Inorganic Chemistry Communications 149 (2023) 110425

Contents lists available at ScienceDirect

Inorganic Chemistry Communications

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

Short communication

# Effect of calcination time on electrochemical performance of hydrothermally grown copper cobalt sulfide nanostructures for use in electrochemical supercapacitors

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ARTICLE INFO

*Keywords:*
Supercapacitors
$CuCo_2S_4$ nanostructures
Hydrothermal method
Calcination times
LiOH electrolyte
Nickel mesh

ABSTRACT

This work reports the fabrication of $CuCo_2S_4$ (CCS) nanostructures (NSs) by a hydrothermal method. The CCS-NSs are synthesized at 170 °C by varying calcination times. Nickel mesh (NM) is utilized as a current collector. The CCS- NSs are derived at different calcination times, such as 12 h, 14 h, and 16 h and are coated onto NM to fabricate electrochemical supercapacitors (SCs). The cyclic voltammetry and galvanostatic charge–discharge analysis of CCS-NM electrodes are performed in 1 M LiOH electrolyte. The electrodes fabricated with the CCS-NSs with a calcination time of 14 h (CCS@14h-NM) showed the maximum specific capacitance ($C_{sp}$) of 995.86 F $g^{-1}$ at a scan rate of 10 $mVs^{-1}$.In addition, the CCS@14h-NM electrode showed an 83 % capacitance retention rate after 10,000 cycles at a current density of 1 mA $cm^{-2}$. The excellent capacitance retention rate of CCS-NM electrodes reflects an extensive scope in fabricating efficient electrochemical SCs involving earth-abundant and environmentally benign elements. Additionally, an asymmetric supercapacitor device with CCS@14h-NM as the anode and AC-NM as the cathode produces excellent $C_{sp}$ (103 F $g^{-1}$), specific energy $E_{sp}$ (16 Wh $kg^{-1}$), and specific power $P_{sp}$ (7.4 kW $kg^{-1}$) as well as remarkable long cycle life (retention of 81 % after 10,000 cycles).

## 1. Introduction

Due to a lack of efficient energy sources, the global energy crisis has gotten worse in recent years [1]. Energy storage is required to make better use of available resources. Batteries, supercapacitors (SCs), and fuel cells are among the many storage devices available today [2]. The SCs are the most appealing among these devices because of their high power density, fast charge–discharge rate, a noteworthy life cycle time and ease of fabrication with low maintenance [3].

The SCs store and release energy electrochemically. Due to their lower energy density, SCs are not commercial products despite having all of these advantages. As a result, researchers are working to increase its energy density [4–7]. The capacitive properties of a device are influenced by the electrical conductivity and electrochemical stability of the material [8]. Carbon-based materials are more appealing in light of these requirements due to their availability, low cost, and high electrical conductivity, but their lower capacitance (50–150 F $g^{-1}$) limits their commercial applications [9–10]. The use of low-cost pseudo-capacitive material is the most beneficial, economical, and effective way to increase the energy density of SCs [11]. However, the cycling performance of pseudo-capacitive materials is limited due to their electrochemical stability. Therefore, various electrode materials and electrolytes are used to overcome this drawback and improve its stability [12–13].

Metal sulfide-based materials are promising electrode materials for constructing SCs. Analogues to metal oxides; metal sulfides have special benefits such as low cost, exceptional electrochemical activity, and dependable stability. Metal sulfides also exhibit greater electrical conductivity and richer redox sites. Besides, the low-density and hollow spherical structures will be advantageous to improve their electrochemical performance [14]. Therefore, there is a growing interest among researchers to design electroactive materials based on metal sulfides for electrochemical SCs [15]. Recently, Zhai et al. have prepared CuS and carbonized cloth as composite electrode materials through hydrothermal method for flexible supercapacitors. They have investigated the significant role of reaction time in improving overall performance of these electrodes [16]. Moreover, the electrodes fabricated from zinc sulfide, copper sulfide and porous carbon have delivered

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https://doi.org/10.1016/j.inoche.2023.110425
Received 16 August 2022; Received in revised form 18 December 2022; Accepted 12 January 2023
Available online 24 January 2023
1387-7003/