MORPHOLOGY-PROPERTIES RELATIONSHIP OF POST-CONSUMER PET and PP BLENDS

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Abstract

Blending of recycled polyethylene terephthalate (RPET) with polypropylene (PP) was studied in the present work in attempts to obtain a new material with enhanced properties, respect to the starting materials. The success of the project depends mainly on the possibility to make products from RPET/PP blend. Therefore, fundamental information in terms of blend composition, compatibilization, molecular weight and processing condition effect on the phase morphology, physical, thermal, and mechanical properties of RPET/PP blends is very important to reveal before product design. This was approached by blending of RPET with PP (RPET/PP) using a single-screw extrusion process in the presence of various amounts of compatibilizer ranging from 0-35 wt% based on the PP content. From the morphological analysis, it is observed that the size of dispersed PP phase in RPET/PP blend was dependent upon PP content and amount of compatibilizer that is it increases as PP content increased. The addition of compatibilizer of up to 15 wt% resulted in a size reduction of the dispersed phase (from 1.8 μm to <0.43 μm) and particle size distribution becomes narrower. The changes in morphological structure significantly affect the tensile and impact resistance of the moldings. An elongation at break (EB) of more than 350% could be achieved with the incorporation of just 5 wt% of compatibilizer (as compared to <90% EB for un-compatibilized specimens) while significantly better impact performance was observed in all compatibilized specimens.

Keywords: Polyethylene terephthalate, Polypropylene, Recycling, Polymer Blends, Compatibilization

1. Introduction

Awareness of environmental and energy Problem from plastics wastes has been attracted to many research groups to challenge how to convert the plastic waste into useful materials and product. Polyethylene terephthalate (PET) is recognized to be one of versatile engineering plastics which are used mainly for textile and bottles. In Japan, the usage of PET bottles, i.e., mineral water, olive and other seed oil and all soft drinks, has been increasing

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year by year. In 2006, a total of about 537,909 tons of PET bottles were collected for recycling.

In the previous work, some efforts were devoted to investigate the possibilities of recycling PET (mainly bottles) through injection, extrusion and thermoforming process that could be used to make structural parts of vehicles[1], automotive textiles[2], food containers[3], bottles[4] and raw materials for polyurethane[5]. At present, Japanese government are drawing up legislation and special programs to promote bottle recycling. There is a continuing need for the availability of efficient, cost-effective recovery and recycling systems that can convert scrap bottles into useful products. Thus, the recycling of PET does not only serve as a partial solution to the solid waste problem such as landfill, but also contributes to the conservation of raw petrochemical substance and energy. Generally, recycled PET costs approximately 10% less than virgin PET and 50-60% energy saving as compared to making the same product from PET virgin resin.

The recycling of PET have been carried out in four main approaches, i.e. primary, mechanical, chemical and energy recycling[6]. Mechanical recycling of post-consumer PET blend with other plastics is an effective means to formulate new materials from existing ones. However, almost polymer pair is immiscible and results in inhomogeneous materials. The morphology and interface of blending are predominant factor influences in determining ultimate properties of these immiscible blends. Therefore, an effective blend is depends on how to control phase morphology and interface in order to improve their compatibility. It is well known that adding copolymer or compatibilizers are effective to enhancing properties of immiscible blend[7]. Usually, the compatibilizer concentrate at the interfaces during melt blending and plays the roles of reducing interfacial tension, preventing coalescence and strengthening interface adhesion, resulted in reduction in the particle size and improving mechanical properties[8].

In the present work, blending of post-consumer PET in the presence of compatibilizer is investigated compared to uncompatibilized blends. The main goal of this study is to explore the potential of a new material made from recycled PET (mostly from bottles) and to relate between the extents of compatibilization to phase morphology and mechanical properties in RPET/PP blends.

2. Experimental

2.1 Sample Preparation

Polymer samples used in this study were recycled polyethylene terephthalate in formed of flake (RPET) and polypropylene (PP). PP used were J900GP (MI = 13, M_w = $2.3x10^5$) which were given by Idemitsu Petrochemical Co., Ltd., Japan. A commercial compatibilizer and antioxidant produced by Teijin Co., Ltd. Japan, were used. Blend compositions in this study were varied from 100/0, 95/5, 90/10, 70/30 and 0/100 for RPET/PP Blends. Various concentrations of compatibilizer were used, from 0-35 wt%, based on the total weight of the dispersed phase.

