Synthesis, Characterizations and electrochemical performance of Graphene decorated with 1D $NiMoO_4$, nH_2O nanorods

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Supporting information

Materials and methods

Nickel chloride ($NiCl_2$) and sodium molybdate dihydrate (Na_2MoO_4, $2H_2O$) were purchased from E. Merck Ltd. India. Nafion was purchased from Aldrich. Graphene was purchased from Sinocarbon Materials Technology Co. Ltd. China. The DC conductivity of the as obtained graphene was calculated to be 4.96 S/cm (disk type sample applying pressure of 500 kg with thickness 0.8 mm, area 132.67 mm^2 and measured by four probe method). The elemental analysis of the pristine graphene suggests the weight % of N, %C and %H element present to be 0%, 82.88% and 1.42%. All the chemicals were used as received without any further purification.

Characterizations

The crysatallinity of the $NiMoO_4$ and Gr-$NiMoO_4$ were confirmed by the XRD analysis using Rigaku difractometer with a Cu Kα radiation (λ =1.54056 Å). XPS analysis was carried out to understand the oxidation state of the component in Gr- $NiMoO_4$ composite using the Kratos Axis-ULTRA XPS analyzer with monochromatic Al Kα X-Ray source (hυ= 1486.71 eV) powered with 10 mA and 15 kV. It was carried out after plasma cleaning at the XPS chamber pressure of about $4x10^{-8}$ Torr for 300s and the C1s peak was corrected by neutralization at 284.6 eV. The Raman spectroscopy was performed by Renishaw Raman microscope equipped with a He−Ne laser excitation source at an excitation wavelength of 632.8 nm. Morphological characterizations were carried out in terms of FESEM and TEM analyses by using Carl Zeiss-SUPRATM 40 and TECNAI G2-20S-TWIN, respectively. The frequency dependent AC conductivity was carried out using HIOKI 3532-50 LCR HI TESTER by applying an alternating electric field of 1volt amplitude. The thickness of the disk type materials were 0.4 mm, 0.7 mm and 0.8 mm, respectively for the pristine graphene, $NiMoO_4$, nH_2O, and Gr-$NiMoO_4$, nH_2O and the electrode diameter was 10 mm. All N_2 adsorption/desorption analysis was carried out at 77 K using Autosorb-1C instrument of Quantachrome Inc. All samples were degassed at 423 K for 3 h prior to the analysis. The composites were electrochemically characterized in terms of cyclic voltammetry (CV), galvanostatic charge discharge (GCD) and electrochemical impedance spectroscopy (EIS) in 6 M KOH electrolyte using Biologic sp-150 VMP-3 instrument. For the electrochemical characterizations we used a conventional three electrode setup, where glassy carbon (GC) electrode, platinum electrode and saturated calomel electrode were used as working electrode, counter electrode and reference electrode, respectively. The samples were made well dispersed in 2% nafion solution in ethanol and the slurry was attached to the GC surface and fully dried prior to use. The loading of the electrode was kept 0.3 mg in all the experiments. A potential window of (+) 0 V to (+) 0.5 V and (+) 0 V to (+) 0.45 V was chosen for the electrochemical characterizations.

Table S1. The various values of specific capacitances, energy densities, power densities and coloumbic efficiencies of $NiMoO_4$, nH_2O working within the potential range of 0 V to 0.5 V

Current density (A/g)	5	10	15	20
Specific capacitance (F/g)	128	107	92	76
Coulombic efficiency (%)	30	43.7	70.9	86
Energy density (Wh/kg)	4.444	3.715	3.194	2.639
Power density (W/kg)	1250	2500	3750	5000

Table S2. The various values of specific capacitances, energy densities, power densities and coloumbic efficiencies of Gr-$NiMoO_4$, nH_2O working within the potential range of 0 V to 0.5 V

Current density (A/g)	5	10	15	20
Specific capacitance (F/g)	312	286	267	246
Coulombic efficiency (%)	43.3	83.8	86.5	96.4
Energy density (Wh/kg)	10.833	9.93	9.27	8.542
Power density (W/kg)	1250	2500	3750	5000

Table S3. The various values of specific capacitances, energy densities, power densities and coloumbic efficiencies of $NiMoO_4$, nH_2O working within the potential range of 0 V to 0.45 V

Current density (A/g)	5	10	15	20
Specific capacitance (F/g)	161	122	100	84
Coulombic efficiency (%)	91%	92%	96%	107%
Energy density (Wh/kg)	4.528	3.43	2.81	2.36
Power density (W/kg)	1125	2250	3375	4500

Table S4. The various values of specific capacitances, energy densities, power densities and coloumbic efficiencies of Gr-$NiMoO_4$, nH_2O working within the potential range of 0 V to 0.45 V

Current density (A/g)	5	10	15	20
Specific capacitance (F/g)	367	335	309	290
Coulombic efficiency (%)	128%	131%	139%	143%
Energy density (Wh/kg)	10.32	9.42	8.69	8.156
Power density (W/kg)	1125	2250	3375	4500