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Application of Graphene and Its Composite Materials in Lithium Batteries

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Abstract:

With the continuous development of lithium battery technology, the exploration of new lithium battery materials to improve battery performance has become a scientific research hot spot. This paper studies the application of graphene in lithium batteries and the advantages of the application of graphene in the future application of graphene in the battery outlook, the main purpose of this research is to find a safer, faster, higher energy density of the battery, for the future application of the battery to do the foundation. Currently, graphene has been used in flexible electrodes, transparent electrodes, organic field effect transistors and so on. The research and application of graphene and its composite materials have a broad prospect, but still need to overcome some technical and cost challenges, as well as many difficulties in application, with the deepening of the research and technological advances, graphene will play an increasingly important role in a number of fields.

Keywords: Graphene application; lithium batteries; graphene electrode

1. Introduction

In the current era of continuous development of lithium battery technology, exploring new lithium battery materials to improve battery performance has become a hot research topic. At present, materials have been widely used in various fields such as new energy vehicles, aerospace, and flexible materials, although they meet the current market requirements to a certain extent. However, there are still limitations in terms of safety, energy density, and other aspects. So, this article investigates the preparation methods of graphene materials, their applications in electrodes, lithium batteries, and prospects for future graphene applications in batteries. The main purpose of this study is to search for electrode materials that are safer and have higher energy density. And by studying the application of graphene and its composite materials in lithium batteries, this paper aim to improve the energy density and safety of the batteries, providing theoretical guidance for further harnessing the excellent performance of graphene.

2. Preparation Methods of Graphene Composite Materials

2.1 In-situ polymerization Method

In situ polymerization refers to the process of adding

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reaction monomers and catalysts together into a dispersed or continuous phase, gradually polymerizing the monomers and depositing them on the surface of the dispersed phase, ultimately forming an ideal composite material. In situ polymerization is a commonly used method for preparing graphene composite materials, and its advantage is that graphene can be uniformly dispersed in the polymer matrix under the interaction between various functional groups. However, due to the complex operation and low yield of this method, it is difficult to apply it to large-scale production, so its production and application are also subject to certain limitations[1].

2.2 Solution Blending

The solution blending method mainly disperses graphene in a suitable solvent to achieve mutual solubility with polymer fillers, and after the solvent evaporates, achieves layer self-assembly to form interlayer polymers of graphene oxide polymer composite materials. This method has multiple advantages such as simple operation and easy control of components, and is widely used in the preparation process of graphene composite materials[2]

2.3 Melt Blending Method

The melt blending method refers to the use of shear force to fully mix graphene with the matrix in a molten state, and then evenly distribute it in the matrix. At present, melt blending is one of the most commonly used methods for preparing graphene polymer composites in industry, especially in the preparation of thermoplastic graphene polymer composites. It does not require any solvents or catalysts during the preparation process and has good environmental friendliness. However, due to various factors such as barrel temperature and screw speed during the mixing process, the mixing effect is weaker than that of in-situ polymerization and solution blending methods [3].

3. Application of Graphene in Electrodes

3.1 Supercapacitor Electrode

Graphene is considered an ideal material for supercapacitor electrodes due to its high specific surface area, high conductivity, and chemical stability. The energy storage density of graphene supercapacitors developed in the laboratory has approached the level of lead-acid batteries. The three-dimensional porous graphene film prepared by high-energy beam induction technology has achieved covalent growth of macroscopic electrodes, significantly improving the interlayer conductivity. For example, in electric vehicles and renewable energy, portable electronic devices, lead-acid batteries, etc., the development and application of supercapacitor technology is the result of the joint efforts of many researchers and enterprises. In the automotive field, supercapacitors are highly valued for their fast charging and discharging capabilities and high power, and they also play an important role in renewable energy storage. Ensure the stability of energy supply and improve energy utilization efficiency. With the advancement and development of technology, there is an increasing demand for miniaturized and high-performance energy storage devices. Supercapacitors are highly valued for their high-speed power, high energy density, and fast charging and discharging. For example, Professor Yang Zhao from the School of Chemistry and Chemical Engineering at Beijing Institute of Technology and Professor Liangti Qu from the Department of Chemistry at Tsinghua University have collaborated to develop a miniature supercapacitor that seamlessly connects with wireless charging coils, providing non-contact charging for wearable electronic devices [4].

