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Preparation and energy storage performance of nanostructured CuO-based composites

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Abstract

With the growing number of wearable electronics, various flexible electronics are emerging. Therefore, the development of high-capacity, flexible electrode materials has become an important topic of research at home and abroad. Due to its high theoretical specific capacity (674 mAh/g), non-toxicity, and low cost, CuO is expected to become a new cathode material for lithium-ion batteries.

Keywords

CuO, Cu-MOF, ZnO, anode materials, flexible lithium-ion batteries

Introduction

After entering the 21st century, due to the rapid growth of the world's population and the rapid development of the world economy, people's requirements for materials are getting higher and higher. Energy generation, transportation (electric bicycles, electric vehicles), etc. all rely on fossil energy for power generation, Vehicles such as electric bicycles and electric vehicles have greatly improved people's basic necessities of life. Therefore, we urgently need to find a new, sustainable and non-polluting new energy source to meet this current demand [1-3].

1. Significance and status quo of the preparation and energy storage performance of nanostructured CuO-based composites

(1) Significance of developing the preparation and energy storage performance of nanostructured CuO-based composites

Under such circumstances, a sustainable low-carbon society has become an inevitable trend of social development, providing a strong guarantee for the long-term development of a country. Renewable energy sources such as solar energy, wind energy, and bioenergy have been developed and applied by more and more scientists because of their easy availability and renewability. However, compared with traditional fossil energy, most renewable resources have certain time and space limitations, and are intermittent and non-exclusive, so they cannot be used directly in the power system. In order to make full use of renewable energy, researchers have proposed the method of "save first and divide later". Therefore, the development of efficient and environmentally friendly devices to store and convert this renewable energy is a high priority [4-5].

(2) Development of nanostructured CuO-based composite materials and the status quo of energy storage performance

Chemical energy such as lead-acid batteries, lithium-ion batteries, and supercapacitors can be stored as chemical energy, and the stored chemical energy can be converted into electrical energy in a reversible way to redistribute energy. It can not only maximize the role of electricity, that is, effectively convert and store unused energy when the electricity is at a low ebb, and release it during peak hours to prevent problems such as energy shortages during peak hours, and at the same time It can also effectively reduce the pollution to the environment [6-8]. Therefore, the energy storage device can be used as a new type of electrochemical storage device, which can effectively reduce environmental pollution and improve people's quality of life. At present, lithium-ion batteries and supercapacitors (EDLC) are the most researched and widely used at home and abroad. The physical adsorption and desorption process of supercapacitor is its biggest advantage, but the specific surface area of its electrode surface is too small, making its energy density very low. Despite its high power density and long service life, it still cannot meet the requirements of high energy density electric vehicles. Compared with traditional supercapacitors, the Faraday reaction of lithium-ion batteries can achieve high energy density, which meets the current energy needs. It has many advantages such as high energy density, small self-discharge, and environmental friendliness in the field of energy storage. Indispensable , and its advantages cannot be ignored. Therefore, in many fields, especially in portable electronic products such as electronic watches and notebook computers, lithium-ion batteries are used as the main energy source, which makes the research on lithium-ion batteries grow geometrically .

2. Preparation and energy storage performance of Cu-MOF / CuO@CuF composites

(1) Preparation of $Cu(OH)_2$ @Cu_F

Will 3A cm x 4 cm copper foil (CuF)was cut into thin slices, soaked in 0.5 M hydrochloric acid, distilled water, and absolute ethanol for 10 minutes, and then dried in a blast oven at 60° C for 2 hours to obtain pre-cleaned Cu_F .

Suspend the pre-washed copper in 20 ml of water with 0.8 g of NaOH, $K_2S_2O_8$0.2703 g, and then reacted at room temperature for 15 minutes, and then washed the copper surface with distilled water and absolute ethanol several times, and washed off the $Cu(OH)_2$ @Cu_F, and then after drying in an air blast oven for 2 hours, $Cu(OH)_2$ @Cu_F grown on one side was obtained .

Preparation of Cu-MOF/CuO@Cu_F

H_3BTCin 10 ml of DMF to obtain a well-mixed solution A, dissolve 0.2101 g of PVP in H_2O to obtain a well-mixed solution B, and stir A solution A at room temperature for 30 minutes. The unilaterally grown $Cu(OH)_2$ @Cu_F was immersed in the above solution for 2 min at room temperature. The surface of $Cu(OH)_2$ @Cu_F was rinsed several timeswith distilled water and ethanol , and then dried with a blower at 60° C for 2 hours to obtain Cu-MOF /$Cu(OH)_2$ @Cu_F .

Finally, under the protection of nitrogen , $Cu(OH)_2$ @Cu_F and Cu-MOF/ $Cu(OH)_2$@Cu_F were respectively placed in porcelain boats in a high-temperature tube furnace at a heating rate of 5° C/min , heated to 180° C.

3. Preparation and energy storage performance of ZnO/CuO@CuM composites

(1) Preparation of $Cu(OH)_2$ @$Cu_{\mathbf{M}}$

First, Cu($Cu_{\mathbf{M}}$) was cut into 3 cm x 4 cm, soaked sequentially with 0.5 M hydrochloric acid, distilled water and absolute ethanol for 10 minutes, and then dried in a 60-degree blower drying oven for 2 hours to obtain pre-cleaned $Cu_{\mathbf{M}}$.

