Journal of Composites and Compounds 4 (2022) 195-208

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Journal homepage: www.JOURCC.com

Journal of Composites and Compounds

A review of recent progresses on nickel oxide/carbonous material composites as supercapacitor electrodes

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ABSTRACT

The rapid economic growth and enormous expansion of the portable electronics market generate a significant need for renewable energy sources, energy storage, and energy conversion technologies. Supercapacitors have emerged as a viable technology for storing renewable energy sources to meet this demand. Recently novel Transition metal oxides/carbon materials (TMC) based electrode materials attracted attention of research community working in supercapacitor field. Redox-active materials, like transition metal oxides, conductive polymers, add pseudo capacitance through quick, reversible redox reactions, and carbon-supported materials Due to their excellent physicochemical stability, large specific surface area, adaptable pore shape, and high electrical conductivity, it has been extensively utilized in supercapacitors (SCs). Of nickel oxide/active carbon composites as electrode materials for supercapacitors are examined in this review article. This review will provide a comprehensive and up-to-date summary of materials composite investigated as prospective electrode in the creation of efficient supercapacitors, along with their respective production processes and electrochemical properties addition, this article will introduce synthesis of supercapacitor electrode composite and fundamental parameters that influence supercapacitor performance.

ARTICLE INFORMATION

Article history:
Received 16 September 2022
Received in revised form 26 November 2022
Accepted 23 December 2022

Keywords:
Nickel oxide
Materials-based carbon
Electrode materials
Electrochemical properties
Supercapacitors

Table of contents

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https://doi.org/10.52547/jcc.4.4.4

1. Introduction

The primary energy source has been fossil fuels for the last hundred years. They are not only depleting but also leading to numerous environmental issues, affecting people's health. Considering the abovementioned issues, a renewable source waste heat from industries [1-3],wind [4] and sunlight [5], that can produce energy without the emission of carbon dioxide can be used. Harvesting energy from the mentioned sources is not adequate for solving the issue until we have appropriate energy storage devices. These days common technologies of energy storage include biological energy storage (the lignocellulose into sugar solutions hydrolysis, making char from biowaste), electrochemical storage of energy (supercapacitor, lithium -sulfur battery, lithium battery), mechanical energy storage (bending/suspending solids, reservoir power generation system).

SCs have attracted extensive consideration as potential energy devices with the ability to charge-discharge fast, high cycle stability, environmental friendliness, high cycle stability and high energy conversion efficiency [6]. SCs, also known as electrochemical capacitors, are a newer kind of technology of energy storage that sits in the middle of regular all of capacitor and secondary batterie.

In comparison to secondary batteries, SCs have a power density more than other batteries, 10 between 100 times, the operation range is from -40 to -70 °C, the charging/discharging speed is faster (10 s-10 min), the cycle life is more than 100,000 cycles, and this supercapacitor is more environmentally friendly. In comparison with conventional capacitors, SCs have higher energy density and higher specific capacitance [7]. Until now, SCs have been utilized in novel energy vehicles and wearable electronic products. SCs have tremendous potential to be taken as modern energy storage technology. Supercapacitors include a diagram, electrolyte, current collector, and electrode. The electrode is the nucleus of SC and the foundation of electrochemical energy storage and efficient conversion. Consequently, the basic way for developing high-performance SCs can be realized by the sensible development and design of electrode materials.

Battery and two fundamental supercapacitors are electric energy storage system that have been utilized broadly in various aspects, from electric devices of portable to smart gride [8, 9]. In comparison with batteries high density of power and a long life cycle are possessed by the supercapacitors that ensure approximately no maintenance charge and fast charging/ discharging [10]. High specific power and comparatively large specific energy contribute to a function that has the advantages of being both efficient and weight of light, and could be utilized as energy resources for a variety of portable electric machines such as mobile phones, laptop computers, and so on SCs can match the demand for high power output during short-term accelerating and high energy storage capacity when braking. conserving energy and preventing battery damage from high frequency quick charge/discharge cycles [8, 9, 11]. In this context, the supercapacitor serves as a power/energy link between the high energy of storage (batteries) and the high-power output (capacitor). In the future, this technology has the possible to play role of a crucial large -scale in hybrid power system development. Normally, power and density of energy are two major indices for measuring the mechanism of energy storage systems. it could be calculated by Eqs. (1) and (2) [12, 13]:

$$E_d = 1/2\ CV^2 \tag{1}$$

$$P_d = V^2 / 4R_s \tag{2}$$

where P_d and E_d are the density of both power and energy, respectively, R_s is the resistance of equivalent series two electrodes, V is the voltage working casement, and C was capacitance. Conforming these equations, Rs, V, and C are the three most significant factors in pd and Ed. Typically, the electrode material determines the capacitance in SCs, whereas the electrolyte and electrode affect voltage. Nevertheless, RS has extra effect factors that include electrode materials' contact with collectors, resistance to charge transfer, and internal resistance of electrolyte and electrode. Therefore, a supercapacitor should simultaneously have low resistance, high voltage and high capacitance for the best efficiency. Of all the agents, Electrode materials are the most significant component in determining supercapacitor performance. Typically, based on charge storage mechanisms, electrode materials are selected. For SCs, there are two categories of mechanism: pseudo capacitors and EDL.

Hence, Supercapacitor electrode materials can be divided in three categories [14]: (1) metal oxides/ hydroxides, (2) conducting polymers and (3) carbon materials.

The electric double-layer (EDL) capacitor, also recognized as an ultra-capacitor, is composed of ions in the electrolyte that form EDLCs with polarity opposite the electrodes. One of the two storage principles is double layer capacitance, where electrostatic storage is accomplished by segregating charge in the Helmholtz model of the double layer and boosting SCs capacitance. Another type of electrochemical storage is called pseudo-capacitance. This is achieved by faradaic(redox) reactions. These two principles can only be segregated by measurement [11, 13-15]. The properties and functionality of the SCs are dependent on the mutual influence of the electrode and electrolyte materials. nanotubes of carbon, graphene, graphite, aerogel, graphene, carbon fiber cloth, and activated carbon (AC) in various carbon appearances are generally make use of as electrode materials for capacitors of EDL, a pseudocapacitive material utilizes polymers of electron-conducting with cycle, high capacitance, low ESR because, for pseudo capacitors, not every material can be utilized as an electrode. The hybrid-type supercapacitor merges two electrodes with high pseudo capacitance double-layer capacitance and is made of Carbone -based materials [9, 16]The extension of hybrid-type SCs electrodes had a positive impact on the electrodes of rechargeable batteries [17] .Research efforts Development has been performed on different metal oxide-formed electrode materials suchlike iron oxide(FeO), zinc oxide (ZnO), NiO, cobalt oxide (CoO), manganese oxide(MgO), iridium oxide (Y_2O_3), and ruthenium oxide (RuO_2) [18]. NiO is an oxide of a transition metal that has been extensively examined for utilization in SCs, Because of its availability, impressive reversible redox reactions, and excellent theoretical capacity. Although, reports of recent show a weak cycling ability and lower specific capacitance as poor conductivity, unstable charge-discharge processes, and incomplete sites of redox-active [19]. To resolve these problems, NiO surfaces are improved by that electrodes have to be arranged at the nanometer scale . Hybridization with very conductive materials similar doping in foreign materials or carbon materials, according to reports, increase its capacitance efficiency [20].

