บทความวิจัย

EFFECT OF RUBBER POWDER ON MECHANICAL AND THERMAL PROPERTIES OF POLY(BUTYLENE SUCCINATE)

Natkrita Prasoetsopha[1*], Tanapol Chalermkiti[2], Nipat Thupjeen[1], Witawat Singsang[1], Benjaporn Yotburut[3] and Santi Maensiri[3]

[1]Department of Materials Engineering, Faculty of Engineering and Architecture, Rajamangala University of Technology Isan, Nakhon Ratchasima, 30000

[2]Seagate Technology (Thailand) Ltd., Korat Plant, Nakhon Ratchasima, 30170

[3]School of Physics, Institute of Science, Suranaree University of Technology, Nakhon Ratchasima, 30000

*E-mail: natkrita.pr@rmuti.ac.th

ABSTRACT

Rubber powder (RP) was blended into biodegradable poly(butylene succinate) (PBS). The PBS/RP blends were prepared by an internal mixer with the ratios of 100/0, 90/10, 80/20, 70/30, 60/40 and 50/50 by weight. Thermal and mechanical properties of PBS/RP blends were investigated. The results of thermal stability showed that the melting temperature of PBS/RP blends tended to decrease with increasing rubber content until the ratio of 70/30 by weight. The degree of crystallinity of blends did not have relationship when the rubber powder was added. Moreover, tensile strength, Young's modulus, elongation at break, hardness and impact strength were significantly related with rubber content.

Keywords: poly (butylene succinate), rubber powder, mechanical property, thermal property

Introduction

Nowadays, the increase of global population brings about the demands of many things such as furniture, house, cloth etc. The basic raw materials that are used as part of these productions are metals, ceramics and polymer. Especially, polymer or plastic became one of the most multipurpose materials in global economy due to the low cost and light weight. With increasing customer demand, it can cause environmental pollutions due to the disposal of plastic waste. As well known, plastic takes too long to decompose. There are many methods to dispose it such as landfill, inclination or recycle (Subramanian, 2000). Especially, recycling process is one of the best ways in plastic waste management. The examples of recycled plastic waste are poly(ethylene tereptalate) (PET) (Awaja and Pavel, 2005), polyvinyl chloride (PVC) (Sadat-Shojai and Bakhshandeh, 2011) and polyethylene (PE) (Jassim, 2017). Moreover, the tire rubber is more produced due to the increased number of the cars. After using of customer, it was disposed. Hence, the best way of its waste management is recycle.

Poly(butylene succinate) (PBS) is one of the most promising biodegradable polyester. PBS is synthesized by the polycondensation of 1,4-butanediol with succinic acid (Zhao et al., 2012). It has a good processability, better than that of poly(lactic acid) (PLA) and polyglycolide (PGA) (Ishioka et al., 2002). Moreover, it exhibits thermal and chemical resistance (Someya et al., 2004). Therefore, it can be used as candidate in various applications such as packaging film, foamed sheet and blown bottles. However, biodegradable materials alone will not meet some requirement by the industries and its high cost. Therefore, there are attempts to improve its mechanical and thermal properties (Hemsri et al., 2015) or reduce cost by adding cheap materials (Gao et al., 2014).

In this research, rubber powder (RP) from recycled tire rubber was blended into PBS to use as mulch film applications. The object of polymer blending is a unique property of RP which its color is black and cost less. The ratio of the PBS/RP blends was studied. Mechanical and thermal properties of PBS/RP blends were investigated including their morphology.

Methods

For the purposes of the investigation, biodegradable poly(butylene succinate) (PBS), BioPBS^{TM} FZ71PM grade was supplied by PTT MCC Biochem Company Limited and recycled rubber powder (RP) was supplied from Q2thailand company, Nakhon Pathom, Thailand. The particle size of RP was 40 mesh. Both raw materials were dried at 50^{o}C for 24 h before the mixing process to decrease moisture in the materials. The ratios of PBS/RP blends were 100/0, 90/10, 80/20, 70/30, 60/40 and 50/50 by weight. The PBS/RP blends were mixed by the internal mixer machine (Chareon Tut Co., Ltd.:

MX500-D75L90) with a rotor speed of 50 rpm at 145°C for 20 min. After that, each PBS/RP blend was ground in plastic grinder machine (Chareon Tut Co., Ltd.) for two times. To prepare the samples for mechanical testing, the ground pellets were compressed in a stainless steel mold by hot compression molding (Chareon Tut Co., Ltd.) at 145°C with pressure of 10^3 psi by using preheat time, pressing time and cooling time for 5 min, 5 min and 3 min.

