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Comparative Analysis of Lithium Battery and All Vanadium Flow Battery

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Abstract

With the increasing maturity of energy saving and new enAergy technologies, the demand for high-quality, green and environmentally friendly batteries has increased. The working principle, characteristics and application of lithium-ion batteries, lithium metal batteries and all-vanadium flow batteries are introduced. The comparative analysis summarizes the advantages of all-vanadium flow batteries in the field of energy storage, and provides directions for energy storage system research.

Keywords

Lithium-Ion Battery; Lithium Metal Battery; All Vanadium Flow Battery.

1. Introduction

The global battery industry and market are gradually expanding, coupled with the widespread use of lithium batteries and all-vanadium flow batteries in new fields and energy storage systems. Based on the different working principles, characteristics and application fields of lithium-ion batteries, lithium metal batteries, and all-vanadium redox flow batteries, contrast and highlight the advantages of all-vanadium redox flow batteries in the field of energy storage to ensure their safe and reliable use in energy storage systems. Recyclable, environmentally friendly, and suitable for large-scale energy storage systems. Based on the safety risks of lithium-ion batteries compared with all-vanadium flow batteries, the safety and recyclability of all-vanadium flow batteries are its biggest advantages in the field of energy storage. Therefore, the formation of a complete industrial chain from materials to applications of all-vanadium flow batteries is just around the corne.

2. Lithium Battery

Lithium battery is a kind of battery that uses lithium metal or lithium alloy as negative electrode material and uses non-aqueous electrolyte solution[1]. Lithium batteries that currently exist and are more common in the market can be mainly divided into two types: lithium-ion batteries and lithium metal batteries.

2.1 Lithium-Ion Battery

2.1.1 Introduction to Lithium-Ion Battery

Lithium-ion batteries generally refer to a type of rechargeable battery that uses lithium alloy metal oxide as the positive electrode material, graphite as the negative electrode material, and a non-aqueous electrolyte solution. The negative materials of lithium-ion batteries mainly include graphite and silicon-carbon negative electrodes.The working principle of lithium-ion battery.

2.1.2 The Working Principle of Lithium-Ion Battery

Lithium-ion batteries are different from general chemical power sources. The charging and discharging process is realized by the insertion and extraction of lithium ions in the positive and

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negative electrodes of the battery. When the battery is charged, the positive electrode releases lithium ions in the electrolyte, this process is deintercalation; the negative electrode absorbs lithium ions from the electrolyte, this process is intercalation[2]. (Take a lithium-ion battery with lithium iron phosphate as the cathode material and graphite as the anode material as an example):

Positive reaction:

$$LiFePO_4 \underset{discharge}{\overset{charge}{\rightleftharpoons}} Li_{1-xFePO_4} + xLi^+ + xe^-$$

Negative reaction:

$$xLi^+ + xe^- + 6C \underset{discharge}{\overset{charge}{\rightleftharpoons}} Li_xC_6$$

2.1.3 Advantages and Disadvantages of Lithium-Ion Batteries

Characteristics and analysis of lithium-ion batteries	
Harmless	Most of the materials needed are harmless substances and have little impact on the environment
Large capacity, high specific energy	he capacity is 3 times that of the equivalent nickel-chromium battery, and the specific energy is as high as 150W·h/k
Small size and light weight	In the case of storing the same energy, the weight of the battery is significantly lighter than other batteries
No battery memory effect	It can be charged at any time, but at the same time the performance of the battery will not be affected
Long lasting	During the charging and discharging process, the battery will not be damaged due to internal short circuit caused by the generation of dendritic lithium on the anode
Low self-discharge rate	The monthly self-discharge rate of lithium-ion batteries is only 6%-8%
Higher cost	The cathode material lithium iron phosphate mainly relies on imports, cobalt in lithium cobalt oxide is a rare metal, and 80% of my country's current

Fig.1 Advantages and disadvantages and analysis of lithium-ion batteries

2.1.4Application of Lithium-Ion Battery

lithium-ion batteries have attracted the attention of related researchers due to their excellent performance such as no memory effect, environmental friendliness and low self-discharge. The development of information electronic products, electric vehicles, and smart grids has created a huge demand for lithium-ion batteries (LIB) with high energy density, long cycle life and low cost[3].

2.2 Lithium Metal Battery

2.2.1 Introduction to Lithium Metal Battery

Lithium metal battery refers to a secondary battery that uses lithium metal or lithium alloy as the negative electrode and non-aqueous electrolyte[4].

