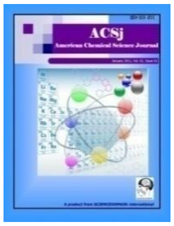

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Supercapacitor Electrode Material Based on Nickel Vanadium Oxide

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Authors' contributions

This work was carried out in collaboration between all authors. Author BP the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors CKD and MCA managed the analyses of the study. Author MCA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Nickel vanadium oxide with rod like architecture has been hydrothermally synthesized and electrochemically characterized as electrode material for supercapacitor application. The maximum specific capacitance of 412 and 297 F/g was achieved respectively at 2 mV/s and 3 A/g for the nickel vanadium oxide electrode in 1 M LiCl electrolyte. The NVO electrode also responded with high energy density of 165 Wh/kg at the power density of 3015 W/kg accompanied by 89.5% specific capacitance retention over 500 consecutive CV cycles at 2 mV/S.

Keywords: Supercapacitor; nickel vanadium oxide; energy density.

1. INTRODUCTION

Supercapacitor, also known as ultracapacitor or electrical double layer capacitor can be considered as an alternative source of energy with the hybrid properties of Li ion battery and capacitors. Although battery can act as a constant source of energy, its low power density restricts its application in many a field. The reverse is true for the conventional capacitors. It

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has got high power density, but suffers from low energy density. Supercapacitor forms a bridge between the two conventional energy sources by virtue of its both high energy density and high power density. Supercapacitor can store charge in two ways: forming electrical double layer at the electrode electrolyte interface and by the charge transfer reaction occurring within the electroactive material [1]. The latter is typically known as pseudocapacitance and is liable for the high specific capacitance of redox active materials. Recently various metal oxides and hydroxides, such as, $Ni(OH)_2$, $Co(OH)_2$, MnO_2, SnO_2etc [2-5] have been studied in detail as supercapacitor electrode. However, study of mixed metal oxide as supercapacitor electrode is still in primary level. Recently, cobaltmolybdate has aroused severe attention and also have shown efficient pseudocapacitive behavior [6]. In our present work we have focused on Nickel Vanadium Oxide (NVO). NVO has been hydrothermally prepared using easily available precursors and tested in a three electrode cell for the possible supercapacitor application.

2. EXPERIMENTAL SECTION

0.1 M $NiCl_2$ solution was mixed with 0.1 M NH_4VO_3 solution in different volume ratio of 1:1, 1:1.25, 1:5 and 1:2 maintaining the total volume of 40 ml and were placed in a 50 ml Teflon lined stainless steel autoclave. The solution mixtures were then hydrothermally treated for 12 h at 180°C. Then the autoclave was cooled to room temperature and the precipitation was washed several times in 4% ethanol in distilled water and then dried at 60°C.

3. RESULTS AND DISCUSSION

The X-Ray diffraction pattern (XRD) of the as prepared materials are shown in Fig. 1. The XRD was carried out by using a Regaku diffractometer with a Cu Kα (λ =1.54056 Å). The XRD patterns of the prepared NVO using different concentration of the precursors were same, indicating excellent purity of the phase of the NVO, regardless of the precursor concentration. As we have tried to prepare a new compound so we could not able to find any available JCPDS card No. But the XRD pattern of our compound matches well with the XRD pattern of $H_2V_3O_8$ which belongs to JCPDS no. 85-2401(orthorhombic crystalline phase). Hence, we also believe that our prepared compound follows the same structural characteristics.

3.1 Morphological Characterizations

Morphological characterizations were carried out in terms of FESEM (Carl Zeiss-SUPRATM 40), and TEM (TECNAI G2-20S-TWIN) analyses. The FESEM images of the as prepared NVO (using 1:1 precursor concentration) are shown in Figs. 2a and 2b at low and high magnifications, respectively. The FESEM images clearly reveals rod like morphology of the as prepared NVO with average diameter around 300-500 nm with very smooth surface.The TEM image (Fig. 2c) also satisfies the previous conclusion of rod like morphology of the NVO. The presence of clear and distinguished spot in the SAED pattern of the NVO microrod indicates its single crystalline nature.

