Journal of Energy Chemistry xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Journal of Energy Chemistry

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

http://www.journals.elsevier.com/journal-of-energy-chemistry/

Vertically aligned NiS nano-flakes derived from hydrothermally prepared $Ni(OH)_2$ for high performance supercapacitor

Q1 A. M. Patil[a], A. C. Lokhande[b], P. A. Shinde[a], J. H. Kim[b,*], C. D. Lokhande[a,c,**]

Q2
[a] Thin Film Physics Laboratory, Department of Physics,Shivaji University, Kolhapur 416004 MH, India
[b] Department of Materials Science and Engineering, Chonnam National University 300 Yongbong-Dong, Puk-Gu, Gwangju, South Korea
[c] Centre for Interdisciplinary Research, D. Y. Patil University, Kolhapur, India

ARTICLE INFO

Article history:
Received 14 March 2017
Revised 27 April 2017
Accepted 24 May 2017
Available online xxx

Keywords:
Anionic exchange process
Nickel sulfide
Nano-flakes
Supercapacitor
Thin film

ABSTRACT

In present work, the vertically aligned NiS nano-flakes composed thin film is prepared by anionic exchange process in which hydrothermally prepared $Ni(OH)_2$ is used as a parent thin film and Na_2S as a sulfide ion source. This synthesis process produced fully transformed and shape-controlled nano-flakes of NiS from nano-flowers of $Ni(OH)_2$. The electrochemical supercapacitor properties of NiS electrode are studied with cyclic voltammetry (CV), galvanostatic charge discharge (GCD) and electrochemical impedance spectroscopy (EIS) techniques. Highly porous surface area (85 m^2/g) of NiS nano-flakes makes large material contribution in electrochemical reaction stretching specific capacitance (C_s) of 880 F/g at scan rate of 5 mV/s and 90% electrochemical stability up to 4000 CV cycles in 2 M KOH electrolyte. Further, the flexible solid-state symmetric supercapacitor device (NiS/PVA–$LiClO_4$/NiS) has been fabricated using NiS electrodes with polyvinyl alcohol (PVA)–lithium perchlorate ($LiClO_4$) gel electrolyte. The NiS/PVA–$LiClO_4$/NiS device exhibits specific capacitance of 56 F/g with specific energy of 14.98 Wh/kg and excellent cycling stability after 2000 cycles. In addition, the NiS/PVA–$LiClO_4$/NiS device demonstrates illumination of red light emitting diode (LED) for 60 s, which confirms the practical applicability of NiS/PVA–$LiClO_4$/NiS device in energy storage.