Carbon-based electrodes like amorphous carbon and amorphous carbon are renowned have high conductivity and excellent stability, making them prefect supports for ultra-capacity applications [21].

The capacitive attributes of NiO are highly dependent on its morphology and structure. Recently, the production of hybridized nanostructures has been explored to creation conductivity loss and enhance redox active sites. Hollow spheres and Core-shell have been in development due to their made better stability and capacitance. In recent years, due to their high performance and low cost, multicomponent carbonous materials and NiO materials composite has become an excellent topic within the subject of SC electrode materials [22, 23]. Although, there needs to be more literature on the collective assessment of electrode materials based on two materials (carbon materials/NiO) within the domain

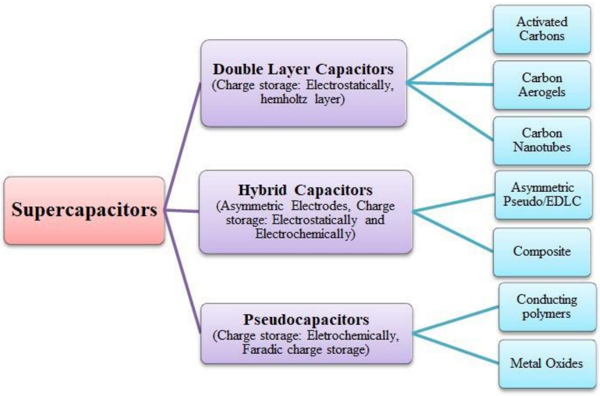

Fig. 1. Taxonomy of Supercapacitors.

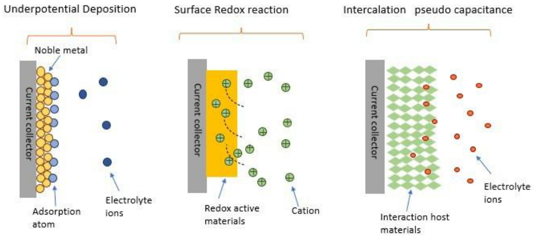

Fig. 3. Charge storage in pseudo-capacitors is depicted schematically as a combination of three different processes: (a) potential deposition, (b) redox processes, and (c) ion insertion/extraction..

of electrodes for SCs, and the assessment of the whole carbon-based materials used by several businesses in connection with NiO. The development of composites and nanostructured materials are offered as two primary solutions for improving the super capacitive performance. This review proffers the prevalent study of supercapacitor performance of nickel oxide/ carbon -based materials composite as electrode material by various method and composite have two advantages: good conductivity and enhanced structure stability. In conclusion of the paper, the development trends of NiO/carbon-based materials composite were predicted, and the forthcoming application prospects prospected in review table for supercapacitor .

2. Type of supercapacitor

Supercapacitors, also called ultracapacitors, have large capacitances because the enhancement surface area electrodes and thin layer separators. As with traditional capacitors, a SCs combine of two electrodes that are segregated via a dielectric. Reveled the charge storage system, supercapacitors could be as electrical double-layer capacitors (EDLCs), pseudo capacitors, and hybrid capacitors [15]. EDLCs use double-layer electrodes to reserve load electrostatically. Pseudocapacitors with redox reactions store charges in faraday by transferring charge between electrolyte and electrodes, and hybrid supercapacitors store start charging via a combined effect of faradaic and non-faradaic materials [24].

2.1. Electric double layer capacitors

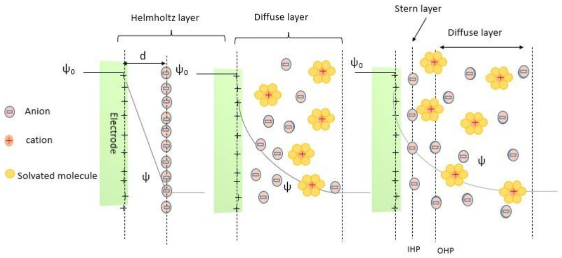

Fig. 2. IHP stands for the inner Helmholtz plane, and OHP stands for the outer Helmholtz plane , d is the Helmholtz distance is potential of the electrode ,W is the potential at the electrolyte /electrode interface.

Von Helmholtz conducted extensive research on colloidal suspension and developed the notion and pattern of EDL in 1853 [25]. According to this concept, at the electrolyte/electrode interface, two substrates of electrically opposing charges organized and were divided by one atomic distance, which is closely resembles the construction of a standard capacitor, Gouy and Chapman then modified this simple models of EDL [26, 27]. Gouy and Chapman's model assumed that cations and anions were continuously released in the electrolyte to form a diffusion layer under thermal motion.

The dissemination of opposing ionic loads in the electrolyte around the charged material was alike when taking into consideration ions that were not attached to the surface. The kinetic energy of the ions affected the thickness of the diffusion layer. However, because the capacitance that emerged across two several distanced charges were reversely associated with the distance between them, this model produced an overestimation of EDL capacitance. As a result, an immense, when point load ions are in close proximity to the electrode surface, a capacitance value is achieved. Stern then integrated the Gouy-Chapman and Helmholtz models to further refine the latter [28].

There are two distinct zones that he identified as being responsible for the distribution of charges: the diffuse and the stern layer

Particularly absorbing charges (SACs) and absorbing countercharges (NACs) were substantially absorbed on the electrode in the Stern- layer, where charges (hydrated usually) were present (nSACs). Though the SACs were represented by the IHP, the nSACs were shown by the OHP. Electrostatic adsorption is the mechanism through which charges are stored at the electrode/electrolyte contact, according to the EDL models No charge transfer is shown to occur within the electrode/electrolyte interfaces themselves during charging cycles and discharge.

The charge/discharge mechanisms of EDLCs are accelerated by the physical electrostatic processes, allowing them to react to potential changes instantly. You can use the following equation to figure out the capacitance of an EDLC electrode [29]:

$$C = \frac{\varepsilon r \varepsilon o}{d} A \tag{3}$$

A represents the effective area of contact between the electrolyte and the electrode, d represents the thickness of the EDL, $\mathscr{E}_0$ and $\mathscr{E}_r$ are a vacuum's permittivity and relative permittivity, respectively. Zhao and Zhang propound the advancement of the aforementioned three EDL modeling processes as shown in Fig. 2 that Each model was described above [29].

2.2. Pseudo-capacitors

Pseudo-capacitance, as opposed to EDL, is determined by the thermodynamic factor and is associated with the acceptance of charges (Dq) and alterations potential (DU) [16, 29].The key electrochemical characteristic is that the Alteration in valence state changes the charge and discharge operations in pseudo-capacitor electrode materials because of the Faraday process, or redox reaction, which occurs during the charge and discharge processes [30, 31] Fig. 3 shows the charge storage methods in pseudo-capacitors [32].When atoms are adsorbed on noble metals via a process called under-potential deposition, the electrodeposition potential is lesser negative than the equilibrium potential for reduction of cations .

