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Short communication

Rational fabrication of carbon nanotubes arrays on porous nickel matrix as advanced electrode materials of supercapacitors

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ABSTRACT

Rational synthesis of advanced carbon materials is of great importance to the development of supercapacitors. In this work, we propose a facile combined electrodeposition-chemical vapor deposition for tailored construction of carbon nanotubes (CNTs) arrays on highly porous Ni matrix forming integrated 3D Ni/CNTs electrode. Interconnected CNTs with diameters of 20–30 nm are strongly anchored on the cross-linked porous Ni branches consisting of nanoparticles of 500–600 nm. Capacitive performance of the obtained porous Ni/CNTs electrode is thoroughly characterized by electrochemical means including charge/discharge tests and cyclic voltammetry. The 3D Ni/CNTs electrode shows good high-rate performance with a capacitance of 186 F g^{-1} at 2.5 A g^{-1}, and excellent cycling stability with a capacitance retention of 99% after 10,000 cycles. The integrated conductive network composed of 3D Ni/CNTs offers large active area, good electronic conductivity and fast transportation paths of ions/electrons, leading to superior capacitive performance.

1. Introduction

The ever-increasing demand of high-power electrochemical devices has stimulated tremendous upsurge of interest in supercapacitors [1–5], which possess attractive advantages in terms of superior charge/discharge ability, high-power density and stable cycling [6–8]. It is well known that supercapacitors are classified into two types: electric double layer capacitors (EDLCs) and pseudocapacitors [9,10]. Though pseudocapacitors have much higher energy densities, their long cycling life and high-power performance are still not satisfactory [11,12]. Therefore, great efforts are devoted to developing advanced EDLCs with stable cycles and high-power characteristics. EDLCs usually adopt carbonaceous materials as electrode materials [13,14]. It is proven that the EDLCs performance is closely related to the morphology and structure of carbon materials [15–17]. Hence, rational design of carbon materials is indispensable to achieve high-rate performance.

To date, there are lots of carbon nanomaterials (such as carbon nanotubes [18], carbon nanospheres [19], graphene [20], carbon nanofibers [15], etc.) have been synthesized and utilized for supercapacitors. Among these carbon candidates, carbon nanotubes (CNTs) are one of the most promising electrodes due to its high electrical conductivity, good chemical stability and large surface area [13,21]. However, the CNTs power electrodes need to be mixed with insulating binders, which can increase inner resistance and introduce undesirable interface, leading to low reaction kinetics and undermined high-power performance [22,23]. To solve this challenge, one of effective strategy is to design/fabricate binder-free CNTs arrays on conductive substrates. Previously, Xia et al. reported carbon cloth supported CNTs arrays for application in supercapacitors and achieved enhanced performance [24]. Meanwhile, three-dimensional (3D) metal skeletons are demonstrated as good matrixes for carbon materials to forming high-performance composite arrays. Xia et al. reported carbon nanospheres/nickel microtube arrays prepared with the help of sacrificial ZnO template [25]. Despite improved performance, the fabrication process is tedious. In parallel with the above research, 3D porous Ni matrix prepared by electrodeposition has attracted great attention because of its higher surface area, larger porosity and excellent electrical conductivity [26]. Nevertheless, there is no report on the synthesis of 3D Ni/CNTs arrays, let along their EDLCs performance.

In this work, we report a facile electrodeposition-chemical vapor deposition (ED-CVD) method for synthesis of binder-free 3D Ni/CNTs arrays. Interconnected CNTs with diameters of 20–30 nm are strongly anchored on the cross-linked porous Ni branches consisting of nanoparticles of 500-600 nm. The 3D Ni/CNTs electrode is used as electrode of supercapacitor and shows good high-rate performance with a capacitance of 186 F g^{-1} at a current density of 2.5 A g^{-1}, and excellent

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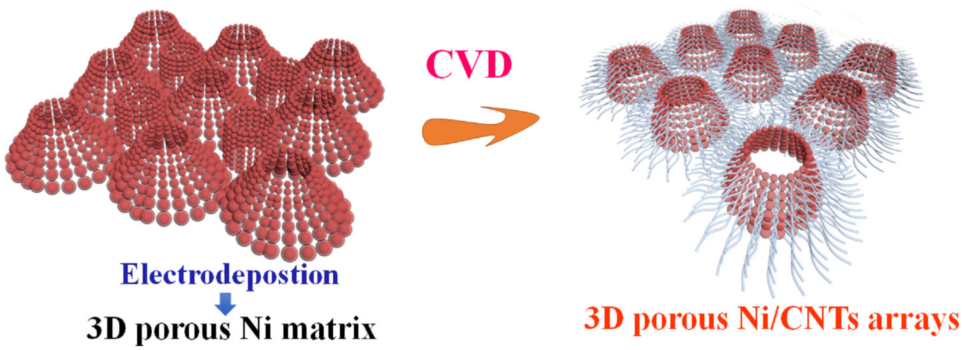

Fig. 1. Fabrication schematics of 3D porous Ni/CNTs arrays.

