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Research progress of graphene in the positive and negative electrodes of lithium-ion batteries

Hongbo Ma

School Ulink College, Shenzhen, 518000, China

honma2564@ulinkcollege.com

Abstract:
With the use of lithium-ion batteries in electric vehicles and portable electronic devices by the majority of users, how to improve their functional performance has become the focus of the research object of researchers. Graphene is widely considered valuable as an innovative carbon-based material because of its excellent conductivity, high surface area ratio and significant mechanical endurance, and it has been gradually selected as the preferred material for lithium-ion batteries in terms of positive and negative electrodes. This research paper summarizes the latest research trend of graphene in the positive and negative electrodes of lithium-ion batteries, and further deepens the exploration of its production method, optimization measures and its impact on battery performance. With the addition of graphene, lithium-ion batteries are significantly enhanced in their energy density, cycle stability, and the speed of charging and discharging. Although graphene's basic materials are practical, we still have to face various practical challenges, such as reducing costs and performing mass production. This study estimates the huge potential of graphene in the lithium-ion battery industry and highlights its profound impact on improving battery performance.

Keywords: graphene; lithium-ion battery; cathode material; cathode material.

1.Introduction

1.1 Research Background

Due to the key of its core storage technology, lithium ion battery has shown broad application potential in various industries such as electric vehicles, wearable tools and portable electronic products. While the current lithium-ion battery cluster still shows many problems in key areas such as energy density, battery life, and charging efficiency, they are all looking for new breakthroughs in new materials and technologies. Due to its excellent conductance characteristics, good heat transfer characteristics, high degree of mechanical endurance and large specific surface area, it provides a new research direction for the perfor-

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mance of lithium-ion batteries.

1.2 Study significance

Graphene has superior electrical conductivity, effectively reducing the battery resistance and accelerating the current propagation, which helps to improve the performance of batteries during charging and discharge. With excellent energy density, flexibility and mechanical stability, these materials not only ensure that the electrode structure remains stable during charge and discharge, but also prevent the expansion and powder of the material resulting in reduced battery capacity. The high-speed electron migration in graphene facilitates the rapid release of lithium ions, which further improves the charging efficiency of batteries and meets the urgent need of modern machines for rapid charging. The development of graphene composites is expected to effectively reduce the use of precious metals and rare materials, and reduce the cost of battery manufacturing.

2.Overview of graphene materials

2.1 Basic properties

Graphene, the raw material of the two-dimensional structure, has won wide attention from international scientific research because of its unique properties, and has been praised as a substance with great transformative potential. Most scientists hold the view that graphene, which has the same level of hardness as diamonds, is even more robust than diamond. The unique material is made of a carbon atom in a hexagonal crystal, just about 0.335 nm thick, or about 10,000 parts of the entire hair. Not only that, but graphene is millions of times as strong as high-quality steel. Not only does graphene show excellent flexibility and malleability, but they have similarities to rubber, are highly adaptable to the external pressure environment, and have high fracture resistance. Graphene has revealed great potential application opportunities in the field of materials science because of its excellent combination of hardness and flexibility. Graphene has received wide public attention and affection in terms of its electric and thermal conductivity. Because graphene has excellent mechanical properties, it has been widely used in the manufacturing of electronic products in low temperature environments. These materials have an electronic mobility higher than 15000cm2 / Vs, and its resistivity is only 10 ^ -8 Ω m. This unique performance makes it one of the best performance of all existing conductive materials, with significantly better conductivity compared with copper and silver.

2.2 Preparation method

In the process of production, physical means are mainly directly decomposed or transformed into precursor substances containing carbon through external forces. Relatively, chemical means involves chemical reactions such as REDOX and chemical solid precipitation. Each strategy has its own advantages and disadvantages, sufficient to adapt to different application environments and research needs.