Redox reactions result in a phenomenon called “redox pseudo-ca-

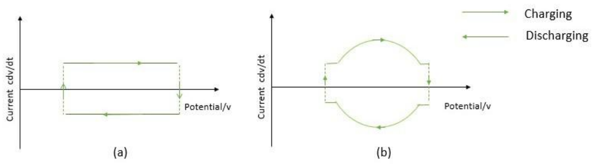

Fig. 4. (a)EDL and(b) pseudo capacitance typical cyclic voltammograms.

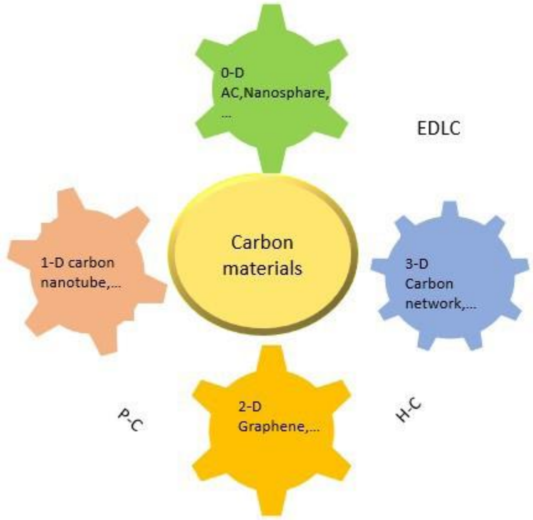

Fig. 6. There are mainly three parts carbon materials.

pacitance.”. The electrolyte/electrode contact experiences a reversible and quick charge transfer as a result of these processes, which are associated with cations being precipitated on the electrode material’s surface [13]. Pseudo-capacitance so can be induced by adding or removing cations from layers or canals of crystalline materials. During the process of insertion and removal, the crystal may stay neutral electrically. intercalation pseudo-capacitance can be viewed as a “transitional” property among a supercapacitor and a lithium-ion battery [33]. Compared to EDL electrodes, the pseudo-capacitance electrode can conduct a many high capacitances, but it has poor cycle stability and electrical conductivity.

2.3. Hybrid capacitors

There are two energy storage mechanisms involved in SCs :Adsorption of ions at the electrolyte / electrode contact (often termed EDL capacitors) [34] and the reversibility of Faradaic reactions (usually called pseudo capacitors) [35]. Another kind of capacitor linked to both of these mechanisms, known as the “hybrid capacitor,” was also introduced in order to utilize the EDL capacitor and pseudo-capacitors benefits fully. Hybrid capacitors are frequently made of a battery-type electrode and a supercapacitor-type electrode, which are composed of two electrodes, one of which stores charge rapidly and another of which store’s charge electrostatically [36, 37]

Using non-faradaic and faradaic techniques to sustain a charge, hybrid capacitors have attained greater power densities and energies than EDLCs despite affecting rate capability. This particular category of SCs uses multiple electrode types that are composites of various electrode materials. On a model or carbon structure, the materials can be conducting polymer or metal oxide. Asymmetric forms employ various electrode combinations. This is done to increase the device’s operational potential window [38]. The high cell capacity of hybrid capacitors is due to the low self-discharge, operating temperatures between -20 ^{0} C and 70 ^{0} C, high reliability, high energy and power density, and large anode capacity.

It has been demonstrated that a supercapacitor’s cyclic voltammetry (CV) curve must be about rectangular if just double layer capacitance is present (as illustrated in Fig. 4a); owing to the effect of Redox reactions and oxidation reactions, the form of the curve will not more be rectangular if pseudo-capacitance contributes. This effect modifies the shape of the curve based on the nature of the electrochemical processes, which have been a trait of the composite when at most one the component is made of pseudocapacitive material (as illustrated in Fig. 4b). As a result, the CV curve in hybrid type capacitors generally has a non-rectangular shape.

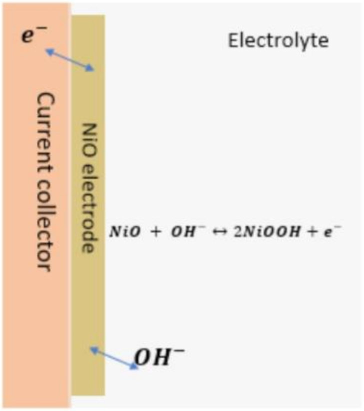

Fig. 5. Mechanisms NiO electrode.

2.4. Operation mechanism of supercapacitors

According to the energy storage concept, superconductors are classified into three primary types. It should be emphasized that SCs are wet electrolytic capacitors that utilize a liquid electrolyte containing ions (charged complexes) to ensure charge transmission. Electric Double-Layer Capacitors (EDLC) supercapacitors, belong to the first type. This is the most popular type of supercapacitor and accounts for the majority of the commercial market. The second category consists of pseudo-supercapacitors (also known as faradaic SCs). This type of supercapacitor, used far less frequently than EDLC supercapacitors, is commercially available from several companies. In terms of the fundamental design, they resemble batteries more than capacitors. The phenomenon of pseudo-capacitance occurs when electrode materials undergo redox reactions and intermediary electron transfer [39]. Hybrid SCs are the third and final type of SCs. This is the most recent type of supercapacitor. The EDLC and pseudo-SCs, the two earlier supercapacitor varieties, are combined in this most advanced supercapacitor. Better gravimetric and volumetric densities and the ability to deliver high currents are the key benefits. Hybrid SCs have higher energy densities because of the faradaic reaction that happens on the negative electrode, which is typically comprised of pseudocapacitive electrode material. AC is commonly used to create positive electrodes because it can store electrostatic energy in the double layer that forms electrode surface. Hybrid SCs can produce large currents due to the electrostatic contact among the surface of the electrode and the charge transfer on the positive electrode side [3, 40].

The most significant parameter affects how efficiently a supercapacitor performs the electrode materials. Typically, different charge storage processes are taken into consideration while choosing an electrode material. Pseudo-capacitors and EDLCs are two forms of supercapacitor mechanisms that can be distinguished. As a result, supercapacitor electrode materials can be classified into three types [8, 10, 41-43]: (1) metal oxides or hydroxides, (2) carbon materials, and (3) conductive

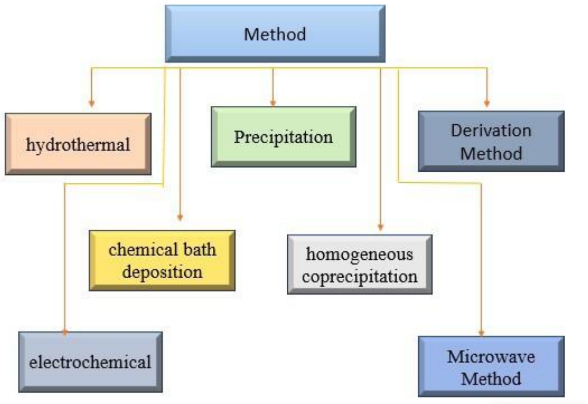

Fig. 7. There are many methods .