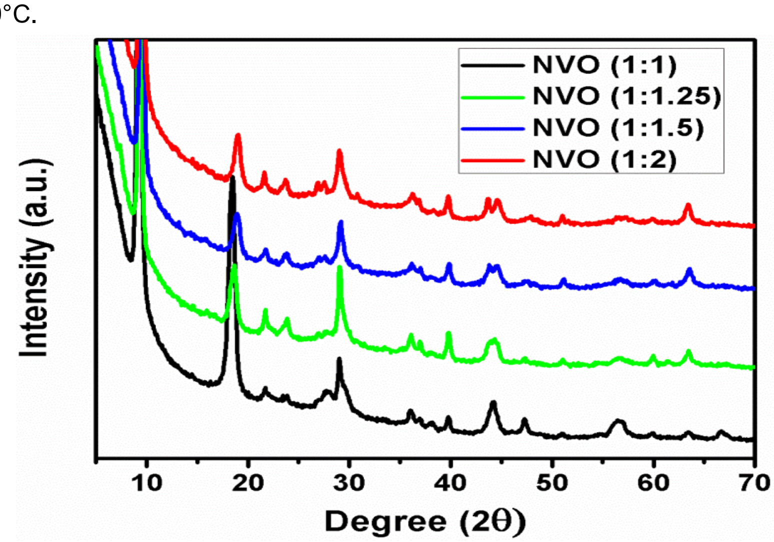

Fig. 1.XRD pattern of NVO using different concentration of precursors

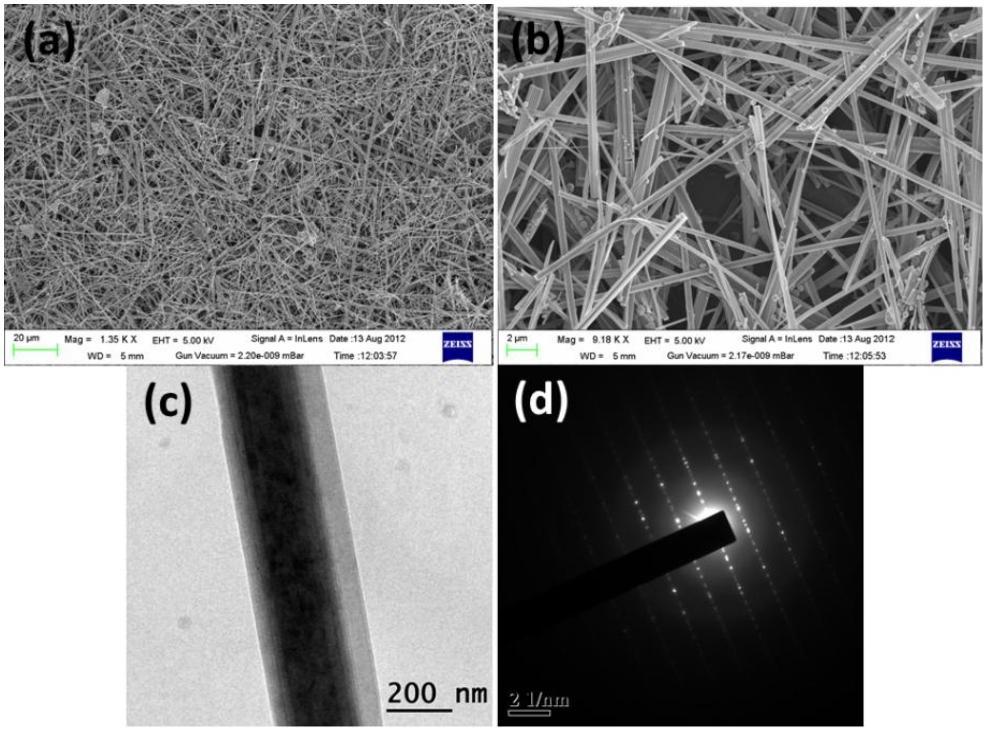

Fig. 2.FESEM images of NVO at different magnifications (a, b), TEM image of NVO (c), SAED pattern on NVO (d)

3.2 Electrochemical Characterization

The electrochemical characterizations were carried out using Biologic sp-150 instrument. The electrochemical characterization of the NVO was carried out in terms of a three electrode cell, where the sample coated glassy carbon electrode, pt electrode and saturated calomel electrode were used as working electrode, counter electrode and reference electrode, respectively.