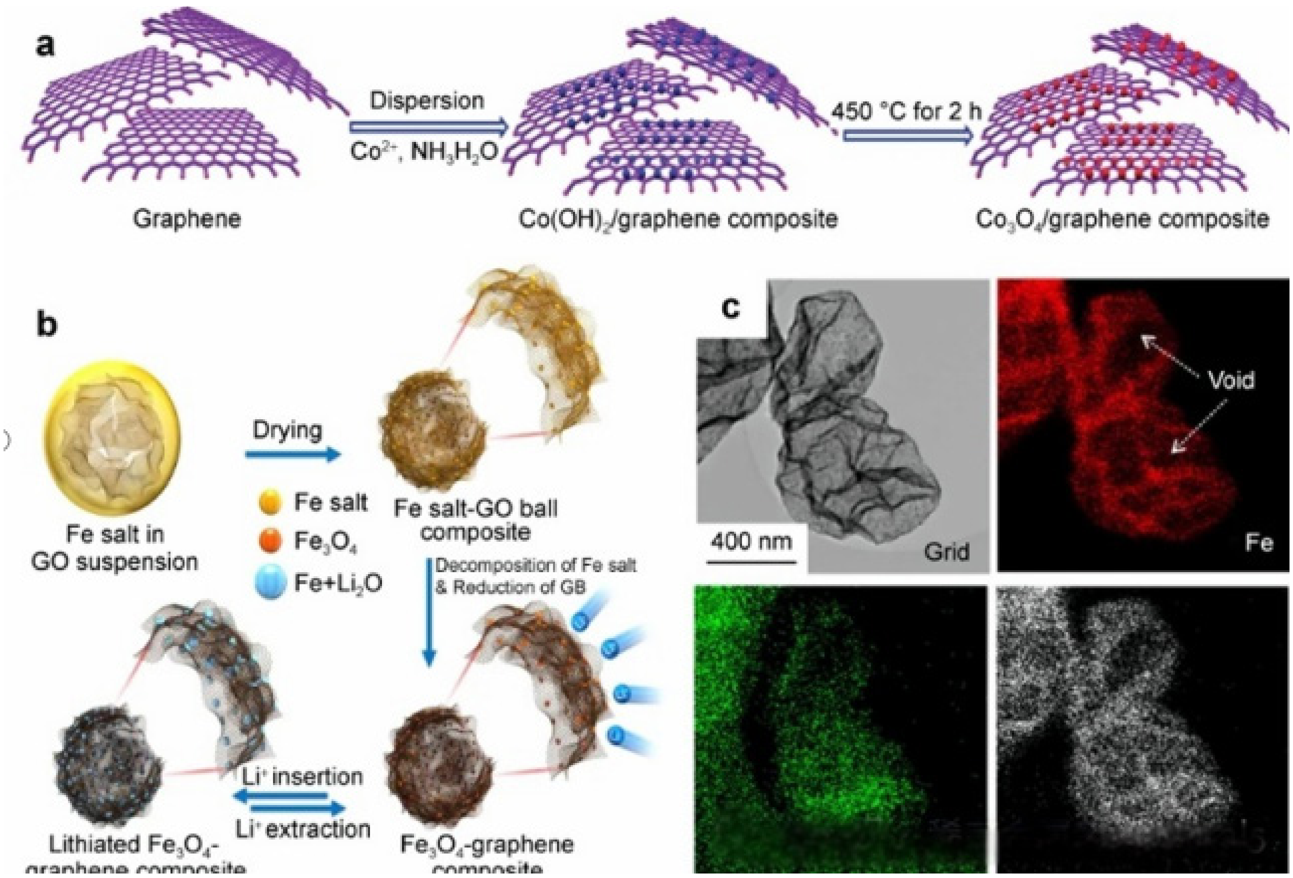

Figure 2-2 Production process flow chart

3.Research progress of graphene in cathode materials of lithium-ion batteries

3.1 Positide material requirements and challenges

Graphene and carbon nanotubes are the most commonly used carbon-based anode materials, but they are prone to oxidation during electrochemical processes, which can lead to disadvantages such as rapid capacity decay. Therefore, how to further improve its ratio characteristics has become a current research hotspot. LiNiO2kLLiCOO2 It has a relatively low production cost, and its performance is comparable to LiC OO. However, due to its complex production process, it is difficult to carry out large-scale production activities. Therefore, how to solve the problems arising in the charging and discharging process of graphene and carbon nanotube electrode materials is very important. In order to enhance its conductive characteristics, doping and coating techniques are mainly used. Among them, the doping technology is one of the most common methods, while the coating technology can significantly improve its tolerance to overload, and enhance its stability to heat. We present two common means of modification, using different kinds of transition metal ion doping and using conductive polymers to improve their conductivity, and compare their respective advantages and disadvantages. LiMnO, which has 10S / cm electronic conductivity, is not only cheaper than LiNiO2. In addition, LiMnO is excellent for overcharge safety, but it has relatively small storage capacity. The structural instability of the manganese ion (M1 “ 1) may cause its dissolution in the electrolyte when charging and discharging, which is a thorny problem. Compared with power lithium-ion batteries, lFOCUSE mainly uses lithium iron phosphate (LiFePO) as the cathode material. In addition, there are other cathode materials, such as Lil1V2 (PO) 3, which has a higher operating voltage and electronic conductivity of 2.4X10 per S / cm than LiFePO. In the process of use, Lil1V2 (PO) 3 itself has a good stability, so it can also be used as an electrolyte additive for the electrolyte system of lithium ion batteries. Such materials have a relatively low conductivity, which usually affects the capacity of lithium-ion batteries. Therefore, in order to improve the electrochemical performance of lithium-ion batteries, it

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has now become very common to use electronic conductive agents as a simple method. Conducting polymers have received much attention due to their excellent electrical properties. Among various electrode materials, graphene has become one of the most popular electrode materials because of its excellent electrical conductivity, large specific surface area and strong mechanical strength.

3.2 Graphene application strategy

Application strategies for graphene can be developed around their superior physical and chemical properties. First of all, graphene's high strength, high thermal conductivity and excellent light transmittance should be fully utilized to promote its applications in high-end manufacturing industries, such as aerospace, defense equipment and electronic devices. In view of the difficult processing capacity and production cost of graphene, we should strengthen technology research and development, optimize the production process, reduce costs and