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Research papers

Rational design of binder free $NiFe_2O_4$@$CoFe_2O_4$ core–shell nanoflake arrays synthesized by chemical bath deposition for supercapacitor application

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ABSTRACT

In recent years, exploiting stable and high-performance electrode materials has attracted researchers interest as the demand for clean, efficient, and sustainable energy storage devices grows. In this study, facile $NiFe_2O_4$@$CoFe_2O_4$ core-shell nanoflake arrays grown on flexible stainless steel mesh (FSSM) were synthesized by a simple, low-cost two-step chemical bath deposition (CBD) method. The synergistic influence between $NiFe_2O_4$ nanoflake arrays and $CoFe_2O_4$ nanoflakes in the mesh form electrode that show a quick electron/ion transfer and a higher electrical conductivity. The $NiFe_2O_4$@$CoFe_2O_4$ core-shell nanoflake array electrode has shown a capacitance of 1459.4 F g^{-1} at a current density of 4 mA cm^{-2}, which is significantly higher than the capacitances of the pristine $NiFe_2O_4$ and $CoFe_2O_4$ electrode. The $NiFe_2O_4$@$CoFe_2O_4$ core-shell nanoflake array electrode shows superb cycling stability with 85 % retention over 5000 cycles at a high current density of 20 mA cm^{-2}. Furthermore, the $NiFe_2O_4$@$CoFe_2O_4$ core-shell nanoflake array symmetric device demonstrated a high energy density of 21.15 W h kg^{-1} at a power density of 0.466 k W kg^{-1}. The improved electrochemical performance is attributed to its unique hierarchical structure, which allows for efficient ion and electron transport, a high number of active sites, and a synergistic impact. This novel integrated nanoarchitecture could hold significant promise as improved electrodes for high-performance supercapacitors due to its remarkable electrochemical performance and cost-effective production procedure.

1. Introduction

Nowadays, innovative energy generation and storage technologies are highly desired due to the rising demand for clean and renewable energy sources as well as the quick depletion and non-renewability of fossil fuels [1–3]. Therefore, environmentally responsive energy storage systems should be developed in the near future [4]. As a result, energy storage devices, such as fuel cells, batteries, and electrochemical capacitors, play a crucial role in solving global energy demands [5]. Among them, the scientific community is working to create high-performance electrode materials for use in supercapacitors (SCs). SCs have recently attracted much interest due to their unique characteristics, including quick charging and slow discharging, high power density, environmental friendliness, and long-term cycle stability [6,7]. However, the main drawback of SCs has been their poor energy density levels. Thus, researchers are interested in creating new kind of active materials to improve their energy density and capacitive performance levels [8]. SCs are classified as electrochemical double-layer capacitors (EDLCs) and pseudocapacitors based on their charge-storage methods [9,10]. For energy storage system, EDLCs based material such as 2-dimensional graphene, carbon nanotubes, carbon aerogel, and activated carbon material employ charge separation and accumulation at the electrode/electrolyte interfaces. Further, the metal oxides, metal hydroxides, and conducting polymers exhibit pseudocapacitor behavior due to the faradic redox reaction. Additionally, the pseudocapacitors have high capacitance and high energy density, in contrast to EDLC-based materials, which have low energy density and a limited life-span. As a result, considerable research has been done to examine the pseudocapacitive materials [11–13].

Consequently, the researchers are concentrating their efforts on

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PAPER

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Design and development of a porous nanorod-based nickel-metal–organic framework (Ni-MOF) for high-performance supercapacitor application

Rakhee Bhosale, Sneha Bhosale, Pramod Kumbhar, Dattatray Narale, Rachana Ghaware, Chitra Jambhale and Sanjay Kolekar *