2.2.2 Working Principle of Lithium Metal Battery

The principle of the discharge reaction is:

$$Li + MnO_2 = LiMnO_2$$

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2.2.3 Advantages and Disadvantages of Lithium Metal Batteries

Analysis of the advantages and disadvantages of lithium metal batteries	
High specific capacity of negative electrode	The theoretical specific capacity of the negative electrode is 10 times that of the graphite
Light weight, high energy	Can be used as a research direction for a new generation of energy storage technology
Large capacity	It can provide electricity for equipment that needs long-term power supply
Coulomb efficiency is low	The anode falls off the lithium metal precipitate during discharge (inactive)
Severe capacity decay	Cycle life will be limited during long cycles

Fig.2 Advantages and disadvantages and analysis of lithium metal batteries

2.2.4 Application of Lithium Metal Batteries

In the context of carbon neutrality, in recent years, due to the continuous exploration and innovation of the new energy automobile industry, lithium metal has the characteristics of light weight and high combustion temperature. Therefore, lithium metal batteries are widely used in the manufacturing industry of new energy automobile power batteries. use. Lithium metal batteries have the three characteristics of light weight, high energy, and long endurance. They are also widely used in fields with clear requirements for load weight and longer single endurance, such as electric aviation and industrial-grade drones.

3. All Vanadium Flow Battery

3.1 Introduction of All Vanadium Flow Battery

The all-vanadium flow battery is a redox battery that uses vanadium as an active material in a circulating liquid state. The vanadium-based redox battery was proposed in 1985. After two decades of exploration and research and development, today's vanadium battery technology has become increasingly mature. The all-vanadium flow battery is a new type of device that can convert electrical energy with high efficiency and is suitable for energy storage.

3.2 Working Principle of All Vanadium Redox Flow Battery

The electrical energy of the all-vanadium redox flow battery is stored in the sulfuric acid electrolyte of different valence vanadium ions (V^{2+} , V^{3+} , VO^{2+} or V^{4+} and VO_2^+ or V^{5+}) in the form of chemical energy. The working principle of vanadium batteries is to use vanadium ion solutions with high and low valence states as the active materials of the positive and negative electrodes, respectively, and store them in their respective electrolyte storage tanks. The active material electrolyte is stored in a storage tank[5]. When the battery is charged and discharged, the positive and negative electrolytes respectively undergo oxidation and reduction reactions on the surface of the electrodes to realize the charging and discharging of the battery[6]. The reaction formula of the vanadium redox flow battery is (To contain V^{2+}, V^{3+}, VO_2^+, VO^{2+} Four kinds of vanadium ions as an example):

Positive reaction during charging:

$$VO^{2+} + H_2O \rightarrow VO_2^+ + 2H^+ + e^-$$

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Positive reaction during discharge:

$$VO_2^+ + 2H^+ + e^- \rightarrow VO^{2+} + H_2O$$

Negative reaction during charging:

$$V^{3+} + e^- \rightarrow V^{2+}$$

The negative electrode reaction during discharge:

$$V^{2+} \rightarrow V^{3+} + e^-$$

3.3 Advantages and Disadvantages of All Vanadium Flow Batteries

All vanadium redox flow batteries are suitable for energy storage systems and fields, and have the following characteristics:

(1) Long cycle life: Because vanadium ions exist in the all-vanadium redox flow battery as an active material, this vanadium ion is stable in the liquid electrolyte. During the reaction of the all-vanadium redox flow battery, the active material Vanadium ions only have a certain change in the valence state, and there is no phase change, and the electrode material of the all-vanadium flow battery does not participate in the reaction, which makes the cycle life of the all-vanadium flow battery higher than other batteries better.

(2) Good charging and discharging characteristics: All vanadium redox flow batteries can realize instantaneous charging, deep charging and discharging, and the service life of the battery exists independently, and the performance of the service life will not be affected by the charging and discharging process. Each battery is single Existence, its uniformity will not be affected in any way.

(3) Environmentally friendly: Because the electrolyte solution of the all-vanadium redox flow battery is a renewable energy source and can be recycled, there are abundant sources of electrode materials, bipolar plate materials, current collector materials, and other materials in the stack, and The material is recyclable and has little impact on the environment. It is a "green battery".

3.4 Application of All Vanadium Redox Flow Batteries

In recent years, with the rapid development of the new energy automobile industry, the demand for energy storage batteries has greatly increased. As a kind of electrochemical energy storage, all-vanadium redox flow batteries have large capacity, high safety, and can achieve " Advantages such as "homeopathic charging" are favored by related industries at home and abroad. All vanadium redox flow batteries are very advantageous at home and abroad and have considerable development potential.

4. Conclusion

Through the comparative analysis of lithium-ion batteries and lithium metal batteries, which are widely used in lithium batteries, and all-vanadium flow batteries, it is found that lithium-ion batteries are more suitable when mobile phones and notebooks have restrictions on storage capacity and volume quality. ; When a large amount of electricity is needed and the battery size is not required, the all-vanadium flow battery is more suitable. The all-vanadium flow battery not only realizes large-capacity storage of electric energy, but also greatly reduces the cost of the battery, and can realize instantaneous charging.

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