Introduction

Polyethylene terephthalate (PET) and polypropylene (PP) have been widely used in conventional and engineering applications. One kind of the application is drinking bottle and constitutes a large portion of post consumer wastes. The recycling of these materials could be the best way to solve the problem of land filling.

Properties of polymer blend are affected by various factors such as composition of the blend, impurities, degradation and especially compatibility between polymer blends. In the production of multi-component blends, it is known that the blending sequence will have strong impact on the morphology and enhanced mechanical properties. Hence properties of polymer blend can achieve by compatibility, suitable processing technologies and blending sequence.

Calcium carbonate (CaCO₃) is a type of mineral that is largely used as filler in plastics for cost reduction, enhance stiffness and induce toughening of filled polymer. The incorporation of CaCO₃ with compatibilized recycled PET (RPET) and its PP-based cap (RPP) blends, obtain from post consumer waste PET bottles, are considered with the aim for investigated the effectiveness of compatibilization of RPET/RPP/CaCO₃ blend as well as the mixing procedure which present key factors for improving the performances and re-use of these recycle materials.

This research studies the effect of melt blending sequence on properties of recycled PET and recycled PP blend filled with CaCO₃. Compatibilizer was used for reducing interfacial energy between two recycled polymers blend. Blending of RPET, RPP, CaCO₃ and compatibizer was prepared by extrusion process with two different of mixing sequences. Injection molding specimens were prepared for investigating on morphological, mechanical and thermal properties of RPET/RPP/CaCO₃ blends.

Experimental

2.1 Materials

Polymers used in this work were RPET and RPP in the form of flakes, which supplied by Yasuda Sangyo Co., Ltd., Japan. A finely ground commercial grade CaCO₃ (SOFTON 1200) with an average particle size of 1.8 μm was purchased from Bihoku Funka Kogyo, Ltd., Japan. A Neoalkoxy zirconate (NZ12L) coupling agents was used as the surfactant, which supplied by Kenrich Petrochemicals, Inc., at contents of 1.0 wt% to the weight of filler. A styrene-ethylene-butadiene-styrene base compound was used as compatibilizer. The ratio of RPET/RPP blend was 95/5. The content of CaCO₃ was fixed at 2.5 wt%. The amount of the compatibilizer was varied at 0, 1, 3, 5 and 7 phr (parts per hundred resins by weight).

2.2 Sample Preparation

RPET was dried at 120 °C for 5 hours in dehumidifier before compounding. Two different mixing methods were used. The first is all compositions were mixed together at the set conditions in a single screw extruder (one step mixing), which is referred as “blend_1”. The extruder barrel temperature was set at 260-285 °C and screw speed at 50 rpm. The second is RPP was melt mixed with CaCO₃ and coupling agent initially in twin screw extruder and pelletized then mixing with RPET and compatibilizer in single screw extruder (two step mixing), which is referred as “blend_2”. The blends were dried at 80 °C for 5 hours in the oven before prepared dumbbell specimens by injection molding machine (Po Yuen UM50) at barrel temperature of 255-290 °C and injection speed of 100 mm/s.

2.3 Characterization

Morphology
Morphology of the blends was characterized from cryogenic fractured surface of the specimens by using a scanning electron microscope (JEOL, JSM5200). Gold coating was sputtered onto the specimens for electron conductivity. The image J program was used to measure the sizes of the disperse phase by the following equation:

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\text{Particlesize diameter } (d_i) = \sqrt{\frac{4 \times \text{area}}{\pi}} \quad (1)
\]

\[
\text{Number average diameter } (d_n) = \frac{\sum N_i d_i}{\sum N_i} \quad (2)
\]

\[
\text{Volume average diameter } (d_v) = \frac{\sum N_i d_i^3}{\sum N_i d_i^2} \quad (3)
\]

\[
\text{Polydispersity } (P_v) = \frac{d_v}{d_n} \quad (4)
\]

Where \( N_i \) is number of particle, which having diameter \( d_i \).

**Mechanical properties**

Tensile test were performed by using an Instron 4206 universal testing machine according to standard ASTM D638. The gauge length was 115 mm at an extension rate of 10 mm/min.