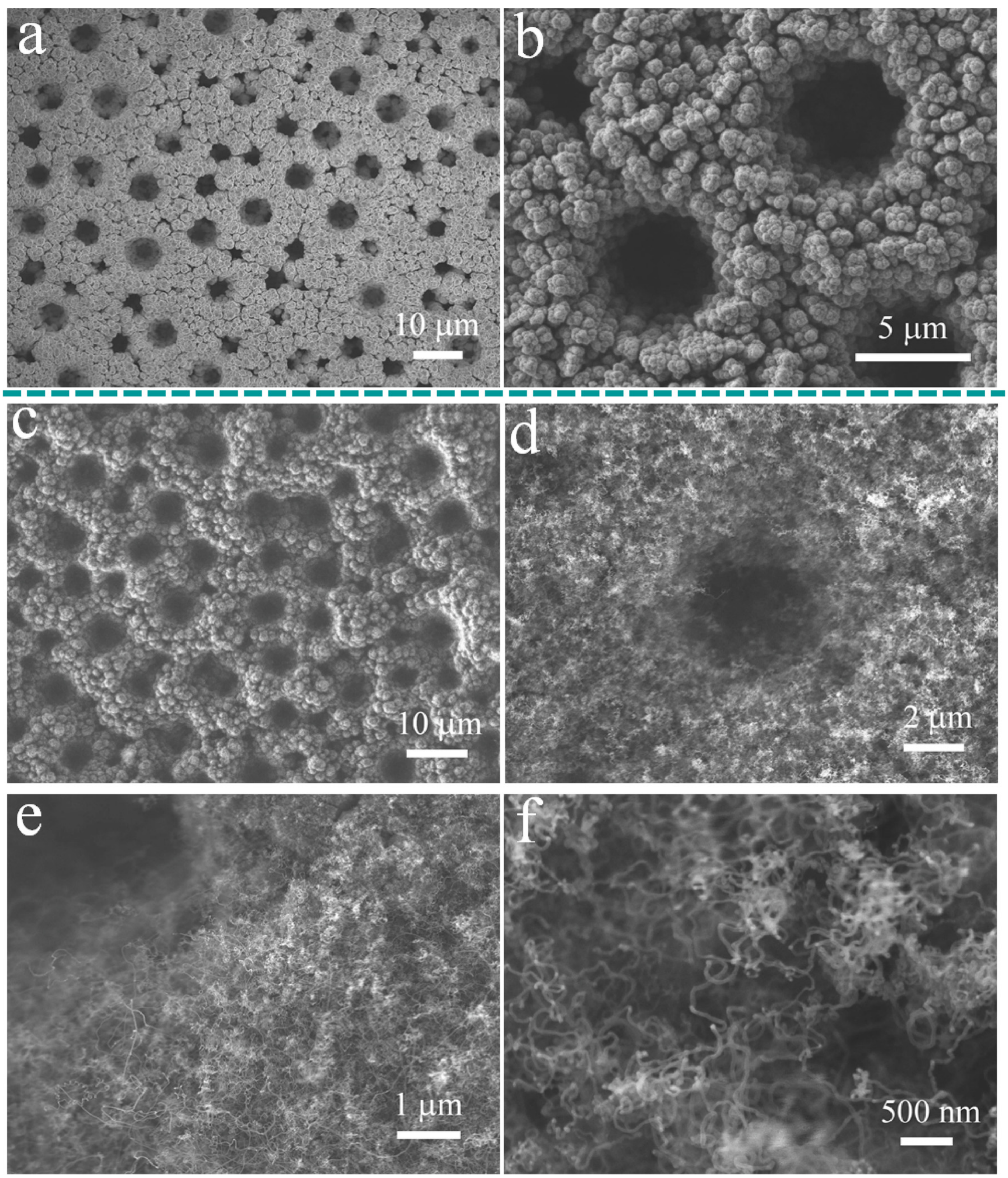

Fig. 2. SEM images of (a, b) 3D porous Ni and (c–f) 3D Ni/CNTs arrays.