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Empowering Portable Industrial Devices

A Strategic Guide to Navigating the NMC vs. LFP Battery Landscape

There has been a rapid rise in the development of portable industrial devices in recent years and Lithium-ion batteries have become essential in powering many of these, especially where weight and space constraints are important. Lithium-ion batteries offer many desirable characteristics, such as high efficiency, long cycle life, compact size, high-energy density, high-power density, and low cost. They have fast re-charging times, and have higher capacities than other batteries like Nickel-cadmium (NiCd), Nickel-metal Hydride (NiMh), or Lead (Pb). Self-discharge rates are also significantly lower than that of other rechargeable batteries.

Battery technology is ever evolving, and Lithium-ion batteries have become an ideal solution for compact electronic applications.

Both Lithium Nickel Manganese Cobalt Oxide (NMC) and Lithium Iron Phosphate ($LiFePO_4$; LFP) are Lithium-based rechargeable batteries. However, they have some notable differences in terms of their chemistry and performance.

NMC batteries use a cathode made up of a combination of nickel, manganese, and cobalt in varying ratios. LFP is a battery that has an iron-based cathode.

Choosing the appropriate Lithium-ion battery for a particular application is not a one-size-fits-all task. It is important to find the right solution that will maximize efficiency and minimize cost, while still meeting the requirements needed for the specific application where it will be used.

When it comes to optimizing products for portable industrial devices, such as medical equipment, drone systems, communications devices, and wearable powered products, a list of requirements and preferences needs to be examined. Factors like size, safety, cost, rate capability, voltage plateau, and operating temperatures must be considered, as they can influence functional outcomes and end-product performance.

SIZE

When the final product size, including weight, is a crucial factor, the energy density of the battery comes into play. NMC batteries tend to have higher energy density when compared to LFP batteries. This means NMC batteries can store more energy per unit of weight than LFP batteries are able to.

For some end-user products—such as drones—the weight of the battery plays an important role, as even a slight excess of weight can alter or even inhibit optimal performance of the product. In other applications, where the end user might need to handle or wear the product for extended periods, weight will also be a significant factor when deciding on a battery type. Product size is crucial when considering portability or wearability.

For the same energy output, NMC batteries weigh less and are smaller in size than LFP batteries. In fact, NMC battery packs can be 20–30% smaller—making them a good choice for size-restrictive applications.

While LFP batteries have a lower energy density, giving them a disadvantage when a lighter battery is preferred, what they do offer is increased safety.

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SAFETY

LFP batteries are known for their good thermal stability when compared to some other Lithium-ion chemistries. The iron-phosphate chemistry in LFP is less prone to thermal runaway and tends to have a higher thermal stability than NMC batteries. This is due to the robust nature of the phosphate bond, which is less prone to oxygen release and thermal decomposition.

The high-energy density of NMC batteries store large amounts of energy in a small space, which means that more energy can potentially be released in an uncontrolled manner if the battery were to be damaged or improperly managed. Further, the materials used in NMC batteries can become unstable at very high temperatures.

External conditions, as well as internal faults, could expose the battery to excessive heat, inciting exothermic reactions from the NMC cathodes that would in turn release additional heat. This can start a positive feedback loop, where the heat generated by these reactions causes more reactions, leading to thermal runaway. Cobalt oxides can also be more reactive and contribute to thermal instability under certain conditions, such as overcharging, deep discharging, or physical damage.

The electrolyte in Lithium-ion batteries, with the exception of LFP, is flammable and can decompose at high temperatures.

Decomposition of the electrolyte can generate gases and further increase internal pressure and temperature, worsening thermal runaway. On the other hand,

> *"The LiFePO4 cathode material does not generate oxygen even when fully decomposed at high temperatures; thus, explaining the lowest heating rate during thermal runaway. For these cells, thermal runaway is dominated by anode-electrolyte reactions, which show high-rate decomposition at higher temperatures."* [1]

Essentially, the cathode metal choice will have great influence over the safety of a battery. Also, mechanical abuse, manufacturing defects, or degradation over time can lead to internal short circuits within the battery. These shorts can cause localized heating, which may trigger thermal runaway if the heat is not quickly dissipated.

Keeping safety in mind, when Power Products is designing a battery management system (BMS), all aspects of protection are built into the battery pack, no matter which chemistries are best suited for the intended application. The primary safety circuits manage all the basic safety functions: over-voltage, under-voltage, over-current, and temperature protection are included. Additionally, most of the world-class designs produced by Power Products also include a secondary safety circuit, which is there to protect the cell in the event the primary safety circuit fails.

