Up to 10 years	About 3 years
NUMBER OF CYCLES	> 2,000 charging cycles	200 - 550 charging cycles
WEIGHT	Light (about ⅓ of the weight)	Heavier (approx. 3x as heavy)
CHARGING TIME	Fast (< 1 hour)	Slow (several hours)
MAINTENANCE	Maintenance-free	Requires maintenance
MATERIALS	No toxic substances	Contains lead and sulphuric acid
RECYCLING	Good recyclability	More complex disposal

Operational safety and reliability

$LiFePO_4$ batteries are considered particularly safe to handle. Their cell chemistry has a high thermal stability, which significantly reduces the risk of overheating, gas formation, or fire. Lead-acid batteries, on the other hand, are sensitive to deep discharge, require regular maintenance (e.g. topping up with water for wet cells), and can release dangerous gases such as hydrogen if handled improperly.

Charging behavior and energy efficiency

Lithium iron phosphate systems can be discharged almost completely without significant charge losses, while lead-acid batteries can only use around 50 - 60 % of their capacity before the voltage drops significantly. In addition, $LiFePO_4$ cells operate with a higher efficiency during charging and discharging - usually over 95% - which reduces energy consumption and extends operating times.

Comparison of the life cycles of lithium iron phosphate and lead-acid batteries

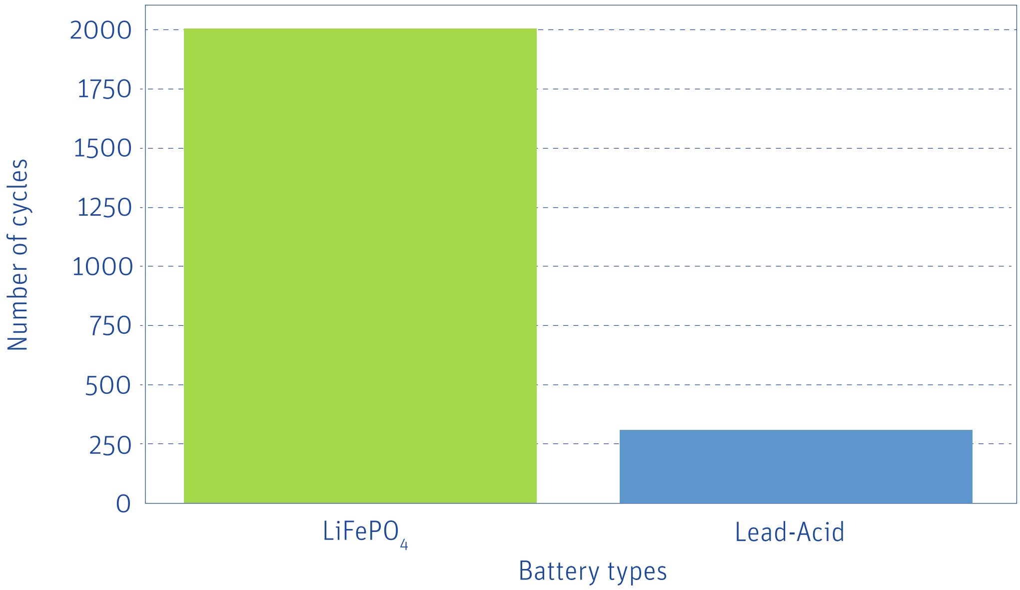

Figure: Lithium iron phosphate batteries achieve around 2,000 cycles, while lead-acid batteries only go through 300 cycles on average - a clear difference in longevity.

Thanks to their high charging/discharging efficiency, $LiFePO_4$ batteries can be charged up to 60% faster, which is particularly beneficial in mobile applications such as electric vehicles or off-grid storage. Their compact design and long service life contribute to lower long-term operating costs, making them a cost-effective alternative.

Ease of use and integration

Thanks to their low weight and compact design, $LiFePO_4$ batteries are easier to install and transport. They do not require ventilation, are maintenance-free, and can be integrated into modern energy management systems - for example, via CAN bus or Bluetooth interfaces. Lead-acid batteries, on the other hand, are heavier, bulkier and mechanically more sensitive to vibrations and temperature changes.

Total cost of ownership

Although the initial costs of a $LiFePO_4$ battery are higher than those of a lead-acid variant, this investment is offset over its service life:

- Lower maintenance and operating costs
- Longer service life and higher number of cycles
- Savings through higher efficiency and shorter charging times

4. INSTRUCTIONS FOR THE SAFE OPERATION OF LITHIUM IRON PHOSPHATE BATTERIES

Lithium iron phosphate batteries are widely regarded as particularly safe in everyday use - provided they are used properly. Their cell chemistry is characterized by high thermal stability, which significantly reduces the risk of overheating, gas formation, or fire compared to other lithium-based technologies. Nevertheless, some basic safety aspects must be observed to ensure long-term operational safety:

Compliance with Charging and Discharging Currents

It is essential to adhere to the recommended charging and discharging currents. Although $LiFePO_4$ cells can withstand high charging currents, a battery management system (BMS) tailored to the cell chemistry should always be used. This monitors the voltage, temperature, and current flow, protecting the battery against deep discharge, overcharging or short circuits.