Metal–organic frameworks have received increasing attention as promising electrode materials in supercapacitors. In this study, we synthesized a nickel-metal–organic framework (Ni-MOF) by a simple and low-cost reflux condensation technique using non-hazardous trimesic acid as an organic ligand. The structures and morphologies of the Ni-MOF material were characterized by X-ray diffraction, Fourier-transform infrared spectroscopy, and scanning electron microscopy techniques. The prepared Ni-MOF was found to have a rod-like morphology and these morphologies can provide beneficial paths for electrolyte ion penetration, obtaining an enlarged contact area between the active material and electrolyte. The Ni-MOF had a considerable specific surface area of 398.4 $m^2\ g^{-1}$. Further, its highly porous structure offered excellent supercapacitor performance. The charge-storage mechanism of the electrodes was investigated by cyclic voltammetry, charge–discharge cycling, and electrochemical impedance spectroscopy using 2 M KOH as an electrolyte in a three-electrode assembly. The specific capacitance of the Ni-MOF was found to be 1956.3 F g^{-1} at a current density of 5 mA cm^{-2} by GCD studies and it retained 81.13% of its initial capacitance even after 3000 GCD cycles at a 35 mA cm^{-2} current density. An as-fabricated Ni-MOF//activated carbon hybrid supercapacitor (HSC) exhibited a specific energy of 98.15 W h kg^{-1} at a specific power of 1253.47 W kg^{-1} and excellent capacity retention of 99.29% over 3000 cycles. The results of this study imply a great potential of the Ni-MOF for application in efficient and sustainable energy-storage devices.

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Introduction

In the 21st century, the production of energy from different sources has tremendously increased, and its transformation is also increasing day by day in different ways with the ever-increasing demands from industry, buildings, utilities, and transportation.[1] The increasing demand for energy and fuel due to the ever-increasing world population has become one of the important worries for all the global prime economies. Today there is an urgent need for environmentally friendly renewable energy resources to solve the problems related to the dwindling reserves of fossil fuels.[2,3] In this regard, energy-conversion and -storage technologies have acquired significant attention to support the future use of renewable energy sources. Many researchers from around the globe are devoted to developing sustainable energy sources, like wind, solar, hydropower, and tidal energy, to address the shortage of fossil fuels and to reduce carbon emissions and global warming. Hence, from various points of view, electrochemical energy-storage devices (EESDs), like rechargeable batteries, supercapacitors, fuel cells, and hybrid devices, have an important part to play in strategies to produce various amounts of energy and power density to meet the demands from different application scenarios.[4–6]

Supercapacitors (SCs), also known as electrochemical capacitors, offer the advantages of batteries as well as conventional capacitors, and have consequently become extraordinary energy-storage devices for large power output applications.[7,8] SCs generally offer a fast charging–discharging process (1–10 s), large power density (500–10 000 W kg^{-1}), high cycling stability (> 500 000 h), and easy operation. However, current SCs have a low energy density (1–10 W h kg^{-1}), which remains a prime challenge in the development of SC technologies. To conquer the drawback of their low energy density, there is a need for the development of high-performance electrode materials for SCs.[9,10] Due to their profitable features, such as high power density, excellent cycling stability, exceptional rate capability, and eco-friendliness, SCs have become key components in many fields, such as aerospace, electronic communications, and electric

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Effect of Small Change in Reaction Conditions on the Size of Monoclinic $BiVO_4$ Nanoparticles and their Photocatalytic Abilities

Rachana Ghaware,[a] Prashant Sanadi,[a] Dattatray Narale,[a] Rakhee Bhosale,[a] Komal Patil,[b] Jin H. Kim,*[b] and Sanjay Kolekar*[a]

$BiVO_4$ is an effective material and highly used in different applications. Here, we have synthesized $BiVO_4$ using bismuth nitrate pentahydrate and ammonium metavanadate by simple reflux condensation method without addition of any surfactant. To check the effect on the structure and activity of $BiVO_4$ different ratios of bismuth nitrate pentahydrate to ammonium metavanadate e.g. 1:1, 1:2 and 2:1 were used. Obtained $BiVO_4$ nanomaterial was successfully analysed using various analytical techniques such X-ray diffraction (XRD), Brunauer–Emmett–Teller (BET), Field emission scanning electron microscopy (FE-SEM) and X-ray photoelectron spectroscopy (XPS). The nanoparticles were shown spherical morphology, high porosity and monoclinic scheelite (m) crystalline phase. It was observed that $BiVO_4$ nanoparticles prepared using 1:1 ratio have very small size as compared to those prepared using other ratios. Further, the photocatalytic activity of the $BiVO_4$ nanoparticles was assessed by photodegradation of crystal violet dye (CV) under visible light irradiation and found that the particles prepared with 1:1 ratio were showing high efficiency of degradation. In addition, prepared nanoparticles have shown good antibacterial properties.