For thermal analysis, differential scanning calorimeter (DSC) was used to investigate the thermal property. Differential scanning calorimeter (DSC 1, Mettler Toledo) was used with a temperature range of 50 to 150 °C under nitrogen atmosphere at heating rate of 10 °C/min. A sample weight of approximately 5-10 mg was used in all blends. The melting temperature (T_m) and melting enthalpy ($\triangle H_m$) of all samples were analyzed.

For mechanical testing, universal testing machine (LS Plus Series, Lloyd) was used to investigate tensile properties. The dumbbell shaped samples were prepared according to ASTM D638 Type I. The tensile tests were conducted under ambient condition with a 10 kN load cell and the crosshead speed of 50 mm/min. Five specimens were performed for each blend. Impact testing, the notched izod impact specimens with dimension of 64 mm x 12.6 mm x 3 mm were test by using impact tester (CEAST 9050, Instron) with pendulum energy of 2.7 J at room temperature. The hardness test was conducted according to ASTM D2240-03 using a durometer (GS-612, TECLOCK Co., Japan) and expressed as Shore D hardness.

The dispersion of rubber powder (RP) in poly(butylene succinate) were evaluated by scanning electron microscope (JEOL JSM-6010LV).

Results and Discussion

DSC technique was used to evaluate the thermal properties of neat poly (butylene succinate) (PBS) and PBS/RP blends. The melting temperature (T_m), the crystallization temperature (T_c), the melting enthalpy ($\triangle H_m$) and the degree of crystallinity (X_c) are shown in Table 1. It was found that the Tm of neat PBS was 115°C according to the materials data sheet from the company, and it was similar to previous reports (Hemsri et al., 2015). The melting temperature of PBS tended to decrease with blend of RP, except the PBS/RP blend at the ratio of 60/40. The addition of RP did not give any effect on the blends for crystallization temperature.

From the DSC thermogram, the second heating scan of the PBS/RP blends was used to determine the degree of crystallinity (X_c). The X_c was calculated by measuring the specific heat required for melting ($\triangle H_m$) through integrating the appropriate peak and dividing this value by the heat of fusion for the pure crystalline phase ($\triangle H^o_m$) (Hemsri et al., 2015). X_c was calculated by using the equation as shown in an equation (1) (Hemsri et al., 2015).

$$\%X_c = [(\triangle H_m / \triangle H^o_m) / (PBS\ wt\%)] \times 100 \quad (1)$$

where $\triangle H_m$ is the experimental melting enthalpy (J/g) of PBS polymer, $\triangle H^o_m$ is the melting enthalpy for 100% crystalline PBS polymer taken from the literature (110.4 J/g) and PBS wt% is weight fraction of PBS in the blends (Hemsri et al., 2015).

The results showed that the degree of crystallinity of PBS was 62.5%, corresponding to previous reports (Hemsri et al., 2015). After blending RP, it seemed that the degree of crystallinity of PBS did not have relationships.

Table 1 Thermal analysis by differential scanning calorimetry

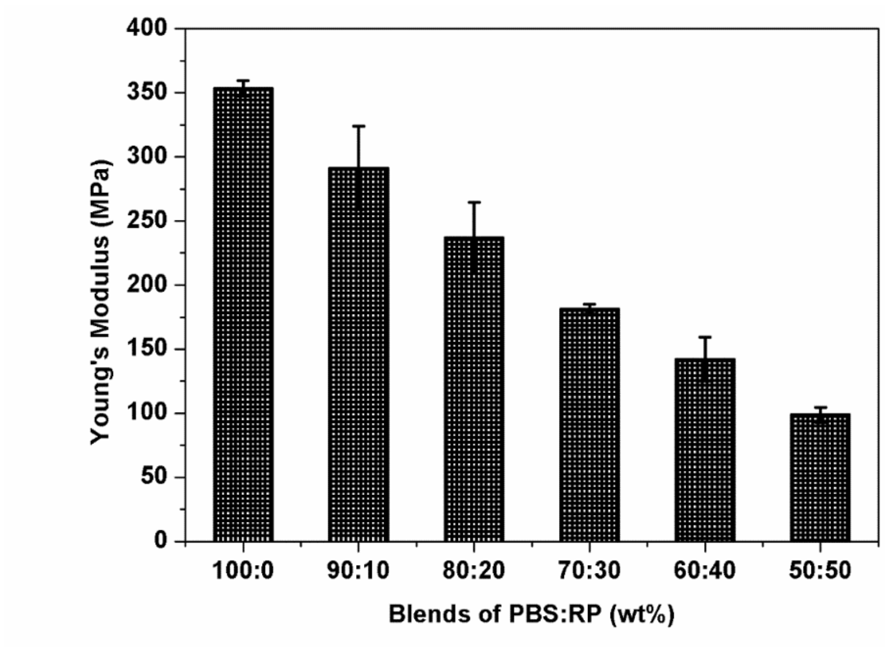
Blends of PBS:RP (wt%)	T_m (°C)	T_c (°C)	ΔH_m (J/g)	X_c (%)
100:0	115.0	81.3	69.0	62.5
90:10	114.7	81.0	58.3	58.7
80:20	113.8	81.0	56.6	64.1
70:30	113.7	81.8	47.9	62.0
60:40	116.3	82.2	31.2	47.1
50:50	114.3	82.3	44.8	81.1

