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Superhydrophobic and superoleophilic porous reduced graphene oxide/polycarbonate monoliths for high-efficiency oil/water separation

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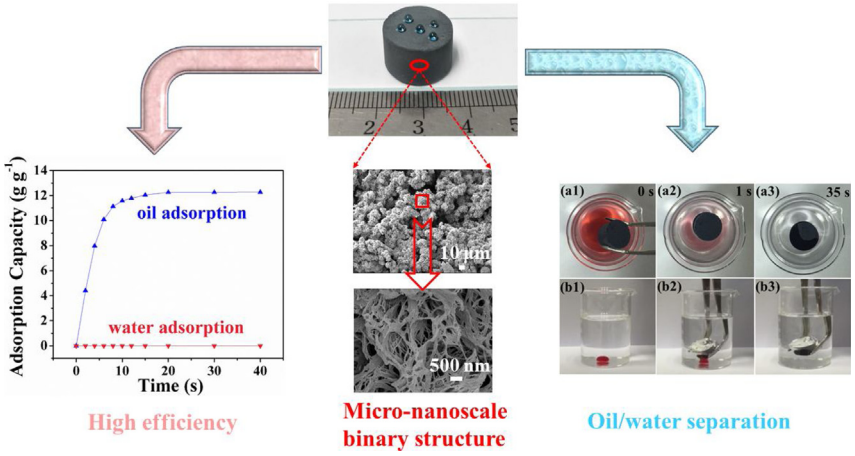
HIGHLIGHTS

- Porous RGO/PC monoliths with novel micro-nanoscale binary structure were prepared.
- Superhydrophobicity of RGO/PC monoliths was ascribed to unique porous structure.
- The monoliths exhibited excellent capability to selectively adsorb oil from water.
- The monoliths possessed stable water repellency against corrosive liquid.

GRAPHICAL ABSTRACT



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ABSTRACT

Superhydrophobic and superoleophilic porous reduced graphene oxide/polycarbonate (RGO/PC) monoliths with novel micro-nanoscale binary structure were first fabricated by thermally impacted nonsolvent induced phase separation (TINIPS) method. Owing to the unique pore structure, the porous monoliths possessed high specific surface area (137.19 m^2/g) and porosity (91.3%). The superhydrophobic RGO/PC monoliths exhibited excellent capability to selectively adsorb a wide range of oils and organic solvents from water. Furthermore, the monoliths could keep a stable repellency against corrosive mediums (e.g., acidic and alkali solutions). Based on these superior properties, porous RGO/PC monoliths will be a promising candidate for high-efficiency oil/water separation to deal with water pollution.

1. Introduction

In recent years, frequent occurrences of water pollution caused by oil spill and chemical leakage have led to severe environmental

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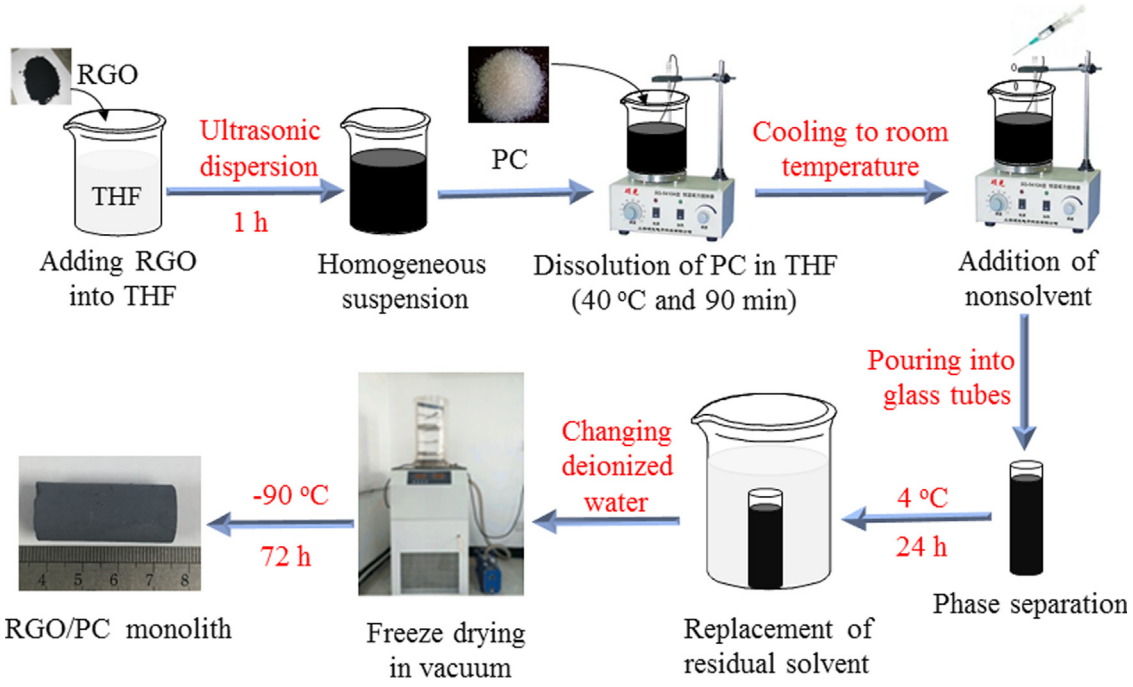