Before blending, PET was dried in a dehumidifying dryer (5 hrs at 120°C). Blending of the dried PET and PP were done in a single screw extruder set at a barrel temperature between 265-290°C and screw rotation speed was 30 m/min. The resulting pellets were then dried using special dehumidifying drier for PET (named Piccolo), which was supplied by ITSWA Co., Ltd, for 5 hrs at 80°C. The dumbbell specimens were prepared using a 50 ton injection molding machine (PO YUEN machinery FTD). The injection molding barrel temperature, mold temperature, injection speed was set at 240-270°C, 30°C and 100 mm/s, respectively.

2.2 Measurements

Morphology, shape and size of the blends was studied by a scanning electron microscopy (SEM), JEOL JSM-5200. The Image J program used to measure the diameters of the dispersed phase and calculate the number average diameter, d_n, the volume average diameter, d_v, and the polydispersity (d_v/d_n), P_d, of the blends from following relation:

$$d_n = \Sigma N_i d_i / \Sigma N_i$$

$$d_v = \Sigma N_i d_i^4 / \Sigma N_i d_i^3$$

$$P_d = d_v / d_n$$

where N_i is number of particles having a diameter d_i.

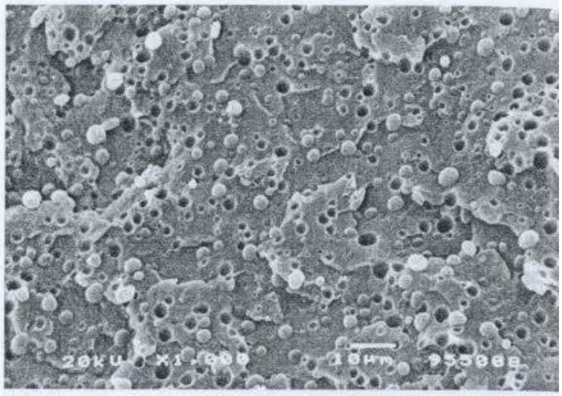
Density measurement was made by a Micromeritics Accupyc B30, Shimadzu Company. The density of the blend samples with and without compatibilizer is an indication of the adhesion in the R-PET/PP blends.

Tensile tests of blends were performed using dumbbell-shaped test specimens at a cross head speed of 50 mm/min using a universal testing machine (Instron 4466, INSTRON USA), following the standard test method ASTM D638. An Izod impact tester (Toyoseikei Inc., Japan) was used to measure the Izod impact strength with notched sample and un-notched sample. Flexural Test was conducted using an Autograph (AG-500E, Shimadzu company, Japan) at speed of 3 mm/min.

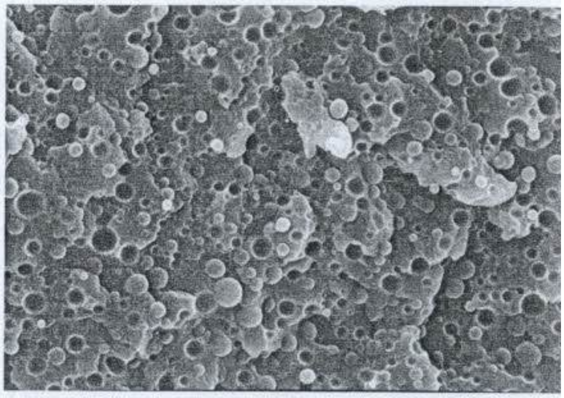
3. RESULTS AND DISCUSSION

3.1 Morphological Properties

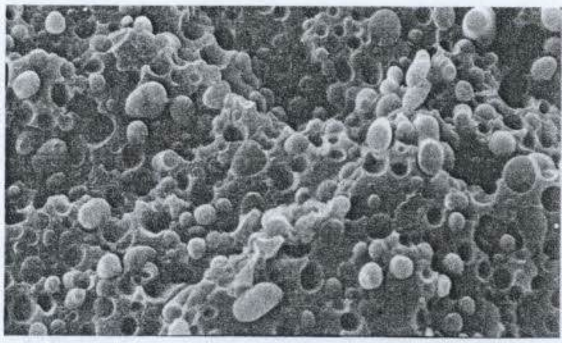
The morphology of fracture surface of uncompatibilized RPET/PP blends at 95/5, 90/10 and 70/30 is shown in Fig. 1. The blend exhibits a typical morphology of immiscible blend with poor adhesion between matrix and dispersed phase and the size of dispersed phase increased as PP content increased. Change in morphology in RPET/PP (95/5) with addition of compatibilizer, are observed in Fig. 2.



