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ЛИТИЙ-МЕТАЛЛИЧЕСКИЕ БАТАРЕИ

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LITHIUM-METAL BATTERIES

Abstract: This article provides how lithium-metal batteries designed; its perspectives of LMB and reasons for the current low prevalence; solutions of LMB battery problems.

Key words: *lithium-ion batteries, lithium-metal batteries, perspectives, LMB*

Introduction

Lithium-metal batteries, which are essential components in various appliances and electronic devices, play a significant role in promoting global sustainability. Utilizing batteries to power electronic devices can aid in minimizing carbon emission and decreasing dependence on fossil fuels.

Nowadays, scientists research method to make batteries last longer, operate more effectively and safely. This is motivated by demand for more affordable transportation option and efficient electronic devices. As a result, an increasing number of scientists are exploring lithium metal batteries and employing analytical techniques to examine various electrical components.

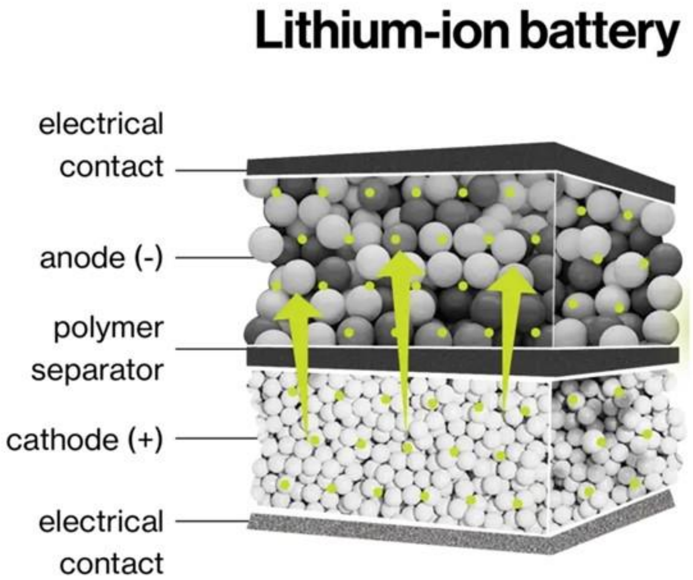
Academia, industry and national laboratories have been researching and developing lithium-metal battery (LMB) continuously for 60 years. Despite this extensive effort, commercial LMBs have yet to displace, or offer a ready alternative to, lithium-ion batteries. Consequently, numerous technological devices, including electric vehicles and smartphones, continue to operate using batteries that feature graphite anodes.

Differences between Lithium metal battery and Lithium-ion battery

Lithium-ion batteries don’t use metallic lithium in their anode. They use a carbon material such as graphite. These batteries consist of the next parts: the cathode, anode, separator, and electrolyte. (Picture 1)

Lithium ions move from the cathode to the via the electrolyte while the battery is charging. The anode stores them in its structure. Upon discharging, the battery releases the lithium ions back to the cathode, generating electrical energy for the device.

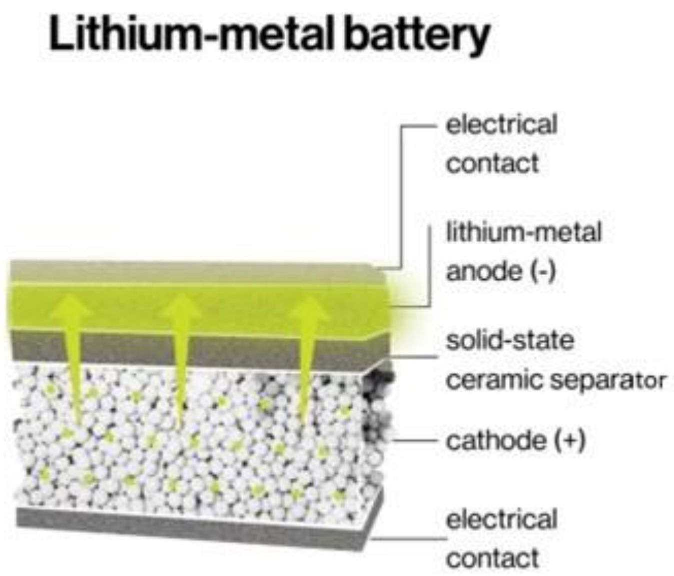
Lithium-ion batteries are great because they last a long time and have quite a lot of power. They're used in smartphones, laptops, power tools, and renewable energy systems because they have shown their reliability and efficiency.



Picture 1

A lithium-metal battery utilizes metallic lithium for its anode, allowing it to store a significant amount of energy in a compact and lightweight design. These batteries are ideal for applications that require high power in a limited space, such as electric vehicles and electronic devices.

