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Morphology controlled synthesis of monodisperse cobalt hydroxide for supercapacitor with high performance and long cycle life

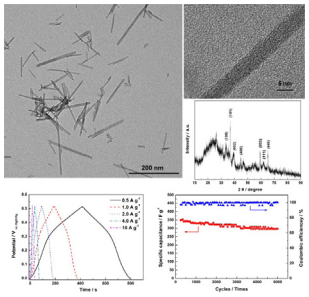
Yongfu Tang [a,*], Yanyan Liu [a], Shengxue Yu [a], Shichun Mu [b], Shaohua Xiao [c], Yufeng Zhao [a], Faming Gao [a]

[a] Hebei Key Laboratory of Applied Chemistry, College of Environmental and Chemical Engineering, Yanshan University, Qinhuangdao, Hebei 066004, China
[b] State Key Laboratory of Advanced Technology for Materials Synthesis and Processing, Wuhan University of Technology, Wuhan 430070, China
[c] Key Laboratory of Catalysis and Materials Sciences of the State Ethnic Affairs Commission & Ministry of Education, College of Chemistry and Material Science, South-Central University for Nationalities, Wuhan 430074, China

HIGHLIGHTS

- Monodisperse cobalt hydroxide nanocubes and nanowires are synthesized.
- Morphology and size of $Co(OH)_2$ are tuned by CTAB content and reaction time.
- $Co(OH)_2$ nanowires electrode exhibits high performance and long cycle life.
- As-prepared asymmetric supercapacitor shows high voltage and energy density.

GRAPHICAL ABSTRACT



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ABSTRACT

A facile hydrothermal process with hexadecyltrimethyl ammonium bromide (CTAB) as the soft template is proposed to tune the morphology and size of cobalt hydroxide ($Co(OH)_2$). Monodisperse β-phase $Co(OH)_2$ nanowires with uniform size are obtained by controlling the CTAB content and the reaction time. Due to the uniform well-defined morphology and stable structure, the $Co(OH)_2$ nanowires material exhibits high capacitive performance and long cycle life. The specific capacitance of the $Co(OH)_2$ nanowires electrode is 358 F g^{-1} at 0.5 A g^{-1}, and even 325 F g^{-1} at 10 A g^{-1}. The specific capacitance retention is 86.3% after 5000 charge–discharge cycles at 2 A g^{-1}. Moreover, the asymmetric supercapacitor is assembled with $Co(OH)_2$ nanowires and nitrite acid treated activated carbon (NTAC), which shows an energy density of 13.6 Wh kg^{-1} at the power density of 153 W kg^{-1} under a high voltage of 1.6 V, and 13.1 Wh kg^{-1} even at the power density of 1.88 kW kg^{-1}.

1. Introduction

Design and synthesis of nanocrystals with well-defined morphologies is significant in tailoring their properties [1]. Cobalt hydroxide nanocrystals have attracted more attentions due to their application in supercapacitor [2–4], additive materials for alkaline secondary batteries [5,6] and electrochemical heterogeneous catalysis [7,8]. Morphology, nanostructured phase and particle size of cobalt hydroxide nanocrystals affect their conductive properties and specific capacitance in supercapacitor [9–11], as well as their catalytic activity for electrochemical reactions [12]. Furthermore, the cobalt hydroxides with well-

* Corresponding author. Tel.: +86 13780351724.
E-mail address: tangyongfu@ysu.edu.cn (Y. Tang).

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defined morphologies are the precursors for the shape-controlled synthesis of cobalt oxides [13–16], which have been widely used in supercapacitor [13], lithium ion battery [14], heterogeneous catalysts [16], and so on.

Various morphologies of $Co(OH)_2$ nanocrystals, such as nanocolumn [17], nanowire [13,18,19], nanocone [11], and nanoflake [2,4,20–22], have been successfully synthesized by different methods. As reported, the reaction temperature, surfactant content, ion concentration and aging time [4,22–24] play important roles in the morphology and size of $Co(OH)_2$ nanocrystals. $Co(OH)_2$ nanoflakes and nanoflowers were widely used for supercapacitor and exhibited high specific capacitance due to their pseudo-capacitive behaviors [2,4,21]. However, monodisperse $Co(OH)_2$ nanowires have rarely been used in the supercapacitor. Due to the well-defined structure, $Co(OH)_2$ nanowires may exhibit high capacitance and good stability for practical application.