Izod impact strength was determined for 2 mm-deep notched specimens. The tests were conducted by using a Toyo Seiki Izod impact tester.

**Thermal stability**

Thermal stability of the composites was investigated by thermogravimetric analyzer (TGA2950, TA Instruments) with Hi-Res™ mode at heating rate of 30 °C/min from 30 °C to 600 °C under air atmosphere.

3 Results and Discussion

Fig.1. presents the effect of blending sequence and compatibilizer on morphology of CaCO₃ filled RPET/RPP blend at various content of compatibilizers. The results show RPP dispersed phase on RPET matrix. It can see that RPP dispersed phase in compatibilized blends are smaller than without compatibilizer. A reduction in RPP disperse phase sizes was evident with incorporation of compatibilizer. A better dispersion and improved adhesion at the RPP-RPET interface was also noted. The difference of RPP dispersed size should be considered due to the difference of interfacial tension between RPET/RPP and compatibilizer. It could be noted that in 2 steps mixing of blend_2 revealed finer sizes and better dispersion of RPP disperse phase than blend_1. Fig.2. shows volume average diameters of RPP dispersed phase in the blends. These results revealed a reduction in disperse phase sizes when incorporated with compatibilizer, which the average RPP dispersed phase sizes in blend_2 are smaller than blend_1.
Fig. 3. Effect of blending sequence on polydispersity of RPP dispersed phase size of CaCO$_3$ filled RPET/RPP blends.

Fig. 3. presents polydispersity of RPP dispersed phase in the blends. The polydispersity exhibits distribution of RPP dispersed phase in the blends. The polydispersity of blend 2 is lower than blend 1, which indicated that RPP in blend 2 is narrower distribution of RPP dispersed phase sizes and more homogeneity as compared to 1 step mixing than blend 1 [1-2].

Fig. 4. (a) to (c) shows the effect of blending sequence on mechanical properties of CaCO$_3$ filled RPET/RPP blends. The addition of compatibilizer revealed the reduction of tensile modulus and yield strength of the blends as presents in Fig. 4 (a) and (b), respectively. These results were due to the low stiffness and strength of the compatibilizer. However, the effect of blending sequence is no significant change in tensile modulus and yield strength of blend 1 and blend 2. Fig. 4. (c) shows notched impact strength of CaCO$_3$ filled RPET/RPP blends. The incorporation of compatibilizer yields higher impact strength. This result was related to the size of RPP dispersed phase in the blends. It is interesting to note that blend 2 exhibits superior improvement in impact strength than blend 1. The smaller dispersed phase size indicated good interfacial interaction between RPP and RPET, which enabled efficient transfer of energy especially during impact loading. Therefore, premixing of RPP/CaCO$_3$ initially and later mixing with RPET and compatibilizer is the preferred blending sequence to maximize the impact strength.

Fig. 4. Effect of compatibilizer and blending sequence on (a) tensile modulus (b) yield strength and (c) impact properties of CaCO$_3$ filled RPET/RPP blends.
Effect of compatibilizer on thermal stability of the blends is shown in Fig.5. (a) and (b) for blend_1 and blend_2, respectively. These results exhibited the shift of peak degradation temperature of the blends to higher temperature when increasing compatibilizer content. It is interesting to note that thermal stability in blend_2 was much higher than blend_1 as shown in Fig.6. This could probably due to smaller RPP particle size and more homogeneity as well as compatible between filler and matrix, which less amount of void to absorb water thus prevent chain scission of RPET during heating process and raise thermal stability of the blend.

Fig.5. Effect of compatibilizer on thermal stability of CaCO₃ filled RPET/RPP blends in (a) blend_1 and (b) blend_2.

Fig.6. Effect of blending sequence on thermal stability of CaCO₃ filled RPET/RPP blends in blend_1 and blend_2 at 3 phr compatibilizer.

4 Conclusions

The incorporation of compatibilizer revealed the reduction of RPP dispersed phase on the RPET matrix. Melt Blending sequence plays an important role on final morphology of the blend, which has a significant improved on impact strength and thermal stability of CaCO₃ filled RPET/RPP blends. The improvement on properties by using processing techniques will promote and guarantee on appropriated of final properties for plastic recycling technologies.

References