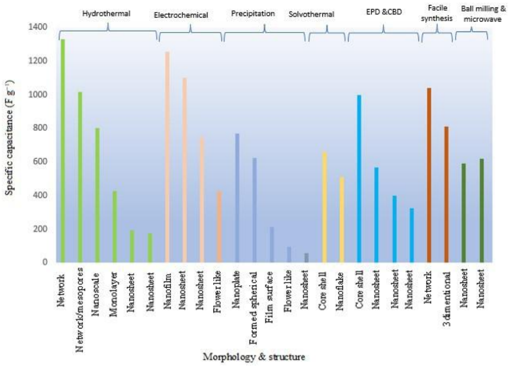

Fig. 9. Graphic of recent article, composite NiO/Carbon materials electrode for SCs.

polymers.

3. Metal oxide electrode

In comparison to carbonous materials substances, transition- metal oxides have a high energy density and stability [44]. A ruthenium oxide is one of the metal oxides (MOs) most commonly considered as active electrode material in SCs because of its high Cs (up to 1580 Fg^{-1}) electrical conductivity and charge-discharge rate [45, 46]. However, ruthenium oxide has numerous limitations, including high toxicity, high cost, and a lack of not easily available. Consequently, there is a need to produce non-toxic, low-cost, and readily available alternative materials for superior electrochemical performance, such as $NiCo_3O_4$, V_2O_5, MnO_2, MoO_3, and CO_3O_4.

NiO for supercapacitor applications because its chemical/thermal stability, cost effectiveness, low toxicity, friendly environmental and ready availability compared to other metal oxides. This act in SCs as a base electrode. Furthermore, due to its unique attributes, NiO is one of the successful materials in various research areas, such as dye-sensitized photo electrodes [47], electrochromic thin films [48, 49], catalysis [50], smart windows [51], fuel cell electrode [52]. NiO prepare by a type number of methods, including chemical bath deposition [53], sol-gel method [48], precipitation method [54], electrochemical method [55], sputtering [56], pulsed laser deposition method [57, 58] and hydrothermal method [59], slurry technique [23] chemical vapor deposition (CVD) [60]. The hydrothermal method has certain advantages over the other methods. The hydrothermal method can create metal oxide nanoparticles with various morphologies and structures that can improve electrochemical attributes. NiO emerges as a hopeful electrode material for pseudo compact due to its affordability and excellent electrochemical function. NiO shows that materials of nanostructure perform peculiar and interesting attributes better than their bulk counterparts. Therefore, electrode materials with crystalline nanoscale grain sizes for SCs have high specific surface areas, resulting in high electrochemical activity and good capacitive performance. Recently, various shape of NiO have been successfully prepared by template synthesis, sol-gel, electrodeposition and liquid chemical precipitation [61, 62]. Prevalent needs for NiO-based electrodes in supercapacitor usage are [63]:

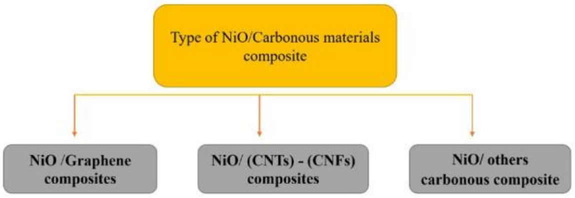

Fig. 8. Type of composite electrode.

1) Metal can coexist in two or more oxidation processes.
2) The oxide should conduct electricity
3) Needed High specific surface
4) The performance of NiO-based pseudo- capacitors is defined whit the redox reaction of Ni or NiO. It is given by the equation (3). and (4).

There are two major theories for NiO formation. One posits theory is that the energy storage process takes place between NiOOH and NiO. It is said that it happens. (oh) instead. 2 and NiOOH [64-66]. These two theories' reactions, as well as the surface faradic reaction (see Fig. 5), can be expressed as follows

$$NiO + OH^{-} \leftrightarrow 2NiOOH + e^{-} \tag{4}$$

$$NiO + H_2O \leftrightarrow NiOOH + H^{+} + e^{-} \tag{5}$$

And between these two hypotheses, the first is commonly recognized while the second is equally applicable since NiO can interact with OH to appearance Ni $(OH)_2$ in alkaline electrolytes and help to capacitance production. Concerning obstacles, NiO's low electrical conductivities can lead to poorer cyclability and lower specific capacitances, hence limiting its practical utilization as a supercapacitor electrode material. To solve this problem, scientists have proposed solutions like the direct deposition of NiO onto conductive materials and the production of nanocomposites with electrical carbon-based materials [67]. In furthermore, the electrochemical properties of NiO are dependent upon its particular porosity and surface area, which can be obtained via efficient synthesis techniques and accurate morphological forms. It is mentioned in a summary of nickel oxide synthesis methods in recent years in table 1 .

4. Carbon material

The corresponding key for SCs is called electrode material, shows a crucial role in enhancing SC performance [83, 84]. Carbon have been utilized widely in the fabrication of SC electrodes among diverse candidates [85, 86]Carbon is an electronically conductive solid with good corrosion resistance, low cost, good stability and low density [87, 88].

Furthermore, carbon porosity and morphology can be easily designed by using oxidizing agents in a high-temperature procedure, a process known as activation. The surface area of these produced highly porous materials was up to 2000 m^2g^1 [89, 90] Controlling porosity in SCs allows not just for a high specific capacity of ion adsorption but as well as for measuring the diffusion rate of ions entering and leaving the pores during the charge/discharge operations. Carbonous materials, from activated carbon (AC) to carbon nanotubes (CNT), are the most commonly utilized electrodes due to their often cited desired chemical and physical attributes. These attributes involve electrocatalytic active sites for a type redox of reactions, controlled porosity, relatively still electrochemistry, processability easiness, low cost and type of form (tubes, monoliths, sheets composites, aerogels, fibers, powders, etc.) [91, 92]. C is used in SCs to provide capacitor capacity. primarily because it can be having a very high internal surface area contrasted to alternatives such as carbon tubes and porous precious metals, it is very affordable and lightweight. AC can be derived from several natural sources Nevertheless, administrating the extent and size distribution of the resulting pores is difficult. Synthetic material or chemical and another polymeric material can determine a more specific activated carbon. It should be noted that the activating agent and circumstances also affect the qualities of the finished product [93]. Graphene sheets organize a part Major of AC, the carbon chemistry details, mostly the pores, and exact structure, are intricate. Little graphitic crystallites of as it were a couple of atomic planes [94] are cross-linked by mostly sp3-bonded carbon units [95, 96].

A newer model based on X-ray and TEM scattering data has shifted the focus, away from the very small graphite crystallites and further toward cross-linking [97]. CB is electrically conductive and is frequently used in polymer technology and electrochemical craft to improve electrical conductivity. It is made up of more or lesser spherical particles (foundational particles) with diameters ranging 10 to 75 nm that combine to form aggregates (fused primary particles) with diameters ranging from 50 to 400 nm.When mixed aggregates with matrix and homogeneously dispersed (possibly additives, binders [98], and for SCs, activated carbon) form dense one-, two-, or three-dimensional networks of phase conductors . CB is generally very pure (about 97–99% carbon) and is called “amorphous”.

