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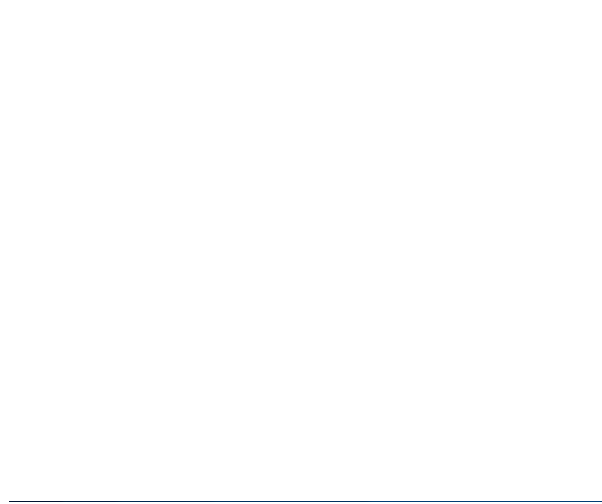
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The potential of using sucrose particles for self-cleaning surface fabrication on recycled high-density polyethylene

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Abstract. Degradation properties of recycled plastic causing it less widely used. By adding extra physical properties, its commercial value and usage can be increased. In this current work, green self-cleaning surfaces from recycled high-density polyethylene (rHDPE) were fabricated using sucrose particles. Water contact angle and sliding angle, self-cleaning properties and surface morphology were characterized. Furthermore, the surface texture was also evaluated by conducting a surface roughness test. By creating porosity onto the rHDPE matrix, the surface exhibits an excellent self-cleaning property with a water contact angle larger than 150°. Surface morphology reveals the porosity and roughness of the surface. In this fabricating process, no chemicals were used while rHDPE is selected for the purpose. Hence, the process is environmentally friendly and low cost for self-cleaning surface fabrication.

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1 Introduction

A superhydrophobic surface is well known for its self-cleaning performance. A surface is categorized as a self-cleaning surface when it can repel the contaminants on it [1]. The superhydrophobicity of a surface is governed by the microstructure and the surface energy of the substrate. By increasing the surface roughness of the substrate, it can help to lower down the surface energy thus, achieving the superhydrophobic property [2]. One of the most common methods to fabricate a superhydrophobic surface is by introducing surfactants to lower down the surface energy. The use of chemical surfactant often gain great attention as improper handling of chemical will easily bring the environmental issue. As a most common reducing surfactant, the silane group surfactant will bring harm to the environment when disposed of [3].

Due to the long-chain structure of the polymer plastic, it is having good durability. Thus, plastic is widely applied in human daily life. There are several commonly mass-produced plastics which are polyethylene terephthalate (PET), high-density polyethylene (HDPE), polyvinyl chloride (PVC), low-density polyethylene (LDPE), and polypropylene (PP) [4]. The HDPE is more commonly used in daily life as from the plastic pail in our home to the application in building construction (piping system). As HDPE is widely used, the waste produced by HDPE is relatively high as compared to the other plastics. Hence, in this research, the use of recycled HDPE (rHDPE) is promoted to help in reducing the carbon footprint of HDPE plastic.

In this research, a green approach to fabricating the superhydrophobic surface for its self-cleaning properties is used. The self-cleaning rHDPE plastic is fabricated by using sucrose particles for surface modification on the rHDPE plastic.

2 Experimental

2.1 Materials

White rHDPE plastic granule was used as the matrix material in this study. The surface modifier used in the study is sucrose particle. The respective source for all the materials used in the study is listed as shown in Table 1.

Table 1. List of material used.

Materials	Description	Source
rHDPE granule	Matrix	Lotte Chemical Titan (M) Sdn. Bhd
Sucrose particle	Surface modifier	Central Sugars Refinery Sdn. Bhd

2.2 Compounding

The recycled high-density polyethylene (rHDPE) granule was hot-pressed by using a compression moulding machine (GT-7014-H, Gotech) to produce the 2 mm rHDPE sheet. Fine sucrose particle was hand-ground for 30 minutes, 60 minutes, 90 minutes and 120 minutes respectively. Ground sucrose particle was weighted with 70 wt% to the weight of rHDPE sheet and was hot-pressed onto the surface of rHDPE sheet, then leached away using ultrasonic bath with distilled water as a medium. The parameter for hotpress and sucrose leaching are as shown in Table 2 and Table 3.

Table 2. The parameter of compression moulding.