Introduction

Earth is gifted with abundant quantity of clean water, however due to huge population and industrial growth the world is at high risk because of environmental and water pollution.[1] Organic dyes are extensively used in many industries e.g. textile, leather, cosmetics, plastic, paper, ink, ceramic, and food processing. Apart from these, large quantities of industrial wastes like agrochemicals and drugs are released in fresh water. Therefore, researchers from all over world are focusing on the prevention of the water pollution by employing advanced environmental technologies.[2–3] Some of the physical and chemical methods which tend to employ to dye effluents, especially photocatalysis have shown great recognition in wastewater treatment.[4] Thus, exploring new materials for wastewater treatment is of vital importance.

Heterogeneous photocatalysis is an emerging method for environmental remediation because it can mineralize pollutants and undesirable compounds.[5] Several materials such as TiO_2, CdS, ZnO, $BiVO_4$, WO_3 and their nanocomposites with other nanomaterials are considered as photocatalysts for the degradation of pollutants.[6–8] The metal oxides like TiO_2 and ZnO, which are semiconductors in nature, shows high chemical stability, low cost, and strong oxidizing power, however, the large band gap of TiO_2 (anatase Eg = 3.2), allows absorbance of photo- energy in UV range only and hence effective only in UV region.[9] To overcome such limitations, researcher devoted their efforts to synthesize non-TiO_2 and non-ZnO based visible light photocatalysts which are metal oxides, sulfides, oxychlorides, carbonitrides and are advantageous for organic dye degradation. Among these, bismuth vanadate ($BiVO_4$) is one of the excellent materials for visible light photocatalytic dye degradation. Moreover, monoclinic $BiVO_4$ has been considered as a very promising photocatalyst due to its small band-gap energy (2.4 eV) and excellent visible light photocatalytic activity. On the other hand, it is well known that the photocatalytic materials can be very effective antibacterial agents due to their capability of generating reactive species. For example, researchers have been using the artificial enzymes with nanoparticles for the inhibition of bacterial biofilms.[10–12] The band gap position of $BiVO_4$ indicates that it can effectively act as antibacterial agent. The reports available in the literature also supports the antibacterial properties of the $BiVO_4$.[13–16]

$BiVO_4$ appears in three crystalline phases, viz, monoclinic scheelite (m), tetragonal scheelite (s–t) and tetragonal zircon (z–t). The monoclinic scheelite (m) crystalline phase has high catalytic activity as compared to other phases. Its unique crystalline structure, size and surface play important role in photocatalytic activity.[1,17] The 2.4 eV band gap of monoclinic $BiVO_4$ is suitable for the degradation of pollutants and for the generation of oxygen by splitting the water. In $BiVO_4$ the conduction band consists of Bi 6P, V 3d, O 2p and valence band Bi 6S, O 2P.[5] Moreover, crystallinity is very important factor for the photocatalytic activity.[18]

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Article

Construction of Well-Defined Two-Dimensional Architectures of Trimetallic Metal–Organic Frameworks for High-Performance Symmetric Supercapacitors

Rakhee Bhosale, Sneha Bhosale, Dattatray Narale, Chitra Jambhale, and Sanjay Kolekar*