a) 95/5

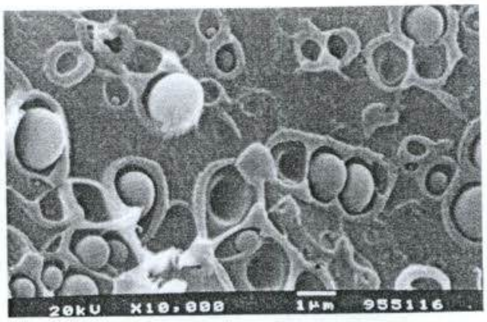


b) 90/10

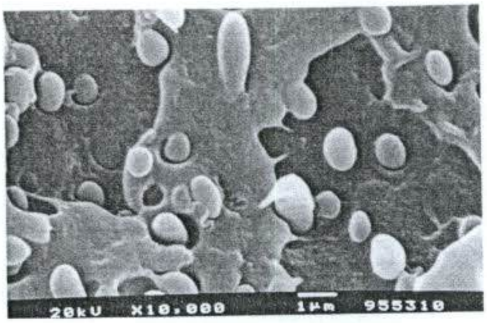


c) 70/30

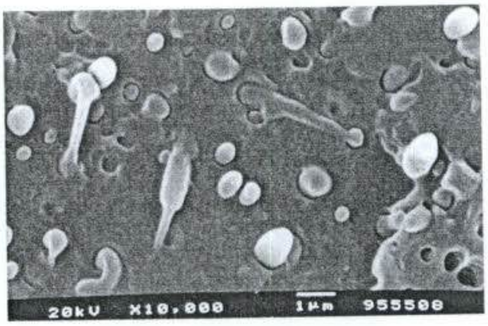
Fig.1 SEM Micrograph for RPET/PP blends (x1,000).



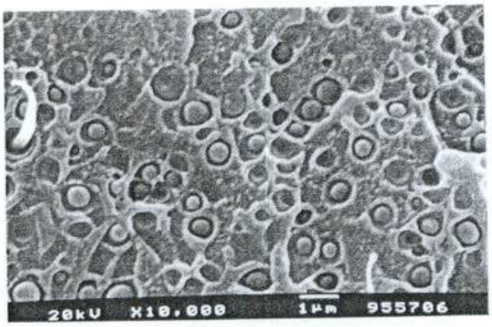
a) 95/5/5



b) 95/5/15



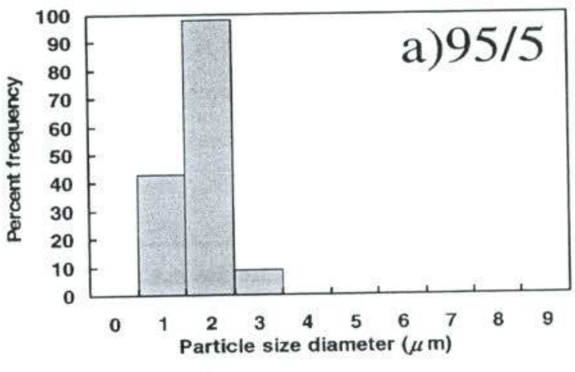
c) 95/5/25

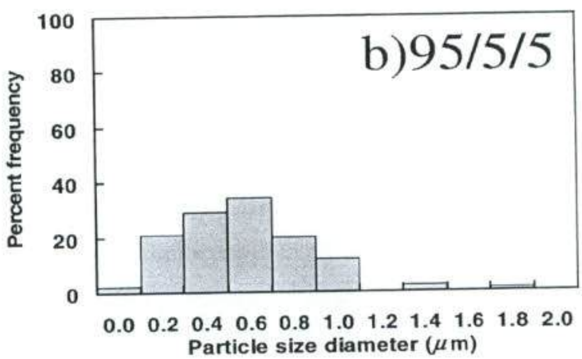


d) 95/5/35

Fig.2 SEM Micrograph for RPET/PP blends (95/5) with compatibilizer 5-35wt%. (x10,000).

