Research Progress of Ternary System High Energy Storage Capacitors

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Abstract: As an important energy storage device, high energy storage capacitors have been widely used in electric vehicles, drones, new manufacturing of robots, wind power generation, smart grid and other energy fields. Among them, ternary system high energy storage capacitor has been widely concerned and studied because of its unique advantages. This paper summarizes the application prospect and the significance of research and development of high energy storage capacitors, introduces the basic principle and classification of high energy storage capacitors, and expounds the research status and existing problems of ternary system high energy storage capacitors. And the future development trend of ternary system high energy storage capacitors is briefly analyzed, and the main influencing factors and key nodes of research and development of ternary system high energy storage capacitors are summarized. As one of the important development directions in the field of energy storage and power transmission in the future, the main characteristics and broad application prospects of ternary system high energy storage capacitors are discussed and prospected. We look forward to greater breakthroughs in improving energy storage density, reducing costs, and improving charge and discharge speed and cycle life. At the same time, the emergence of new materials and manufacturing processes will also promote the further development and application of three-ring system high-energy storage capacitors.

Key words: Ternary System; Basic Principle; Existing Problems; Development Prospect

1. Introduction

As an important energy storage device, high energy storage capacitors have extremely important strategic significance in the fields of daily life, military and scientific and technological development. In the field of daily life, high energy storage capacitors are often used in smart home systems, which can store electrical energy and release it quickly when needed to provide a stable energy supply for smart home devices. In addition, in new energy vehicles, high energy storage capacitors also have important applications, which have the characteristics of fast charging and fast discharge, which can improve the performance of new energy vehicles, reduce energy consumption, and increase the driving range. In the military field, the role of high energy storage capacitors is particularly important [1]. For example, in laser weapons, high energy storage capacitors can be used as energy storage and release systems to provide enough energy for laser emission in a timely manner [2]. In addition, in equipment such as military radar, missiles and aircraft, high energy storage capacitors are also used to provide stable and efficient energy. High energy storage capacitors are also important in many other areas. For example, in the field of energy, high energy storage capacitors can solve the problem of uneven energy distribution. In the field of communication, high energy storage capacitors can provide a stable and efficient energy supply to ensure the normal operation of communication equipment. Similarly, high energy storage capacitors are also widely used in medical, national defense and other fields for energy supply such as instruments and weapons. At present, high energy storage capacitors have been widely used in electric vehicles, drones, new manufacturing of robots, wind power generation, smart grid and other energy fields. Among them, ternary system high energy storage capacitor has been widely concerned and studied because of its unique advantages.

2. Basic Principles and Classification of

High-Energy Energy Storage Capacitors

The basic principle of high energy storage capacitors is based on the physical process of electric field energy storage, in which the charge is stored by forming a double electric layer on the electrode surface. According to the different energy storage mechanism, high energy storage capacitors can be divided into two categories: double layer capacitors and Faraday fake capacitors [3]. Among them, the double electric layer capacitor mainly relies on the electrostatic adsorption on the electrode surface to store the charge, while the Faraday pseudo capacitor stores the charge through the redox reaction on the electrode surface. The double layer creates a potential difference between the electrode plate and the electrolyte, which stores a large amount of charge. The electrode materials of such high energy storage capacitors are usually materials with high specific surface area, high conductivity and good chemical stability, such as carbon fiber and graphene. These materials can provide a larger surface area and faster charge transfer speed, thereby improving the energy storage density and charge and discharge efficiency of the capacitor. Faraday pseudo capacitors use REDOX reactions on the electrode surface to store energy. In the process of rapid charge and discharge, electrons and ions on the electrode surface can be rapidly adsorbed and desorbed to form Faraday "quasi-capacitance". The capacitor has high energy density and fast charge and discharge speed, and is widely used in new energy vehicles and new power grids.