Soak the pre-cleaned copper in 20 ml of solution in which NaOH0.8 g, $K_2S_2O_8$0.2703 g, react at room temperature for 15 minutes, then rinse the copper surface several times with distilled water and absolute ethanol, and wash the $Cu(OH)_2$ attached to the surface, then dry it in a blower oven at60° C Drying in medium for 2 hours yielded $Cu(OH)_2$ @Cu_M .

(2) Preparation of ZnO seed layer

Dissolve 0.0439 g of $Zn(Ac)_2$-$2H_2$ O in 10 ml of C_2 H_5 OH. $Cu(OH)_2$ @Cu_M was immersed in the above solution for 20 seconds , and dried at 60° C. for 15 minutes. Repeat this step for 4 times of soaking and drying. Put the dried sample into a tubular heating furnace at a heating temperature of 5° C/min, and heat it to 200° C for 2 hours to obtain CuO@Cu_M containing a zinc oxide seed layer .

(3) Preparation of ZnO/CuO@Cu_M

In 35 mL of distilled water, successively dissolve 0.0768g of $Zn(Ac)_2.2H_2O$ 0.0491 g of hexamethylenetetramine, and dissolve them separately in 35 mL of distilled water, and stir at room temperature for 30 min, then transfer to 50 mL in the reactor. CuO@Cu_M with ZnO seed layerwas immersed in the above solution by heating in water at 90° C for 4h . Cool down to room temperature in the reactor, discharge CuO@Cu_M in the zinc oxide seed layer, and then wash it continuously with distilled water and absolute ethanol to remove the zinc oxide adhering to it. Dry in an air drying oven for 2 hours to obtain ZnO/Cuo@Cu_M .

4. Preparation and energy storage performance of nanostructured CuO-based composites

Aiming at the volume expansion problem of copper oxide negative electrode energy storage materials, CuO@Cu was coated with Cu-MOF or ZnO nanowires for surface modification, and a higher battery capacity was obtained. The morphology and structure of four different types of samples were analyzed by SEM, XRD and other analytical methods, and finally they were combined to measure their electrochemical properties with a lithium-ion battery. Its conclusion is:

(1) In situ growth of copper (OH) nanowires on copper flakes, in situ growth of copper hydroxide nanowires, and then replacing the H of the internal carboxyl groups of H_3BTC with copper to realizethe surface of Cu$(OH)_2$ nanowiresThe role of coating Cu-MOF hexagons, and then calcined to obtain Cu-MOF/CuO@Cu$_F$. CuO@Cu$_F$ was prepared by direct calcination of Cu$(OH)_2$ @Cu$_F$. The effect of copper oxide doping on the electrochemical properties of the battery was investigated. The experimental results show that CuO@Cu$_F$nanowiresare coated with Cu-MOF. Cu-MOF/CuO@Cu$_F$ is used as a negative electrode energy storage material for lithium-ion batteries, and its specific capacity and cycle stability are very good. The cycle characteristic test shows that the initial specific capacity reaches 901.2 mAh/g, and after 200 cycles, the specific capacity is still maintained at 800.6 mAh/g, and the Coulombic efficiency is greater than 99%. Through the amplification rate characteristic test, it is found that the high reversible capacity of 405.8 mAh/g is still maintained at a high current density of 2 A/g. When the current density returns to 0.1 A/g again, the specific capacity returns to 708.2 mAh/g. g, close to 719 mAl/go for long cycling, the results show that it maintains a specific capacity capacity of 452.4 mA/g at a current density of 1 A/g and has a Coulombic efficiency greater than 99%.

(2) Using Cu mesh as a flexible conductive substrate, Cu(OH)z nanowires were grown on copper foil by in-situ growth method, and then ZnO seed layer was formed on copper nanowires by impregnation and calcination process, and the ZnO growth was induced on CuO nanowires, resulting in ZnO / CuO@ $_{CuM}$. CuO@Cu $_M$ prepared from Cu(OH) $_2$ @Cu $_M$ was directly calcined. The effect of ZnO on the specific capacity and cycle stability of the battery was studied. Using ZnO / CuO@Cu $_M$ as the negative electrode storage material of lithium-ion batteries, its specific capacity and cycle stability are very good. Through the test of its cycle characteristics, it was found that its initial specific capacity reached 1189.3 mAh/g, and after 100 cycles After cycling, its specific capacity is still maintained at 851.1 mAh/g, and the Coulombic efficiency is greater than 99%. Through the amplification characteristic test, it is found that it still has a high reversible capacity of 230.5 mA/g when the maximum current density is 10 A/g, and its ratio returns to 903.8 when the current density returns to 0.1 A/g mA/g, far exceeding the current density of 796 mA/g. Through long-term cycling at a current density of 0.5 A/g, the results show that it maintains a specific volume of 725.6 mAh/g at a current density of 0.5 A/g and has a Coulombic efficiency greater than 99%.

Conclusion

In conclusion, Cu -MOF or ZnO can be used for surface modification on copper oxide nanowires, resulting in better chemical energy and better cycling stability of copper nanowires. It is a potential energy storage technology. At the same time, this research still needs to be further improved: First, the structural characterization of composite materials is not comprehensive, and the research on its valence state, morphology and other aspects is not deep enough. The study of its structure and electrochemical properties still needs further research. Second, by improving the above problems, the influence of the corresponding reaction concentration of zinc ions on the morphology and electrochemical properties of ZnO/CuO@Cu$_M$ can be further explored, and the application of Cu-MOF/CuO@Cu$_F$ in other energy storage fields can be further explored. The application of ZnO/CuO@Cu$_M$ in other energy storage fields [9-10].

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