The variation in histogram for uncompatibilized and compatibilized RPET/PP (95/5) blends is shown in Fig. 3. For uncompatibilized blends (Fig.3a), a boarder distribution of dispersed particles size is observed due to the occurrence of coalescence phenomena of the minor phase during melt mixing. The effect of compatibilizer addition on the particle size distribution is also examined (Fig.3b-e). When 5 wt% of compatibilizer is added, the particle size distribution become narrower and particle size diameter significantly reduced to about 75% (<0.43 μm), compared to the uncompatibilized blend (1.77 μm). By increasing the compatibilizer content up to 35wt%, the polydispersity of size distribution decreased as evident from the decrease in the width of the histogram. This is due to the addition of compatibilizer into immiscible polymer blend not only reduces the size of the minor phase, but also results in uniform size distribution, as reported in the previous paper [11-12].





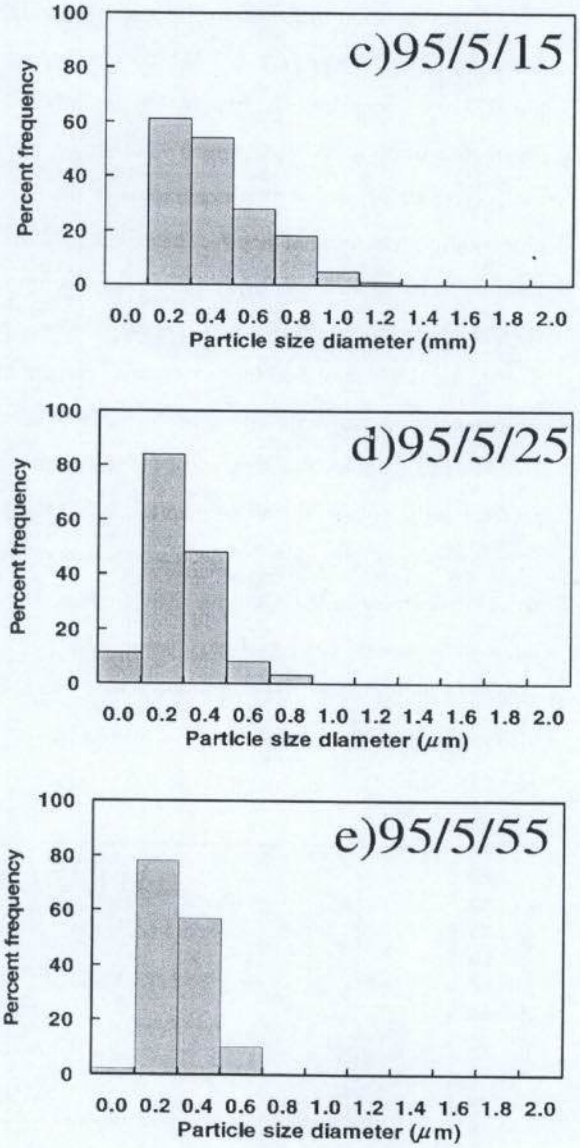


Fig. 3 Particle size distribution determined from SEM micrographs of the RPET/PP/C blends (95/5). At least 100-200 particle diameters were measured for each composition.

The dependence of the average dispersed phase size diameter (d_n, d_v) as a function compatibilizer is shown in Fig. 4. The addition of the compatibilizer causes a reduction in the dispersed phase size until saturation of the interface is achieved. At about 15-25wt% of compatibilizer content is indicated a critical concentratio of compatibilizer in RPET/PP (95/5) blends. It was als found that the apparent density of the blends is increase after adding compatibilizer suggests an improvement i interfacial interaction following the depletion of hollo ligaments between the PP and RPET phases.