improve the production efficiency. At the same time, actively develop graphene composite materials to further improve the comprehensive performance and application value of graphene by combining with other materials. Graphene also shows great potential in energy, biomedicine, environmental protection and other fields. Therefore, the application research of graphene in these fields should be promoted to develop more products and technologies of practical application value. Strengthen industry-university-research cooperation and establish a graphene industrial innovation system.

3.3 Research results and case analysis

In January 2014, Changzhou Sixth Element Material Technology Co., Ltd. was successfully listed on the New Third Board. This major event confirmed that the company is not only the first listed company in Jiangsu province, but also the second NEEQ company in China to enter the graphene-related fields. At present, Changzhou Six Elements Company is striving to become a giant of the global graphene industry into —— science and technology industrial park in West Taihu Lake[1]. The West Taihu Lake Science and Technology Industrial Park has established the Jiangnan Graphene Research Institute, China's top graphene research center, which has successfully attracted the attention of three major graphene innovation organizations and 19 enterprises. At the present stage, the scale of this industry has exceeded the milestone of 1 billion yuan. Our information shows that China has established a number of scientific research and higher education institutions, including the Chinese Academy of Research Sciences, which are mainly committed to the research and development of graphene, and have successfully developed a set of key technology products with independent intellectual property rights. Graphene films and their related applications have been officially rated as important national technological innovation projects. The data reveal that China's investment in graphene and its related fields has reached an impressive scale. This situation is closely related to the national strategic objectives and China's existing resources and environmental conditions. Within the industry scope of graphene in China, graphene-based materials are undoubtedly one of the most influential and representative material categories. The technology has achieved remarkable success in scientific research, research and development, and in real-world applications, and is gradually moving toward industrialization and spread to a wider range. China's leading position in the research and expansion of graphene is not only because of its huge share in the global market, but more importantly, its large amount of resources and investment, which has brought great changes and improvements to China in the global economy. The positive electrode composite material of graphene and lithium battery has been widely adopted in many industries, and has demonstrated excellent application performance. In the electric vehicle industry, those lithium-ion batteries made using graphene combined with cathode materials show stronger energy efficiency and higher power recovery rate, bringing a huge improvement in the endurance and user experience of electric vehicles. In energy storage systems, graphene lithium batteries have been widely adopted in mobile electronic devices and in mobile electronic devices and unmanned drones.