In this work, nanosized cobalt hydroxides with morphologies of nanocube and nanowire were synthesized via a facile hydrothermal process with CTAB as the soft template. Morphology and particle size can be controlled by the CTAB content and reaction time. The electrochemical capacitive performance of $Co(OH)_2$ nanowires was evaluated by cyclic voltammetry and galvanostatic charge–discharge measurements. Asymmetric supercapacitor was assembled using $Co(OH)_2$ nanowires as cathodic electrode and HNO_3 treated activated carbon (NTAC) as anodic electrode. Capacitive performance, cycle life and efficiency of $Co(OH)_2$ nanowires/NTAC based asymmetric supercapacitor were measured to investigate its potential application in electric vehicles and energy storage.

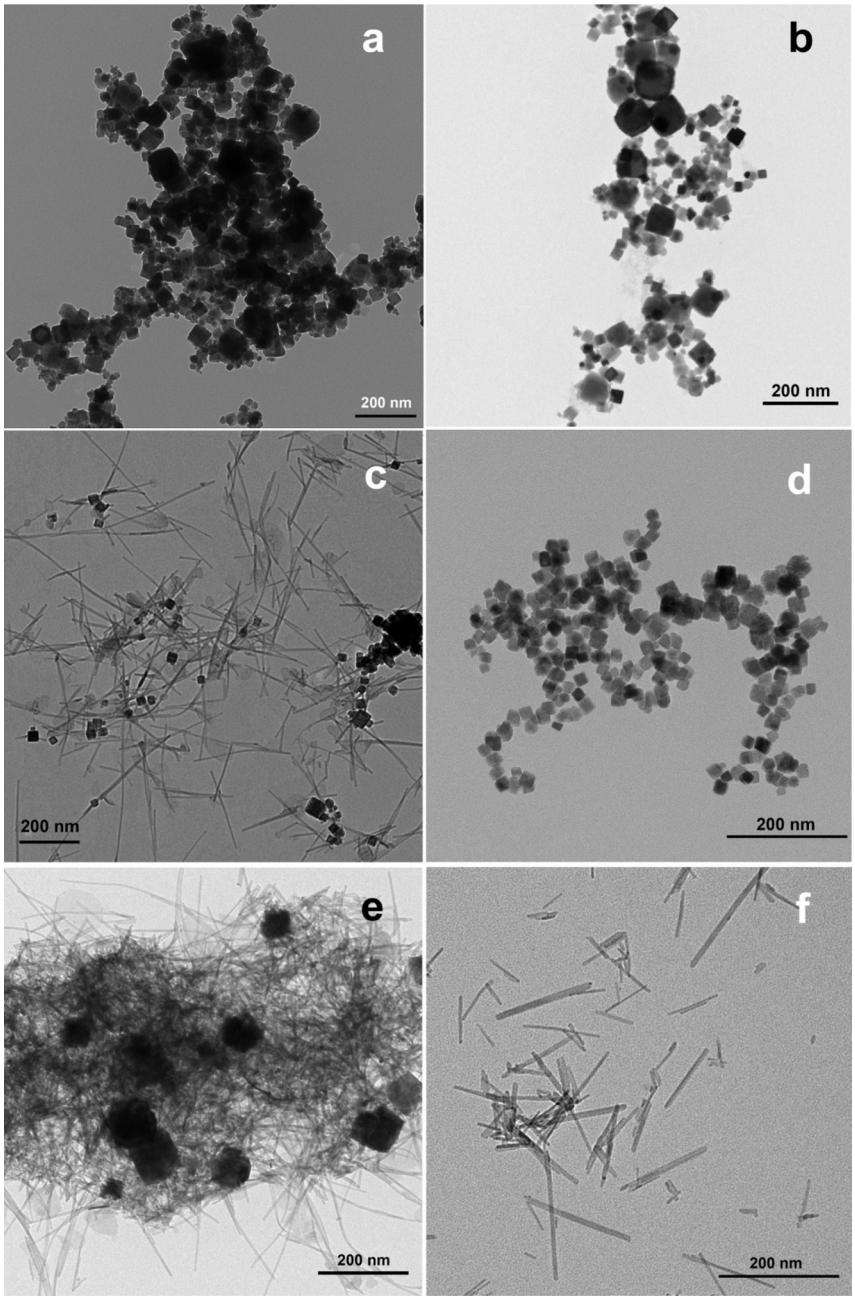

Fig. 1. Typical TEM images of $Co(OH)_2$ nanocrystals obtained from the hydrothermal process for 4 h at 120 °C with the CTAB content of 2.75 mM (a), 6.90 mM (b), 13.8 mM (c), 69.0 mM (d), 138 mM (e) and 690 mM (f).