Young's modulus of neat PBS and PBS/RP blends are shown in Figure 1(a). The Young's modulus of neat PBS was 353 MPa. The addition of RP reduced the Young's modulus of the PBS as expected. Moreover, tensile strength of the blends showed the same trend with Young's modulus as shown in Figure 1(b). These phenomena were found in the investigation of poly(butylene succinate)/acrylonitrile butadiene rubber blend (Hemsri et al., 2015).

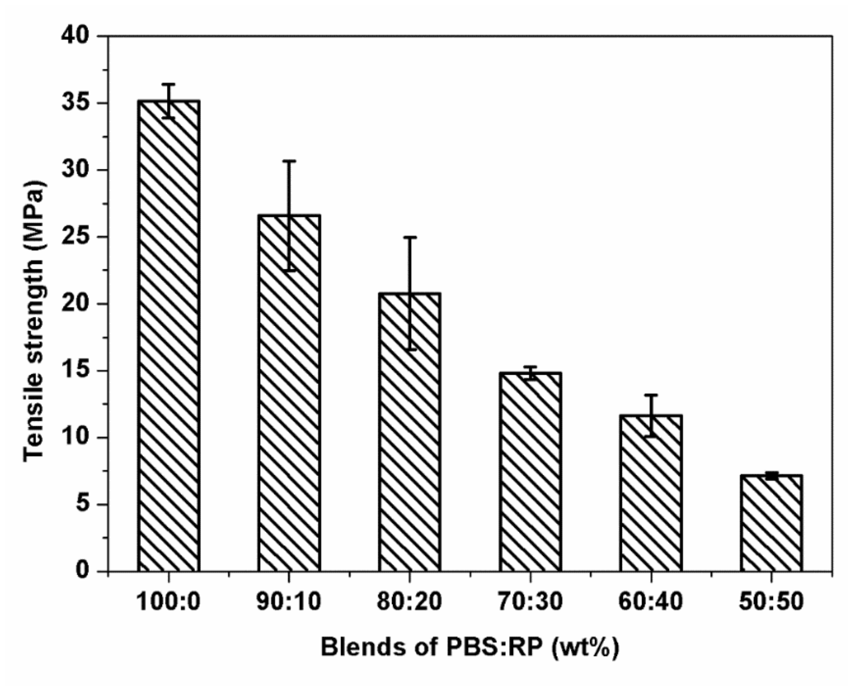
Figure 2 exhibits the elongation at break of blends. It was slightly decreased with an increase of rubber content. The dramatic decrease of elongation at break was found in PBS/RP blends of 50/50. The reason of this reduction might be due to the interfacial adhesion between the rubber and the polymer matrix.

The impact strength of neat PBS and PBS/RP blends are illustrated in Figure 3. The results show that the impact strength of PBS was 5.7 kJ/m^2. After addition of RP, the impact strength decreased with increasing RP content. This might be due to the poor interfacial adhesion and the rubber acting as stress concentration.

Figure 4 shows the hardness of neat PBS and PBS/RP blends. The rubber content was quite a small effect on the hardness of blends.