3.4 Existing problems and solutions

Although graphene lithium batteries show many advantages, they still face a series of problems that need to be solved. The first thing is to face the challenge of the capacity reduction in the long cycle operation, we must adjust the structure of the cathode material and ensure the interface stability to achieve this goal. In addition, the battery has a high multiplier characteristic, which is limited by its conductive ability. However, the distribution and connectivity patterns of graphene in cathode materials can be optimized and improved with more refined strategies. Further, the overall economic benefits of the battery may be affected by its relatively short service cycle[2]. Therefore, the attenuation mechanism of cathode materials and the development of more stable solutions and technologies. The promotion of graphene lithium batteries faces high costs. To reduce this economic burden, the main strategy is to implement mass production, technological innovation, and optimize supply chain management.

4. Research progress of graphene in the anode materials of lithium-ion batteries

4.1 Characteristics and requirements of cathode materials

The properties of the cathode material used in lithium-ion batteries will directly determine the storage capacity, cycle stability, the rate of charging and discharge, and the overall safety status. The ideal cathode material should have excellent reversible characteristics of lithium ion embedding and release, outstanding electron and ion conduction ability, and should have excellent mechanical stability and chemical stability. When preparing cathode materials, there is a process that is considered simple and monitored, which not only reduces costs, but also ensures that the material is friendly to the external environment. Its unique design and excellent conductive properties provide a broad opportunity for research and innovation of lithium-ion battery cathode materials. The large specific surface area and excellent conductance properties of graphene can significantly improve the efficiency of cathode matter in charge exchange. In addition, the flexibility and chemical stability of the battery can help to further strengthen its functional cycle and ensure safety for use[3]. By using scientific and rational design methods, such as mixing graphene with high-capacity materials such as silicon and tin bases, we can more effectively balance the energy consumption of the battery with its reuse period.

4.2 Application of graphene in the negative electrode

1. About the use of graphene as a negative material: although pure graphene in some practical applications show excellent performance, but considering the overlap between π - π, may lead to material reunion and lithium ion embedded have negative effect, this means that only use graphene as a negative material is not necessarily the optimal option. To some extent, these challenges can be partially addressed with sophisticated optimization of production processes and improved surface characteristics.
2. Graphene composites research is an area of focus, and the team chose to combine graphene with other materials (such as silicon, tin and carbon nanotubes) to maximize the advantages of graphene while overcoming its inherent shortcomings. The composites consider the efficient conductivity of graphene, its extensive surface adsorption capacity, and thus demonstrate their excellent electrochemical properties. Taking the composite material of silicon and graphene as an example, the buffer characteristics of graphene to successfully limit the expansion behavior of silicon volume, thus improving the cycle stability of silicon-based anode material; the hybrid material of graphene and carbon nanotubes significantly improves the amplification performance of the battery by constructing a three-dimensional electronic navigation network.
3. Graphene can not only be selected as a conductive additive or as a surface coating. Adding graphene to the cathode material or covering a special layer of the material in the outer layer can not only increase the electrical conductivity of the cathode material. This application strategy does not only make the production process simpler, but also advances in reducing costs.