Fig. 1. Fabrication procedure of porous RGO/PC monoliths.

destruction on a global scale [1,2]. A tremendous amount of attention has been paid to exploring effective methods for rapid and selective removal or collection of oils and organic solvents from water [3,4]. A lot of approaches, such as oil skimmers [5], booms [6], solidifiers [7], dispersants [8], bioremediation [9], controlled burning [10], physical diffusion [11], and adsorption materials [12–14], are used to clean up the pollutants. However, most of them still have some limitations for practical application including high cost, low efficiency, poor recycling ability, hazardous by-product, etc [15,16].

Adsorption materials are considered as the most effective pathway for oil/water separation due to the advantages of low cost, excellent recyclability, and environmental friendliness [17–19]. They are usually divided into three types [20–24]: inorganic mineral materials (e.g., zeolite, activated carbon, natural clay), natural organic materials (e.g., corn straw, milkweed, cotton), and synthetic organic materials (e.g., polyurethane sponge, polypropylene fiber). Nevertheless, these conventional adsorption materials generally adsorb water and oil at the same time, which decreases separation selectivity and efficiency [25]. Porous polymer-based monoliths with remarkable hydrophobicity have attracted great interest in the field of oil/water separation, because only oil is adsorbed while water is completely repelled outside the monoliths [26,27]. Jing et al. prepared porous polystyrene monolith which can be used in the purification of oil contaminated water [28]. Liu et al. fabricated biodegradable polylactic acid porous monoliths as highly efficient and recyclable oil sorbents [29]. On the basis of previous pioneering works, it is of great significance to develop novel porous polymer-based monoliths with superhydrophobicity and superoleophilicity for high-efficiency oil/water separation.

Polycarbonate (PC), a typical engineering plastics containing carbonate and benzene ring in its molecular chain, exhibits many outstanding properties such as mechanical property, dimensional stability and thermostability [30]. On account of its superior overall performance, porous PC monolith has great potential in the field of adsorption materials. In our previous work, we have prepared PC monolith with a water contact angle of 143.9°, and the maximum oil adsorption capacity of monolith reaches 4.2 times its own weight [31]. In order to further enhance the efficiency of PC monolith in oil/water separation, the modification with inorganic nanoparticles is a usefull way. Reduced graphene oxide (RGO, a carbon nanosheet consisting of condensed six-membered rings) has a number of excellent physical properties like good hydrophobicity, high specific surface area and strong mechanical property, which make it very suitable for tailoring pore structure and hydrophobicity [32–34].

In this article, superhydrophobic and superoleophilic porous RGO/PC monoliths were first prepared by thermally impacted nonsolvent induced phase separation (TINIPS) method [31]. The as-prepared monoliths showed prominent capability to adsorb a wide range of oils and organic solvents. They also possessed stable water repellency against corrosive liquids such as acidic and alkali solutions. Therefore, porous RGO/PC monoliths can play a big role in the cleanup treatments of oil spill and chemical leak.

2. Experimental

2.1. Materials

PC pellets (Wonderlite PC-110) were obtained from Chi Mei Corporation, Taiwan. RGO with diameter between 0.5 and 3 μm, thickness between 0.55 and 3.74 nm, and purity over 98 wt% was purchased from Chengdu Organic Chemicals Co., Ltd., China. Deionized water was supplied by Nabaichuan Water Treatment Equipment Co., Ltd., China. Organic solvents including tetrahydrofuran (THF), cyclohexane, ethyl acetate and carbon tetrachloride (CCl_4) were purchased from Tianjin Fuyu Fine Chemical Co., Ltd., China. Oils (soybean oil, pump oil, and gasoline) and coloring agents (methylene blue and oil red) were used as received.

2.2. Fabrication of porous RGO/PC monoliths

The fabrication procedure of porous RGO/PC monoliths is shown in Fig. 1. Firstly, 70 mg RGO (2 wt% relative to the weight of PC) was added into THF (50 mL), followed by ultrasonic dispersion for 1 h. Then 3.5 g PC pellets were dissolved in the above suspension with vigorous magnetic stirring at 40 °C for 90 min to form a homoge-