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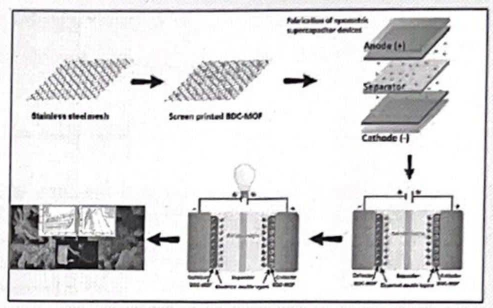
ABSTRACT: The high surface-to-volume ratio and extraordinarily large-surface area of two-dimensional (2D) metal–organic framework (MOF) architectures have drawn particular interest for use in supercapacitors. To achieve an excellent electrode material for supercapacitors, well-defined 2D nanostructures of novel trimetallic MOFs were developed for supercapacitor applications. Multivariate MOFs (terephthalate and trimesate MOF) with distinctive nanobrick and nanoplate-like structures were successfully synthesized using a straightforward one-step reflux condensation method by combining Ni, Co, and Zn metal species in equimolar ratios with two different ligands. Furthermore, the effects of the tricarboxylic and dicarboxylic ligands on cyclic voltammetry, charge–discharge cycling, and electrochemical impedance spectroscopy were studied. The derived terephthalate and trimesate MOFs are supported with stainless-steel mesh and provide a suitable electrolyte environment for rapid faradaic reactions with an elevated specific capacity, excellent rate capability, and exceptional cycling stability. It shows a specific capacitance of 582.8 F g^{-1}, a good energy density of 40.47 W h kg^{-1}, and a power density of 687.5 W kg^{-1} at 5 mA cm^{-2} with an excellent cyclic stability of 92.44% for 3000 charge–discharge cycles. A symmetric BDC–MOF//BDC–MOF supercapacitor device shows a specific capacitance of 95.22 F g^{-1} with low capacitance decay, high energy, and power densities which is used for electronic applications. These brand-new trimetallic MOFs display outstanding electrochemical performance and provide a novel strategy for systematically developing high-efficiency energy storage systems.



■ INTRODUCTION

Over the past few decades, the need to develop clean and sustainable energy has become extremely urgent due to the increasing requirement for clean energy and solving serious environmental problems.[1] Nowadays, much research is focused on current renewable energy storage devices in order to minimize pollution and raise worries about future energy problems.[2,3] Under some environmental circumstances, it is challenging to produce power from sustainable energy sources (biomass, hydro, solar, wind, etc.), which causes an imbalance between the supply and demand of energy. In order to balance and equalize energy needs, energy storage devices must be integrated with energy production, which is crucial for a renewable energy supply.[4,5] Because of their excellent energy capability and clean electrical systems, electrochemical energy storage equipment have gained widespread interest. One energy storage device that stands out above most of the others is the supercapacitor, which shows the utmost characteristics like high energy density, fast charging/discharging process, and excellent cycle stability, and also they are feasibly used in many fields.[6−8] The energy storage mechanism is non-identical for every class because of the different materials used within the components.[9] It is broadly confessed that the features of electrode materials like structure, morphology, electronic conductivity, electrochemical activity, and chemical and mechanical stability all put up to their electrochemical performance.[10,11] Transition metals have fascinated ample interest for many energy storage devices due to their good physical and chemical characteristics, high conductivity, improved redox activity, and long cycle stability.[12] The supercapacitor's performance is also affected by the electrolyte utilized. Electrolytes are important and necessary components of supercapacitors. Due to their physical and chemical characteristics, they have a significant impact on the electrochemical performances of specific capacity, energy density, power density, rate capability, cycle stability, and safety. In comparison to aqueous electrolytes, the solid-state electrolyte

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Geomorphometric Analysis to Deduce Groundwater Potential of Kumbhi River Basin, Kolhapur District, M.S. India