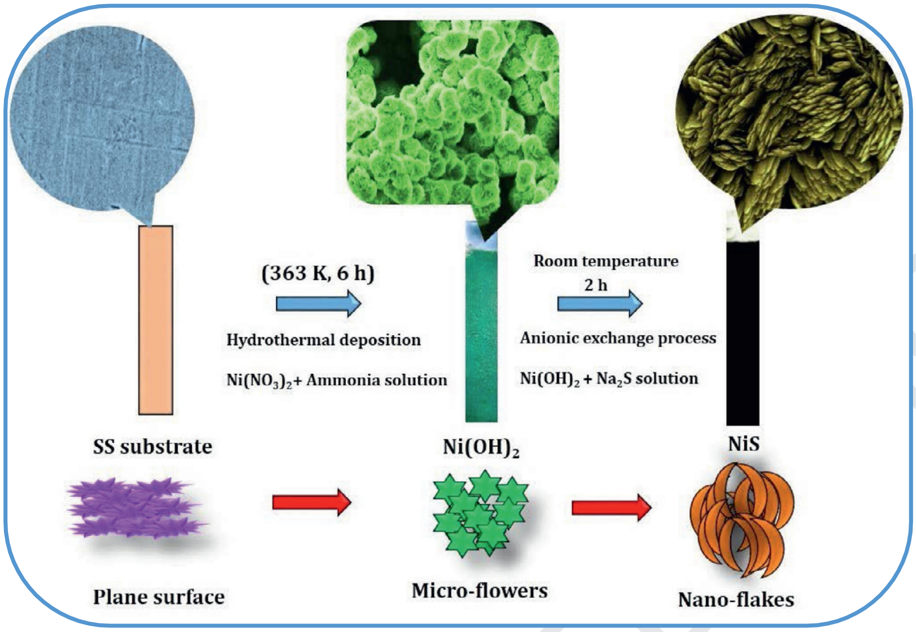
1. Introduction

In present day, rising demands for power sources of transitory high power density have motivated a great attention in supercapacitor with major uses in digital cameras, electric hybrid vehicles and memory back-up devices, which require higher specific power density (PD) [1]. The fast development of the worldwide economy elevates the enervation of fossil fuels as well as growing environmental pollution. There is a need of proficient, unpolluted, and supportable sources of energy and new technologies connected Q3 with energy storage [2]. Supercapacitor exhibits emerging, fascinating and substituting to battery and ordinary capacitor due to its vital properties like fast charging-discharging, higher PD and excellent electrochemical cycling stability [3]. Supercapacitor store electric charges at the interface of electrolyte and electrode. Supercapacitors can be divided in to two types on the basis of different energy-storage mechanisms as electrochemical double layer capacitor (EDLC) and pseudocapacitor, which store charges by charge separation at electrode-electrolyte and at electrode interface by faradaic charge transfer reaction, respectively. In comparison, the pseudocapacitor offers a higher specific capacitance (C_s) than EDLCs because of their fast charge-discharge faradaic reaction. Generally, carbon materials such as graphene oxide (GO), carbon nano tubes (CNT) and carbon aerogel exhibit the properties of EDLC [4,5] and metal oxides [6,7], metal sulfides [8] and conducting polymers [9] are used as a pseudocapacitive material. To overcome drawbacks like lower specific energy density (ED) and electrochemical cycling stability, a new species of hybrid capacitor is developed.

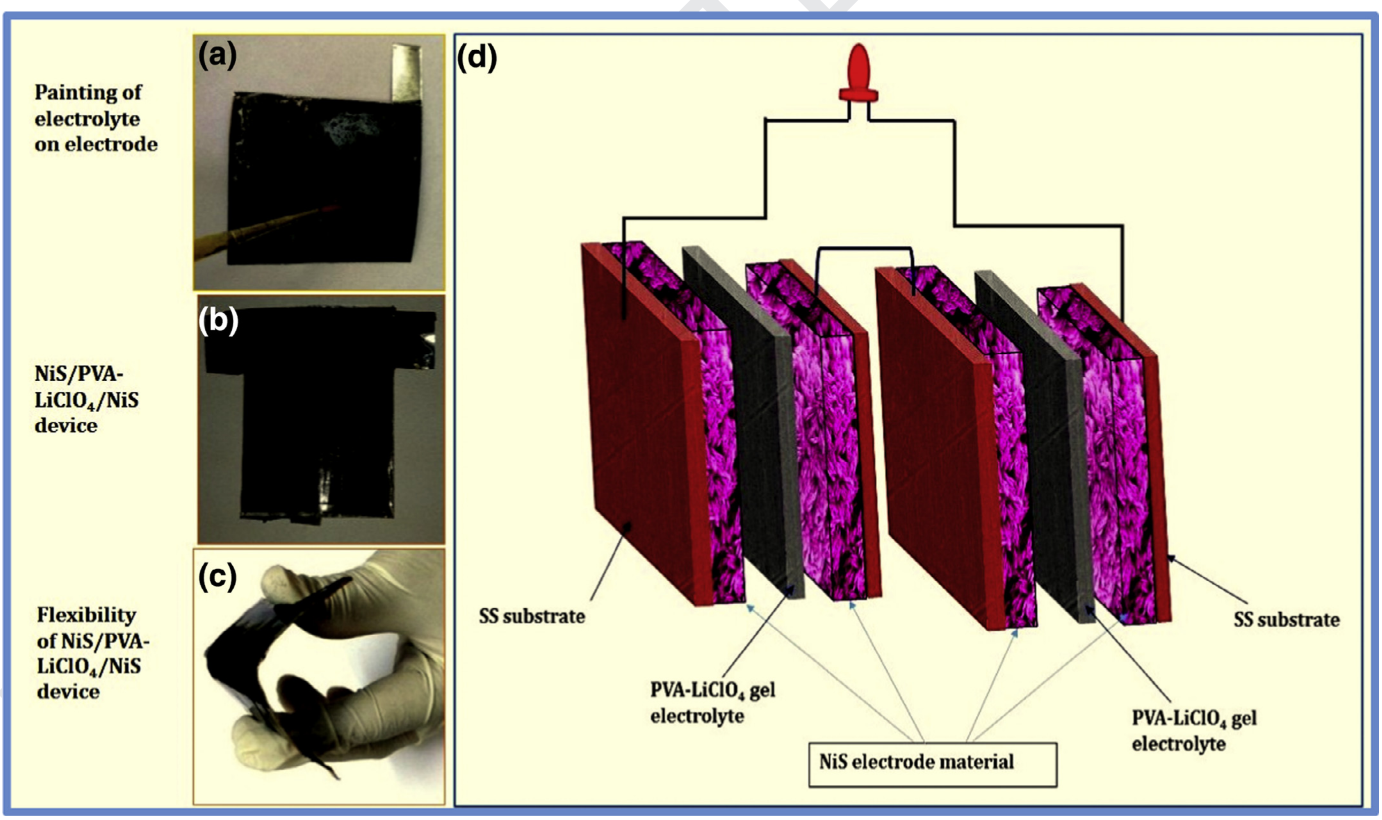
In order to improve the storing capacity of supercapacitors, there is a need of particular highly porous morphological electrodes. Accordingly, metal sulfides have much attention because of their facile preparation and excellent performance with nanostructured surface morphologies [10–12]. Al-doped β-NiS mesoporous nanoflowers show excellent energy density (36.6 Wh/kg) as well as power density (12,296 W/kg) [13]. Yan et al. [14] synthesized porous NiS nanoflake arrays by ion exchange method and achieved an energy density of 14.1 Wh/kg. Alternatively, results of current

