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Facile fabrication of underwater superoleophobic SiO_2 coated meshes for separation of polluted oils from corrosive and hot water

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A B S T R A C T

Separation of oils from water becomes a challenging global task due to the frequent oil spill accidents and expanding industrial oily waste water. Here, we introduced a facile one-step spraying coating method to prepare synergistic superhydrophilic–underwater superoleophobic SiO_2 meshes for removal of oils from water. The underwater superoleophobic SiO_2 meshes were then used to investigate gravity driven separation of a series of oils from water, where only the water was allowed to permeate through the mesh while the oils were repelled on the mesh surface. Separation efficiency up to 99.0% could be achieved with the coated meshes for the kerosene/water mixture. In addition, the coated meshes still retained underwater superoleophobic properties after 50 separation cycles with the separation efficiency larger than 98.0%. Moreover, the SiO_2 coated meshes showed excellent environmental stability under a series of harsh conditions, which were utilized for separation of polluted oils from corrosive and active water, such as strong acidic, salt aqueous solutions and even hot water with the separation efficiency above 98.0%. Thus, such synergistic superhydrophilic–underwater superoleophobic SiO_2 coated meshes might be a potential candidate for water body restoration, especially oily seawater.

1. Introduction

Environmental conservation and sustainable development has become the consensus of the international community. Owing to the frequent oil spillage and oily pollutant enrichment, marine ecosystem suffers from severe environmental and ecological damage [1]. Thus, there is an urgent need of energy-efficient and environment friendly method in oily sewage treatment. Because oil/water separation is an interfacial challenge, researchers recently prefer to the studies on functional membrane materials and adsorbents with special wettability for separation of oil from water [2–6]. Materials with both superhydrophobic and superoleophilic properties (termed as oil-removing type) have aroused great attention in recent years, which allow oil phase to penetrate through and water phase to be repelled on the surface, thus selectively and efficiently separating oil from water [7–16]. However, these oil-removing materials are easily fouled or even plugged by the adhered oil which resulting in the decrease of oil-water separation efficiency. Unfortunately, the water usually has a higher density than oils, leading to limit the practical applications of aforementioned materials.

Inspired by fish scale, superhydrophilic and underwater superoleophobic materials (termed as water-removing type) render an alternative route to settle the aforementioned issues faced in the field of oil/water separation [17]. Until now, various materials such as hydrogels [18], polymers [19–23], graphene oxide [24,25], silica [26,27], TiO_2 [28,29], ZnO [30,31], zeolite [32–34], cellulose [35,36], and palygorskite [37]. have been already studied for desirable underwater superoleophobicity to separate oil/water mixtures. Thereinto, hydrogel and polymer materials are utilized most widely to achieve underwater superoleophobicity. However, the main obstacle that constrains them to use is actually their weak environmental adaptability because of their swelling characteristics in water and metamorphosis of polymeric membranes under long-term scouring by water. The lifetime of these water-removing membranes would be largely extended if they are durable under severe environmental conditions, such as strong acidic, salt aqueous solutions and even hot water. Therefore, it is of great significance to developing functional materials with robust underwater superoleophobic property for the removal of polluted oils from corrosive and active water by a facile, eco-friendly and economical way.

Herein, we presented a facile and efficient method to achieve underwater superoleophobic mesh surfaces by spraying mixtures of hydrophilic SiO_2 nanoparticles (NPs) and waterborne polyurethane (PU) onto stainless steel mesh substrates. The

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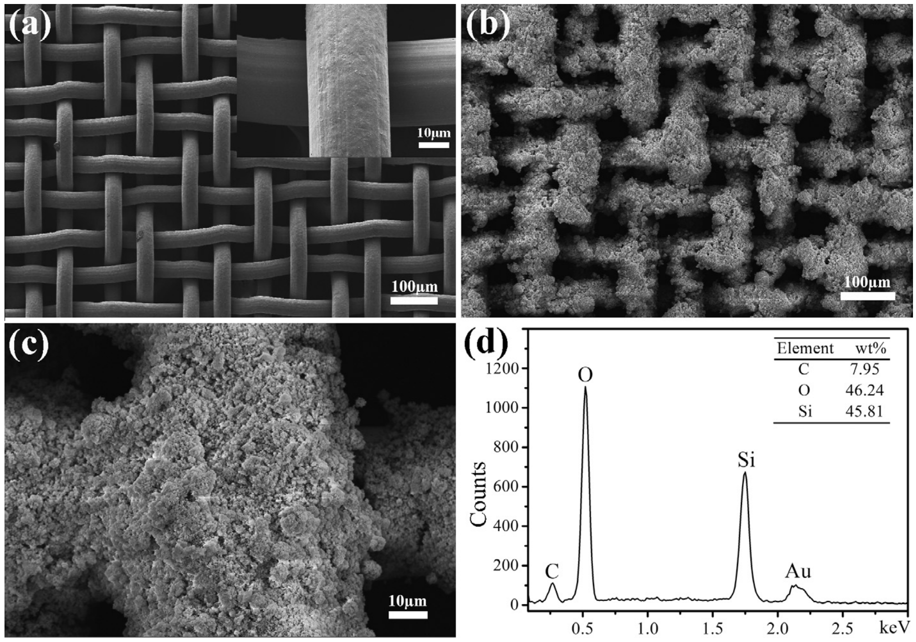

