ORIGINAL RESEARCH PAPER

Physics

STUDY OF STRUCTURAL AND ELECTROCHEMICAL PROPERTIES OF 3-D MICROFLOWER-LIKE NICKEL HYDROXIDE

KEY WORDS: Nickel hydroxide, Microflower, deposition time variation, supercapacitor, marigold flower.

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ABSTRACT

Recent work reported on nickel hydroxide chemically synthesized by simple cast effective chemical bath deposition method at room temperature. During reaction, nanoflakes developed and time enhance nanoflakes interlinked to form marigold like microflower which reveals from SEM. Structural properties analysis by XRD and FT-IR gives hexagonal crystal structure and presence of Ni-O bond to confirmation of deposition of $Ni(OH)_2$ material. Highest value of specific capacitance of electrode at deposition time 90 min without aniline from Cyclic voltammetry is 553 Fg^{-1} at scan rate 10 mV s^{-1} and from Galvanostatic charge discharge 215 Fg^{-1} at current density 3 mA cm^{-2} with 6.04 W h kg^{-1} and 1687.5 W kg^{-1} of energy and power density respectively. EIS analysis reveals least charge transfer resistance of 90min deposition time electrode.

INTRODUCTION

Supercapacitor is permissible option in energy storage device. Supercapacitor have versatile nature with different properties like high power density, high stability, durability, fast faradic reaction, low maintenance. Supercapcitor have types i.e. EDLC, pseudocapacitor and hybrid[1,2]. Two main principles used in above types are charge stored electrostatically and charge stored by electrochemically. In EDLC type charge stored electrostatically but in pseudocapacitor charge stored electrostatically. Selection of electrode material from its qualities like high surface area, presence of number of activated site, high electroconductivity, thermal and chemical stability[3,4]. Transition metal oxide and hydroxide turn more attention of researcher for their high specific capacitance, cost effectiveness and stability. Nickel hydroxide is more promising material used as electrode material. Nickel hydroxide a high theoretical specific capacitance of 2082 F g-1, good rate capability, ready availability, lower cost, environmental friendly and good thermal stability[5]. Wu et al. Reported deposited self-assemble three dimensional microflower by hydrothermal method with higher specific capacitance 1111.3 F g-1 for current density 1Ag-1.This self-assemble microflower Ni(OH)2 material have high stability upto 90.6% for 1000cycles[6]. Biny et al. compared structure, morphology and electrochemical properties of nickel hydroxide deposited by chemical precipitation method. Nickel hydroxide confirmed nanopetal-like morphology with a larger specific capacitance of 701 Fg1 at 1 Ag 1 in 2□M KOH aqueous electrolyte [7].Li et al., simple coordination homogeneous precipitation method used to fabricate coin-like nickel hydroxide nanoplates. A specific capacitance of 1532 F g1 is obtained at a current density of 0.2 A g□1[8].

EXPERIMENT

10.54 gm of NiSO4.6H2O, 2.02gm of K2S2O8 and 90mL of DDW used to prepare chemical bath. Stir this solution for few minutes and transparent green colour solution formed. Drop wise add 10 mL of aqueous ammonia (30% NH3) in solution. After addition of ammonia reaction started colour of solution terns green to dark blue and it becomes dense. Preclean stainless steel substrates were immersed in the bath and the bath was place at room temperature without stirring. Substrate coated with nickel hydroxide remove after time intervals 75, 90 and 105 min respectively then washes films several times in double distilled water and kept dry naturally. Film deposited at time 75, 90 and 120 min noted as Ni-1, Ni-2 and Ni-3 respectively.

RESULT AND DISCUSSION

STRUCTURAL AND MORPHOLOGICAL PROPERTIES:

Fig. 1 (a) represent XRD pattern of Ni-2 optimize electrode. Spectrum shows peaks at 32 and 59° corresponding to (1 1 0) and (3 0 0) plane have interatomic spacing 2.73 and 1.55A°. XRD data well matches with JCPDS card 022-0444 which indicate hexagonal crystal structure[9]. Fig.1 (b) shows crystal structure of Ni(OH)2 at deposition to time 90 min. A small number of reflection peaks is an indication of poorly ordered samples. The strong reflection peak at 2□ = 32° had a d-spacing of 11.2 Å.

Fig.1 (c) shows FT-IR analysis of Ni-2 electrode. This experiment run over range 400 to 4000 cm-1 wavenumber. Sharp peak at 403 cm-1 indicate Ni-O stretching mode[10]. Presence of O-H molecule represent by peak values of 3404 and 1634 cm-1 [11]. The S=O bond represent by wavenumber 1121cm-1.

Fig.1 (d) indicates SEM images of Ni(OH)2 material. Images indicates nanoflakes develop during reaction. Initially, some nanoflakes interconnect with each other and form small flower as time increases rate of interconnection of nanoflakes increases and size of flower increases.Fig.1 d) iv) shows marigold like nanoflower deposited on electrode Ni-2.