Nevertheless, The microstructures are comparable to those of graphite-based materials,and applications of individual organization of carbon electrodes and terms of structural design virtues such as C/metal oxides, graphene, and CNTs. so recent advances and carbon-based materials for supercapacitor electrodes and systems should be thoroughly understood and summarized [21, 99]. Carbon materials have including distinct 0D, 1D, 2D, and 3D nanomaterials.In addition to their considerable investigation in, light emitting diodes (LEDs), solar cells and lasers, 0D carbon materials such as graphene quantum, carbon quantum dots, and carbon nanoparticles supercapacitors. graphene and Graphene quantum dots are microscopic graphene particles with a single or a few layers that combine the key qualities of graphene [100]. For the fabrication of a wearable and flexible supercapacitor system, 1D carbon materials, such as graphene-based fibers, carbon fibers, and carbon nanotubes (CNTs), have garnered significant attention from the scientific community. Lower electrical conductivity and low cycling stability were the primary difficulties with the previously mentioned carbon-based electrodes for supercapacitor applications.Graphene, 2D carbon substance, can solve this problem. A 2D graphene sheet has a thickness of one atom and is

Table 1.
NiO- based materials.

Compound	Synthesis	Morphology	Nanoparticle (nm)	Specific capacitance (F g^{-1})	Retention%	Cycles	Ref
NiO	Sol gel	Nanoflower dimensional (3D)	233	480	-	-	[68]
NiO	solvothermal	uniform NiO granules	380	1386	78.5%	5000	[69]
NiO	one-step thermal oxidation	NiO nanoflakes	-	1784.2	75.8%	20000	[70]
NiO	Hydrothermal	urchin-like NiO architectures	5 to 10	540.5	80%	1000	[71]
NiO	facile sonochemical	nanoclutser like NiO	~6	449	74%	500	[72]
NiO	successive ionic layer adsorption and reaction	sponge-like nano-flakes	40 to 5	674	72.5%	2000	[73]
NiO	hydrothermal route	NiO nanocube	120	1012	89.3%	10000	[74]
NiO	solvothermal	nanoflakes	-	305	84%	5000	[75]
NiO/MnO	two-step method	core/shell nanocomposites	-	266.7	81.7%	2000	[76]
$NiCo_2O_4$/NiO	hydrothermal	hierarchical structure	-	1188	85%	7000	[77]
Ag/NiO	surfactant-assisted hydrothermal	nanoarrays	-	204	96%	4000	[78]
NiO/Ni-MOF/NF	Facile hydrothermal	cylindrical cage-shape structure	20	144	94%	3000	[79]
Co_3S_4@NiO	hydrothermal	hollow structure	8-15	1877.93	92.6%	10000	[80]
CuO/NiO/N-rGO)	probe sonication assisted solvothermal	hexagonal shaped	130	220	97%	5000	[81]
NiO@$NiFe_{2O}$4	hydrothermal	porous interconnected network structure	-	248.4	89.2%	2000	[82]

composed of carbon atoms with sp 2 bonds [101, 102]. 3D graphene networks (3DGN) with an interconnected porous microstructure have demonstrated the considerable possibility for hybrid SC systems [103]. This review is divided into three sections, as illustrated in Fig. 6.

5. NiO/carbonous material composites and the preparation

Metallic nanoparticles have received much attention because of their great potential for the development range of efficient comprehensive technology. Nevertheless, pure metal nanoparticles are difficult to use due to dissolution in acids, aggregation and their instability due to oxidation in air. It restricts their potential usage in both scientific research and industry. To dominate these limitations, protective shell application has been proposed as a promising method to better metal nanoparticle chemical stability. Polymer silica, carbon and etc, as a coating material are proposed [104, 105]. Carbon is considered the most favorable material for encapsulation because it has high surface activity, good biocompatibility and high stability both physically and chemically.

NiO nanoparticles, which have various catalysts activity, have played important role in different Research and development [20]. The production of a nanocomposite between the NiO layer and the carbon sheet, in addition to the distinctive textural crevices of the biomass-derived AC, results in a wide range of nanoscale crevices that allow the electrolyte ions to access the electrode surfaces. Carbon/metal oxide composites have found widespread use as effective electrode materials for alkaline SCs, because of their high redox capacitances. [29–32] However, there is little information on AC/NiO nanocomposites, and literature reports on the use of ACs produced from biomass are extremely rare [106].

Carbon nanocomposite materials containing metal nanoparticles such as Ni, Co, or Cu or their oxides are appealing for a wide range of applications, including components of scatter radiation absorbent media, heterogeneous catalysts for petrochemical processes, biomedicine, supercapacitor electrode materials and magnetic resonance tomography [107, 108]. Metal-carbon nanocomposites with very promising physical, chemical, and mechanical properties are of particular interest to researchers as heterogeneous catalysts for a variety of chemical processes.

Because of their exceptional electromagnetic wave absorption attributes, Ni/C nanocomposites have possessed a great deal of interest as key members of the group of carbon-encapsulated metal nanoparticles. [109]. Notably, metal-carbon composites have been demonstrated to be effective magneto-sensitive sorbents for the absorption of explosives, water contaminants, and dyes [110, 111]. Due to the excellent adsorption capacity and enhanced magnetic properties of the sorbents, they may be swiftly and efficiently removed from the solutions using a magnetic field, or delivered to the relevant nodes of the equipment for cleaning.

There are two primary types of electrode materials used in SCs, each with its unique mechanism of operation: (1) Redox active materials, like conducting polymers and transitional-metal oxides, which add pseudocapacitance through quick, reversible redox reactions; and (2) High-surface-area carbonous materials that are charged and discharged using an electric double-layer mechanism [112]. Typically, EDLCs have a high long life and power density, however very low specific capacitance. Pseudo capacitors, on the other hand, can theoretically process between 10 to100 times more capacitance but in practice suffer from low conductivity and low active material utilization [13, 113]. To address these issues, attempts have been made to develop hybrid materials that mix large surface area pseudo capacitance materials with materials based on carbon to increase electrochemical performance [114, 115]. By increasing the electron transfer between active materials, connecting NiO particles with some conductive additives like CNTand graphene may also aid to increase their electrochemical performance. Due to its unique features, like it is incredibly high electric conductivity and a relatively large surface (2630 m^2 g^{-1}), graphene has drawn significant scientific attention in energy-storage technologies [116, 117].

5.1Preparation methods

Numerous materials have been immediately coated on nickel foam layers using various synthesis techniques, such as solution immersion followed by heat treatment, chemical bath deposition (CBD), chemical vapor deposition, electroless plating, and electrodeposition.

Both chemical and electrochemical approaches could be used to produce supercapacitor electrodes containing NiO. The method of preparation results in the formation of diverse morphologies of NiO, which influences the material's electrochemical characteristics. NiO produced as a thin layer possesses the maximum capacity [118]. In addition, there is a growing interest in mixing carbon with transition metal oxides to take advantage of their synergistic effects in order to improve electrochemical performance [119]. Below is several types of the synthesis schematic of The NiO composite and some carbon materials.

6. Electrochemical performance in supercapacitor

As stated previously, the charge storage and the capacitance and an electrochemical supercapacitor (ES) are dependent on the electrode materials utilized. Growing novel high-capacitance materials and enhanced operation compared to currently available electrode materials is, therefore, the most significant strategy for overcoming these challenges [120].

