Journal of Power Sources 402 (2018) 43–52

Contents lists available at ScienceDirect

Journal of Power Sources

journal homepage: www.elsevier.com/locate/jpowsour

Hollow mesoporous carbon spheres enwrapped by small-sized and ultrathin nickel hydroxide nanosheets for high-performance hybrid supercapacitors

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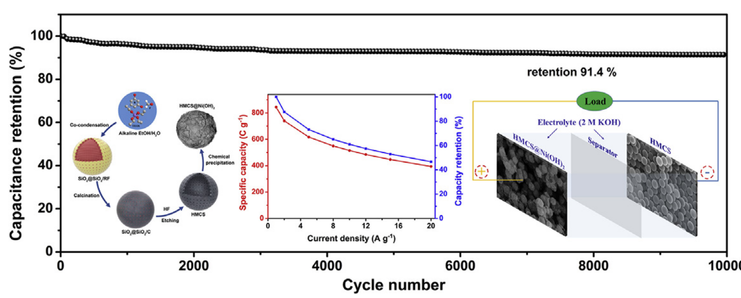
HIGHLIGHTS

- Hollow carbon spheres are enwrapped by small-sized and ultrathin nickel hydroxide.
- The optimized electrode shows excellent specific capacity and rate capability.
- The assembled hybrid supercapacitor delivers high energy density (45.84 Wh kg^{-1}).
- The device exhibited long-term cycling durability after 10,000 cycles.

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Nickel hydroxide
Hollow mesoporous carbon spheres
Hybrid supercapacitor
High energy density
Excellent cycle life

ABSTRACT

$Ni(OH)_2$-based composites are promising electrode materials for high-performance hybrid supercapacitors due to their high theoretical specific capacity and unique nanostructures. Unfortunately, most regular $Ni(OH)_2$-based electrodes can deliver much lower specific capacity in comparison with the theoretical value and exhibit poor rate capability and cycling stability due to the low electrical conductivity and large volume variation. Herein, we present a facile chemical precipitation method to fabricate a hierarchical core-shell nanocomposite of hollow mesoporous carbon spheres enwrapped $Ni(OH)_2$ nanosheets. The $Ni(OH)_2$ nanosheets possess unique small-sized and ultrathin morphology, which endues the resulting nanocomposite with a large specific surface area (481.64 $m^2\,g^{-1}$) and good conductivity, thus giving a high specific capacity of 844 $C\,g^{-1}$ at a current density of 1 $A\,g^{-1}$ with excellent cycling stability and superior rate capability. Furthermore, a hybrid supercapacitor is constructed which presents a high energy density of 45.84 Wh kg^{-1} at a power density of 799 W kg^{-1} and delivers an excellent cycling stability of capacitance retention rate of 91.4% after 10,000 cycles at 10 $A\,g^{-1}$, demonstrating potential application for high-performance hybrid supercapacitor.

1. Introduction

Hybrid supercapacitors, as a novel supercapacitor-battery hybrid energy storage system, have recently drawn tremendous attention in both academia and industry because of the complementary advantages of the fast charging rate of supercapacitors and the high energy density

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https://doi.org/10.1016/j.jpowsour.2018.09.022
Received 29 July 2018; Received in revised form 3 September 2018; Accepted 9 September 2018