Fig. 1. FE-SEM images of (a) original mesh, the inset is the high magnified image of native mesh and (b and c) the coated mesh surfaces at low and high magnifications, respectively; (d) the EDX spectrum of the SiO_2 coated mesh.

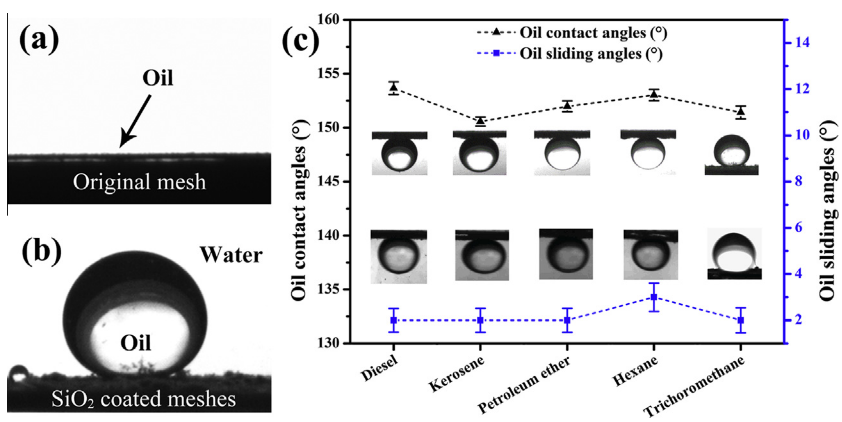

Fig. 2. (a) Wetting behavior of the original mesh toward oil in air; (b) wetting behavior of the SiO_2 coated mesh toward oil in water. A heavy oil (trichlormethane) droplet was selected as the detecting probe; (c) photographs of various oil droplets on the coated mesh underwater with the CA more than 150° and SA less than 4°.

spray-coating is a facile and low-cost method to obtain the independent properties for the substrate, such as electrical conductivity and shape [38–40]. The as-prepared mesh showed excellent water affinity and strong underwater superoleophobicity, which could be used for oil/water separation driven solely by gravity with the separation efficiency larger than 99.0% for the kerosene/water mixture. In addition, the coated meshes still retained underwater superoleophobic properties after 50 separation cycles with the separation efficiency larger than 98.0%. Furthermore, the coated meshes maintained remarkable superoleophobicity under corrosive and active aqueous solutions, which could use for the separation of oils from strong acidic, salt aqueous solutions and even hot water with high separation efficiency.

2. Experimental

2.1. Materials

SiO_2 nanoparticles (NPs) and waterborne polyurethane (PU) were purchased from Sinopharm Chemical Reagent Co., Ltd. and used without further purification. The stainless steel mesh (300 mesh size) was pre-cleaned sequentially with acetone and ethanol before use.

2.2. Preparation of SiO_2 coated mesh

The amount of 0.05 g waterborne polyurethane (PU) was dissolved in 20 mL acetone, and then 0.3 g SiO_2 with average diameter of 50 nm were dispersed in the acetone and stirred magnetically for at least 1 h to gain a homogeneous suspension. Subsequently, the suspension was sprayed onto a steel mesh substrate with 0.2 MPa compressed air gas using a spray gun. Finally, the mesh was dried at ambient temperature for 1 h to allow the acetone to evaporate completely.

2.3. Separation of oils from water

In this study, the oil-water mixture was composed of water colored with methylene blue and oily pollutants colored with Oil Red O, including diesel, kerosene, petroleum ether, hexane, trichloro-