Robust Design

The mechanical integrity of the battery unit is also crucial. Shocks, vibrations, or improper installation can cause cell damage, which has a negative impact on service life and safety. $LiFePO_4$ batteries should therefore always be installed in suitable housings and protected against external influences.

Temperature Range Compliance

Ambient temperature plays an important role in battery performance. Ideally, operation should occur within a range from 0 °C to +45 °C. At extreme temperatures - especially below freezing - the charging capability may be limited. For applications in harsh environments, specialised cell variants with extended temperature tolerance should be selected.

Proper Disposal

Finally, ensure proper disposal procedures are followed. Although $LiFePO_4$ batteries do not contain any toxic heavy metals, they are still subject to the legal requirements for return and recycling. Disposal via certified collection points is therefore mandatory.

By observing these safety guidelines, the full potential of $LiFePO_4$ technology can be harnessed safely and sustainably.

5. APPLICATIONS

Lithium iron phosphate batteries have proven to be particularly suitable for numerous demanding applications in recent years:

Stationary Energy Storage

In the field of stationary energy storage, $LiFePO_4$ cells are used in residential and industrial storage systems - for example, for the intermediate storage of solar power or for grid stabilization. Their high cycle stability and ability to work reliably for years make them a popular battery for these applications.

Medical Technology

In medical technology, lithium iron phosphate cells are primarily used in mobile diagnostic and therapeutic devices, where a reliable power supply is vital. Thanks to their low self-discharge and high cell stability, they ensure safe operation even over long periods of inactivity. They also offer a particularly high level of safety thanks to their thermal and chemical stability - a decisive advantage in sensitive medical applications where failure or overheating could have serious consequences.

Electromobility

$LiFePO_4$ batteries are also becoming increasingly important in electromobility - particularly in electric buses, light commercial vehicles, and electric forklift trucks. Their robustness, short charging times, and high level of safety, even under harsh operating conditions, are impressive.

Industrial and Emergency Power Supply

Lithium iron phosphate batteries ($LiFePO_4$) are widely used in industrial applications such as uninterruptible power supply (UPS) systems, control units, and backup systems, where a constant and fail-safe power supply is essential. Other areas of use include telecommunications and safety-critical systems such as access control or fire alarm systems, where a reliable power supply is also essential. Their high cycle stability and maintenance-free operation ensure long-term reliability, even with frequent charging and discharging processes or in demanding environments with temperature fluctuations and vibrations.

Thermal Imaging Camera for Firefighters

A concrete example of the use of lithium iron phosphate technology in action is the integration of a robust $LiFePO_4$ battery from Jauch in thermal imaging cameras for firefighters, developed by Austrian manufacturer Leader Photonics. These cameras are worn directly on the breathing apparatus and provide real-time infrared images for orientation in smoke-filled environments - such as fires in enclosed spaces.

The demands on the power supply are extremely high, devices must be able to withstand temperatures of up to +260 °C for several minutes without any functional failures or safety risks. This is where the special properties of the lithium iron phosphate cell come into their own: not only are they highly thermally stable, but they are also exceptionally safe to operate, even in direct contact with the body and under extreme conditions.

6. BATTERY TECHNOLOGY AT JAUCH

Founded in 1954, Jauch Quartz GmbH has been active in the battery industry since 1976. The company has increasingly specialized in lithium battery technology and has successively expanded its product portfolio in this area.

Whether standard batteries or application-specific developments - Jauch has a wide range of primary lithium batteries and rechargeable battery systems. Many of the batteries are available directly from stock.

In-House Test and Certification Center

Jauch's new test and certification center in Villingen-Schwenningen supports companies in the safe market launch of lithium batteries. In the new test laboratory, cells and batteries can be comprehensively tested and certified - either directly or in cooperation with renowned, accredited test laboratories to meet standards such as UL, PSE, KC and CCC.
In addition to individual tests, Jauch conducts all assessments required for the United Nations transport test UN38.3, as well as for IEC 62133, the key safety standard for rechargeable batteries issued by the International Electrotechnical Commission (IEC). These comprehensive testing and certification services provide companies with a reliable foundation for marketing their products globally.

Jauch is certified to DIN EN ISO 9001:2015 and the company's environmental management system is certified to ISO 14001. As a result, its batteries and battery packs meet the highest international production and quality standards. All products comply with RoHS and REACH regulations and are free from lead and conflict minerals.

Sources

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Jérémie Deloof has been part of the Jauch Group since 2015 and has over ten years of experience in the battery industry. As a project manager, he is primarily responsible for technically sophisticated and customized lithium battery solutions - from the initial idea to series production.

Jérémie Deloof has been part of the sales management team since July 2023, where he actively shapes the strategic development of the battery division.

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