3. Research Status and Existing Problems of High Energy Storage Capacitor in Ternary System

Ternary system high energy storage capacitor refers to the capacitor composed of three kinds of materials, including electrode material, electrolyte and diaphragm, etc [4]. At present, the research of ternary system high energy storage capacitor mainly focuses on the selection of electrode materials, electrolyte design and the optimization of capacitor performance. Among them, the electrode material is the key, which directly affects the performance and cost of capacitors, carbon materials, metal oxides, etc., are currently commonly used electrode materials. At the same time, the design of the electrolyte is also very important, which directly affects the energy density and charge and discharge performance of the capacitor. Finally, the optimization of capacitor performance mainly involves the composite mode of electrode material and electrolyte, the preparation process of electrode layer and the packaging process of capacitor. Compared with traditional capacitors, it has higher energy density, faster charge and discharge speed, longer cycle life and higher reliability. Research status: First, in the academic research. At present, many academic institutions and universities at home and abroad are studying ternary system high energy storage capacitors. It mainly focuses on the synthesis of ternary materials, electrochemical performance research, energy storage mechanism and so on. These studies provide theoretical basis and technical support for the application of ternary system high energy storage capacitors. The second is in the experimental research. Many companies and laboratories are also conducting experimental research on ternary system high energy storage capacitors. It mainly focuses on the preparation of ternary materials, optimization of capacitor components, energy storage performance testing and so on. These experimental studies provide experimental basis and data support for the practical application of ternary system high energy storage capacitors. The third is applied research. In electric vehicles, smart grids, renewable energy and other fields, ternary system high energy storage capacitors are used to improve energy efficiency and reduce energy costs. These application studies provide practical experience and cases for the further promotion and application of ternary system high energy storage capacitors. Existing problems: Problems that need to be solved continuously and intensively include capacitors' capacity and safety issues, energy density and power density issues, cycle life issues, and environmental impact and cost issues.

4. The Development Trend and Prospect of High Energy Storage Capacitor in Ternary System

The development trend and prospect of ternary system high energy storage capacitor are very broad, in the future, the ternary system of high-energy storage capacitors will make

important progress in the following aspects:

First, the development and application of new electrode materials. New electrode materials will continue to emerge, such as new carbon materials, nano-metal oxides, conductive polymers and so on [5, 6]. The emergence of these new electrode materials will greatly improve the performance of capacitors and reduce the cost. Such as graphene and carbon nanotubes, with high electrical conductivity and good mechanical properties also allows it to maintain stable performance in a variety of working environments. The unique crystal structure and electronic characteristics of nano-metal oxides, such as cobalt oxide and nickel oxide, can greatly improve the electrochemical activity of the electrode, thereby improving the energy storage capacity of the capacitor. By adjusting the type and proportion of metal elements, its energy storage performance can be further optimized. Conductive polymers, such as polypyrrole and polyaniline, have excellent electrical conductivity and large area of conjugated π bonds, which have high electrochemical activity. Compared with other electrode materials, conductive polymers can provide higher electrochemical reaction speed and higher energy storage density. At the same time, they also have good processing performance and low cost, which makes them have great potential in commercial applications.

Second, the design and optimization of electrolyte: the design and optimization of electrolyte is an important way to improve the performance of high energy storage capacitor in ternary system [7]. In the future, the design of the electrolyte will focus more on improving the energy density, charge and discharge performance, and stability. Through repeated testing and verification and iteration, from the multi-disciplinary fields of material science, chemical engineering, physics and electrochemistry, comprehensive selection of more suitable materials, and according to the actual application needs, optimize the electrolyte structure, maintain the stability of the interface between the electrolyte and the electrode, continuously improve the mechanical strength of the electrolyte, and better ensure its safety and economy.

Third, integrated and modular design. In the future, ternary system high energy storage capacitors will pay more attention to integrated and modular design to improve the integration and reliability of capacitors. Integrated and modular design can also help reduce costs and improve production efficiency [8]. By organically combining multiple functional modules together, the miniaturization and lightweight of the device are realized. Precision process and material technology ensure the perfect fit between each unit, which can store more energy, increase energy storage density, and show unparalleled stability and reliability during operation. Even in extreme working environments, it can work stably for a long time to provide users with continuous and efficient energy storage services. When a module is faulty, you can quickly replace the faulty module to restore the normal running of the device and greatly improve the availability and reliability of the device.