The electrochemical characterizations were carried out in terms of cyclic voltammetry (CV), and galvanostatic charge discharge (GCD) analysis in 1 M LiCl electrolyte. The CV plots of the NVO electrode is shown in Fig. 3a at different scan rates of 2, 20 and 50 mV/s. All the CV plots show two pair of redox peaks indicating the pseudocapacitance nature of the NVO electrode. The increased scan rate resulted in increasing intensity of the redox peaks [7]. However, with the increasing scan rate the redox peaks showed a little shifting indicating its quasi-reversible nature. The maximum specific capacitance obtained from the CV plot was 412 F/g at 2 mV/sscan rate. With the increasing scan rate the specific capacitance decreases, however, still high specific capacitance of 268 F/g and 202 F/g was obtained at 20 and 50 mV/s, respectively indicating excellent rate capability.

To further understand the practical application of the as prepared NVO electrode the GCD test was carried out at different currents of 3 and 8 A/g and the plots are shown in Fig. 2b. Both the GCD plots are nonlinear in nature also supporting its pseudocapacitive in nature. The maximum specific capacitance obtained from the GCD plot was 297 F/g at 3 A/g current. At high current of 8 A/g, the specific capacitance decreased still high specific capacitance of 208 F/g was achieved. The decreased specific capacitance at increased current is due to the low diffusion of the electrolyte ionat high current, as a result only the outer surface of the electrode remains active [8]. From the GCD test the maximum energy density of 165 Wh/kg at the power density of 3015 W/kg was obtained. To understand the cycling stability of the NVO electrode the CV test was continued upto 500 consecutive cycles at 2 mV/s scan rate and high specific capacitance retention of 89.5% was achieved at the end. This indicates the long term cycle stability of the NVO electrode.

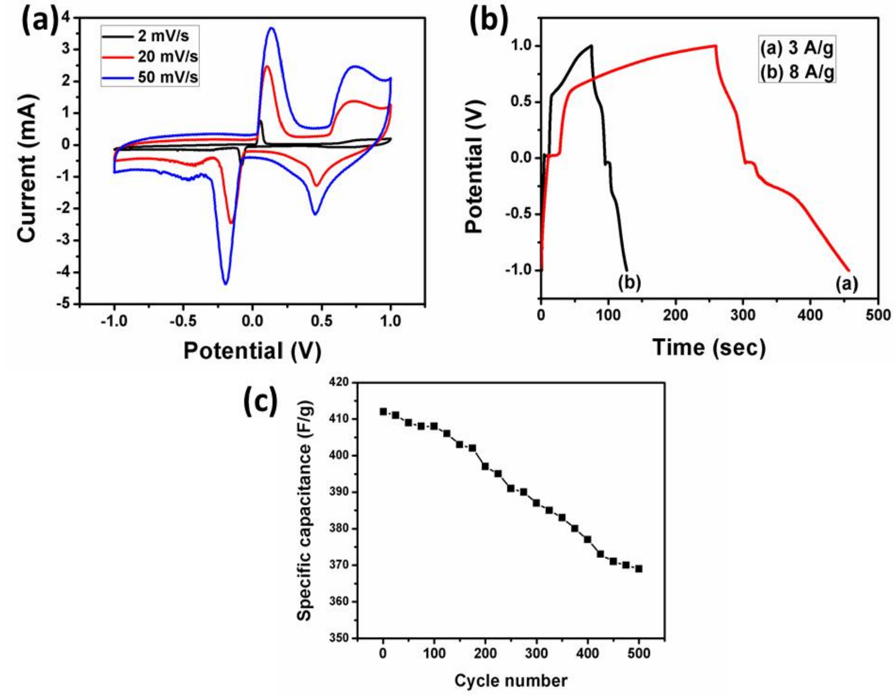

Fig. 3. CV plot of NVO at different scan rates (a), GCD plots of NVO at different current densities (b), cycle life plot of NVO (c)

4. CONCLUSION

Nickel vanadium oxide was prepared using a simple and cost effective hydrothermal approach and was tested as electrode material for supercapacitor application. The maximum specific capacitance of 412 F/g was achieved at 2 mV/s scan rate and after 500 consecutive CV cycles about 89.5% specific capacitance retention was achieved, indicating the high utility of the as prepared NVO as supercapacitor electrode.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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