[1] Daniel H. Doughty and E. Peter Roth 2012 Electrochem. Soc. Interface 21 37

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COST

The cost-effectiveness of NMC batteries versus LFP batteries can vary depending on specific use cases, applications, and market conditions. Both battery chemistries have their advantages and trade-offs in terms of cost, and the choice between them often depends on the requirements of the application. Here are some general considerations:

Raw Material Cost

NMC batteries typically contain more expensive materials, including nickel, manganese, and cobalt, when compared to the iron and phosphate used in LFP batteries. "LFP is still exposed to rising lithium prices, but it does not contain nickel and cobalt, thus avoiding price and market volatilities typically associated with these commodities."[2]

Energy Density

The higher density of NMC batteries allows them to store more energy in a smaller and lighter package. This, in turn, can influence the overall cost effectiveness for specific applications where space and weight are also critical factors.

Cycle Life

LFP batteries generally exhibit a longer life cycle when compared to NMC batteries. LFP chemistry is known for its robust cycle life and can withstand a higher number of charge/ discharge cycles before experiencing a significant decline in performance.

If a longer lifespan is a critical requirement for the end-product, then LFP batteries may be more cost effective in the long run, as they may not need to be replaced as frequently. Under ideal conditions, LFP batteries can have 3000+ charge/discharge cycles, while NMC batteries will have an average of around 1000+ charge-discharge cycles.

[2]IEA. 2022. Global supply chains of EV batteries.
https://www.iea.org/reports/global-supply-chains-of-ev-batteries

RATE CAPABILITY

NMC batteries may have a higher energy density, allowing certain cells designed for power to have faster charging and discharging rates when compared to LFP batteries. This can be advantageous when fast recharge times are required for the intended application. However, the specific rate capabilities can vary between different formulations and designs of these batteries.

VOLTAGE PLATEAU

LFP batteries have a flatter voltage plateau during discharge when compared to NMC batteries. This means that the voltage of an LFP battery remains relatively constant during most of the discharge cycle, providing a more predictable voltage profile.

The flatter voltage plateau of LFP batteries during discharge offers the following benefits:

Stable Performance

The constant voltage profile of LFP batteries means that the voltage remains relatively stable throughout most of the discharge cycle. This stability ensures consistent performance of the consumer product, providing a reliable power supply without significant fluctuations.

Predictable Power Output

The consistent voltage output of LFP batteries allows for a more predictable power delivery, which is important for devices that require steady power.

Extended Device Runtime

Since the voltage remains relatively constant, devices powered by LFP batteries may operate efficiently until the battery is depleted. In certain applications, this can result in longer device runtime when compared to batteries with voltage profiles that drop more rapidly during discharge. But for most applications the higher energy density NMC cells will produce the longest run times.

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OPERATING TEMPERATURE

Another important factor to consider when choosing between LFP and NMC batteries is the environment and circumstances where the final product will be used. For example, consider

if the product needs to be operated in extreme temperatures.

Discharge rates for LFP batteries tend to have a larger operating range when compared to NMC batteries. Standard LFP batteries operate within a temperature range of -20–60°C (-22–140°F) and some special models are able to go to -30ºC or up to +70ºC. NMC batteries will function in temperatures from -20–60°C (23–122°F).

The charging temperature range for both LFP and NMC batteries is from 0–45°C (32–113°F). Charging at temperatures below freezing can cause lithium plating, leading to permanent battery damage. Both battery types have reduced performance outside of their optimal temperature ranges.

LFP batteries typically offer better performance and safety at extreme temperatures when compared to NMC batteries, which may require more sophisticated thermal management solutions in challenging conditions.

CONCLUSION

LFP batteries offer increased safety and an extended lifespan, though they provide moderate specific energy and experience higher self-discharge rates.

NMC batteries boast robust overall performance with a standout feature in higher specific energy.

By exploring various build options, it becomes possible to optimize efficiency and performance while also minimizing cost. In addition, analyzing the precise requirements of a product makes it easier to find the most suitable battery solution.

With Lithium-ion batteries tailored to these specifications and crafted with unique features, you can ensure that your application receives the best possible design, optimizing performance and effectively meeting your specific needs. Power Products can help by providing a full turnkey solution, from design to development and obtaining required certifications and professional manufacturing in ISO9001:2016 facilities.

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