Fourth, the application and development of intelligence. The ternary system high energy storage capacitor will be more widely used and developed in the smart grid, intelligent transportation and other fields. At the same time, the application and development of intelligence will also help to improve the safety and reliability of capacitors [9, 10]. For example, the active and reactive power in the power grid can be effectively balanced and adjusted to improve the stability and reliability of power supply. It is used to solve the unstable problem of solar and wind power generation and ensure the efficient use of energy. For example, as a supplement or alternative to the power battery of new energy vehicles, it significantly improves the driving range of electric vehicles, optimizes the acceleration performance, and lays the foundation for the popularity of electric vehicles. In the field of intelligent application by integrating sensors and controllers, real-time monitoring of capacitor operating status and working parameters. When there is an abnormal situation, it can give early warning and take appropriate control measures in time to prevent accidents or reduce the impact of accidents. At the same time, centralized monitoring and management of multiple capacitors can be achieved through remote monitoring and management system to ensure long-term safe and stable operation of capacitors.

5. Analysis of the Influencing Factors of the High Energy Storage in the Ternary System

First, the chemical composition. The three components in the ternary system determine its energy storage properties, such as the type and proportion of cathode materials, cathode materials and electrolyte. With rational chemical composition design, the electrochemical properties of ternary systems can be optimized with improved energy density and cycle life.

Second, the crystal structure. Each component of a ternary material has its own unique crystal structure, which can affect the electron conduction capacity of the material and the diffusion coefficient of lithium ions. Reasonable crystal structure design can improve the conductivity of the material, reduce the diffusion resistance of lithium ions, and thus improve the energy storage performance of the ternary system.

Third, the particle morphology and size. The particle morphology and size of ternary materials can also affect their energy storage performance. Irregular particle morphology, wide particle size distribution, or excessive particles can lead to decreased electrochemical performance of materials [11]. Therefore, the optimization and control of the preparation process is essential to obtain the ideal particle morphology and size.

Fourth, the interfacial properties. The interface properties between different components in the ternary system also have an important impact on their energy storage performance. Good interfacial compatibility and stability can reduce interfacial resistance and increase energy efficiency and cycle life of ternary system [12].

Fifth, the temperature and the pressure. Temperature and pressure are also important factors affecting the high energy storage of the ternary system. The electrochemical properties of the ternary system may change under high temperature or high pressure environment, so the working temperature and pressure range need to be reasonably selected and controlled [13].

Sixth, battery management system. The battery management system can monitor the status of the battery in real time, which plays an important role in ensuring the safety, stability and long-term use of the battery [14].

Seventh, the application scenario. Different application scenarios have different requirements for high energy storage in the ternary system. For example, the key pain points of current electric vehicles are battery life, safety and range, and energy storage stations can solve all three problems at the same time [15, 16]. Therefore, reasonable battery design and optimization for different application scenarios is necessary.

6. Conclusions

At present, the research and development of global supercapacitors is mainly concentrated in the United States, China, Japan and South Korea. The vast majority of manufacturers are mainly small capacitors below 100F. Large capacitors (above 1000F) used in rail transit, electric vehicles and power grid are mainly concentrated in China, except for the US Maxwell, but the technical level is uneven. In 2016, the Ministry of Industry and Information Technology issued the "Industrial Strong Foundation 2016 Special Action Implementation Plan" pointed out that the core basic components (components) focus on supporting the robot "three major components", high-end sensors, high-end medical equipment components, supercapacitors, high-speed optical communication devices, industrial basic software and other aspects. The following year, the Chinese government issued the "Guiding Opinions on Promoting the Development of Energy Storage Technology and Industry", which clarified the significance, overall requirements, key tasks and safeguard measures for promoting the development of energy storage technology and industry in China; It is also pointed out that a batch of energy storage technologies with industrialization potential and new molten salt heat storage devices with large capacity have been demonstrated in the experiment, which can be applied to smart grid and distributed power generation supercapacitor power quality regulation system. In addition, the Comprehensive Department of the National Energy Administration issued the "25 Key Requirements for Preventing Power Production Accidents (2022 version) (draft for comment)", which requires large and medium-sized electrochemical energy storage power stations to use ternary lithium batteries, sodium-sulfur batteries and power batteries to prevent fire accidents; Safety evaluation

should be based on traceability data.

The ternary system high-energy storage technology is still in the stage of research and development, and some technical and safety problems still need to be solved. In addition, due to the different reaction mechanisms and characteristics of different elements, the applicable scenarios and advantages of high energy storage of each ternary system are also different. Therefore, in the field of technical research should be carried out according to the actual situation.

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