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Novel Method of Preparing CNF/$NiCo_2S_4$ by Electrospinning Method for High Performance Supercapacitor

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ABSTRACT

In this paper, a novel CNF/ $NiCo_2S_4$ nanofibres were synthesized by simple one step inexpensive electrospinning process. CNF/$NiCo_2S_4$ material was used as electrode material for supercapacitor. The synthesized material was characterized for the study of surface morphology, elemental configuration and functional group identification by using scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDAX) and Fourier transform infrared spectroscopy (FTIR). The electrochemical performance of as synthesized material was further studied in 1M H_2SO_4 electrolyte by using cyclic voltametry (CV) with potential window of 1.4V, Galvanostatic charge-discharge from which the maximum specific capacitance of 370F/g with energy and power density of 12.85Wh/g and 124.92W/kg respectively at current density of 1A/g was obtained. The charge transfer mechanism was studied from electrochemical impedance spectroscopy (EIS). These results show that the CNF/$NiCo_2S_4$ electrode could be promising material for supercapacitor application.

I. INTRODUCTION

The global increase in human population has contributed to a requirement of high energy storage devices. Until now, petroleum based fuels have been widely used but due to limited petroleum resources their is a need for an alternate energy resource. An example of such an energy storage device is a supercapacitors which is also referred to as ultracapacitors or electrochemical capacitors have attracted a considerable attention [1]. Supercapacitors have high power density, fast recharging capability, high performance flexibility and long cycling stability [2]. Supercapacitors are compared with other energy storage devices by using ragon plot. This type of graph presents the power densities of various energy storage devices versus their energy densities. This graph reveals that supercapacitor occupy a region between batteries and conventional capacitors. However, the energy density of supercapacitor is lower than that of batteries and fuel cells. Therefore, their is requirement of increasing the energy density in supercapacitor to a level comparable to batteries. Supercapacitors are classified into three types, electrochemical double layer capacitor (EDLC), pseudocapacitor and hybrid capacitors. EDLC store charge electrostatically or non-faradaically and their is no direct transfer of charge between electrode and electrolyte. The electrode material used to store charge in EDLC are carbon materials. Some of the examples are activated carbon (AC), carbon nanotubes(CNTs) , carbon nanofibres(CNFs), templated carbon and graphene. Pseudocapacitors store charge faradaically through the transfer of charge between electrode and electrolyte. Two electrode materials are used to store charge in pseudocapacitors are metal oxides and conducting polymer. Hybrid capacitors consists of combined features of EDLCs and pseudocapacitors. It has greater energy and power densities and possess better performance characteristics [3]. Hybrid carbon nanofibres have superior electrochemical performance with high mass capacitance, good rate capability and cycle stability[4]. Hybrid capacitors are further classified into three types: composite hybrids , asymmetric hybrids and battery type hybrids. In our present work, we have taken CNF/$NiCo_2S_4$ as a composite material and synthesized it by simple one – step inexpensive electrospinning process.

II. EXPERIMENT

2.1- Preparation of CNF/$NiCo_2S_4$

The electrospinning solution was prepared by dissolving 1gm PAN in 10ml DMF and stirred for 2hrs. at 70°C. After 2hrs nickel, cobalt, sulphur precursors were added in stiochiometric ratio of 2:4:8 and kept for magnetic stirring overnight. Then the stirred solution was transferred to 10ml syringe for electrospinning process. The distance between the needle tip and collector plate was 15cm, the voltage was maintained at 20KV and the flow rate of solution was 0.8ml/hr. After electrospinning process obtained nanofibres were transferred to oven for drying overnight. Further , the dried nanofibres were carbonized in horizontal quartz tube furnance in an inert atmosphere of N_2 .

III. RESULT AND DISCUSSION

The fabricated PAN and CNF/$NiCo_2S_4$ was analysed by SEM images for morphological studies at magnification of 5.40 KX and 8.46 KX respectively at a scale of 2μm.