Materials	Description	Parameter
rHDPE sheet	Temperature	180°C
	Pressure	20MPa
	Duration (preheat-hotpress-coldpress)	5-10-5 (minutes)
Sucrose particle	Temperature	135°C
	Pressure	20MPa
	Duration (preheat-hotpress-coldpress)	5-10-5 (minutes)

Table 3. The parameter of sucrose leaching.

Description	Parameter
Frequency	53 Hz
Temperature	60°C
Duration	30 minutes

2.3 Characterization and Testing

2.3.1 Wettability

The water contact angle and sliding angle test were performed to measure the wettability of the modified rHDPE surface. The angle obtained from the test was captured and analyzed by using Image-J software.

2.3.2 Surface Morphology

The modified rHDPE sample was coated with gold by using a sputter coater (Coxem Ion Coater SPT-20) and scanned under the scanning electron microscopy (SEM), Hitachi (TM3000) for the study of the surface morphology. The surface roughness was measured by using a surface roughness tester (Mitutoyo FORMTRACER Avant FTA-3000).

2.3.3 Self-Cleaning Performance

Fine charcoal powder was dusted on the modified rHDPE surface with distilled water, 1 ppm Methyl solution and 3.5% NaCl solution were dropped onto the dust on the surface by using a water dropper. Self-cleaning ability was observed in both parallel and tilted surfaces.

3 Results and Discussion

3.1 Wettability

Table 4 illustrated both the water contact angle and the sliding angle of the water from the modified rHDPE surface with a different grinding duration of sucrose particles as the surface modifier. A superhydrophobic surface which having a great self-cleaning ability is

categorized as the surface which forms a 150° and above of water contact angle. Besides, the sliding angle of the water droplet on the surface must not be over 10° [2,5].

A trend of increase in the water contact angle formed can be observed with the increases of the grinding duration for the surface modifier, sucrose particles. The sample produced with 120 minutes of ground sucrose particles formed the largest water contact angle on the surface which is 154.8° as shown in Fig.1 (b) while the surface produced by 30 minutes of ground sucrose particles having the smallest water contact angle which is 152.4° .

The water sliding angle formed by the modified rHDPE surface is also tabulated. It can be observed from the table, as the water contact angle increases, the sliding angle will experience a decrease [6]. The control sample, which is free from micropores and protuberances having the largest sliding angle. By this, it shows the water is hardest to be rolled away from the control sample as compared to the other sample surface. The sample was modified by using 120 minutes of ground sucrose particles forming the lowest sliding angle which is 4.1° while when using 30 minutes ground sucrose particles, the modified surface forming the largest sliding angle, 9.6° . When the water contact angle increases, it indicates a more perfect spherical water droplet is formed. Thus, water droplets are easier to roll away, creating a smaller sliding angle.

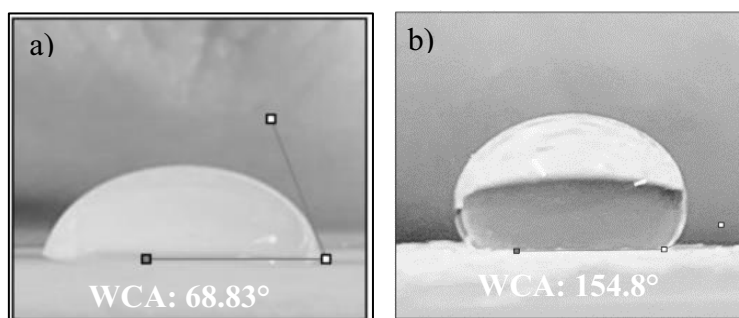


Fig. 1. Water contact angle for **a)** Control sample and **b)** rHDPE sample modified by 120 minutes grinded sucrose particles.

Table 4. Water contact angle and sliding angle of rHDPE sample modified by sucrose particles with different grinding duration.

Sample	Contact Angle ($^\circ$)	Sliding Angle ($^\circ$)
Control	68.8	10.3
30 Minutes Ground Sucrose	152.4	9.6
60 Minutes Ground Sucrose	153.2	6.7
90 Minutes Ground Sucrose	154.7	5.2
120 Minutes Ground Sucrose	154.8	4.1

Sample which is modified by the finer surface modifier can in result producing a denser coverage and smaller size of the micropores on the surface. Thus, as the increase of grinding duration for sucrose particle, a finer sucrose surface modifier produced and the smaller size of micropores can be formed on the surface. Following, a larger water contact angle and smaller sliding angle are formed on the corresponding surface. Thus, the surface poses better superhydrophobicity.

