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Short communication

Controlled fabrication of non-fluoro polymer composite film with hierarchically nano structured fibers

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ABSTRACT

Hierarchically nano structured composite fibers were fabricated and characterized. The fibers composed of expanded polystyrene foam (EPF) embedded with varying graphite content were spray coated onto glass substrate. The FESEM and AFM images indicate well dispersed graphite and formation of thin nano fibers, which exhibited water contact angle of 151°. Diameter of a single fiber was noted to be ~500 nm. The uniqueness of the present method is use of fluorine free raw materials, environment benign solvents and feasibility of applying over large surfaces.

1. Introduction

Superhydrophobic solid surfaces with excellent water repellent property have been increasing used in various scientific applications including self cleaning surfaces, ice prevalent solid surfaces, drag reduction in fluid flow, anti corrosive surfaces etc. [1,2] due to low surface energy and hierarchal rough surface [3,4]. Biological surfaces have inspired extensive investigation on hierarchal nano structures and are mimicked to understand their surface chemistry [6]. Though such surfaces demonstrate structural wettability and functional properties, they require complex fabrication process to achieve the desired properties [5]. Traditional methods for formulating superhydrophobic surfaces include lithography, spin coating, spray deposition, self assembly, electro-deposition, plasma etching etc. [7]. All these methods are time consuming and highly expensive. Thus use of fluoro polymers or organic/inorganic materials is considered as alternative methods for attaining superhydrophobicity.

Polystyrene is considered as a versatile polymer for fabrication of excellent water repellent surfaces. Superhydrophobic surfaces of polystyrene nanotubes have been successfully developed mimicking the surface of gecko foot [8]. Spray coated slippery superhydrophobic surfaces are reported by Tan et al. [9]. Alteration from hydrophilic to hydrophobic surface using TiO_2/Polystyrene composite surface has been described by Xu et al. [10]. Literature also reports the fabrication of SiO_2/Polystyrene nano composite for obtaining superhydrophobic surface [11].

In this study, we demonstrate a simple and cost effective technique for fabrication of ultra hydrophobic surfaces using EPF–graphite composites without use of any fluorination treatment as shown in Fig. 1. The superhydrophobicity of EPF–graphite composite (rare to obtain in literature), wettability of EPF and surface morphology of the composite films have been investigated.

2. Materials and method

The fiber forming materials, graphite powder (250 mesh), toluene (anhydrous, 99.8%), acetone and 100% ethanol were procured from Sigma-Aldrich. Expanded polystyrene foams (EPF) were procured from POLYFOAM Corporation Pvt. Ltd. All chemicals/materials were used without any purification. Glass slides (30 × 35 × 3 mm) were purchased from Fisher Scientific, ultrasonicated for 15 min in ethanol followed by deionised water [12].

2.1. Preparation of composite fiber coatings

As shown in schematics (Fig. 1), the EPF–graphite coatings were prepared by mixing EPF, the binder (3 g in 10 mL toluene) and graphite powder (3 wt% and 5 wt%). The mixture was ultrasonicated

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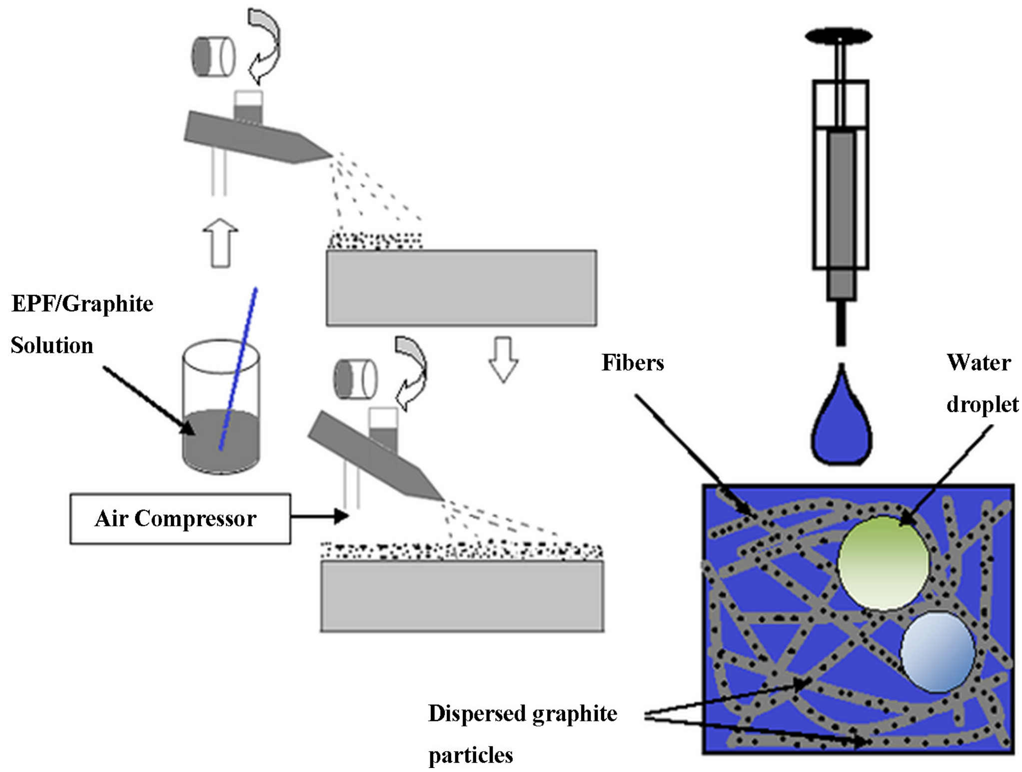