* Corresponding author.
** Corresponding author at: Centre for Interdisciplinary Research, D. Y. Patil University, Kolhapur, India.
E-mail addresses: jinhyeok@chonnam.ac.kr (J.H. Kim), l_chandrakant@yahoo.com (C.D. Lokhande).

http://dx.doi.org/10.1016/j.jechem.2017.05.005
2095-4956/© 2017 Published by Elsevier B.V. and Science Press.



Schematic 1. Formation of NiS nano-flakes by anionic exchange process using $Ni(OH)_2$ micro-flowers.



Schematic 2. (a) Painting of PVA–$LiClO_4$ electrolyte on NiS electrode deposited on flexible SS substrate, (b) symmetric NiS/PVA–$LiClO_4$/NiS device, (c) flexibility of device and (d) schematic for fabrication of NiS/PVA–$LiClO_4$/NiS device.

research indicate that metal sulfides are applicable for pseudocapacitor applications [15]. Nickel sulfide inaugurate an important type of metal sulfide having different phases such as NiS, NiS_2, Ni_3S_2, Ni_3S_4, Ni_7S_6, and Ni_9S_8 with application in dye-sensitized solar cells, supercapacitors and lithium ion batteries [16–20]. Peng et al. [21] reported C_s of 845 F/g for NiS nanoparticles synthesized by microwave-assisted method. Yang et al. [22] prepared NiS nanorods, which exhibit C_s of 583.2 F/g. The metal hydroxide/oxide shows lower electric conductivity compared to metal sulfides. Because of lower conductivity, metal hydroxide/metal oxides have lower supercapacitor performance. Zang et al. [23] synthesized $Ni(OH)_2$/rGO composite by solvothermal method and reported

Please cite this article as: A.M. Patil et al., Vertically aligned NiS nano-flakes derived from hydrothermally prepared $Ni(OH)_2$ for high performance supercapacitor, Journal of Energy Chemistry (2017), http://dx.doi.org/10.1016/j.jechem.2017.05.005