3.2 Surface Morphology

Fig. 2. shows the micrographs for the control sample while Fig. 3. (a)-(d) shows the scanning electron microscopy (SEM) micrographs for the surface of the rHDPE sample which had been modified by using the sucrose particles with different grinding duration. Surface morphology is one of the most decisive factors that affect the wettability of the surface [2,7]. Therefore, from the micrographs, it can be noticed that all 4 modified rHDPE surface poses a microporous surface while the surface of control sample remains smooth. The sample surface which was modified using sucrose particles showing an improvement in the surface roughness as compared with the control sample. This indicates that the sucrose particles which act as the surface modifier help increase the surface roughness of the rHDPE plastic by creating the micropores structure.

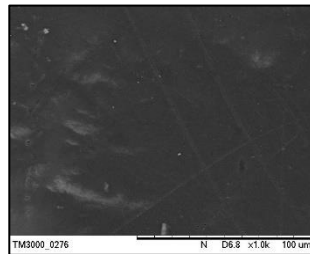


Fig. 2. SEM micrographs for the surface of rHDPE sample (control sample).

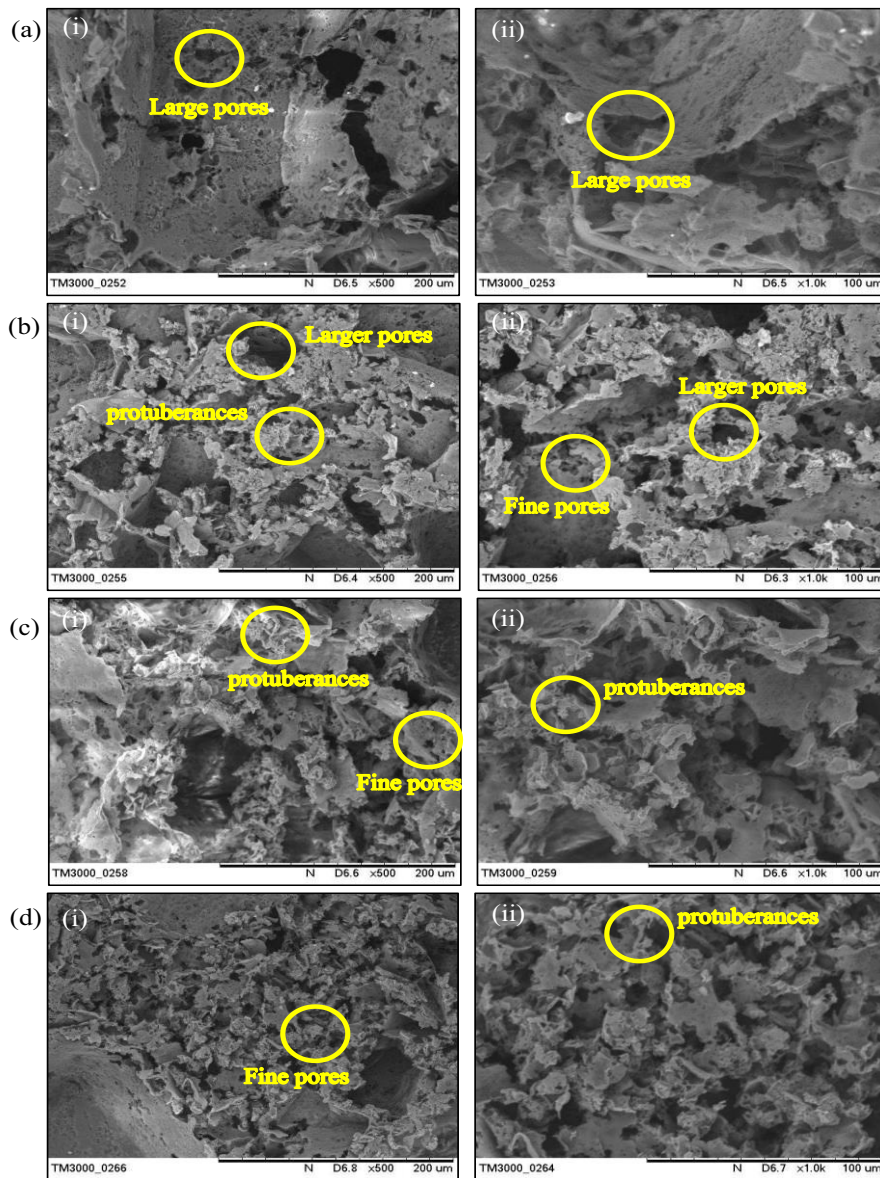


Fig. 3. SEM micrographs for the surface of rHDPE sample modified by sucrose particles with different grinding duration **a)** Ground for 30 minutes **b)** Ground for 60 minutes **c)** Ground for 90 minutes and **d)** Ground for 120 minutes