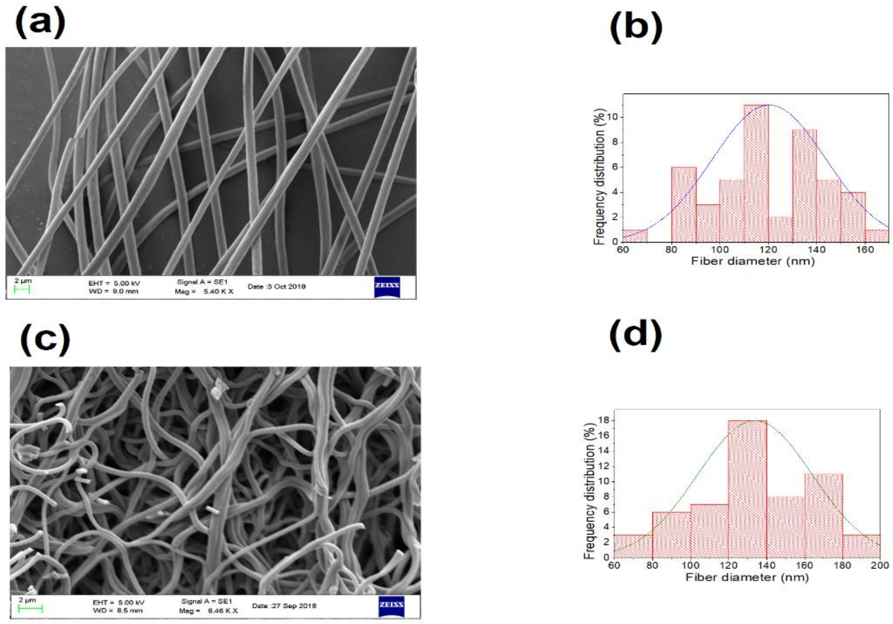

Figure 1. SEM Morphologies of (a) PAN/ $NiCo_2S_4$, (b) histogram for diameter range in nm, (c) CNF/$NiCo_2S_4$, (d) histogram for diameter range in nm

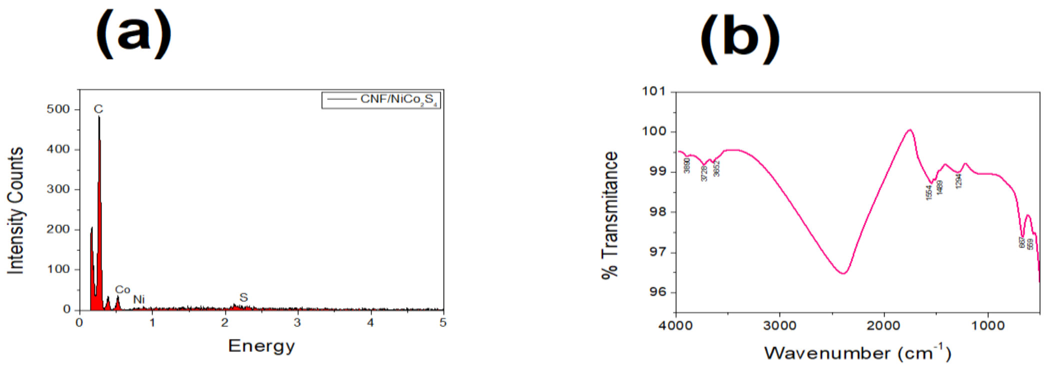

Figure 2. (a) Energy dispersive X-Ray spectroscopy of CNF/$NiCo_2S_4$, (b) FTIR for CNF/$NiCo_2S_4$,

The elemental configuration of Carbon, Nickel, Cobalt and Sulphur was confirmed by Energy Dispersive X-ray Spectroscopy (EDAX). The functional groups were determined by Fourier Transform Infrared Spectroscopy (FTIR) and the various peaks have a particular IR frequency which corresponds to different functional groups.

