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Metal Sulfide - Carbon Based Material – Polymer Nanocomposite Electrode Material for Supercapacitor: A Review

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ABSTRACT

Due to the growing energy problem, effective and reliable energy storage technologies are becoming necessary. Regardless of time, the accessibility of affordable, environmentally friendly energy sources. Batteries and supercapacitors (SCs) are the most important energy storage technologies to be taken into account. While supercapacitors are generating a lot of research attention as a high-performance energy storage device, batteries have several unique characteristics such as increased energy density and stable undeviating discharging at a given voltage. In comparison to other standard capacitors and batteries, supercapacitors exhibit exceptional cycle stability, a high value for specific capacitance, the ability to charge and discharge quickly, and a high energy density.

The electrodes used in a supercapacitor's construction have a big impact on how well it performs. Activated carbon, graphene, carbon nanotubes, conducting polymers, and other metal oxides, metal sulfide are frequently utilized electrode materials in supercapacitors. When selecting an electrode material, considerations including specific capacitance, power density, cyclic stability and cost are generally balanced with the particular needs of the application.

Cos-rGO-PPY nanocomposite has outstanding cyclic stability, specific capacitance, and high electrical conductivity, making it a potentially attractive electrode material for a high-performance supercapacitor.

1. Introduction

1.1 Supercapacitor

Researchers and the scientific community now have a new avenue towards the development of renewable energy resources thanks to the rapidly rising demand for energy storage devices. Scientists and researchers have discovered that it offers high specific capacitance, quick dynamic response, prolonged cyclic stability, high energy density, and high power capacity. Its capacity to meet the rising demand for mobile electronics, hybrid cars, and power sources demonstrates its supremacy over other energy storage technologies [1, 2].

Supercapacitor gives higher output powder than that of the battery but lower as compare to other capacitors. Supercapacitors shows superior characteristics such as higher specific capacitance, more cyclic stability and powder density by reason of charges storing mechanism and high-power performance at temperature below 40°C [3-5].

1.2 Types of Supercapacitors

1.2.1 Electrostatic Double-Layer Capacitor

At the junction of electrolyte and electrode static charge separation occur results the capacitance of EDLCs . At this junction of electrolyte and electrode , formation of double layer of charges occur while electrode is plunged in electrolytes solution. Charges are stored electrostatically at the intersection of electrolyte as well as electrode. There is no transfer of charge between electrolyte and electrode and this is the positive aspect of EDLCs. The main factors on which the capacitance depend are the area of available electrode material and the corresponding features of the surface. As they are based on non-faradaic reactions, excellent stability is exhibited by them but lower energy density [6, 7].

Electrodes constructed of carbon-based material are used to fabricate EDLCs. The most fascinating substance is carbon, which can be converted into over ten million different chemical compounds. Activated carbon, graphene, and carbon nanotubes are examples of carbon allotropes with unique characteristics.

1.2.2 Pseudocapacitors

Charges are quickly stored in pseudo capacitors by the redox activity of the electrolyte and electrode. Due to differences in the states of oxidation in the components of pseudocapacitive devices, redox charge transfer reactions enable them to have superior energy density. Pseudocapacitors have fewer commercial applications due to their poor conductivity and short lifespan. In comparison to EDLCs, pseudocapacitors showed higher specific capacitance and energy density. Pseudocapacitors electrodes can be made from a variety of polymers and metal oxides and sulfide [8-10].

1.2.3 Hybrid Supercapacitors

Hybrid supercapacitors are created by combining EDLCs and pseudo capacitors. For charge accumulations that result in enhanced energy storage, both faradaic and non-faradaic development take place. In hybrid supercapacitors, higher specific capacitance pseudo capacitance qualities are more important than EDLCs, whereas EDLCs are responsible for the good cyclic stability and power density [11, 12].

1.3 Components of Supercapacitors

Supercapacitors main components are electrodes, separators, electrolyte and current collector. Separator act as a membrane between two electrode as electrical isolation. For supercapacitors performance electrolyte and electrodes are the fundamental constituents.

1.3.1 Electrode Material

An effective electrolyte and the right electrode material can contribute significantly to a wide potential window and increased specific capacitance[13]. Numerous nanomaterials were thought to be suitable electrode materials for supercapacitors due to their exceptional and one-of-a-kind physical and chemical capabilities.

1.3.2 Separator

In supercapacitors, the positive and negative electrodes are physically separated by separators, which also permit ion movement between them. The selection and design of separators significantly affect the efficiency, security, and general performance of the supercapacitor by preventing short circuits, guaranteeing ion permeability, and lowering internal resistance [14].

