Effective use of carbon embedded electrode by an atmospheric DBD plasma for hybrid supercapacitor

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1. Introduction

The usages of supercapacitors (SC) encouraging electrochemical storage applications and widely used with the impact of to their enormous power density, quick charging/discharging rate, and outstanding longevity[1–3]. Researchers are considerable efforts for supercapacitors committed to finding inexpensive electrode materials with the excellent electrochemical performance[4–6]. Besides, several authors reported that the active electrode materials covered by amorphous carbon layer demonstrated improved cyclic sustainability due to the enhanced structural stability [7]. Herein, easy and effective conversion of pollutant to useful carbon by the low-temperature cost-effective method has not been proclaimed for the fabrication of transition metal phosphide-based SC electrode.

2. Abstract

Hybrid supercapacitors are emerging the electrochemical storage device for diverging application due to their high energy density, fast ion transportation, and sustainable life-span. Three-dimensional (3D) metal phosphide compounds have been considered as a promising superior electrode for supercapacitors. Herein, we report a 3D- porous nickel phosphide nanoarrays are successfully enrooted on the surface of nickel foam (Ni_2P/Ni) by low-temperature hydrothermal treatment. Subsequently, nanocarbon was embedded over $Ni_2P@Ni$ by efficient utilization of environmentally pollutant ethylene gas via an atmospheric DBD plasma reactor. Remarkably, the hybrid supercapacitor device (Ni_2P-C/NF//PNS-AC) delivered an enormous amount of areal capacity (318.8 µAh cm^{-2}) and gravimetric capacity (106.2 mAh g^{-1}) at a current density of 1 A g^{-1}. Likewise, the hybrid supercapacitor device accomplished outstanding energy density (108.1 Wh kg^{-1} at 1 A g^{-1}) and power density (14370.4 W kg^{-1} at 15 A g^{-1}) with excellent cyclic stability (91.2%) even after 3000 cycles at 7 A g^{-1}.

3. Results

The specific capacity, specific capacitance, mass balance, energy, and power density can be determined from the charge-discharge profile using the following mathematical equations. The specific capacity of the device is estimated from the CD analysis using the relation[8].

$$Q = \frac{I \times \Delta t}{m\ (or) A} \dots\dots\dots\dots\dots\dots (1)$$

$$E = \frac{I \int V(t)dt}{m} \dots\dots\dots\dots\dots\dots (2)$$

$$P = \frac{E}{\Delta t} \dots\dots\dots\dots\dots\dots\dots\dots (3)$$

Here "Q" is the specific capacity (Ah g^{-1} or Ah cm^{-2}), A is the area of the electrode (cm^2), and "I" is the current (A), "Δt" is the discharge time (s), "ΔV" is the potential window (V), and "m" is the mass of the electrode (g). E is the energy density (Wh kg^{-1}), and P is the power density (W kg^{-1}).

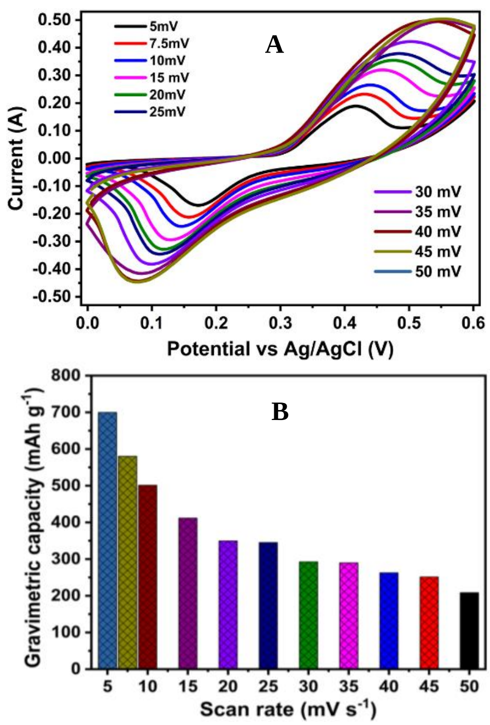

Fig.1 Cyclic voltammetry curves of Ni_2P-C/NF electrode at different scan rates between 5 mV s^{-1} to 50 mV s^{-1} (A), Gravimetric capacity of Ni_2P-C/NF

electrode effect of the scan rates (5 mV s^{-1} to 50 mV s^{-1}) (B).

Table 1 Summary of electrochemical performance of Ni_2P-C/Ni electrode and recently reported binder-free electrode materials using three-electrode configurations

Electrode Material	Current density (A g^{-1})	Specific capacitance (mAh g^{-1})	Ref
Ni_2P-rGO	1	314.7	[9]
$NiCo_2O_4$/NiCoP	22	228.3	[10]
Ni2P-Graphene	1	70.9	[11]
Ni_2P-C	6	699.7	This work

4. Conclusions

We successfully prepared binder-free Ni_2P/NF nanosheets via a typical hydrothermal method followed by phosphorization reaction and their electrochemical performances investigated as an electrode in a three-electrode system. Further, the resulting Ni_2P/NF electrode has improved the capacity by embedding carbon nanoparticles using DBD-jet plasma. The remarkable output is due to the synergic effect of carbon nanoparticles placed in between the interconnected space of self-assembled Ni_2P/NF electrode benefits the fast ion transportation for the faradic reaction, which facilitates to the enhanced capacity. Collectively, the electrochemical performances suggest that Ni_2P-C/NF as a promising candidate for an electrode material for energy storage devices.

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