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Superoleophillic electrospun polystrene/exofoliated graphite fibre for selective removal of crude oil from water

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During oil spills, the aquatic environment is greatly endangered because oil floats on water making the penetration of sunlight difficult therefore primary productivity is compromised, birds and aquatic organisms are totally eliminated within a short period. It is therefore essential to remove the oil from the water bodies after the spillage. This work reports on the fabrication of oil loving electrospun polystyrene-exofoliated graphite fibre with hydrophobic and oleophillic surface properties. The fibre was applied for the selective adsorption of crude oil from simulated crude oil spillage on water. The maximum oil adsorption capacity of the EPS/EG was 1.15 kg/g in 20 min while the lowest oil adsorption capacity was 0.81 kg/g in 10 min. Cheap oil adsorbent was developed with superoleophillic and superhydrophobic properties.

1. Introduction

Accidental discharge of oil into water bodies greatly depletes water quality; such water is considered unsafe for human consumption. During oil spills, carcinogenic substances such as persistent organic pollutants (POPs) are released into water bodies (Goldberg, 1991; Owens, 1994; Kingston, 2002; Jernelov, 2010; Ugochukwu et al., 2014). Also, industrial oils prevent penetration of sunlight into water bodies by floating of the water surface due to their hydrophobic nature (Gaaseidnes and Turbeville, 1999). Aquatic plants which can adsorb the pollutants are completely destroyed during oil spill (Nordvik, 1995; Wayment and Wagstaff, 1999). Several efforts have been developed to selectively remove oil from water; notable is the use of adsorbents (Shannon et al., 2008; Sakthivel et al., 2013; Wahi et al., 2013).

Oil adsorbents can be categorised into two classes: natural and synthetic adsorbents. Natural oil adsorbents are natural materials used for oil removal from water these include: plants, animal waste and mineral (Wang et al., 2012; Wahi et al., 2013). Its use had suffered set-back due to high hydrophilic nature (Sakthivel et al., 2013; Wahi et al., 2013). It is important to note that good oil adsorbent must have high hydrophobic (water repelling) and oleophillic (oil adsorption) properties. These properties favour synthetic materials for selective removal of oil from water. Synthetic materials can also be divided into three groups: organogels, structure-assembled fibres and porous materials (Sakthivel et al., 2013; Wahi et al., 2013). Carbon aerogels materials have received great attention as oil adsorbent due to their extremely high hydrophobic nature similar to the lotus effect, high porosity and oleophillic properties (Jing et al., 2012; Korhonen et al., 2011; Wrede et al., 2012; Zhu et al., 2013). Gui et al., 2013 reported carbon nanotube/graphene aerogels with oil adsorption capacity of 215–913 g/g (Gui et al., 2013; Zhang et al., 2013). Tryba et al., reported 14.4 g/g as exfoliated graphene (EG) adsorption capacity for engine oil (Tryba et al., 2003). Also, Toyoda and co-workers declared that EG can absorb 70–80 g/g of heavy oil (Toyoda et al., 1999a; 1999b; 2000; Toyoda and Inagaki, 2000; 2003). In spite of high oil adsorption capacity and hydrophobic natures, the use of carbon aerogels materials have been limited due to ultralow density and high cost (Gui et al., 2013; Hu et al., 2013a; Zhang et al., 2013). Practical applications of these materials in spill sites have been limited because it can be easily blown away by a gentle

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breeze. Integrating this class of material into a fibrous network will result into new oil absorbent with enhanced density.

Expanded polystyrene is a packaging materials, it is one of the most predominate polymer waste in the environment. It is hydrophobic, oleophillic and porous fibrous network have been obtained from its electrospun fibre (Alayande et al., 2012a, 2012b; 2013). Integrating carbon aerogels such as EG with this polymer waste will result in low cost oil absorbent with enhanced density. In this present study, we present electrospun EPS-EG nano fibre with oleophillic and hydrophobic properties for selective adsorption of oil from water in a laboratory prepared crude oil spill solution.

2. Experimental

2.1. Exfoliated graphene (EG)

Natural graphite particles were intercalated by immersing the particles in a mixture of concentrated sulphuric and nitric acid ratio 3:1 by volume for 24 h at ambient conditions. The material was washed with distilled water and air dried. Exfoliation was carried out by introducing the material in a pre-heated furnace. Exfoliation was carried out at 800 °C in air for 1 min (Ndlovu et al., 2011).

