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The electrochemical enhancement due to the aligned structural effect of carbon nanofibers in a supercapacitor electrode

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ABSTRACT

Aligned carbon nanofibers (ACNFs) were fabricated by electrospinning using a high speed of rotary collector (2000 rpm). To achieve a synergy effect of the electron double layer and redox faradaic reaction, $NiCo_2O_4$ was deposited on the surface of the ACNFs using an electrodeposition method. The improved electrochemical performance of the electrodes was investigated by cyclic voltammetry, galvanostatic charge-discharge testing, and electrochemical impedance analysis. Among the prepared electrodes, which were deposited for different times (5, 10, 20, and 30 s), the sample deposited by $NiCo_2O_4$ for 10 s had the highest specific capacitance (90.1 $F g^{-1}$ at 5 $mV s^{-1}$), good rate capability (64.7%), and cycle stability (85.2% after 1000 cycles). In addition, to examine the effects of the alignment and redox faradaic reaction of $NiCo_2O_4$, the ACNFs covered with $NiCo_2O_4$ for 10 s (NC-ACNFs) were compared with the ACNFs deposited by Co_3O_4 (C-ACNFs) and randomly oriented carbon nanofibers covered with $NiCo_2O_4$ (NC-RCNFs). The NC-ACNFs had a 15.8% and 11.3% higher specific capacitance than that of the C-ACNFs and NC-RCNFs, respectively. These results suggested that the electrochemical properties of carbon nanofibers could be improved through the structural effects of aligned nanofibers and a redox faradaic reaction of $NiCo_2O_4$.

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1. Introduction

With the advances in science as well as population and economic growth in the last century, the dependence on energy has increased steadily. As the demand for energy increases, modern society is faced with problems of environmental pollution caused by the use fossil fuels to produce energy. To overcome these problems, developments of alternative energy technologies are required, such as solar and wind energy systems. On the other hand, this energy is intermittent requiring efficient and economical storage systems. In this regard, electrochemical energy storage devices, involving a high energy and power density as well as high cycle capacity, play an important role in the efficient storage of energy. Among energy-storage devices, batteries and supercapacitors have taken center stage. In particular, supercapacitors have a higher specific power density than batteries and a higher specific energy density than dielectric capacitors [1–4].

Supercapacitors are based on an electrical charging and discharging mechanism at the electrode-electrolyte interface of high surface area materials. According to the mechanism, supercapacitors can be divided into two types: i) electric double layer capacitors (EDLCs) and ii) pseudo-capacitors (PCs) [5–7]. EDLCs use an energy storage mechanism that prepares an electric double layer at the electrode/electrolyte interface by physical charge accumulation. PCs accumulate energy by a redox faradaic reaction process of electrochemically active electrode materials, e.g., metal oxides, conducting polymers [8]. On the other hand, some disadvantages of each supercapacitor have been exposed, such as low average specific capacitance value, energy density (in case of EDLCs), and poor cycle stability (in case of PCs) [9–12]. To overcome these demerits, hybrid supercapacitors, the systems containing combinations of double layer, and pseudo capacitance, have used for industry applications [10,13].

In the hybrid capacitor system, the low electrical conductivity of metal oxides, which act as a PC is a hurdle that should be solved to improve the properties of a hybrid capacitor. To clear the obstacle, a range of carbon materials with diverse morphologies have been used for applications in hybrid systems, because it has high electrical conductivity and large surface area for power applications and enhanced capacitance [14]. Among them, carbon

Abbreviations: CNFs, carbon nanofibers; NC, ACNFs aligned carbon nanofibers coated with $NiCo_2O_4$; C-ACNFs, aligned carbon nanofiberr coated with Co_3O_4; NC-RCNFs, randomly oriented carbon nanofibers coated with $NiCo_2O_4$.

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