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Short communication

Large-scale blow spinning of carbon microfiber sponge as efficient and recyclable oil sorbent

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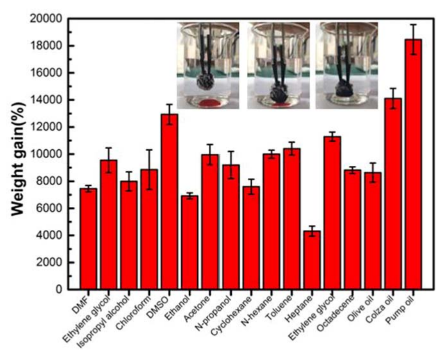
HIGHLIGHTS

- The sponge is constructed with carbon microfiber by blow spinning.
- The sponge exhibits high sorption capacity/efficiency and reusability.
- The sponge exhibits high efficiency in oil/water separation.
- The fabrication method is environment-friendly and cost-effective.

GRAPHICAL ABSTRACT



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ABSTRACT

In this study, we developed a novel blow spinning technology to construct large-scale porous sponges composed by carbon microfibers with strong absorption of oil. The microfiber sponge had a weight expansion of 184 times after oil absorption. Considering the outstanding mechanical properties and good thermal stability of the 3D carbon sponge, the carbon microfiber sponge could be regenerated with various methods, such as squeezing, combustion and distillation. More importantly, the preparation process of carbon microfiber sponges is very environment-friendly and cost-effective. Therefore, it has great potential to be further used in industrial applications for water treatment.

1. Introduction

Water pollution caused by leaking of crude oil and toxic organic solvents has become one of the hot environmental issues [1,2]. In order to solve this problem, a variety of sorbents have been used to reduce pollution [3–8]. These sorbents can be classified into three categories, carbon-based sorbents such as activated carbon [9], polymers such as polypropylene nonwoven fabric [10] and inorganic absorbents such as zeolites [11] and clays [12]. The problem is that these sorbents either might disintegrate or have low capacities, which would lead to

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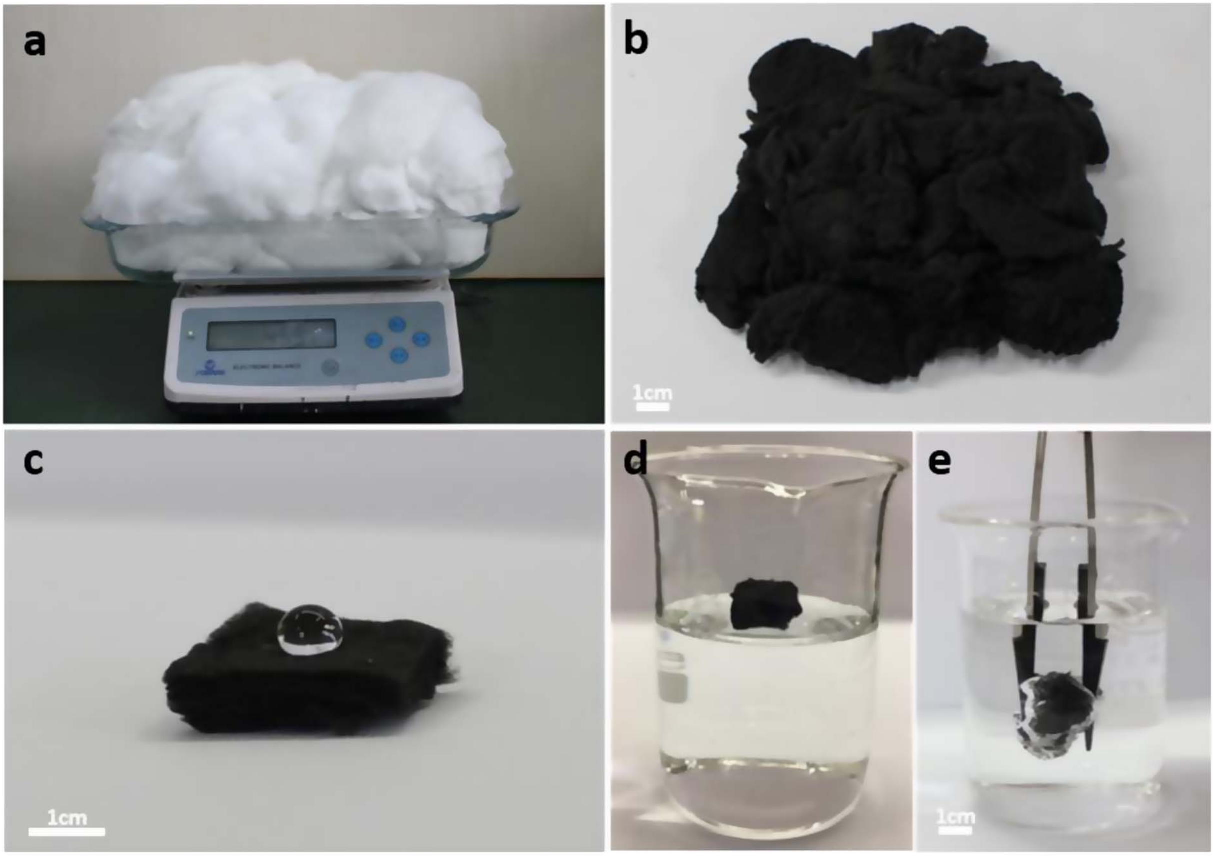