2.2. Electrospinning of EPS/EG

11 (w/v) % of (10:1) EPS/EG solution was prepared in DMF at room temperature stirring for 12 h for homogeneity. The solutions were electrospun horizontally to yield fibre on aluminium foil used as collector. The size of the needle syringe was 20 gauges and 20 cm was the distance between the tip of the syringe and collector. The flow rate was 10 μl/min, voltage at 18.5 kV. The schematic diagram of electrospinning set-up is known in Fig. 1.

2.3. Characterisation

the resulting EG was characterised with SEM. The fibre was characterised using Data Physics optical contact angle (OCA) using 15 EC GOP, SCA20 (software) to determine water contact angle (WCA) (hydrophobicity) and oil (using crude petroleum oil) contact angle (OCA) (oleophobicity)at a dosing rate of 5 μL/s, dosing volume 2 μL/s using Braum 1 mL disposable syringe. The fibre was also characterised using scanning electron microscope to examine surface morphology using (TESCAN model), pore size and surface area was analysed with BET micromeritics ASAP 2020 surface area and porosity analyser by Brunauer–Emmett–Teller technique. The infrared spectrum of the sample was collected using a Raman infrared spectrometer.

2.4. Adsorption capacity

efficiency of adsorbent for the removal of crude oil from spillage solution was investigated against time (10–100 min). Laboratory simulated oil spillage solution was prepared by treating the crude oil as solute and water as solvent. Crude oil-water solution of known concentration (4–6 g/L) were prepared in 250 mL Erlenmeyer flasks and equal mass of the fibre was added to the solutions at a fixed pH of 7 then placed on Merck millipores shaker at 150 rpm for 10–100 min at room temperature (303 K). The samples

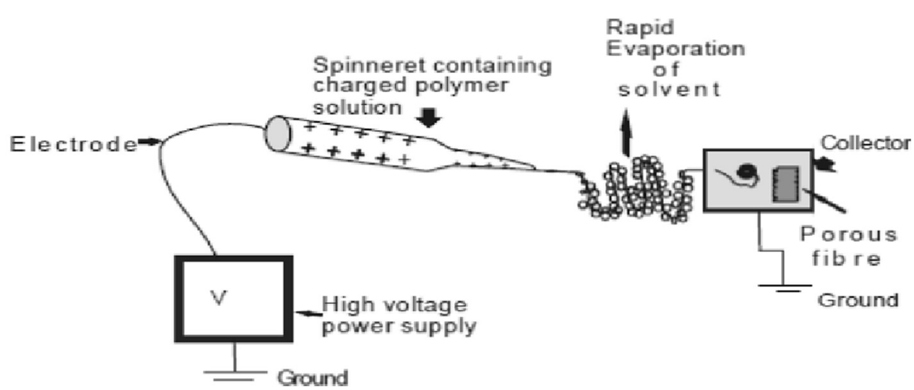

Fig. 1. Schematic diagram of electrospinning set up.

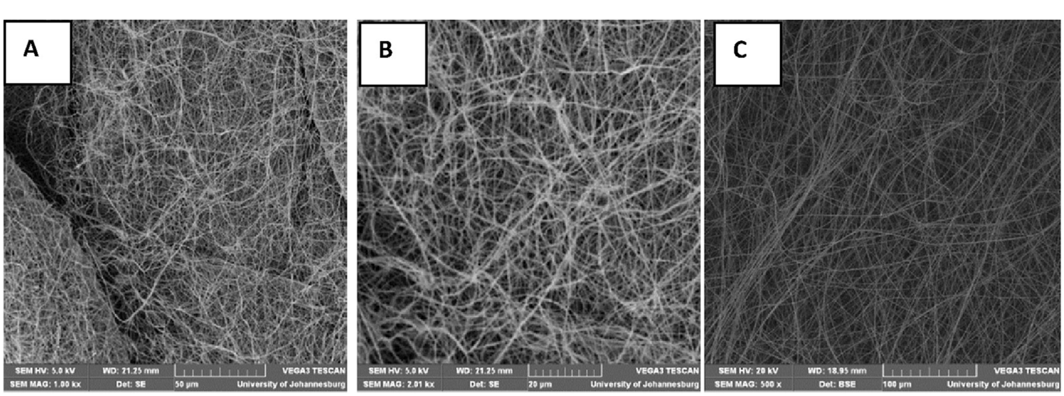

Fig. 2. SEM micrographs of EPS/EG at A] 1000 x B] 2001 x C] EPS only.