Applied Physics A (2023) 129:158
https://doi.org/10.1007/s00339-023-06449-9

Applied Physics A
Materials Science & Processing

Supercapacitor performance of vanadium-doped nickel hydroxide microflowers synthesized using the chemical route

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Received: 15 August 2022 / Accepted: 24 January 2023 / Published online: 1 February 2023

Abstract

A supercapacitor is a high-capacity device that interfaces electrolytic capacitors and batteries by possessing a capacitance value significantly larger than conventional capacitors but with lower voltage limits. Nickel hydroxide is a potential material exhibiting tempting properties such as high specific capacitance, various oxidation states, morphologies, and large surface area. However, various limitations must be overcome, such as increasing the current density and improving the stability after doping of vanadium in $Ni(OH)_2$ material-doped $Ni(OH)_2$microflowers were successfully fabricated using a chemical bath deposition process in this study. XRD studies show hexagonal crystal structure with γ-phase of $Ni(OH)_2$. The presence of V=O at peak positions 1023, and 923 cm^{-1} reveals in the FT-IR study. Increased interlayer distance demonstrates the presence of vanadium ions between the superior and inferior layers of $Ni(OH)_2$. The 0.3% V-doped $Ni(OH)_2$ electrode displayed a remarkable specific capacitance of 1456.8 F g^{-1} at 3 mA cm^{-2} and high performance with 88.17% capacity retention at a scan rate of 100 mV s^{-1} over 2000 cycles.

Keywords Nickel hydroxide · Vanadium doping · Microflower · Supercapacitor

1 Introduction

Nickel-based materials are utilized in batteries and supercapacitors [1]. The nickel-based material is in high demand for supercapacitor designs. Nickel oxides [2], hydroxides [3–5], sulphides [6, 7], and selenium [8] are used to make supercapacitors. Excellent electrochemical properties and environmental friendliness have made nickel hydroxide a strong contender in the list of supercapacitors [9, 10]. The specific capacitance of nickel hydroxide does not rise above a certain value and is not stable in alkaline solutions [11]. A better option to overcome the above problem is to develop nanomaterials [12, 13] or doping the transition metal with higher electrical conductivity and stability [14]. Different dimensional nanostructures were developed by chemical methods like sol–gel [15, 16], solvothermal [17], electrodeposition [18], microemulsion [19], templet-derived method [16], etc. nanoparticles are used for different practical applications such as supercapacitor, photocatalyst [20], and antibacterial properties [21]. Cobalt [22], yttrium [23], aluminium [24], phosphorus [25], manganese [26], iron [27], etc., these metals are doped in nickel hydroxide, and their compositional, morphological, and electrochemical properties change to a great extent. Doping a metal will increase its electrical conductivity and stability properties.

Zhang et al. [26] used a doping approach to increase the specific capacitance of nickel hydroxide. Researchers realize that manganese is a better option for increasing specific capacity. The hydrothermal approach was used to make Mn-doped $Ni(OH)_2$ using $Ni(NO_3)_2$ as a nickel source and $Mn(CHCOO)_2$ as a manganese precursor. Hexamethylenetetramine surfactant was utilized to control the rate of reaction, and a deposition temperature of 100 °C was maintained for 2 h. Nanosheets with a height of 200–300 nm are cross-connected during this reaction,

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