(a)



(b)

Figure 1 (a) Young's modulus of PBS/RP blends and (b) tensile strength of PBS/RP blends

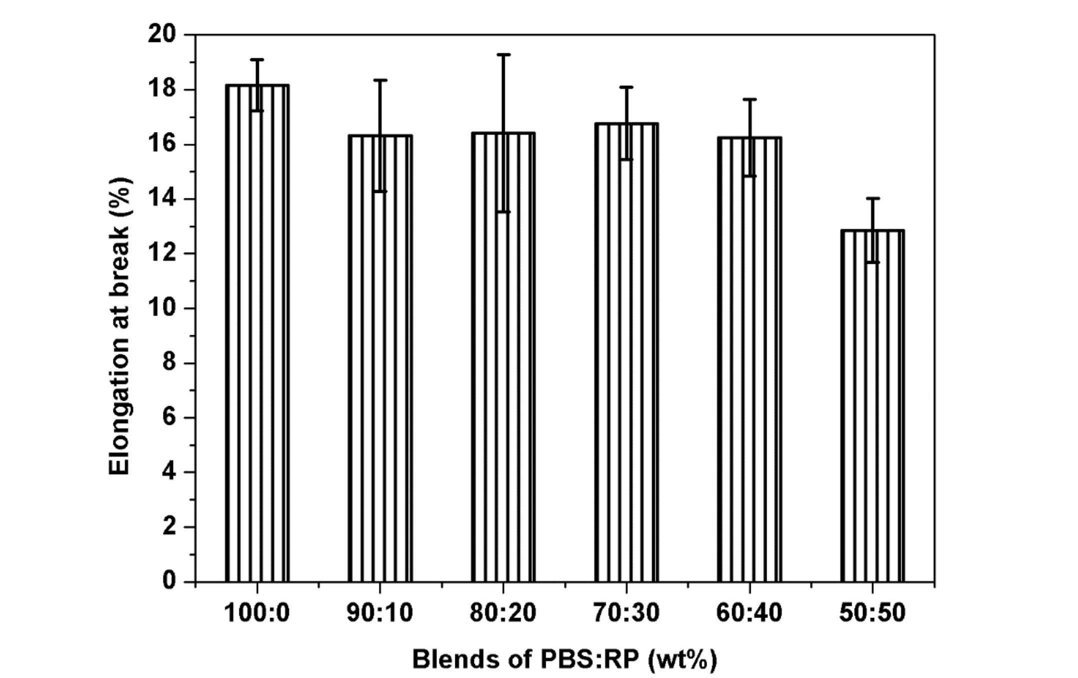


Figure 2 Elongation at break of PBS/RP blends

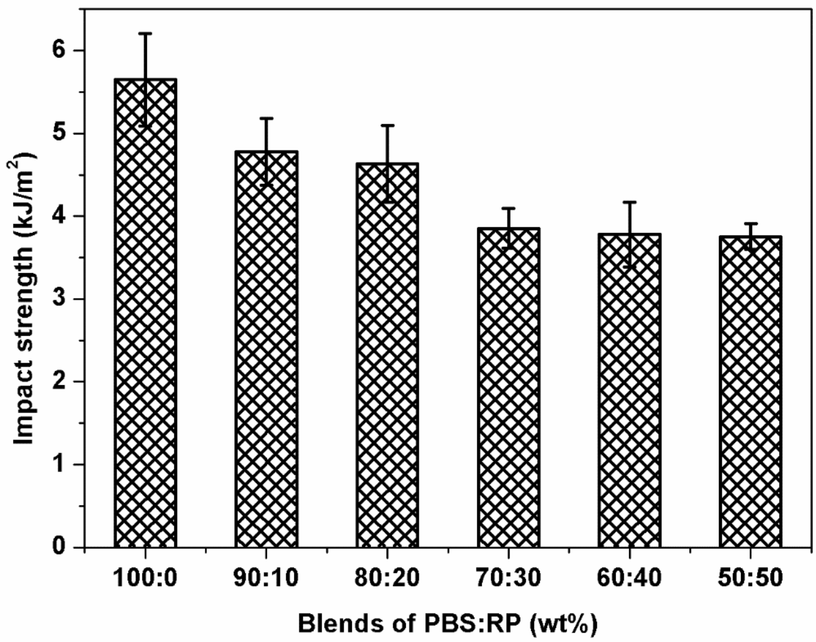


Figure 3 Impact strength of PBS/RP blends

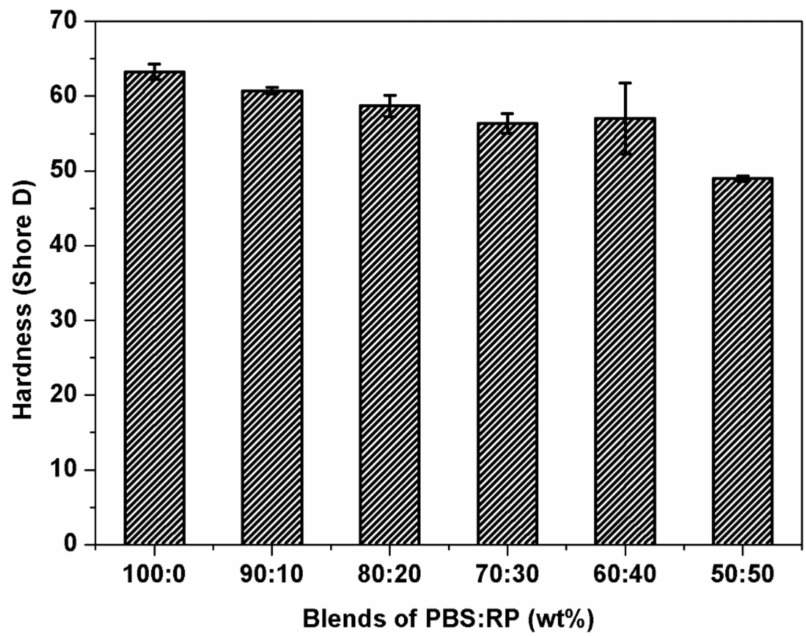


Figure 4 Hardness (Shore D) of PBS/RP blends

Figure 5 shows the cross-sectioned surface of tensile specimen and the particle size of the rubber powder (RP). The fracture surface of neat PBS shows the coarse surface as shown in Figure 5(a). This feature is similar to the previous report (Hemsri et al., 2015). Figure 5(b) and (c) are PBS/RP blends with the ratios of 90:10 and 50:50, respectively. The PBS/RP blends showed a dispersion of RP in the PBS matrix. The particle size of RP of 20-100 μm is shown in Figure 5 (d). However, the interfacial adhesion between PBS and RP was not good. Therefore, the mechanical properties of blends tended to decrease with increasing RP content.

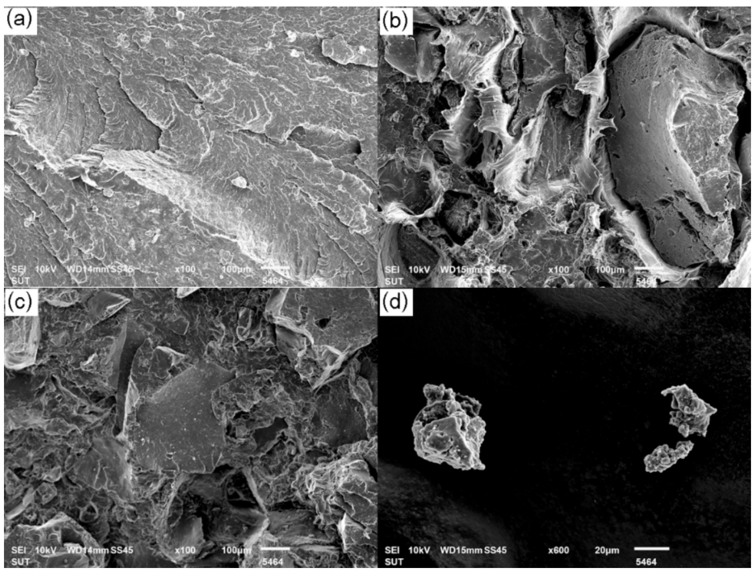


Figure 5 SEM micrographs of : PBS/RP blends with the ratios of (a) 100:0, (b) 90:10, (c) 50:50 and (d) rubber powder (RP)

Conclusion

The influence of rubber powder (RP) content on the thermal properties of poly(butylene succinate), PBS, was investigated. DSC measurement showed that the melting temperature of PBS/RP blends tended to decreased but the rubber powder did not have relationship with the degree of crystallinity of the blends. The tensile strength and Young's modulus decreased as an increase in RP content. Moreover, the elongation at break and impact strength decreased with increasing rubber content due to the poor interfacial adhesion. Addition of RP into PBS led to a decreasing of hardness of the blends. Further work will focus enhancement of adhesion and/or interaction of PBS and RP surfaces.

Acknowledgement

This work was supported by the Faculty of Engineering and Architecture, Rajamangala University of Technology Isan, Nakhon Ratchasima and Advanced Materials Physics Laboratory, School of Physics, Institute of Science, Suranaree University of Technology, Nakhon Ratchasima.

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