ES capacitance is highly dependent on electrode material surface area. Since not every surface area becomes electrochemically, active available when the capacitance of various materials in contact with an electrolyte does not enhancement linearly with rising the specific surface area. Therefore, it may be correct to demonstrate the electrode capacitance behavior using an electrochemically active surface area for the electrochemically available or valuable surface area. Pore size is crucial to the electrochemically active surface area from electrode material.

There are two challenges for using to NiO -based electrodes for ES: (I) Failing to perform well during the cycle, (II) high resistance

(I): For instance, the capacitance of Ni $(OH)_2$ film formed via electrodeposition was 578 Fg^{-1}. Nevertheless, about. The specific capacitance was reduced by 4.5%. Couse of the microstructure of the material degrading, after 400 cycles [121]. A further illustration is a NiO layer fabricated by electrochemical techniques, demonstrating poor cycle performance [122]. After 5000 cycles at 0.49 mA cm2 current density, its capacitance reduced from 160 to 140 Fg^{-1}, representing 12.5% of its original capacitance has been lost. A supporting strategy employing CNT and Co as composite supports was investigated to fix this degradation.

At discharge, the composite material produced by thermal decomposition of cobalt and nickel nitrates on the surface of a graphite/ CNT electrode displayed a capacitance of 569 Fg^{-1}.10 milliamperes per square centimeter of water is the density of the fluid in a 1 M KOH solution. This composite electrode also shown remarkable cycle stability.

A little 0.2% of the specific capacitance was lost after being subjected to 1000 cycles at a current density of 10 mA cm-2. [123].

(II): The high resistivity of NiO electrodes is another difficulty (low electrical conductivity Creating NiO composites and materials of conductive carbon is an efficient strategy for addressing this issue. In nanocomposite of nickel oxide/ CNT, [124] The electrical conductivity of the host NiO was greatly enhanced by the CNT electrical conduction network. . The high specific surface area CNTs surface area also can boost the number of active sites in redox reactions. Therefore, When

Table 2.
Various methods and electrochemical NiO / carbonous materials electrode in supercapacitor.

Synthesis technique	NiO/Carbonous composite	Morphology	Electrolyte (mol/L)	Specific capacitance (F g^{-1})	Current density (A/g^{-1}) or ScanRate (mV/s)	specific surface area(m^{2}g−1)	No. of cycles	Retentionon capacity	Ref.
one-step electrochemical technique	NiO/C	nanosheets	-	750,1100	-	137	-	97%	[131]
hydrothermal preparation	NiO/RGO	NiO nanoparticles /the graphene sheets	6 M KOH	171.3	0.5 A/g^{-1}	-	2000	-	[132]
homogeneous coprecipitation	RG-O/NiO	RG-O platelets/Nio nanoparticles	6 M KOH	770	2 A/g^{-1}	-	1000	96%	[133]
precipitation method	AC/NiO	NiO nanoparticles formed spherical structures	6 M KOH	624.20	1 A/g^{-1}	-	1000	95.25 %	[134]
Precipitation	NiO/AC	film surface looks highly porous and fine particles	1 M KOH	214.48	40 mA g^{-1}	1290.67	-	-	[135]
by a facile hydrothermal	RGO/NiO	3D graphene conductive network/ the mesoporous structure	-	1016.6	-	-	5000	94.6%	[136]
ball milling method	NiO/RGO	-	1M KOH	590	1-15 A/g^{-1}	103.1	1000	88%	[137]
hydrothermal	NiO/CNT	-	1M KOH	1329	84 A/g^{-1}	111.30	1000	-	[138]
hydrothermal	G-NiO	monolayer graphene/ NiO nanocomposites	6 M KOH	429.7	1 A/g^{-1}	174.1	2000	86.1%	[139]
Precipitation	NiO /AC	flower-like shape	6 M KOH	95	200 mA g^{-1}	702	-	-	[140]
Precipitation	NiO/AC	Graphite sheet-nanoparticles Nio	6 M KOH	56.3	50 mV/s	-	1100	88%	[141]
EPD and CBD	NiO/RGO	graphene sheet/porous NiO	1 M KOH	400 and 324 F g1	2 and 40 A g^{-1}	-	2000	94%	[142]
Microwave based in situ	GN/NiO	Graphene/NiO composite	5 M NaOH	617	1 A g-1	-	5000	-	[143]
preparation of electrochemical active materials and modification	NiO/GO	NiO/graphene oxide (GO) films	6 M KOH	1258	5 A/g^{-1}	-	2000	98.3%	[144]
hydrogen gas reduction	NiO/rGO	Flowerlike	6 M KOH	428	0.38 A g^{-1} or 5 mV s–1	-	5000	90.2%	[145]
via a facile chemical bath deposition	CNT@NiO	core–shell hybrids	1 M KOH	1000	1 A g^{-1}	-	10000	93.5%	[146]
Self-assembly	MG/NiO	monolayer graphene/ NiO sheets	6 M KOH	525	200 mA g^{-1}	134.5 m^2 g^{-1}	1000	95.4%	[147]
Electrophoretic deposition	CO/NiO	Nanosheet	0.5 M KOH	569	10 A g^{-1}	110 m ^{2} g^{-1}	3000	100%	[148]
vapor deposition polymerization (VDP)	NiO/ACC	Amorphous carbon-coated NiO nanofibers (NiC NFs)	1 M KOH	288	0.3 A g^{-}	144 m ^{2} g^{-1}	3000	89%	[149]
green and facile synthesis	PC-NiO	three-dimensional porous structure	6 M KOH	811	1 A g^{-1}	187 m ^{2} g^{-1}	1000	84.55%	[150]
solvothermal	NiO QDs/Ni@ NC-4-CNT	core shell	2 M KOH	660.1	0.3 A g^{-1}	263 m ^{2} g^{-1}	5000	-	[151]
via heat treatment after hydrothermal	NSCDC/NiO	nanoscale pores	3M KOH	804	1 A g^{-1}	111.7 mAh g	5000	84%	[152]
solvothermal	porous graphene-NiO (PGNO)	NO flakes and PG sheets	2 M KOH	511.0	5 mV s-^{1}	-	10000	80%	[153]
facile synthetic strategy	NiO/N-doped carbon	multi-layered network structure	6 M KOH	1039.4	1 A g^{-1}	-	1500	83.4%	[154]
hydrothermal	NiO/rGO	nanosheet	6 M KOH	192	0.2 A g^{-1}	-	2000	72.1%	[155]

compared to a NiO_x thin-film electrode's 350 F g^{-1}, a NiO_x/CNT electrode's specific capacitance can reach 1000 F g^{-1}, substantially double the value [125].This has greatly improved performance. For example, While NiO was being coated on nickel foam, the CBD method produced a maximum voltage of 1.5 V for both hybrid capacitor cells [126]. Li et al [127]Electrochemical supercapacitor (ES) electrodes were fabricated by impregnating porous nickel foams with MnO2 and carbon nanotubes, yielding a maximum 155 F g^{-1} specific capacitance. Nickel foam is extensively used as an electrode material, but to our knowledge, this was an attempt to simultaneously deposit two types of electroactive materials on such substrates to take advantage of their nearly nonexistent good characteristics. Processes lead to electrode cracking and weak long-time stability. Therefore, with an intelligent choice, the electrochemical properties have been improved by a composite-based NiO electrode.