The observation from the micrograph is also aligned with the result of the surface roughness test as shown in Table 5. The smooth control sample surface having the lowest surface roughness among all of the samples which is $0.9 \mu\text{m}$. However, denser coverage of fine pores and protuberances can be observed from Fig. 3. (d). It also having the lowest surface roughness and creating the largest water contact angle among all modified rHDPE samples. This is in line with the study reported that the microscopic rough surface structure and low surface free energy is the key to fabricate a superhydrophobic surface [8].

Table 5. Surface roughness of rHDPE sample modified by sucrose particles with different grinding duration.

Sample	Surface Roughness (μm)
30 Minutes	59.8
60 Minutes	36.6
90 Minutes	19.6
120 Minutes	17.7
Control (rHDPE)	0.9

3.3 Self-Cleaning Performance

The self-cleaning test on the modified rHDPE surface is displayed in Fig. 4. Through the self-cleaning test, it was proved that the surface adapted a self-cleaning ability as the charcoal powder, which simulating as the dust can be washed away by the distilled water droplet when the sample is tilted. Besides that, even when the modified rHDPE surface are stay parallel, the surrounding area of the water droplet poses a clean condition.

By observing Fig. 4 and Fig. 5, besides distilled water, another type of solution such as 1 ppm Methyl Blue solution and 3.5% NaCl solution can perform the cleaning effect on the sample surface. Therefore, due to the self-cleaning performance of the modified sample surface, the dirt on the surface can be simply washed away by flushing with water which saved cleaning time and eases the cleaning process of a contaminated surface [9].

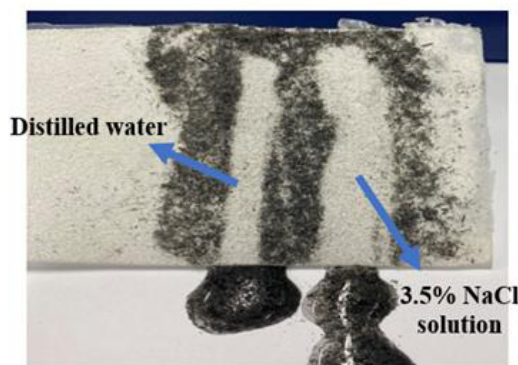


Fig. 4. Self-Cleaning property with different liquid when sample tilted.

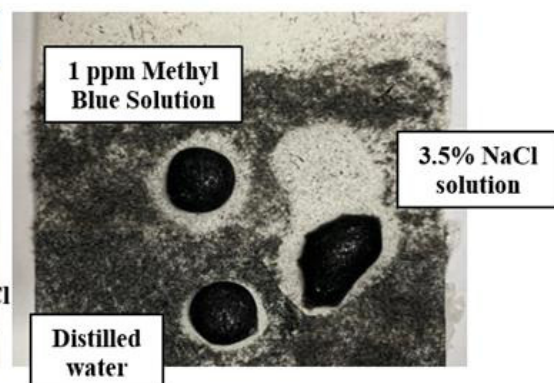


Fig. 5. Self-cleaning property by a different kind of water droplet.

The self-cleaning ability of the superhydrophobic surface can be explained by the nature of the spherical water droplet formed on the sample surface. The modified rough surface with fine pores, causing air trapped in the micropores. Through the air cushion formed, water droplet able to stand in spherical shape on the sample surface. The rolling effect is developed on the spherical water droplet and when the sample is tilted the water droplet rolled away with gravitational force and washed wash away the dirt [10].

4 Conclusion

In this study, sucrose particle is proved to be an applicable surface modifier to perform the surface modification on the rHDPE surface. By modifying the surface microstructure, micropores structure and protuberances can be fabricated on the rHDPE surface greenly without the usage of the hazardous chemical. The finer the micropore produced on the rHDPE surface will be resulting the better superhydrophobicity of the surface which brings the self-cleaning ability to the modified rHDPE surface.

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