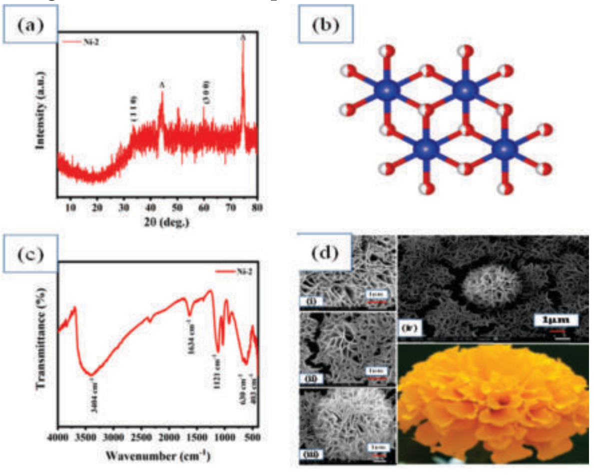

Fig. 1 structural and morphological study (a) XRD pattern (b) Crystal structure (c) FT-IR spectrum (d) SEM image i- iii) growth mechanism iv)SEM image of electrode Ni-2.

ELECTROCHEMICAL PROPERTIES AND ELECTRO CHEMICAL IMPEDANCE SPECTROSCOPY

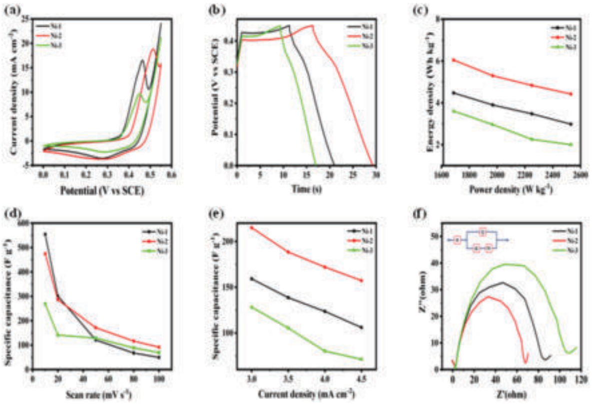

Fig. 2 Supercapacitor study of nickel hydroxide electrode for different deposition time (a) cyclic voltammograms of different electrode at scan rate 10mV s-1. (b)Galvanostatic charge-discharge study of different electrodes at current density 3 mA cm-2. (c) Rogene plot of different electrode. (d)Variation of scan rate vs. specific capacitance of different electrodes. (e) Current density vs. specific capacitance of different electrodes. (f) Nyquist plot for different electrode.

Fig.2 (a) indicate CV of Ni-1, Ni-2 and Ni-3 electrode. Specific capacitance calculated from CV are 474, 553 and 270 Fg^{-1} at scan rate 10 mV s^{-1}.Fig 2 (b) shows GCD of Ni-1, Ni-2 and Ni-3 electrode. Discharge time of electrode Ni-2 is maximum, in GCD analysis specific capacitance depends on discharge time. Value of Specific capacitance are 160, 215 and 128 Fg^{-1} at current density 3 mA cm^{-2}. Fig 2 (c) shows Regone plot. Fig. 2 (d) shown in Variation of scan rate vs. specific capacitance of different electrodes. Current density vs. specific capacitance of different electrodes shown fig 2 (e). The Ni-2 electrode shows the maximum energy density of 6.04 Wh kg^{-1} and the corresponding power density of 1687.5 W kg^{-1}.

Fig 2 (f) shows Nyquist plot for different electrode and inset have circuit diagram. EIS plot consist of semicircle and line which indicates nature of pseudocapacitor. Diameter of Semicircle have value of charge transfer resistance[12]. Electrode Ni-2 have smallest value of charge transfer resistance this one of reason of high value of specific capacitance[13]. Solution resistance of all electrode are approximately same and low which allows electrons reaches towards electrode. Effective resistance of material, morphology and crystallite size affect to specific capacitance. Ni-2 electrode have least charge transfer resistance because nanoflakes provide pathway for electrons and increases affected surface area for electrode and electrolyte interaction. Ni-2 electrode have high specific capacitance.

CONCLUSION

Chemical bath deposition method used to synthesize $Ni(OH)_2$ on stainless steel at different time interval 75, 90,105min respectively. Structural properties shows hexagonal crystal structure and presence of Ni in electrode material. 3-D microflower clearly observe in SEM images. specific capacitance of Ni-2 electrode by Cyclic voltammetry is 553 Fg^{-1} at scan rate 10 mV s^{-1} and by Galvanostatic charge discharge 215 Fg^{-1} at current density 3 mA cm^{-2}. Power density and energy density of Ni-2 electrode are 6.04 Wh kg^{-1} and 1687.5 W kg^{-1}. EIS analysis reveals least charge transfer resistance of 90 min deposition time electrode. From above result it conclude that Nickel hydroxide is better option for supercapacitor electrode material.

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