Lithium ions move between the cathode and anode in lithium-metal batteries when charging and discharging. The battery stores lithium ions as metallic lithium at the anode during charging. During discharging, it releases stored energy as lithium ions return to the cathode.



Picture 2

Lithium-metal battery advantages and limitations

Advantages:

1) Superior Energy Density: LMBs boast significantly higher energy density, leading to longer operational times for a single charge.

2) Weight Reduction: Their lightweight nature is ideal for mobile devices and electric vehicles, optimizing portability and efficiency.

3) Rapid Charging Capabilities: Faster charging rates mean quicker power restoration, reducing downtime in daily use.

4) Temperature Resilience: These batteries excel under extreme temperature conditions, ensuring consistent performance from hot to cold climates.

5) Extended Lifespan: With a longer service life compared to traditional options, lithium-metal technologies contribute to reduced environmental impact through less frequent replacements.

Limitations:

1) Ensuring safe operations with lithium-metal batteries: The propensity for dendritic growth within these cells poses grave hazards such as short circuits and unchecked heat escalation, which often culminates in fiery incidents or explosions. Prioritizing rigorous safety protocols and the design of robust battery structures is paramount to safeguard against future calamities.

2) The delicate balance act with charging and discharging: Lithium-metal batteries exhibit heightened sensitivity to overcharging and over-discharging events that can severely impact performance, potentially leading to irreversible harm. The integration of sophisticated battery control systems becomes imperative for maintaining operational reliability without compromising safety or efficiency standards.

3) Economic considerations in production scalability: Presently, lithium-metal battery production is plagued by higher costs compared to conventional lithium-ion technologies, which acts as a significant barrier to their broad market acceptance – particularly within cost-conscious sectors. Richard Wang of Cuberg, subsidiary of the Northvolt, projects that overcoming this financial hurdle will necessitate over a decade's worth of optimization and price adjustments.

4) Navigating regulatory complexities: The inherent flammability and environmental concerns associated with lithium-metal batteries subject them to stringent transport and disposal regulations. Compliance with these intricate guidelines presents logistical challenges in the handling and management processes across their lifecycle.

The Role of SEI in Battery Dynamics

At the heart of battery functionality lies the solid-electrolyte interphase (SEI), a critical surface layer on electrodes that facilitates electrochemical reactions, thereby ensuring optimal performance through maintaining stability. Given its pivotal role in battery efficiency, delving into the nature and behavior of this interface is essential for enhancing anode-free lithium metal batteries. Leading this research frontline are Professor Lauren Marbella's team at Columbia University. By employing advanced nuclear magnetic resonance (NMR) imaging and spectroscopic techniques to monitor real-time material transformations, they have unlocked profound insights into the chemical processes that drive degradation within both lithium-metal and broader battery systems [3, 4].

Achievements in development of LMB

The burgeoning research into lithium metal anodes as alternatives to traditional graphite is revolutionizing the landscape of energy storage:

Thermodynamic Differentiation in Solid-State Batteries:

Research by Li and his team highlight a paradigm shift with solid-state batteries, which fundamentally differ from liquid electrolyte-based lithium-ion systems. - A multi-layered design incorporating varying stability levels among solid electrolytes prevents dendrite formation through controlled decomposition and expansion screw effect that fills cracks dynamically. This innovative strategy ensures high current density (8.6 mA/cm2 at 10C) without the risk of dendrite penetration, showcasing remarkable capacity retention – 82% after an astounding 10,000 cycles. The design achieves a specific power of 110.6 kW/kg and energy up to 631.1 Wh/kg at the micro-scale level[1].

In-Depth Analysis of Solid-Electrolyte Interphase (SEI):

Gu and colleagues employing depth-sensitive plasmon-enhanced Raman spectroscopy, delved into the intricate processes within SEIs. This advanced analytical method provides a detailed understanding of how chemical reactions at the interface affect battery performance and longevity.

Innovative Lithium Metal Anode Architecture:

The collaborative effort by POSTECH and KIER introduces an innovative LMA model: Utilizing hyper porous/hybrid conductive architecture on SWCNT film (HCA/C), it serves as both a Li host and current collector. This approach significantly reduces the weight of the anode compared to traditional Cu or stainless-steel foils, paving the way for high-energy-density battery systems with stable electrodeposition/dissolution processes.

Conclusion

While the promise of lithium metal anodes holds significant potential, overcoming technical challenges – particularly those related to chemical stability, safety, cost reduction, and regulatory compliance – remains a critical focus for researchers. The ongoing advancements in materials science and battery design are paving the way towards next-generation energy storage solutions that could dramatically impact electric vehicles' market competitiveness and sustainability.

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