1.3.3 Electrolyte

Supercapacitors require the proper electrolyte for proper design and operation [15]. Solid-state electrolytes hold out the possibility of fusing the two with increased safety. While organic electrolytes focus on higher energy densities, aqueous electrolytes target high power densities. As supercapacitor technology advances, efforts to discover and produce novel electrolytes continue to drive progress toward producing energy storage solutions suitable for a range of applications.

1.3.4 Current collector

Charge/discharge rates are maximized by the designed of current collector. Physical characteristics of current collector improves the supercapacitor's overall performance and stability [16]. The capacities of supercapacitor depend on the structure and characteristics of current collector.

Material for electrode

1.4.1 Transition Metal Sulfides

In energy storage applications, transition metal sulfides represent an important class of materials that can lower the gap between conventional capacitors and batteries. They are perfect for applications requiring high power and quick charge/discharge rate because to their special combination of electrochemical activity and electrical conductivity. Among the most important examples are iron disulfide, also known as pyrite (FeS_2), which has good redox characteristics and an impressive theoretical capacitance that can be improved by specific production methods including nano-structuring. Cobalt sulfides (CoS and CoS_2) have a lot of potential, but using them in composites with carbon-based materials is an important way to use them as supercapacitor electrodes because of their poor electrical conductivity, agglomeration, and cyclic stability problems [17]. These substances have a lot of potential to transform energy storage technology.

1.4.2 Activated carbon

Activated carbon is testified as employed material in electrode attributable to some outstanding characteristics for instance modified area of surface and decent electric characteristics while being cost effective , simplistic fabrication as electrode [18].

Activated carbon are synthesized by activation process and porous in structure varying as micropores, mesopores and macropores ranging from 2-50 nm,0.5-2nm and >50 nm respectively [19]. The specific capacitance of activated carbon is much lower than theoretical capacitance belonging to EDLCs in site of possessing elevated surface area and conductivity. Electrochemical properties of activated carbon are enhanced by doping of activated carbon by nitrogen, boron, phosphorus and sulfur.

Scientists revealed electrochemical properties of activated carbons on behalf of its nano porous assembly keeping elective electrolytes. Specific capacitance of activated carbon was more develop in electrolyte with aqueous nature than electrolytes with organic nature. Although activated carbons are considered as markable electrode material for supercapacitor yet it is not considered as ideal due to lack of enough rate aptitude and energy storing.

1.4.3 Carbon Nanotubes (CNTs)

CNTs are considered as compatible and desired candidate for application of supercapacitors due to its extraordinary electrical conduction in exterior area. CNTs have gained significant attention of the researchers in energy storage and are considered as emerging and advanced storing energy technologies as due to flexibility of results in structural chemical , electrical and physical characteristics [20, 21] .

On the basis of their physical structure there are two types of CNTs

I. Single walled carbon nanotubes (SWCNTs)

II. Multiwalled carbon nanotubes (MWCNTs)

As compared to MWCNTs electrochemical performance of SWCNTs is much greater. Due to their limited electrochemical performance, high cost and toxicity CNTs are not considered as ideal. However, composite of CNTs elevate electrochemical efficiency owned to outstanding surface area and electrical conduction.

1.4.4 Graphene

Graphene is a single layer of carbon atom. It is 2D material with excellent electrochemical properties, excellent cyclic stability , large surface area , low cost and environmental friendly in nature and are suitable electrode material for supercapacitors [22, 23]. Electrochemical properties of graphene are modified by doping. So, composite of metal sulfide with graphene can enhance their electrochemical performance and cyclic stability. composite of metal sulfide with carbon-based material has excellent cyclic stability and high specific capacitance.

1.4.5 Conducting polymers

Charge storing mechanism exhibited by conducting polymers is pseudo capacitors type. Conducting polymers that are commonly use are polypyrrole, polyaniline, polythiophene and byproduct by reason of greater characteristics for instance facile polymerization , low cost availability of monomer [24, 25]. Due to better capacitive behavior and higher specific energies in comparison to carbon built supercapacitors conducting polymer shows superior properties of fast redox reaction [26].

Polypyrrole are considered as good constituent for electrode in supercapacitor as well as for battery application and can be used for commercialization purpose and can be synthesized in large quantity. short comes of conducting polymers has been observed during charging and discharging phenomena which include low mechanical stability and high equivalent series resistance.

1.5 Suggestion

CoS -rGO-PPY nanocomposite could be a promising electrode material for a high-performance supercapacitor because it shows excellent cyclic stability, specific capacitance and high electrical conductivity.

1.6. References

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