4.3 Research progress and case analysis

Mangn compounds have been widely studied due to their excellent electrochemical properties. They have an extremely high Li storage capacity. For example, lithium manganese oxygen compound is one of the most successful cathode materials for high energy density lithium-ion batteries[4]. Among many metal oxides, ferric oxide (Fe2O) has attracted the attention of many researchers and manufacturers due to its high theoretical capacity (924 mAh / g), low cost and low impact on the environment. Because ferrite has a large specific surface area and good electrical conductivity, it is widely used in various energy storage devices. However, FeO has a very poor cyclic charge-discharge performance in lithium-ion batteries as a cathode material. This is because when lithium ions are embedded or unembedded, there is a large volume expansion, accompanied by a large degree of contraction, and this contraction will cause severe stress concentration inside the electrode. This is because of the agglomeration of Fe2O during lithium ion insertion / unembedding and the large volume change in jfDcHsIada. To solve this problem, it is often used to add conductive agents or use other additives to inhibit this phenomenon. A proven strategy is to coat the Fe2O surface with carbon-based material to slow its volume expansion, and subsequently enhancing the electrochemical representation of Fe2O. This method usually requires the addition of large amounts of binders to achieve, and the use of binders reduces the conductivity of carbon-graphene composites, limiting their practical applications. According to the relevant literature, many graphene fund oxide materials have been reported as cathode materials for lithium ion batteries, such as Fe2O3, three iron oxide (Fe3O4), titanium oxide (TiO2), tin oxide (SnO), cobalt trioxide (C03O4) and manganese trioxide (Mn3O4). It is reported that the Fe2O3 / graphene composite prepared by hydrothermal method shows higher re-

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versible capacity (660 mAh / g, 100 cycles of charge and discharge at a current density of 160 mA / g) and higher multiplier performance, and its cycle performance is significantly better than FeO and graphene electrodes. In this paper, a new composite nanoparticle. In the prepared composite of stripped GO / FeO, the Fe3O4 particles were adhered uniformly to the GO surface. Due to its unique structural characteristics, it can provide a good electron transmission channel, improve the embedding and stripping ability of lithium ions in it, but also has a large specific surface area and good electrical conductivity.

4.4 Challenges and future trends

The complexes composed of graphene and silicon have begun to be used in various ways. When silicon is used as a negative electrode material, its theoretical specific capacity shows a very high value, which is obviously beyond the material properties of traditional graphite. However, due to the obvious volume expansion effect of silicon, this disadvantage has limited its widespread use in commercial situations. Graphene has the ability to combine with silicon nanoparticles, such a hybrid mode that helps to slow down the volume change of silicon during charging and discharging, thus ensuring the stability of the electrode structure, and ultimately increasing the service life of the battery and improving its operating safety. Experimental studies have found that the complex maintains a high volume ratio and exhibits excellent electrochemical performance. This case not only highlights the great possibility of graphene to enhance the anode composition characteristics of lithium-ion batteries, but also points out a new direction for the development of high-efficiency lithium-ion batteries.

5. Conclusion and outlook

Significant breakthrough progress has been achieved in the research field of positive and negative electrode materials for lithium-ion batteries. In positive electrode applications, graphene not only acts as a conductive enhancer or coating, which significantly improves the effect of the material on electronic transmission and the stability of the structure, but also enhances the energy concentration and recycling characteristics of batteries[5]. In the field of negative electrode research, the graphene complex has significantly enhanced the cycle stability and multiple amplification ability of the negative electrode material in reducing the volume expansion and strengthening the migration speed of lithium ions. In the application of lithium-ion batteries, the efficient use of graphene as a basic component is largely due to the continuous progress and improvement of its preparation technology. Even so, high costs and mass production remain a continuing challenge.

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