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A Nanocomposite of Sulfide-Carbonaceous Material-Conducting Polymer for Electrode Material: A Review

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ABSTRACT

Enhancing component parts including separators, electrode materials, electrolytes, current collectors, binders, and separators to improve electrochemical and capacitive properties has been the focus of recent developments in supercapacitor technology. In particular, the improved electrochemical characteristics of metal sulfides—particularly those based on nickel—have drawn attention in the context of capacitors and batteries. With its large specific surface area and conductivity, graphene has become a material of great promise, particularly when paired with active ingredients to solve conductivity problems. Because of their high conductivity, ease of synthesis, and durability, conducting polymers like polypyrrole (PPy) are suitable materials for energy storage systems.

Ternary nanocomposites are useful electrode materials for cutting-edge energy storage systems since they have demonstrated greater capacitance than binary ones. These findings open the door to the creation of extremely robust and effective electrode materials for use in upcoming energy storage projects.

Keywords: Supercapacitors, Electrode materials, Nickel subsulfide, Graphene oxide, Polypyrrole

Introduction:

In order to improve electrochemical and capacitive properties, recent developments in supercapacitor technology have concentrated on upgrading component parts such as separators, electrode materials, electrolytes, current collectors, binders, and separators. In particular, metal sulfides—particularly those based on nickel—have drawn interest due to their improved electrochemical qualities in batteries and capacitors. When paired with active components to address conductivity difficulties, graphene's large specific surface area and conductivity make it a promising material. Conducting polymers, such as polypyrrole (PPy), are suitable materials for energy storage devices because of their high conductivity, ease of production, and durability. Advanced energy storage systems can benefit from the use of ternary nanocomposites as electrode materials because they have a higher capacitance than binary ones. The creation of extremely stable and effective electrode materials for upcoming energy storage applications is made possible by these discoveries.

Types of super capacitor:

1. Electrochemical double layer capacitor:

Supercapacitors are cutting-edge energy storage devices with high power density and quick charge/discharge capabilities. Electrochemical double-layer capacitors (EDLCs) are also referred as ultracapacitors . Supercapacitors have two main properties which are a high cycle life and quick energy transfer as they store energy electrostatically. Compared to conventional batteries. It lays the groundwork for a discussion different kinds of supercapacitors and their components.

2. Hybrid super capacitor:

Among all types of supercapcitors the hybrid supercapacitors have benefits of many materials to produce improved performance. It also represent a cutting-edge approach to supercapacitor design. By combining conducting polymers and pseudo capacitive materials with carbon-based electrodes we can improve cycle stability, power density, and energy density [1]. These hybrid systems is used in a variety of applications, such as portable electronics, renewable energy storage, electric vehicles and many more.

3. Pseudo capacitor

Pseudo capacitors are one of the best sources of energy storage because it provides quick and reversible redox reactions at the electrode-electrolyte interface. Metal sulfides have high specific capacitance and stability, they are used as promising pseudo capacitive materials[2]. One example of such materials are sulfides. Conducting polymers with pseudo capacitive properties can store more energy such as Polyaniline and Polypyrrole.

Components and operation of a EDLCs

1. **Electrodes:**

Activated carbon, carbon nanotubes, or graphene, are commonly used to make the electrodes in an EDLC because they have high surface area. The interaction between electrode and electrolyte is used to store a significant amount of charge due to its huge surface area.

2. **Electrolyte:**

The Electrolyte helps ions to move between the electrodes and charge and discharge is called the electrolyte[1]. In EDLCs, common electrolytes include aqueous solutions (potassium hydroxide, sulfuric acid) for having the lower voltage applications for organic higher voltage applications.

3. **Separator:**

A permeable membrane is positioned between the electrodes to make ions moving while preventing short circuit. Maintaining the physical separation between the electrodes and the electrolyte is also aided by the separator[2]. The charge which is build up at electrolyte-electrode interface helps to drives the operation of an EDLC. The Electrolyte ions are drawn to electrodes with the help of the voltage which helps to store electrical energy.

4. **Pseudo Capacitive material:**

When the reversible redox reactions goes on at the electrode-electrolyte interface the pseudo capacitive materials allows the charge storage [2]. A promising metal sulfide that shows pseudo capacitive behavior is nickel sulfide it helps to enhance specific capacitance and electrochemical stability in supercapacitors. Conducting polymers also contains the pseudo capacitive characteristics, which enhances quick charge storage via reversible redox processes[3]. Supercapacitors are used in almost every sectors, such as electronics and renewable energy storage. Pseudo capacitive materials improve their energy storage capacity and performance[4]. By using these pseudo capacitive materials into electrode designs energy storage technology increased the performance of supercapacitors.

Methods to prepare Ternary Nano composite:

Sol Gel Method:

Sol gel method is used to synthesize many materials at one of them is the syntheisi of the nanocomposite. The method involves the transition of material like Sol to the solid gel. The Sol is prepared by hydrolysis and then condensation of the material. After that gel is formed and Calcination process is performed on the sample.

Hydrothermal or Solvothermal Method:

The method is used to make many materials like nanocomposite, crystalline solid and above all the nano particles. In Hydrothermal method carbon material is prepared using ultrasonication method. Stainless steel autoclave is used so that chemical reactions can takes place. In hydrothermal method water is used as solvent but in solvothermal method many inorganic and organic solvents care used. After preparation of carbonaceous material, sulphide is formed and lastly conducting polymer is coated on it.

Chemical Vapor Deposition:

Chemical Vapor Deposition method is used to make high performance and quality materials like thin films. Chemical reactions takes place on vapor phase precursors, In this method carbonaceous material is made and after that sulfide is deposited on it with the use of CVD setup. Insitu polymerization is done to deposit the polymer on the binary nanocomposite.

Electrodeposition:

Electrodeposition method is also use for the formation of ternary nanocomposite. The process offers precise control over the thickness, and composition of the material. The method is used because it enhances the performance and longevity of the material. The method involves the making of carbonaceous material and the deposition of the sulfide. The potential is applied to initiate polymerization to deposit polymer onto the created binary composite.

Solution Mixing and Casting:

The method is used for the preparation of the polymeric materials and the composites. In this method materials are dispersed in the solids to form the homogenous solution. The suspension is then cast in mould and let it dry which will form a solid film or the structure.

Conclusion and Future Perspectives

In a nutshell, ternary nanocomposite electrode material that can be used in supercapacitors has been developed. This promising combination improved electrochemical performance, including high specific capacitance, and long-term cycling stability. Further fine-tuning of the composite structure, and electrolyte composition could lead to even greater energy storage[5]. The discovery opens up new possibilities for the formation of improved electrode materials for supercapacitors with better power densities.

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