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Synergistic effects of dual nano-type electrode of NiCo-nanowire/NiMn-nanosheet for high-energy supercapacitors

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ABSTRACT

A unique three-dimensional hybrid $NiCo(CO_3)(OH)_2$ nanowire/$NiMn(CO_3)(OH)_2$ nanosheet composite was fabricated using a facile hydrothermal method as a binder-free electrode directly grown on Ni foam for supercapacitors. We examined the synergistic effect by fabricating Ni-Co-Mn ternary electrodes that used Ni-Co with a large specific surface area and Mn with a very high theoretical capacity. The new hybrid electrode had good electrochemical characteristics, exhibiting remarkably high specific capacitances of 1673.3 and 453.0 $F\,g^{-1}$ at 3 and 15 $A\,g^{-1}$, respectively. Compared with other samples, the capacitance showed less reduction as the current density increased. This result indicates stable electrode properties with increasing voltage. The cycling stability of the hybrid $NiCo(CO_3)(OH)_2$/$NiMn(CO_3)(OH)_2$ composite was measured as 82.1% after 5000 cycles. Additionally, we fabricated an asymmetric supercapacitor employing the $NiCo(CO_3)(OH)_2$/$NiMn(CO_3)(OH)_2$ composite as the positive electrode and graphene as the negative electrode, which exhibited a high energy density of 27.2 $W\,h\,kg^{-1}$ at a power density of 702.7 $W\,kg^{-1}$ and a remarkable cycling stability, with 89.4% capacitance retention after 5000 cycles. Thus, for the first time, we investigated the dual nano-type structure of an $NiCo(CO_3)(OH)_2$ nanowire/$NiMn(CO_3)(OH)_2$ nanosheet electrode for supercapacitors and obtained satisfactory results.
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1. Introduction

The 21st century is a period of change, characterized by the fourth industrial revolution and 5G. Therefore, all human life will be related to digital equipment that will require a small and high-capacity storage device. Additionally, high-energy storage devices are required owing to the emergence of renewable energy and hybrid industry [1,2]. Among the various power source devices, supercapacitors are attractive because they are eco-friendly and provide a high-capacity energy-storage system. Recently, two interesting types of supercapacitors have been studied, with different charge-storage mechanisms: electrical double-layer capacitors using C-based active materials and faradaic capacitors using redox-based faradic reactions [3–5]. Among them, the faradaic capacitors we studied have the high specific energy of a capacitor as well as the redox characteristic of a battery [6]. Regarding the electrode material, good electrochemical characteristics are required, including an excellent electrical conductivity, a large specific surface area, and no reactivity with the electrolyte. To satisfy this requirement, cathode materials based on RuO_2 have been actively studied, which theoretically have a high capacity exceeding 1000 $F\,g^{-1}$ [7,8]. However, these materials are rare and expensive and require the use of electrolytes that are environmentally harmful, making commercialization difficult. Therefore, to replace them, studies on metal oxides having a relatively low cost and high capacity have been continuously performed. In this respect, transition metals have been widely used as cathode materials. Currently, transition-metal oxides/hydroxides such as NiO [9], MnO_2 [10], CuO [11], Co_3O_4 [12], and $Ni(OH)_2$ [13] and their binary arrays are widely studied as the positive electrode material for faradaic capacitors owing to their eco-friendly nature, low cost,

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