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Transition Bimetal Sulphides-Carbonaceous Material-Conducting Polymer as an Electrode Material for Supercapacitor: A Review

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ABSTRACT

With the increasing consumption of energy, limited fossil fuel resources, population growth and increasing pollution, energy storage and availability has been a serious threat to humanity. Batteries provide high energy density but cannot fulfill the requirement of immediate power supply due to their low power density. Supercapacitors with their high power density and retainable cyclic stability, are a good alternative to batteries [1].

The electrochemical properties of a supercapacitor are highly dependent on the electrode material being used. There are different classes of electrode materials including metal oxides, sulphides, hydroxides, carbonaceous materials and conducting polymers. Carbon containing materials in the form of fibers, nanotubes and graphene remains appealing due to its availability and affordability. Metal sulphides show favorable properties as compared to their oxides as the materials can undergo redox reactions. Transition metals are combined to get the synergistic properties of both the metals; thus, bimetal sulphides show superior properties as compared to their analogue transition metals. Moreover, conducting polymers can easily be synthesized and show redox properties due to their structure. Thus combining a bimetal sulphide with a carbonaceous material and a conducting polymer with boost the electrochemical properties and the efficiency of the synthesized material overall [2].

1. Introduction

1.1 Supercapacitors

In addition to traditional batteries, supercapacitors are used in many energy storage applications to their remarkable characteristics, which encompass higher specific capacitances in contrast to traditional capacitors, prolonged cycle life, and improved power supply capacity relative to batteries. As a result, these unique characteristics have generated significant research attention within the supercapacitors [3].

1.2 Types of Supercapacitors

Three primary categories of supercapacitors currently exist: hybrid capacitors, EDLCs and pseudo capacitors. The methods of charge storage that these classes often use can be classified as either Faradaic or non-Faradaic, or their combination. In pseudo capacitors, faradaic process includes charge transfers between electrolytes and electrode such as redox reactions while the non-Faradaic approach does not need chemical redox processes, surface charges are physically dispersed and do not comprise chemical processes [4], this group heavily depend on the electrode surface area that is accessible to the electrolyte ions. Capacitance is obtained owing to electrostatic charge collected on the electrode-electrolyte interface.

1.2.1 Electric Double Layer Capacitor

A separator, an electrolyte, and two electrodes made of carbon make up an EDLC. EDLCs have the ability to store charge electrostatically, in which the electrode and electrolyte do not transfer any charge [5, 6].

The electrochemical double layer is used to store energy in EDLCs. Charges build up on the surfaces of electrodes when a voltage is applied. As a result of the electrolyte ions diffusing over the separator and onto the pores of the opposite electrode, the potential difference attracts opposing charges. A second layer of charge is generated to avoid ion recombination at electrodes. Shorter electrode spacing, an increase in specific surface area, and a double layer provide EDLCs a higher energy density [7, 8].

1.2.2 Pseudo Capacitor

Pseudo capacitors store charge using a faradic process that involves the transfer of charge between electrodes and electrolytes [9]. The reduction and oxidation of the electrode material in a pseudo capacitor causes charge to flow across the double layer when a voltage is applied to the device. The supercapacitor cell then undergoes faradic current flow. Pseudo capacitors have superior electrochemical properties for instance higher specific capacitance and energy density as compared to EDLCs, owing to their use of faradic processes. Examples include metal oxides, metal sulphides and conductive polymers. The interest in these materials arises from their faradic nature, characterized by reduction-oxidation processes similar to those seen in batteries. Nevertheless, they exhibit a deficiency in cyclic stability and generate a poor power density [10].

1.2.3 Hybrid Supercapacitor

Hybrid capacitors have the capability to use both faradic and non-faradaic mechanisms, allowing them to integrate the benefits of pseudo capacitors and EDLCs inside a single device. Furthermore, they surpass EDLCs regarding both the energy density and power density. These capacitors are made with uneven electrodes.

1.3 Components of Supercapacitors

The key components of a supercapacitor include electrolytes, electrodes, separators and the current collectors [11]. Each of the components of a super capacitor has a specific function in the device's operation. The electrode material primarily stores the charges, whereas the electrolyte supplies the ions needed for adsorption at the electrode-electrolyte interfaces. As a semi-permeable membrane, the separator permits ion transport while preventing short circuits in the device. By moving charge through an external circuit, the current collector improves the super capacitor's performance.

1.4 Supercapacitor’s Electrode Material

A supercapacitor's properties are heavily dependent on the electrode materials being used. Electrode materials that are attractive because to their low cost, lack of toxicity, long cycle life and increased energy density are the focus of intense research efforts worldwide [12].