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Abstract

Various factors like geology of the area, soil type, hydrological setting of the area etc. have an impact on drainage basin characteristics. Morphometric study of these features of a particular area is helpful to throw light on, geomorphological features, lithology, structural features, and ground water conditions of the area. Lineaments and hydrological setting of the area which in turn throws light on ground water conditions and movement of groundwater. The study area is Kumbhi River Basin. The study area is bounded by latitudes 16° 28' 20.77"N to 16° 44' 0.35" N and longitude 73°07' 13.74" E to 74 °49' 31.91" E on Survey of India (SOI) toposheet numbers 47H/14, 15 and 47L/2. Morphometric analysis has been carried out. Kumbhi River Basin is of 6th order. There is total 1571 streams. The Rb value of Kumbhi River Basin indicates minimum structural disturbances. The basin has coarse texture and elongated shape Hence runoff is high and infiltration is low. These low values of rho coefficient indicate that the basin is likely to be less affected during the time of floods and elevated discharge. The relief of the basin is moderate to high and it indicates low to moderate infiltration rate and high run off conditions. The frequency of lineaments in the KRB indicates large number of sub-surface openings which can act as conduits for underground water. The area has moderate to good groundwater potential.

Keywords: Drainage basin, morphometric characters, lineaments, relief, drainage density, ground water potential

Introduction

Morphometric analysis of a drainage basin can provide valuable insight into the hydrological properties of the rocks within the basin, including how topography, geology, and climate influence the organization and shape of the drainage network [3, 4, 5, 6, 12, 19]. According to Clarke (1996) [1], basin morphometry deals with the measurement and mathematical analysis of earth's surface configuration, landform dimensions, and drainage characteristics. Evaluation of the hydrological nature of rocks exposed within a basin, using quantitative morphometric analysis in relation to geomorphological features-which can provide useful information on yield potential for the watershed-is a reliable index of rock-permeability [13, 21]. The study of basin morphometric parameters helps understand basin processes and compare their characteristics. Anthropogenic activities have had a serious impact on the physical structure of rivers, streams, biotic communities, and ecological functioning of aquatic ecosystems throughout the world [20].

GIS strategies have rapidly grown in popularity among scientists and researchers in India, and they have been tried on different hydrological regimes [2, 6, 7, 8, 14, 6].

Study Area

The study area is bounded by latitudes 16° 28' 20.77"N to 16° 44' 0.35" N and longitude 73°07' 13.74" E to 74 °49' 31.91" E on Survey of India (SOI) toposheet numbers 47H/14, 15 and 47L/2. Kumbhi River is one of the main tributaries of the Panchganga River. Kumbhi River originates near Lakhmapur Village (Taluka-Gaganbawada), Kolhapur District, Maharashtra. The location map of Kumbhi River Basin is shown below. (Fig.1)

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Short communication

Facile synthesis of nanogranular PPy thin films for sensitive and selective detection of toxic NO_2 gas

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ABSTRACT

Nanogranular polypyrrole (PPy) have been synthesized by *in-situ* oxidative polymerization of pyrrole monomer followed by deposition of PPy thin films onto a glass substrate by drop casting method. The deposited thin films were characterized for their structural, morphological, compositional studies using X-ray diffraction (XRD), transmission electron microscopy (TEM), field emission scanning electron microscopy (FE-SEM), and X-ray photoelectron spectroscopic (XPS) studies. The XRD patterns revealed that the synthesized films are amorphous in nature. FE-SEM microscopic images exhibit agglomerated granular-like morphology of PPy thin films with high degree of roughness. The XRD patterns confirm the amorphous nature of PPy thin films. XPS analysis reveals the formation of PPy. The gas sensing properties of PPy thin film based gas sensor were studied in terms of sensitivity, response-recovery time, selectivity and stability by varying the concentration of nitrogen dioxide (NO_2) gas. The optimized PPy thin film gas sensor showed highest sensitivity of 40.08 % at room temperature with stable response even after 45 days with retention of stability around 86 %. The gas sensing results suggested that nanogranular PPy sensor exhibited an excellent response toward NO_2 and also showed high sensitivity even at low concentrations upto 10 ppm level.

