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Review

Preparation and supercapacitor performance of assembled graphene fiber and foam

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ABSTRACT

Graphene-based materials have been full of vigor and tremendous potentiality for application in supercapacitors due to its variety of unique properties such as electronic properties, simple synthesis, etc. In developing new macroscopic nanostructured graphene materials for supercapacitors, considerable efforts have been made by the scientist including our research group. In this account, we describe our development of the construction of the assembled graphene especially fiber and foam, which have great potential in addressing the challenges in the synthesis of graphene-based electrode materials for supercapacitors. As the supercapacitors are reviewed in this article, they are accordant with the rapid development of flexible, lightweight, and wearable-electronic devices, overcoming the major some drawbacks of conventional bulk supercapacitors. We hope that this summary will benefit the further research of graphene-based materials for the applications in electrochemical energy storage devices and beyond.

1. Introduction

Graphene, with large specific surface area, high intrinsic carrier mobility [1–3], strong mechanical strength [4], and superior flexibility [5], has shown a wide range of promising application [6–13]. Notably, its exceptional properties qualify graphene as supercapacitor electrode material which has caused extensive research enthusiasm in the past few years of clean energy devices [14].

Recent years, energy source and environment has become one of the most severe problems in the world. The clean and renewable energy shows its more significant role in future and have attracted increasing research interest. Supercapacitors, with characteristics of fast charging and discharging, high power density, long cycle life, are supposed to be a promising candidate for alternative energy storage devices. High effective utilization of supercapacitors has positive effects on solving energy and environment problems [15–17].

Supercapacitors can be divided into electrochemical double-layer capacitors (EDLCs) and pseudo-capacitors on the basis of the different energy storage mechanisms. EDLCs where the specific surface area, electrical conductivity, and pore size and distribution are essential elements to achieve high performance absorb both anions and cations to store energy. In EDLCs, for example, carbon nanotubes (CNTs) [18] belong to porous carbon materials have been served as electrodes. Surface redox reaction is the reaction principle of pseudo-capacitors to store energy in comparison to EDLCs [19]. Electroactive materials [20] which belong to pseudo-capacitors have been widely explored. Moreover, graphene-based materials play an important part in supercapacitor owing to the beneficial combination of some excellent features [21–23]. However, the application of two dimensional (2D) pristine graphene sheets directly as practical electrode materials is low efficiency to store energy. There are two basic reasons of poor efficiency. One is the strong van der Waals between two apposed graphene layers the other is π–π stacking interactions to make the graphene sheets aggregate easily [24]. Hence, 2D graphene sheets as building blocks is converted into advanced materials with designed superstructures and functions [12,24–30], which is the optimum growth of graphene. In other words, it is still a problem to be solved that how to transform the micro structure and properties of graphene into macroscopic graphene materials. To avoid the limitations mentioned above, chemists including us have designed and developed some methods in the past period to provide efficient ways for the construction of graphene systems. As the typical assembled graphene materials, graphene fiber (GFb) has the merits of flexibility, lightweight, and knitability, while graphene foam (GFm) has the advantages of lightweight, high specific surface area, and preventing aggregation. In this review, we summarized our recent advances of assembled graphene fiber and foam in supercapacitors, including synthesis methods and applications. Naturally, it has guiding significance to the future study of the assembled graphene.

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2. Assembly of graphene

2.1. Assembly of graphene fiber

Carbon-based fibers are an essential part in our daily life because of their light weight, high mechanical strength and environmental stability. Meanwhile, graphenes possess outstanding features, and therefore, they have been applied in supercapacitor. Furthermore, assembled GFb that are the combination of the two are promising as new types of flexible building blocks for the construction of wearable architectures and devices, especially supercapacitors [31]. However, it is difficult to assemble 2D microscopic graphene sheets into macro 1D fibers because the poor dispersibility and irregular size/shape of microscopic graphene sheets seriously obstructed the formation of high-quality graphene fibers. Targeted at these problems, Li et al. first reported that a flat CVD-grown graphene sheet on an ethanol surface to form a fiber-like structure [32] (as opposed to planar configuration when it was placed on the water surface). It shows excellent electrical conductivity of 1000 S m^{-1}. Later, Xu and Gao used a wet-spinning technique to prepare GO fibers [33] The reduced graphene fiber was obtained and possessed high conductivity of 2.5×10^4 S m^{-1}. In this regard, the methods of hydrothermal assembly and wet spinning of aqueous GO suspension were developed to fabricate GFb recently by our groups [5,34,35].

