Journal of Energy Storage 82 (2024) 110540

Contents lists available at ScienceDirect

Journal of Energy Storage

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

Research papers

Mo-doped porous Co_3O_4 nanoflakes as an electrode with the enhanced capacitive contribution for asymmetric supercapacitor application

Sharad L. Jadhav [a], Amar L. Jadhav [a], Pradip B. Sarawade [b], Bhalchandra K. Mandlekar [a], Anamika V. Kadam [a,*]

[a] *Lab of electrochemical studies, The Institute of Science, Dr. Homi Bhabha State University, Mumbai 400032, India*
[b] *Department of Physics, University of Mumbai, Kalina, Mumbai 400098, MH, India*

A R T I C L E I N F O

Keywords:
Porous cobalt oxide
Mo-doped Co_3O_4
Electrodeposition
Asymmetric hybrid supercapacitor device

A B S T R A C T

Cobalt oxide (Co_3O_4) electrode materials have tremendous properties for supercapacitors, such as being environmentally friendly, having a high surface area, being low cost, and having high theoretical specific capacitance (3560 Fg^{-1}). However, its poor electronic conductivity restricts the performance of the practical application. Doping transition metal ions into the host materials is an effective method to improve conductivity and enhance storage capacity. In this research work, we studied Mo-doped Co_3O_4 nanostructure electrodes synthesized using the electrodeposition technique. The integrated material samples were characterized by XRD, SEM with EDAX, XPS, FTIR, Raman spectra, UV–visible, and BET for their structure, morphology, composition, optical, and surface area properties. The 2 mM Mo-doped Co_3O_4 electrode exhibits excellent electrochemical pseudocapacitive properties. The optimized Mo_2-doped Co_3O_4 shows a maximum specific capacitance of 1674 Fg^{-1} at 10 mA cm^{-2} current density in 1 M KOH electrolyte solution. Finally, the asymmetrical hybrid supercapacitor device (AsHScD) Mo_2-Co_3O_4//rGO) demonstrates the highest power density of 159.0 $KWKg^{-1}$ and maximum energy density of 13.80 $WhKg^{-1}$ with a long-term stability of 95 % up to 2000 cycles. The Mo_2-Co_3O_4 electrode is a promising candidate material for a charge-storage hybrid supercapacitor in an aqueous 1 M KOH electrolyte.

1. Introduction

Non-renewable energy sources like fossil fuels (coal, oil, and natural gas) have a limited supply and contribute to environmental issues such as air pollution and greenhouse gas emissions. Renewable energy sources (solar, wind, hydro, and geothermal) are more sustainable and have a smaller environmental footprint. Supercapacitors can play a role in renewable energy systems by helping to smooth out the intermittent nature of these sources [1]. They can store excess energy generated during sunny or windy periods and release it when energy demand is high or when renewable generation is low. Several researchers have suggested ways to address energy problems and boost storage capacity while maintaining the device's stability. In this regard, supercapacitors find value in applications that require rapid energy storage with release, high efficiency, and the ability to manage power fluctuations [2]. They can complement or replace traditional batteries in scenarios where these characteristics are more important than storing large amounts of energy over extended periods [3].

Electrical double-layer capacitors (EDLCs) and pseudocapacitors are two kinds of supercapacitors, respectively, based on their charge storage mechanisms. Carbon nanotubes (CNT), graphene oxide, and extremely porous activated carbon are typically used to create electrode materials in EDLCs [4]. Conducting polymers and transition metal oxide (TMO)/hydroxide are frequently used for producing electrodes in pseudocapacitors [4,5]. TMOs show the best properties, such as low cost, environment-friendliness, multiple oxidation states, high theoretical capacity, excellent redox properties, and electrochemical stability [6]. Cobalt (III) oxide (Co_3O_4) is a material that has gained attention for its potential use in supercapacitor applications due to several advantageous properties. The tunable nanostructures of Co_3O_4 can be synthesized in various nanostructured forms [7]. The nano-structuring can enhance the surface area, leading to improved charge storage and more efficient electrochemical reactions [8]. Co_3O_4 possesses reasonable electrical conductivity, which is essential for efficient charge transfer between the electrode material and the electrolyte [9,10]. Higher conductivity results in lower internal resistance and faster charge-discharge rates.

* Corresponding author at: Lab of Electrochemical Studies, The Institute of Science, Dr. Homi Bhabha State University, Fort, Mumbai 400032, MH, India.
E-mail address: anamika@iscm.ac.in (A.V. Kadam).

https://doi.org/10.1016/j.est.2024.110540
Received 18 September 2023; Received in revised form 14 December 2023; Accepted 8 January 2024