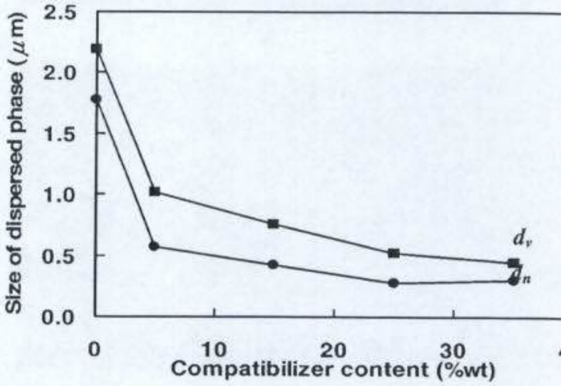


Fig. 4 Effect of compatibilizer content on the particle size of P dispersed phase in RPET/PP blends.

3.2 Mechanical Properties

The changes in morphological structure significantl affect the tensile and impact resistance and a plot o stress-elongation for of RPET/PP blends are presented i Fig. 5. An elongation at break (EB) of more than 350% could be achieved with the incorporation of just 5 wt% o compatibilizer, as compared to <90% EB fo un-compatibilized specimens while significantly bette impact performance was observed in all compatibilize specimens. Impact strength for RPET/PP blends was als tabulated in Table 1. As shown in table 1, the impac strength of REPT/PP blends adding with compatibilize 15-35wt% increases significantly (> 100 KJ/m^2). It i interesting to note that a consistent property improvemen can be obtained for these recycled PET blends, even i the presence of a low amount of compatibilizer.

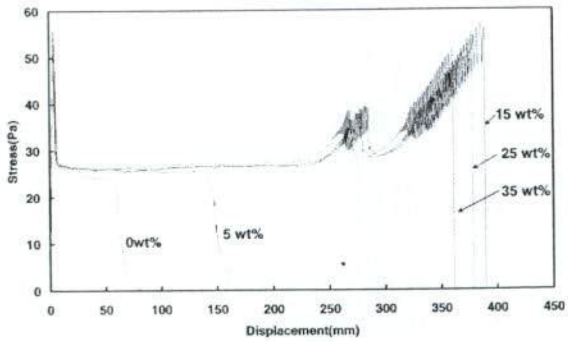


Fig.5 Stress-strain diagram for RPET/PP blend (95/5) with and without compatibilizer.

Table 1 Relation between PP particle size and Izod Impact strength for RPET/PP900 blends

Sample	Composition (wt%)	PP particles size, d_n (μm)	Izod Impact Strength (KJ/m^2)	
			Un-Notch	Notched
RPET/PP0	100/0	-	NB	1.395
RPET/PP5	95/5	1.77	36.992	1.692
RPET/PP10	90/10	2.32	32.780	1.933
RPET/PP30	70/30	3.97	18.188	2.299
RPET/PP100	0/100	-	52.068	1.006
RPET/PP/C5	95/5/5	0.57	100.809	1.882
RPET/PP/C10	95/5/10	0.43	NB	1.766
RPET/PP/C25	95/5/25	0.28	NB	1.611
RPET/PP/C35	95/5/35	0.30	NB	1.689

NB - No break

4. Conclusions

In this investigation, the relation of morphology to mechanical properties of RPET/PP blend was examined with and without compatibilizer in the concept of sustainable recycling development. Addition 5-35wt% of compatibilizer into REPT/PP blend showed a consistent decrease of the average size of PP dispersed phase (from about 1.8 μm to 0.3 μm). Consequently, the interfacial adhesion, elongation at break and impact strength of the blending was improved, as compared to uncompatibilized one.

5. References

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Achievements list

1. W. Klinklai, H. Inoya, Y. Takai, A. Yasuda, Y. W. Leong, H. Hamada, Effect of Composition on Recycled PET/PP Blends, *Proceeding in Japan Society Polymer Processing (JSPP),* 18th Annual Meeting, Tokyo, Japan. 6-8 June 2007. p.157-158
2. W. Klinklai, H. Inoya, Y. Takai, A. Yasuda, Y. W. Leong, H. Hamada, Compatibilization Effect on Morphology and Mechanical Properties in Recycled PET/PP Blends. *Proceeding in Japan Society Polymer Processing (JSPP),* 18th Annual Meeting, Tokyo, Japan. 6-8 June 2007. p.155-156

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