3.2 Transparent Electrode

Graphene, as a core component in optoelectronic devices such as light-emitting diodes (LEDs), liquid crystal displays (LCDs), and organic solar cells, requires high transmittance and low surface impedance at 550nm. The high electronic conductivity and ideal capacitive energy storage properties of graphene make it promising for constructing high-performance transparent conductive films. Graphene is considered a promising material for manufacturing transparent electrodes due to its excellent conductivity and transparency. In 2009, Li et al. developed a new solar cell structure that uses graphene as the anode and combines it with silicon semiconductors to form a graphene silicon Schottky junction solar cell structure. With the discovery of graphene. Researchers have begun to explore its application in transparent electrodes[5]. Peternal, Blanke, and others successfully prepared liquid crystal displays using graphene as a transparent electrode, demonstrating the potential of graphene in display technology.

3.3 Organic Field Effect Transistor (OFET)

The high carrier mobility and excellent electrode semiconductor contact characteristics of graphene make it an excellent material for electrodes in organic field-effect transistors. Researchers have explored methods for preparing patterned graphene and demonstrated its performance advantages by applying it to OFET electrodes. For example, high flexibility PFETs and graphene OFETs are ideal materials. Graphene thin films prepared by chemical vapor deposition are used as the active layer of PFETs, achieving high conductivity and good mechanical stability. Graphene based OFETs have shown great potential in the field of sensors due to their high sensitivity and fast response time. For example, graphene OFET can be used to detect environmental pollutants, chemicals, and even biomolecules[6].

4. The Application Advantages of Graphene and its Composite Materials in Lithium Batteries

4.1 Improve the Energy Density of Batteries

Graphene has excellent conductivity and mechanical properties. By compounding with silicon and other high-capacity anode materials, it can effectively improve the energy density of lithium-ion batteries and meet the market demand for high-energy batteries. Liu zhaoping team of Ningbo Institute of materials technology and engineering, Chinese Academy of Sciences developed a kind of self mechanical inhibition graphene composite silicon carbon anode material, which effectively inhibited the volume expansion of silicon-based anode material in the process of charge and discharge, and improved the cycle stability and energy density of the battery[7].

4.2 Improve Battery Safety

The mechanical strength and flexibility of graphene help to improve the structural stability of the battery and reduce the potential safety hazards caused by physical damage. Researchers at Swansea University have developed a defect free graphene current collector. This graphene foil has excellent thermal conductivity and durability, which can significantly reduce the risk of thermal runaway, thereby improving the safety and performance of the battery. Researchers from Ningbo Institute of materials technology and engineering, Chinese Academy of sciences have developed graphene composite silicon carbon anode material, which not only improves the energy density of the battery, but also helps to improve the safety of the battery. Graphene fluid collector can provide an effective heat transfer path and avoid heat concentration inside the battery by rapidly emitting heat, so as to prevent the occurrence of thermal runaway. These studies show that graphene has many applications in improving the safety of batteries, including improving thermal management, enhancing the performance of electrode materials, developing new battery materials and improving the mechanical properties of batteries. With the in-depth research, graphene is expected to play a greater role in the future battery technology.

4.3 Improve the Charge and Discharge Rate of the Battery

The high conductivity of graphene helps to improve the charge and discharge rate of battery and realize rapid charging. In the cathode material, graphene can be used as a conductive additive to improve the electron transfer rate. Graphene can be used as a conductive additive to improve the charge discharge rate of batteries. For example, liuzhaoping team from Ningbo Institute of materials technology and engineering, Chinese Academy of Sciences developed a self mechanically inhibited graphene composite silicon carbon anode material, which effectively improved the cycle stability and charge discharge rate of the battery[7]. Graphene can be combined with silicon and other materials to prepare lithium-ion battery anode materials with high specific capacity and good cycle stability. This composite material can significantly improve the charging speed and energy density of the battery. Researchers at Rensselaer Institute of technology in the United States treated graphene paper with the flash of laser or camera flash to expand the internal structure spacing, thus providing more electrolyte channels, and achieving a charge and discharge rate 10 times faster than that of traditional lithium-ion batteries

