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Original Research

Sonochemical synthesis of nanostructured nickel hydroxide as an electrode material for improved electrochemical energy storage application☆

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ABSTRACT

A facile and fast approach for the synthesis of a nanostructured nickel hydroxide ($Ni(OH)_2$) via sonochemical technique is reported in the present study. The X-ray diffraction results confirmed that the synthesized $Ni(OH)_2$ was oriented in β-phase of hexagonal brucite structure. The nanostructured $Ni(OH)_2$ electrode exhibited the maximum specific capacitance of 1256 F/g at a current density of 200 mA/g in 1 M $KOH_{(aq)}$. $Ni(OH)_2$ electrodes exhibited the pseudocapacitive behavior due to the presence of redox reaction. It also exhibited long-term cyclic stability of 85% after 2000 cycles, suggesting that the nanostructured $Ni(OH)_2$ electrode will play a promising role for high performance supercapacitor application.

1. Introduction

Supercapacitors have attracted great attention as energy storage devices because of their high power density, fast charging time and long lifespan. It can be classified into two types such as electrical double layer capacitor (EDLC) and pesudocapacitor. In EDLC, the electrical charge is stored at the electrode-electrolyte interfaces but in pesudocapacitor, the charge is stored from reversible faradaic reactions occurred at the electrode-electrolyte interfaces [1–4]. The electrochemical performances of the device are mainly depending on physicochemical properties of the electro-active materials. Carbon based materials such as activated carbon, graphite, graphene, carbon nanotubes and etc., have been used in EDLC. On the other hand, transition metal oxides/hydroxides and conducting polymers are significantly employed for pesudocapacitor, which are having high energy density than that of EDLC. There are several metal oxides have been used as an electrode materials such as RuO_2, NiO, CuO, MnO_2. TiO_2, MoO_3, etc. The metal oxides have wide band gaps (semiconductors or even insulator nature), which leads to exhibit high specific capacitance but poor electrical conductivity, resulting to limit the power density. Conducting polymers have flexible properties and low-cost. However, they have relatively low specific capacitance (< 100 F/g) and poor cyclic stability due to their chemical instability in the electrolytes [5–7]. These disadvantages can be overcome by introducing alternative inexpensive electrode material of nickel hydroxide ($Ni(OH)_2$) due to low cost, well-defined electrochemical redox nature, and easy to prepare with different structural morphologies.

Nickel hydroxide possess a hexagonal layered morphology with two polymorphs such as α-$Ni(OH)_2$ and β-$Ni(OH)_2$. Upon oxidation, α-$Ni(OH)_2$ is converted into γ-NiOOH at a lower potential than that of oxidation potential range for conversion of β-$Ni(OH)_2$ into β- NiOOH [8,9]. However, it is very hard to synthesis of α-$Ni(OH)_2$ and also unstable during preparation or on storage/testing period in strong alkaline medium, which is quickly transform into β-$Ni(OH)_2$ [10]. Until now, there are different sizes and shapes of nanostructured materials received tremendous attention in electrochemical applications due to the influence of physicochemical properties. For example, Li et al. reported that nanosheet morphology of $Ni(OH)_2$ revealed specific capacitance of 953.67 at 0.2 A/g in presence of 6 M KOH electrolyte [11]. Wang et al. reported fish-like morphology showed the specific capacitance of 1000 F/g at 0.01 A/g [12]. Yang et al. reported that the electrodeposited $Ni(OH)_2$ on Ni foam showed 3D nanostructure with porous morphology with the specific capacitance of 3152 F/g at 4 A/g. The electrochemical performances of $Ni(OH)_2$ are significantly varied with respect to the morphology, which is compared with other energy storage materials as provided in Table 1.

Various methods have been reported to synthesize the nickel hydroxide with different structural morphologies and shapes, such as

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Table 1
Summarize the $Ni(OH)_2$ work with latest reported results of energy storage material.

Materials	Synthesis method	Surface morphology	Current Density (A/g)	Specific capacitance (F/g)	Electrolyte	References
$Ni(OH)_2$	Chemical precipitation	Nanosheet	0.2	953.67	6 M KOH	[11]
NiO	Hydrothermal method and followed by calcination	Ball-like structure	0.2	411	2 M KOH	[13]
$Ni(OH)_2$ particles	Repeated immersion method	fish-like shape	0.01	1000	3 M KOH	[12]
NiO	Sonochemical and followed by calcination	Nanocluseter	0.3	448.5	1 M KOH	[14]
rGO–Co_3O_4	Hydrothermal	Cubical shape decorated rGO sheet	0.2	278	1 M KOH	[15]
NiO	Electrohydrodynamic atomization	anisotropic nanoplatelets	0.1	110	1 M of KOH	[16]
NiO	surfactant-templated wet chemistry followed by the decomposition	Porous nanosheets	3	993	6 MKOH	[17]
$Ni(OH)_2$	Electrodeposition	3D and porous superstructure	4	3152	3% KOH	[18]
CdO–$Co(OH)_2$	Electrodeposition	Nanoplates	0.01	1119	0.1 M KOH	[19]
Graphene/$Ni(OH)_2$	Mechanically assisted method	Nanoparticles dispersed on graphene sheet (nanocomposite)	4	1568	1 M KOH	[20]
nickel-cobalt layered double hydroxide	Hydrothermal	Ultrathin nanosheets	3	2682	1 M KOH	[21]
Nickel-cobalt layered double hydroxide						
$NiCo_2O_4$	Hydrothermal	nanoplates	0.375	132	2 M KOH	[22]
$Ni(OH)_2$	Chemical precipitation	Nanosheets	0.3	282.4	6 M KOH	[23]
$Ni(OH)_2$-graphene sheet-carbon nanotube composite	Two step process of Solvo thermaland chemical precipitation	Nanosheets are dispersed into the 3D graphene–CNT framework	0.2	1170.38	6 M KOH	[11]
α-$NiMoO_4$	solution combustion synthesis	Irregular shaped	1.2	1517	2 M NaOH	[24]
$Co(OH)_2$ loaded carbon fiber	Electrodeposition	nanoflakes	0.001	386.5	1 M LiOH	[25]
β-$Ni(OH)_2$ films	Chemical bath deposition	Hierarchical multilayer nanosheets clusters	0.0005 A/cm^2	462	2 M KOH	[26]
Co_3O_4	Electrodeposition	Nanoflakes	6.25	598.9	1 M H2SO4	[27]
$Ni(OH)_2$	Electrodeposition	nanospheres	20	1,868,	1 M KOH	[28]