Standard electrode materials for supercapacitor production include various carbon compounds. This is due to its readily availability, low-cost, significant surface area and conventional methods of manufacture while in the field of electrochemical supercapacitors, transition metal sulfides (TMSs) have gained a lot of respect as innovative electrode materials owing to their remarkable properties, such as high specific capacitance, unique crystal structures, and robust redox activity, moreover, conducting polymers may be used as supercapacitor electrodes due to their flexible morphology, rapid doping and de-doping, and charge-discharge properties [13].

1.4.1 Electrode materials for EDLCs

Electrode materials used for developing supercapacitors mostly consist of carbon compounds in their various forms. Its large surface area, affordability, accessibility, and well-established electrode manufacturing technology are among the contributing factors. The electrochemical double layer that forms at the electrode-electrolyte interface serves as the storage mechanism for carbon compounds. Therefore, the surface area that electrolyte ions can penetrate determines the capacitance primarily. Specific surface area, pore size distribution, surface functionality, and electrical conductivity are significant determinants of electrochemical performance [14].

1.4.2 Electrode materials for pseudo capacitors

Electrode materials for pseudo capacitors often consist of electrically conductive polymers, transition metal oxides and transition metal sulphides. The pseudo-capacitor electrodes use redox processes on the surfaces of the electroactive materials. The redox reactions are influenced by the electrode voltage and are varied throughout the process of discharging and charging. This technique exhibits superior specific capacitance and energy density when compared to EDLCs that are only carbonaceous materials [15]**.**

1.5 Suggestions

Choosing an electrode material that contains the material for both the individual types of supercapacitors can be a promising electrode material as it would offer enhanced cyclic stability, specific capacitance, high energy density and electrical conductivity.

1.6 References

[1] J. Libich, J. Máca, J. Vondrák, O. Čech, and M. Sedlaříková, "Supercapacitors: Properties and applications," Journal of energy storage, vol. 17, pp. 224-227, 2018.

[2] P. Sharma and T. Bhatti, "A review on electrochemical double-layer capacitors," Energy conversion and management, vol. 51, no. 12, pp. 2901-2912, 2010.

[3] W. Raza et al., "Recent advancements in supercapacitor technology," Nano Energy, vol. 52, pp. 441-473, 2018.

[4] S. Karthikeyan, B. Narenthiran, A. Sivanantham, L. D. Bhatlu, and T. Maridurai, "Supercapacitor: Evolution and review," Materials Today: Proceedings, vol. 46, pp. 3984-3988, 2021.

[5] M. V. Kiamahalleh, S. H. S. Zein, G. Najafpour, S. A. Sata, and S. Buniran, "Multiwalled carbon nanotubes based nanocomposites for supercapacitors: A review of electrode materials," Nano, vol. 7, no. 02, p. 1230002, 2012.

[6] M. Jayalakshmi and K. Balasubramanian, "Hydrothermal synthesis of CuO-SnO2 and CuO-SnO2-Fe2O3 mixed oxides and their electrochemical characterization in neutral electrolyte," International Journal of Electrochemical Science, vol. 4, no. 4, pp. 571-581, 2009.

[7] M. Halper and J. Ellenbogen, "Ultra-capacitors: A Brief Overview," MITRE Nanosystems Group, 2006.

[8] H. Choi and H. Yoon, "Nanostructured electrode materials for electrochemical capacitor applications," Nanomaterials, vol. 5, no. 2, pp. 906-936, 2015.

[9] S. Mohapatra, A. Acharya, and G. Roy, "The role of nanomaterial for the design of supercapacitor," Lat. Am. J. Phys. Educ, vol. 6, no. 3, pp. 380-384, 2012.

[10] S.-M. Chen, R. Ramachandran, V. Mani, and R. Saraswathi, "Recent advancements in electrode materials for the highperformance electrochemical supercapacitors: a review," International Journal of Electrochemical Science, vol. 9, no. 8, pp. 4072-4085, 2014.

[11] A. González, E. Goikolea, J. A. Barrena, and R. Mysyk, "Review on supercapacitors: Technologies and materials," Renewable and sustainable energy reviews, vol. 58, pp. 1189-1206, 2016.

[12] R. B. Choudhary, S. Ansari, and M. Majumder, "Recent advances on redox active composites of metal-organic framework and conducting polymers as pseudocapacitor electrode material," Renewable and Sustainable Energy Reviews, vol. 145, p. 110854, 2021.

[13] S. Banerjee and K. K. Kar, "Conducting polymers as electrode materials for supercapacitors," in Handbook of Nanocomposite Supercapacitor Materials II: Performance: Springer, 2020, pp. 333-352.

[14] H. Yang, S. Kannappan, A. S. Pandian, J.-H. Jang, Y. S. Lee, and W. Lu, "Graphene supercapacitor with both high power and energy density," Nanotechnology, vol. 28, no. 44, p. 445401, 2017.

[15] L. Yu and G. Z. Chen, "Redox electrode materials for supercapatteries," Journal of Power Sources, vol. 326, pp. 604-612, 2016.