1. Introduction

Chemical sensors for the detection of toxic and hazardous species have attracted considerable attention in recent years because of the increased human safety concerns and environmental monitoring requirements. In this regards high performance gas sensors have emerged for environmental monitoring and safety industrial production. Over the past decades, various kinds of gas sensors have been developed based on inorganic transition metal oxides, conducting polymers and composite materials. Currently, the gas sensor based on metal oxides are lagging in terms of sensitivity, selectivity and their higher operating temperatures (200 – 400 °C). Among several materials conducting polymers have attracted much attention because of their numerous advantages such as low cost, high sensitivity, facile synthesis, flexibility in operation and short response-recovery time [1–3]. The most widely studied conducting polymers include polyaniline, polypyrrole, and polythiophene. Polyaniline is appealing because it is environmentally stable, easily synthesized, and can react with chemical species at room temperature [4,5].

Among these numerous conducting polymers, PPy has been widely studied due to its inherent properties. PPy is the most representative one for its ease of polymerization and extensive use in gas sensor field. It has remarkable physicochemical properties, ease of synthesis, excellent sensitivity, tunable conductivity, optimum performance at room temperature, fast response time, rapid adsorption/desorption kinetics for analyte. Therefore, it gives noticeable response to different type of chemical vapors like acid, base, alcohols etc. [6]. These outstanding properties are reasons for intense focus on PPy in the gas sensor field [7,8]. PPy synthesis is quite simple because of easier Pyrrole oxidation, its solubility in water, great adherence to different types of substrates, and commercial availability. However, their selectivity is low because of its sensitivity to various gases and vapors which brings their self limitation to gas sensor application . On the other hand, gas sensitivity of PPy based gas sensors originates from ...

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RESEARCH ARTICLE

Flood Hazard Zone Mapping of Kasari River Basin (Kolhapur, India), Using Remote Sensing and GIS Techniques

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Abstract

Flood is the most ubiquitous environmental hazard on the earth perhaps because rivers are the most dominant geomorphic agent in the present geological epoch. The actual process of flooding is the outcome of a complex set of control factors where nature and humans play a conjoint role. Unpredictable climate change with its weather phenomena increases the chances of disastrous events like floods, so it is a need to undertake in depth study using advanced techniques like GIS and remote sensing with accurate methods, including appropriate basin factors. The present study has identified the flood hazard zones of the Kasari River catchment, located in the Kolhapur District of Maharashtra. Remote sensing (RS) and geographic information system (GIS) techniques have been used for the attempted research work. Analytic hierarchy process (AHP) and weighted overlay analysis are the multi-criteria decision-making tools that have been used for preparing the flood hazard zone map of the Kasari River basin. A number of popular approaches to flood hazard mapping use DEMs, discharge data, and flood frequency data such as remote sensing, GIS, and hydrological data. As a phenomenon, flood is complex—caused by a multiplicity of factors—thus, this often overlooks its multidimensionality. This study used a multi-criteria decision-making tool, such as AHP, which has the added advantage of analyzing a large number of input parameters and their comparative analysis; this led to the identification of factors of relative importance. In order to create the map, twelve control parameters were calculated, viz. elevation, slope, distance from the river, flow accumulation, drainage density, topographical wetness index (TWI), stream power index (SPI), curvature, rainfall, land use/land cover, geomorphology, and geology. Among these parameters, elevation is the dominant factor that influences floods, followed by distance from the river. Both factors show a strong negative correlation of $r = -0.81$ and $r = -0.70$, respectively. Flooding is directly related to the drainage density of a river basin. High drainage density is directly associated with a higher probability of disastrous floods since it indicates high runoff from the surface. The stream network was extracted from the ASTER DEM and a drainage density map was created using the spatial analyst ArcGIS (10.8). This drainage density ranges from 2.2 to 3.8 km/ km^2 in the middle and downstream parts of the study area, which are more likely to cause flooding. Zones of very high flood vulnerability are located in the downstream region, i.e., in the eastern part of the basin. More than 50% of agricultural land and 16% of the settlement areas come under the zone of very high flood vulnerability. The high and moderate flood hazard zone affected areas are 23.05 and 32.11 percent, respectively, which is a cause for concern.

Keywords Flood hazard map · AHP · Weighted overlay analysis · GIS · Remote sensing · Kasari River

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