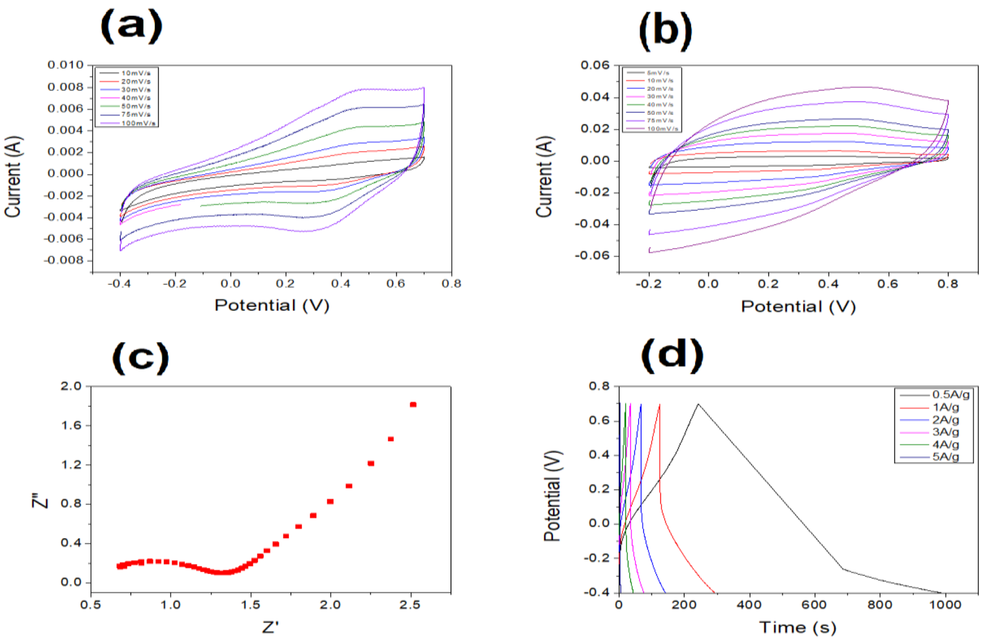

Figure 3. (a) (b) shows the CV curves for CNF/$NiCo_2O_4$ and CNF/$NiCo_2S_4$ respectively, (c) shows the Nyquist plot for CNF/$NiCo_2S_4$, (d) Galvanostatic Charg-Discharge curves at various current densities

Figure 3 (a) illustrates the CV curves of the CNF/$NiCo_2O_4$ at various scan rates of 10,20,30,40,50,75,100 mV/s. 3b illustrates the CV curves of the CNF/$NiCo_2S_4$ at various scan rates of 5,10,20,30,40,50,75,100 mV/s. The area covered by CV curves of the CNF/$NiCo_2S_4$ was much larger than that of the CNF/ $NiCo_2O_4$, which indicates the outstanding electrochemical performance of CNF/$NiCo_2S_4$. From the CV curves the current obtained in $NiCo_2S_4$ is 9 times higher than the

$NiCo_2O_4$. Figure 3(c) EIS is typically used to investigate the performance of the electrochemical capacitors such as internal resistance, capacity. At high frequency the intercept on the real axis represents a combined resistance (R_s) which contains the intrinsic resistance of the electrode materials, ionic resistance of the electrolyte, and the contact resistance between the electrode and the current collector[5]. The present EIS plot exhibit R_s value of 0.056Ω. A semi-circle was observed and its diameter represents the charge transfer resistance(R_{CT})of approximately 0.7Ω. To determine the application potential of the CNF/$NiCo_2S_4$ as an electrode material , Figure 3(d) shows GCD curves, GCD measurements were performed at various current densities from 0.5 to 5 A/g as shown in figure . The maximum specific capacitance of 338.11F/g was obtained at 0.5A/g.

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