According to another research, Measurements of electrochemical were accomplished in three -an electrode system on a CHI600E electrochemical workstation. Cyclic voltammetry, galvanostatic discharge-charge, and electrochemical impedance spectroscopy were done using a 6 M KOH solution at room temperature, an Ag/AgCl (in saturation KCl) reference electrode, and a Pt wire in the numerator). After analyzing the CV curve, the following formula was used to determine the electrode's specific capacitance [128]:

$$Cs = \int Idv / \left(2m \times v \times \Delta v\right) \tag{6}$$

Here, specific capacitance is denoted by Cs(F/g), the reduction current or oxidation is (A), m(g) is the electrode material's charge mass, (mV s^{-1}) demonstrates the sampling rate of the potential, (V) is the voltage range of the sweep portion. Despite upgrading NiO's micro/nano structure to increase capacity and cycle stability, NiO still has a few drawbacks. Specifically, cycle performance, rate performance, and conductivity must be enhanced. This issue is anticipated to be resolved by embedding NiO evenly into a conductive second phase with volume buffering capacity. For the formation of NiO/carbon nano - composites, carbon materials are one of the primary options for the phase 2 [129, 130]. The advantages provided by the mixture of carbon-based materials and NiO are as follows: (I) active components conductivity and electron transmission progress, maybe prevent the aggregate of NiO nano-particles, (II) alleviate the active components volume change throughout charge / discharge, (III) carbon based- materials that envelopment the active components can prevent feasible way reactions, (IV) enlarge electrochemical, that stability window, which is conducive to major capacity enhancement. As a result, carbon materials such as graphene, organic carbon, carbon nanotubes, and carbon fiber are utilized as conductive matrices in NiO-based electrode materials, yielding a range of nanostructured NiO/C composite electrode materials.

As shown in Table 2, the electrochemical characteristics of several NiO/C composite electrode materials have been summarized.

In general, the electrode NiO / carbon-based materials can be categorized into three types.

6.1. NiO /Graphene composites

Graphene is a 2-dimensional (2D) material having intriguing mechanical, electrical and optical properties owing to its nanocrystalline structure. Graphene seems to have more interlayer electrons, leading to greater conductivity. NiO is uniformly incorporated into the graphene layers of 2D graphene, preventing the graphene layers from aggregating and restacking. Multiple type of research has been released so far on the production of hybrid graphene/NiO electrode materials for SCs. The monolayer NiO /graphene composite was created in all of the NiO/graphene composites by the electrostatic interaction between the Ni_2 ions and both sides of GO [156]. Bello et al. [157] reported on a nickel foam template, few-layer graphene was produced by (CVD). Nickel oxide nanostructures were bound to the resulting 3D graphene using the sequential ionic layer adsorption and reaction (SILAR) method. The NF-G/NiO electrode material performed well as a pseudocapacitive sensor at 2 mVs^{-1} with a capacitance of 783 Fg^{-1}. After 1,000 cycles, Capacitance was maintained at 84% of its original value demonstrating outstanding cycle stability. The results indicate that 3D graphene-based composites are flexible and show great potential as electrode materials for supercapacitor usage. In Yuping Zhang et al. [158] researched about graphene oxide/NiO composites, the electrolytic plasma-produced composite rGO/NiO showed, the specific capacitance at 1 Ag^{-1} current density was 1093 Fg^{-1}. Further, the rGO /NiO composite demonstrated outstanding cycle durability, retaining 87% of its initial capacitance and After 5000 iterations, coulomb efficiency is at 90.6%.For the rapid and cost-effective production of rGO-metal oxide composites for use as energy storage materials, electrode-assisted plasma electrolysis is a promising method. Meenaketan Sethi et al. [153], Through the use of an unique mixed solvent solution and a solvothermal technique, they detail the straightforward synthesis of porous graphene-NiO (PGNO) nanocomposites. Microscopical examination of porous graphene (PG) verifies the presence of pores into the bilayers, whereas X-ray diffraction analysis of NiO(No) reveals a flake-similar structure, and a PGNO composite shows that NO nanoflakes are anchored to PG sheets.. Variations in the percentage content of PG was used to create a variety of electrode materials designated as 5 to 30 PGNO, respectively. The electrochemical analysis revealed a satisfactory capacitance value of 511.0 F g^{-1} at a scan rate of 5 mV s^{-1} for the 10 PGNO composite in a three-electrode method and 10,000 cycles at 8 A g^{-1} and 80% capacitance retention. At a scan rate was 5 mV s^{-1}, the symmetrical hybrid supercapacitor constructed with 10 PGNO electrodes exhibited a good capacitance value of 86.0 F g^{-1}.

In 2018, researchers discovered that after a hydrothermal process, many NiO platelets developed on Ni foam, whereas on graphene surface foam, flower-like NiO with many microscopic mesoporous nanoflakes formed. The NiO/graphene composites have very high specific capacitance 1062 F g-1 at 1 A g-1 and excellent cycling stability (90.6% capacitance retention after 5000 cycles). graphene /NiO supercapacitors outperformed NiO platelets on Ni foam. The former supercapacitor performed well due to the 3D graphene active layer and mesoporous NiO nanoflakes, which enabled electrolytes diffusion and effective charge transportation. NiO in the composite contributes a significantly greater S.C. This is because the composite's high Conductivity of graphene sheets and special 3D flowerlike NiO shape have synergistic and functional properties that improve the process of electron transport. The graphene-based on NiO nanoparticles performed well electrochemically as well [159].

6.2. NiO/ (CNTs) - (CNFs) composites

Composite structural materials made of one or more fundamental structural units repeated according to a given law, 3D nanostructures are a type of nanoscale structure. These include hollow structures, polyhedrons, flower-like structures, yolk-shell structures, microspheres, etc. Many people think that structures that can store a specific space (like multilayer core-shell structures, core-shell structures, multilayer core-shell structures, hollow spheres, etc.) can help reduce the volume expansion that occurs during charge and discharge, making them a promising electrode material [160, 161]. Increased Conductivity and a sizable surface area are characteristics commonly associated with CNFs and CNTs. NiO-based/CNTs composites have been researched in depth in recent years. They are forecasted to exhibit increased capacitance values due to the CNTs' high electronic Conductivity [162, 163].S.C was steadily reduced as the CNT material increased because the EDL capacitance would enhance, and the pseudo-capacitance would drop as the CNT content grew. It is demonstrated that the EDL capacitance contribution to the composite is significantly lesser than the pseudo-capacitance for a fixed amount of material. Also, CNTs' tendency to aggregate in most solvents may severely limit their usefulness, prompting efforts to alter their surface before practical deployment [23, 164]. This allows CNTs to generate 3D porous networks on the nanoscale scale. During an electrochemical examination, the porous channels within the composite allow for the absorption and transport of electrolyte ions. In recent years, there has been a much attracted using soft-/hard-template techniques to create porous NiO with a large surface area [144, 165-167]. Hemraj M. Yadav et al. [168], In their research, they described the thermal reduction Making supercapacitor-useful composites of nickel oxide multi-walled carbon nanotubes (NiO/NMWCNT/PPy).The electrochemical characteristics of a NiO/MWCNT/PPy composite were studied in a 2 M KOH electrolyte. The greatest specific capacitance of the NiO/NMWCNT/PPy electrodes is around 395 F g^{-1}. When compared to pure NiO materials, the composite electrodes' retention was above 90% after 5000 cycles of cycling. The enhanced electrochemical performance is a result of the synergistic interaction of NMWCNT/PPy and nickel oxides.