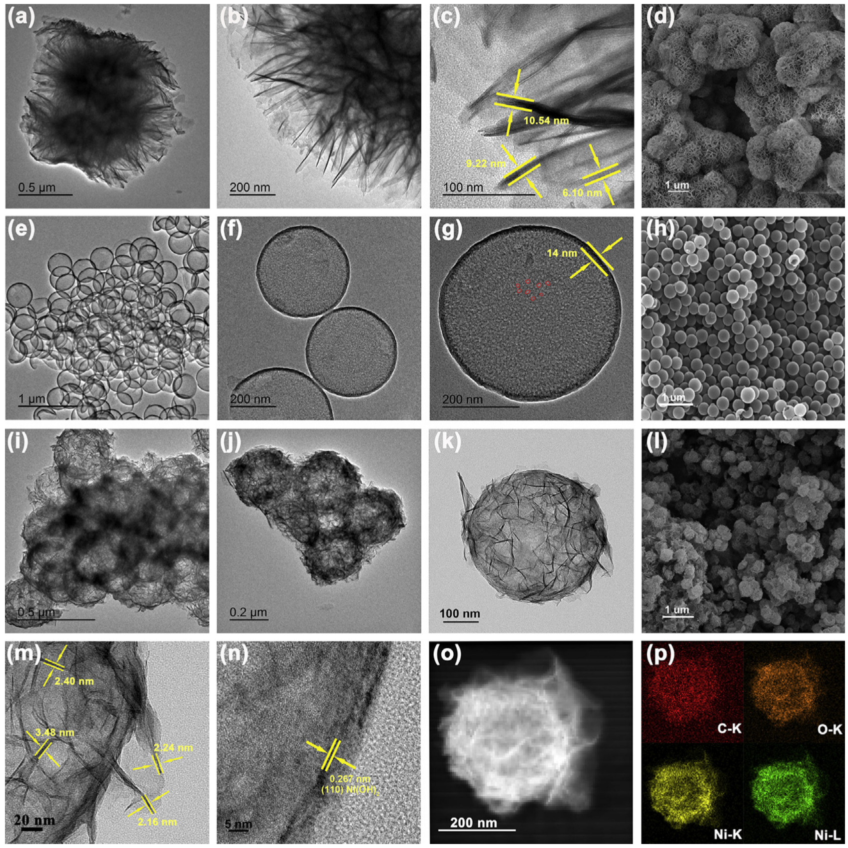

Fig. 1. (a–c) TEM images of pure $Ni(OH)_2$; (d) SEM image of pure $Ni(OH)_2$; (e–g) TEM images of HMCS; (h) SEM image of HMCS; (i–k) TEM images of HMCS@Ni$(OH)_2$; (l) SEM images of HMCS@Ni$(OH)_2$; (m,n) HRTEM image of HMCS@Ni$(OH)_2$; (o,p) EDS mapping of C, O, Ni elements of HMCS@Ni$(OH)_2$.

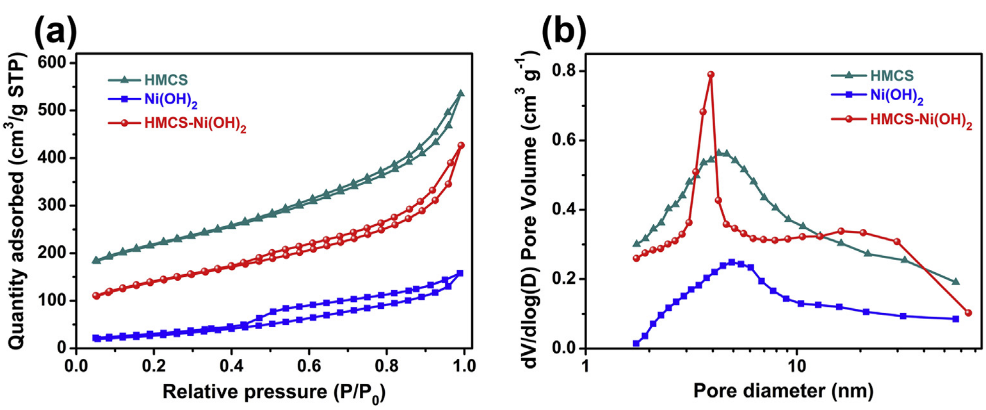

Fig. 2. (a) N_2 adsorption-desorption isotherms and (b) the BJH pore size distribution plots of the HMCS, pure $Ni(OH)_2$ and HMCS@Ni$(OH)_2$.

of rechargeable batteries [1,2]. In a typical hybrid supercapacitor, there are a capacitor-type electrode and a battery-type faradaic electrode in aqueous or non-aqueous electrolytes [3]. This ingenious combination of two electrodes with different types made it possible to achieve a considerably higher energy density than conventional electrochemical double-layer capacitors (EDLCs) and a significantly larger power density than regular rechargeable batteries [4]. Therefore, it is of great interest to design and construct an excellent-performance hybrid supercapacitor using appropriate electrode materials in the device. It is known that the capacitor-type electrode is generally made from carbon-based materials (such as activated carbon [5,6] or graphene [7,8]), while the battery-type electrode is fabricated from lithium electroactive materials (such as $Li_4Ti_5O_{12}$ [9,10], Sn [11]) or an anionic redox active transition metal-based oxide/sulfide/hydroxide (such as NiS [12] or Ni$(OH)_2$ [13]).

Among the above battery-type electrode materials for hybrid supercapacitors, $Ni(OH)_2$ has been proved to be one of the most favorable candidates in alkaline aqueous electrolyte due to its relatively low cost, natural abundance and environmental friendliness [13,14], especially, $Ni(OH)_2$ can deliver a pair of clearly separated redox peaks, resulting in an attractive theoretical specific capacity [15,16]. However, most regular $Ni(OH)_2$-based electrodes can deliver much lower specific capacity in comparison with the theoretical value and exhibit poor rate capability and cycling stability because of their low electrical conductivity and large volume variation [17,18]. To address the above issues, two major strategies have been devoted to improving the overall electrochemical performance of $Ni(OH)_2$ electrode including constructing nanostructured $Ni(OH)_2$ with desirable morphology and large surface areas or fabricating hybrids with well-conductive materials (graphene [18], porous carbon [19], etc.). Furthermore, it has been demonstrated