Fig. 1. a) Photograph of PAN fiber sponge. b) Photograph of a piece of carbon microfiber sponge. c) Photograph of a carbon microfiber sponge supporting a water droplet. d) Photograph of a piece of carbon microfiber sponge floating on water and e) when the carbon microfiber sponge was immersed into water, there is a mirror-reflection.

secondary pollution during the cleanup process [9–12]. Therefore, carbon-based sorbents have received great attention during recent years because of their chemical inertness, the high sorption capacity for organic compounds and the highly hydrophobic nature of its surface. The removal of pollutants and the separation of oils and water lies intensively with the pore volume and bulk density [13–19]. In particular, it is shown that carbon-based sorbents should have high porosity and low density. Carbon based 3D frameworks meet these demands [20–30]. Generally, carbon-based 3D frameworks can be classified into four types including organic aerogels carbonized in an inert atmosphere [31–33], graphene-based aerogels from self-assembly [34–37], carbon nanotube (CNT) sponges fabricated by chemical vapor deposition (CVD) [38–41] and sorbent based on exfoliated graphite modified by chemical reactions [42].

Each type has some problems associated with them. The low sorption capacity of exfoliated graphite based sorbents hamper their viability in practical applications [42]. Although CNT-based sponges have quite high sorption capacity, their complex and expensive productive process don't conform to the massive production [38–40]. The fragility of the organic aerogel is not suitable for oil sorption [31,32]. Graphene-based aerogel shows excellent recyclability and high capacity but, it requires freeze -drying during preparation to shape the graphene-based aerogel [34–37] which, is a very energy-consuming procedure that also hinders its industrialization. Therefore, the method to produce cost-effective 3D carbon-based sorbents need to be further explored.

In this study, we introduce a novel and environmental-friendly strategy for mass fabrication of hydrophobic, porous carbon microfiber sponges. The obtained carbon microfiber sponge has excellent sorption performance for a variety of oils and organic solvents with weight expansion to a maximum 184 times of its original weight after absorption. Moreover, it has great recyclability and keeps a high sorption capacity after 10 cycles of absorption-regeneration *via* combustion, distillation or squeezing. In comparison with the previous work for the preparation of carbon-based 3D sorbents, the carbon microfiber sponge has great advantages, such as a convenient and effective fabrication process which has excellent adaptability, high chemical stability and outstanding mechanical strength, making it a suitable material for environment protection and industrial applications.

2. Experiment material preparation

The precursor solution was prepared according to a typical process as follows. To obtain a homogenous solution, a 14 wt% polyacrylonitrile (PAN) polymer solution in *N*,*N*-dimethlyformamide (DMF) was magnetically stirred under 80 °C for 6 h. Blow spinning of solution was implemented according to the procedure which was described previously [43]. All fiber sponges used in this work were accumulated naturally in an air-permeable cage during blow-spinning fabrication. Notably, a blow spinning instrument for the massive-scale production was developed by our team.

The stabilization process was implemented in a conventional muffle furnace in an air atmosphere. PAN microfiber sponge was heated from room temperature to 230 °C with a heating rate of 5 °C min^{-1}, then the temperature was increased with 1 °C/min from 230 °C to 280 °C. Afterward, the stabilized PAN microfiber sponge was carbonized through heating to 800 °C at 5 °C min^{-1}, and kept at 800 °C for 1 h in a nitrogen atmosphere.

2.1. Characterization

A field-emission scanning electron microscope (let-1530, Zeiss) was adopted to observe the microstructure of the samples.