Another paper, described an electrode material for SC consisting of (NiO) nanoparticles based on different orientation multi-walled (CNTs) made with a tiny mesh of stainless steel for structure (CNT-NiO). The multi-walled structure of CNT scaffolds was demonstrated by their interlayer spacing of 0.32 to 0.02 nm and their diameter of 20 to 100 nm. NiO nanoparticles typically ranged in size from 2 to 7 nm. The presence of NiO in the scaffold was verified by X-ray analysis. In an aqueous 1.0 M Li2SO4 solution, a wide supercapacitors range of voltage 2.0 V was achieved. From galvanostatic discharge curves, high specific capacitance measurements of 1200 F g^{-1} at 5 A g^{-1} for the NiO-CNT electrode composite were derived. By using a voltametric technique, they found that at 0.02 V s^{-1}, the specific energy was 140 Wh kg^{-1} and the energy was 9 Wkg^{-1}, both when the effect of negative voltages was taken into consideration. At this scan rate, a capacitance was 1028 F g^{-1} [169]. In 2020, Yi-Hsuan Lai et al. [170], the used of conductive CNTs in the fabrication of multilayered CNT*/NiO composite sheets results in outstanding electrochemical performance. NiO is the essential component for achieving a high specific capacitance via a redox reaction. In multi layered NiO / CNT composite sheets, the imperfections and functional groups containing oxygen found on the surface of CNTs, which are produced by acid treatment, serve as active sites for the growth of nickel oxide. To keep the totality of the paper-like electrode, the composite sheets were blended with varying percentages of pure. In order to achieve the best results, the capacitance of M-CNT /NiO-0.5 composite paper electrodes should be set to 713,9 F/g.It has a power density of 698.6 W/kg, an excellent stability of 88.2% delivering maximum after 3000 cycles of testing, and an energy density was 23.9 Wh/kg. Seoyoon Shin et al. [171] reported, for the application of supercapacitors, a novel combination of NiO–carbon composites was created by exposing a nickel metal-organic framework directly to carbon, (CNF)/ (Ni/MOF). The CNF film is used as a substrate with strong electron transfer capability and as the basis of a self-standing electrode in the new method. Increasing electrical conductivity is attributed to the evenly dispersed 8 nm Doped NiOs across the carbon matrix, as shown. Capacitances of 742.2 and 671.1 F g^{-1} (at 1 - 10 A g^{-1}), respectively, demonstrate the high-rate capabilities of a CNF/NiO/C composite electrode.

A supercapacitor (ASC) made from NiO/C-CNF, activated carbon has a power density of 1,947 W kg^{-1} with a good specific energy density of 58.43 Wh kg^{-1}. According to research in recent years, suggest a simple approach for "in-situ" preparation of a novel type of NiO on a network of N/ doped carbon of nanofibers (CNF/NiO). The CNF/NiO composite possesses high specific area and 3-dimensional porous network structure facilitate efficient electron/ion transport and interaction between the active component and electrolyte, respectively. Furthermore, NiO nanoparticles attached to a network of carbon nanofibers can produce good and durable pseudo capacitance. The NiO-based electrode/CNT may reach applied to supercapacitors, the capacitance values reach 674 F g^{-1}, with 98.6% retention after 5000 cycles. Also, the CNF/NiO composite based asymmetrical supercapacitors reach a capacitance value of 86 F g^{-1} at a broad voltage was 1.6 V, with energy was nearing 30,2 Wh kg^{-1} and power densities was 8.1 kW kg^{-1} .The technique offers the advantages of being simple to operate, environmentally friendly, and scalable [172].

6.3. NiO/ other carbonous composites

The two main structures of composites are mentioned above, and now we will examine the composite of nickel oxide/ and other carbon materials. Rahul Kumar et al. [173] reported that The colloidal synthesis of sucrose-derived carbon-coated nickel oxide (SDCC-NiO) for high-function supercapacitor applications was achieved. SDCC-NiO composite was created using a dissolved carbon principle (sucrose) and nanoparticles of nickel oxide. Following annealing in an inert environment, nanoparticles have sucrose transformed to carbon and coated on their surface.

SDCC-NiO as produced was employed as an electrode. At 5 mV s^{-1} was scan rate in a 1 M KOH electrolyte, SDCC-NiO displayed the maximum specific capacitance of 473 F g-1, 4.5 kW $kg^{-1}$was energy density, and 15 A g^{-1} was current density. in 2014,Shin et al. [174] made NiO nanofibers (NiC NFs) with an SC of 288 F/g by coating them in amorphous carbon derived from polypyrrole (PPy). As coating thickness increased, SC values decreased, which should be noted. This is because the electrolyte ions' diffusion route length is shorter in the thinner layers of amorphous carbon (created from PPy) than in, the thicker ones. The electrode outperformed the other pure pseudo-capacitive materials in terms of cycle life. The composite's core component (pseudo-capacitive materials contribute to quick structural deformation) is shielded from structural degradation by the double-layer-based carbon covering. In the graph below, the capacitance compared to the morphology with different synthesis methods of nickel oxide/carbon material composite is shown in summary.

7. Conclusions and future insights

In this review, we have methodically checked recent signs of progress in (NiO)/carbonaceous materials composite as vitality capacity materials for S.C. Studied structure and electrochemical NiO nanoparticle / carbonous materials when combining and producing composite as electrode materials, along with new developments and techniques for their development. NiO has very low electrical Conductivity that restricts the power of the capacitor performance. To make strides electrode SC, NiO is frequently composed of nanostructured several carbon materials like carbon, graphene and CNTs, CNF, and etc, NiO-based composite cathodes. Thus, superior electrical Conductivity and an abundance of locations where electrolyte ions can react are obtained. composite takes advantage of the pseudo-capacitance metal oxides and the conductive capacity EDL of carbonaceous materials, suggesting efficient applications for S.C.s. The morphology of cathode materials has a significant effect on their charge-storage capacity; it is so important to synthesis materials with the right morphology. The performance of a supercapacitor is determined in large part by its specific storage capacity (SSA) and its conductivity. Optimization is required. In this work, we studied electrochemical composites and synthesis methods. Authors' focus on later work, the nanocomposites and fabrication methods developed in this work may apply to other electrochemical applications, including energy storage and energy storage and conversion systems. Furthermore, for future other metal oxide and carbonous materials need extensive investigation. A large number of investigations have been conducted on bioactive glasses.

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