4.4 Optimize Battery Thermal Management

Graphene has excellent thermal conductivity, which can be used to study the problem of heat dissipation when the battery is working and improve the thermal management of the battery. The high thermal conductivity of graphene makes it an ideal choice for the preparation of efficient thermal management materials. Graphene films prepared by chemical vapor deposition (CVD) and other methods can be used as thermal management materials for lithium-ion batteries, which can effectively improve the thermal conductivity and heat dissipation performance of batteries. Graphene and phase change material (PCM) can be combined to prepare composite materials with high thermal conductivity for thermal management of batteries. This composite material can absorb and store heat when the battery generates a large amount of heat, so as to maintain the stability of the battery temperature. It is found that the thermal conductivity of graphene film is related to the transverse size of the raw material. Large size raw materials are conducive to improving the thermal conductivity, because there are fewer interfaces between the raw materials, which is conducive to heat transport. Through these methods, graphene can not only improve the thermal management efficiency of the battery, but also

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improve the performance and safety of the battery. With the in-depth research, graphene will be more widely used in the field of battery thermal management.

5. Application Prospect of Graphene

5.1 Energy Sector

The application of graphene in lithium-ion batteries can improve the energy density, charge discharge rate and cycle stability. In addition, the high thermal conductivity of graphene helps to improve the thermal management of batteries. Graphene can be used as a conductive additive for lithium-ion batteries to improve the charging and discharging speed and cycle performance of batteries. Research shows that the lithium-ion battery with graphene can be charged to 89% in less than 3 minutes, and its service life is about twice that of ordinary lithium batteries. Because of its high specific surface area and conductivity, graphene supercapacitor can provide high power output, which is suitable for occasions requiring rapid charge and discharge, such as wearable electronic devices, communications, rail transit, etc. Graphene can be used as a catalyst for fuel cells to improve the efficiency and stability of oxygen reduction reaction, and has the potential to replace expensive platinum based catalysts

5.2 Flexible Electronics

The flexibility and transparent conductivity of graphene make it an ideal material for flexible display, wearable devices and electronic skin applications. Graphene can be used to manufacture flexible displays, such as flexible electronic screens, which will provide more possibilities for the design of wearable devices and flexible electronic devices. Graphene is also widely used in flexible batteries and supercapacitors, providing high energy storage performance and good mechanical stability, which is particularly important for wearable devices and portable electronic devices. The high thermal conductivity of graphene has potential application in the thermal management of flexible electronic equipment, which can effectively disperse the heat generated by batteries and other electronic components, and improve the safety and performance of the equipment.

5.3 Automobile Industry

Graphene composites can be used in the manufacture of new energy vehicles to achieve the safety of batteries, improve the service life, energy density and performance of batteries. Graphene can significantly improve the energy storage capacity and charging speed of batteries. For example, the graphene polymer battery developed by graphenano in cooperation with the University of corvado has three times the power storage capacity of the best product on the market[8]. The electric vehicle can travel up to 1000 kilometers, and the charging time is less than 8 minutes. The high strength and low density of graphene make it an ideal material for automotive lightweight, which helps to improve fuel efficiency and reduce emissions. Graphene has potential applications in automotive circuits and electronic equipment due to its high carrier mobility and high frequency operation ability, and may become an alternative material for silicon. Graphene semiconductor materials can be used to manufacture infrared sensors on the front windshield of automobiles, providing night vision function and enhancing driving safety at night.

6. Conclusion

The application of graphene in lithium-ion batteries is not only limited to the negative electrode material, but also can be used as the conductive additive of the positive electrode material to form a continuous three-dimensional conductive network, which can effectively improve the electronic and ion transport capacity of the composite material. The microstructure of graphene and its composites has a significant impact on the performance of the battery. For example, energy, flexible electronics, automotive, sensors and new energy

Graphene has high conductivity, large specific surface area and high chemical stability due to its unique structure of single atomic layer thickness and excellent electrical, thermal and mechanical properties. These characteristics make it show great potential in the application of lithium-ion battery materials. In the automotive industry, the application prospects of graphene composites include manufacturing lightweight materials, improving battery performance, and improving thermal management. The high strength and light weight characteristics of graphene help to improve the fuel efficiency and performance of vehicles. At the same time, its application in battery technology can significantly improve the range and charging speed of electric vehicles. In the field of flexible electronics, graphene is an ideal material for manufacturing flexible electronic devices due to its flexibility and conductivity. Researchers predict that graphene composites will be widely used in flexible displays, wearable devices, flexible sensors and other fields in the next few years.

In general, graphene and its composites have broad prospects for research and application, but some technical and cost challenges still need to be overcome. With the in-depth research and technological progress, graphene is expected to play an increasingly important role in many fields.

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