Fig. 1. Schematics for fabrication of EPF/graphite composite films on glass substrate.

for 30 min at 40 °C and sprayed on cleaned glass slide using a spray gun (pressure 0.6 MPa).

2.2. Characterization

The thickness of the composite film was measured using profilometer. Surface morphology of the fabricated surfaces was observed by FESEM (JSM-6700F) and AFM (Asylum research). Surface wettability property was measured by the sessile drop technique [13]. The water contact angle (WCA) measurements were carried out on a Krüss DSA100 (Germany) contact angle goniometer using deionised water at ambient temperature. 4 μL DI water was used to form a sessile drop on the coated glass substrate. Average of five measurements was used for analysis of contact angle.

3. Results and discussion

3.1. Characterization of the composite mixture

EPF with excellent thermal insulation, water resistance, compressive strength, non-abrasive to delicate parts was used in the study. Molecular weight and concentration of dissolved polymer affects the viscosity of mixture. Thus viscosity was controlled by varying the concentration of EPF. Viscosity was found to increases proportionally from 900 cP to 1300 cP with an increase in the EPF content (3–7 g) (Fig. 2). Increase in EPF content in the mixture leads to entanglement of polymer chains which results in enhanced viscosity. Viscosity of mixture also affected the morphology of surface since spraying behaviour is highly dependent on the viscosity of the spraying mixture [14]. Thus controlling viscosity of mixture was essential for obtaining a uniform thin coating on the glass substrate. Viscosity imparted by 3 g EPF in mixture was found suitable for formation of uniform thin coat over the substrate. Viscosity below 900 cP resulted in droplet formation during spraying. Above 900 cP, fibrous structures were observed.

Fig. 3 shows the FESEM images of the EPF–graphite composite films. For pure EPF films, the surface was essentially smooth without any surface roughness. This coating exhibited water contact angle of 89°. Formations of rock like nano structures were observed with incorporation of graphite. The formation of such surface structure is reported [15]. These structures remarkably change the wettability of composite surface from hydrophilic to hydrophobic (water contact angle 115°). In contrast, formation of thin fibrous nano structure was observed with 5 wt% graphite in the mixture (Fig. 3c and d).

Literature reports the formation of nano fibrous structure from electrospun PMMA fibers [16] and electrospun polystyrene fibers with water contact angle of 150° [17]. However, the spray coated films revealed the formation of hierarchical nano fibrous

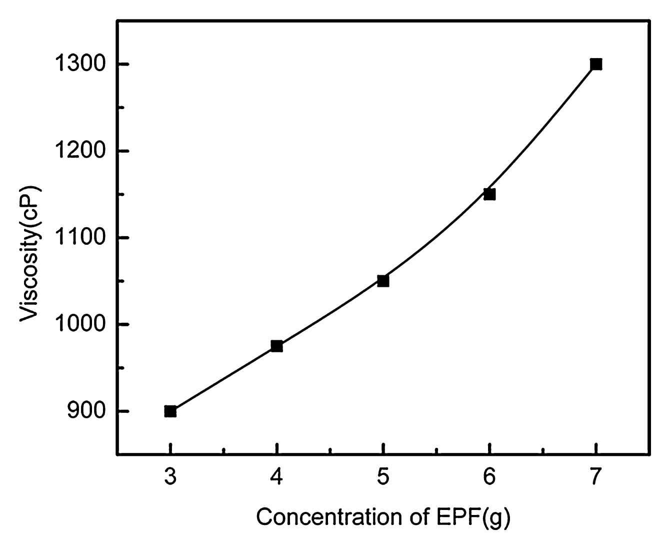

Fig. 2. Effect of EPF concentration on viscosity of the mixture.