As a recent achievement, a core of GFb is covered with a sheath of 3D porous network-like graphene framework to fabricate a unique all-graphene core–sheath fiber (Fig. 1a and b). With the

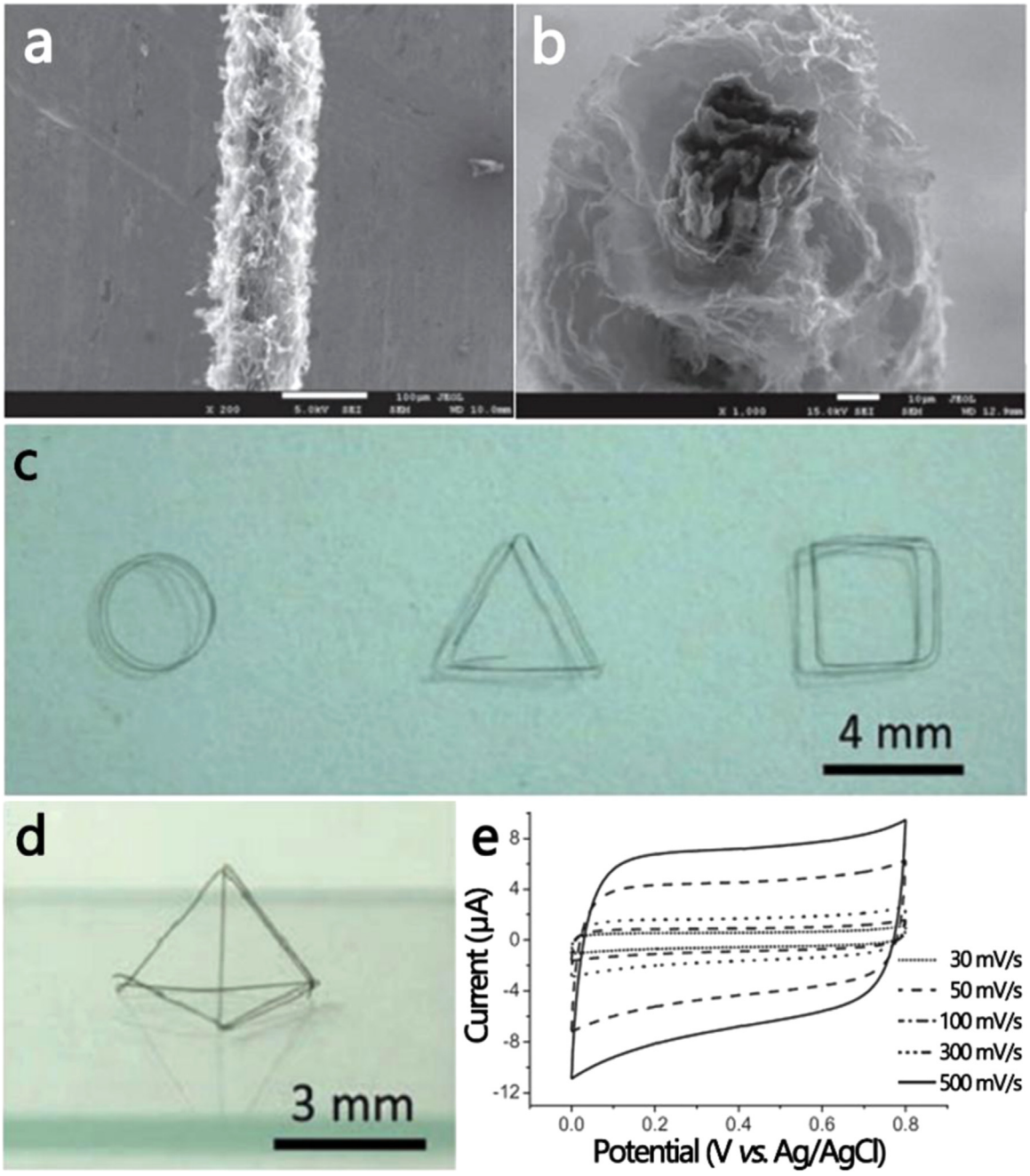

Fig. 1. (a) SEM images of a GF@3D-G (b) Cross-section view of a GFb@3D-G (reprinted with permission from Ref. [28] Copyright 2013 Wiley-VCH). (c) The planar structures of Gb and (d) 3D structures of GFb (reprinted with permission from Ref. [5]. Copyright 2012 Wiley-VCH). (e) CV curves of GFb@3D-G under different scan rates (reprinted with permission from Ref. [28]. Copyright 2013 Wiley-VCH).