



# Improvement of electrical performance by surface structure of Ni-material as a high-performance asymmetric supercapacitor electrode



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## ABSTRACT

Binder-free Ni-material array electrodes on Ni-foam are fabricated using a facile hydrothermal method for high-performance supercapacitors. Instead of a binder, urea is added to increase the adhesion of Ni-foam as both the substrate and electrode material. In this paper, we present the contribution of urea to the formation of the material. The surface characteristics and the electrical properties of the Ni-material array change with the amount of urea. When 2.4 g of urea is added to the sample for the first time, a  $\text{Ni}(\text{HCO}_3)_2$  microrod electrode is obtained; it shows large wire growth on the Ni-foam, which can be explained about the abnormal grain growth behavior because there is little energy barrier for atomic attachments with a disordered or rough interface atomic structure. Its specific capacitance is  $346 \text{ F g}^{-1}$  at a current density of  $3 \text{ A g}^{-1}$ . In contrast, when the amount of urea is reduced to 0.8 g, a  $\text{Ni}_2(\text{CO}_3)(\text{OH})_2$  array electrode is produced; it exhibits a nano-size wire array and a specific capacitance of  $833.2 \text{ F g}^{-1}$  at a current density of  $3 \text{ A g}^{-1}$ . Thus, it is confirmed that the large surface area of  $\text{Ni}_2(\text{CO}_3)(\text{OH})_2$  exhibits outstanding electrical properties. And, the fabricated asymmetric supercapacitor of  $\text{Ni}_2(\text{CO}_3)(\text{OH})_2$  composite as the positive electrode and graphene as the negative electrode, which has a high energy density of  $22.1 \text{ Wh kg}^{-1}$  at a power density of  $673.1 \text{ W kg}^{-1}$ . In addition, this obtained asymmetric supercapacitor can turn on the LED light.

## 1. Introduction

Recently, high-performance energy-storage systems have been studied because worldwide energy consumption has grown rapidly over the past few decades. Supercapacitors are an ideal battery storage device owing to their high power density, high charge/discharge rate, long cycle life, and excellent cycle stability [1–3]. In addition, supercapacitors can be used with secondary batteries to compensate for slow charging characteristics. They can be applied to hybrid vehicles that require fast charging speeds. These supercapacitors can convert the kinetic energy generated during automotive braking into electrical energy quickly and easily, and the secondary battery life is extended by reducing the work of the battery. Based on these various advantages, supercapacitors are a promising power source for automotive applications and portable systems. Electrodes of supercapacitors can be classified into two types according to their charge-storage mechanism [4–6]. The first is an electric double-layer capacitor (EDLC) using ion

adsorption and desorption. In general, carbon materials such as activated carbon, graphene, and carbon nanotubes have been studied for EDLC electrodes, which have the advantages of electrochemical stability, conductivity, and a wide surface-area interface [7–10]. However, preparing high-quality carbon materials requires complex procedures and expensive equipment. The second type of supercapacitor, the faradaic capacitor, overcomes these drawbacks. It is charged and discharged using the redox reaction of the electrode [11–14]. These reactions have been studied for electrode materials such as  $\text{RuO}_2$  [15],  $\text{NiO}$  [16],  $\text{MnO}_2$  [17],  $\text{Co}_3\text{O}_4$  [18], and  $\text{Ni}(\text{OH})_2$  [19], as active materials of redox reactions. These metal oxides/hydroxides have been studied with various fabrication methods and under various conditions to produce high-quality capacitances. Among these candidate materials,  $\text{NiO}$  is proposed as the most promising electrode material for supercapacitors, and has many interesting properties such as low cost, eco-friendly characteristic, natural abundance, and high theoretical capacitance ( $116 \text{ F g}^{-1}$  at a current density of  $1 \text{ A g}^{-1}$ ) [20]. Thus far,  $\text{NiO}$

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