Thermal Property of Polypropylene (PP)/Recycle Polyethylene Terephthalate (rPET) Blends

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Abstract

Plastics such as polyethylene terephthalate (commonly referred as PET) are currently having tremendous demand from consumer. However due to its properties, which take longer time to naturally degrade, it became one of the major contributor to the environmental waste problem. So, an investigation is conducted to study the thermal properties of polypropylene (commonly referred as PP) composites that contain recycled PET (rPET) as its filler. The PP/ rPET blend was made using of single screw extruder machine and produced a hot long chain. Next, the long chain was cooled before its get shredded into pallet form by using a palletizer. Then, the product was tested using Differential Scanning Calorimetry (DSC) to analyze its thermal properties. The result shows that by blending PP composites with rPET makes the thermal properties of PP composite increase. Increasing the composition of rPET in a PP/ rPET blend had increase the melting point, T_m and the transition-glass temperature, T_g.

Keywords: Polypropylene (PP); Polyethylene terephthalate (PET); Thermal properties

Introduction

One of the major environmental problems these days is plastic waste as most of it was not biodegradable (Hassan, Taimur & Yasin, 2017). Thus, if it does not dispose properly, these plastic wastes will take centuries to degrade (Nonato & Bonse, 2016). Nowadays, the worldwide generation of plastics have reached 311 million tons/year (Hassan, Taimur & Yasin, 2017) and predicted to reach approximately 400 million tons in 2020 based on a conservative growth rate of 5% yearly (Chen, Ahmad & Gan, 2017). Besides, rubber and plastic waste disposal has raised some problems especially from ecological and economical point of view as these waste often trashed to the landfills (Cazan, Cosnita & Duta, 2017). Moreover, the large amounts of polymer waste also threaten people life (Mallakpour & Behranvand, 2017). In the past, polymeric waste usually disposed either in landfill or incinerated but it no longer practiced as it also contribute in damaging the environment (Hassan, Taimur & Yasin, 2017).

Plastic based polymers are classified into two categories which are thermoplastics and thermo setting plastics (Islam, Meherier & Islam, 2016). Thermoplastics can be melted through melting and harden through cooling and their examples are polypropylene (PP), polyethylene terephthalate (PET) and polystyrene (PS) while thermo setting plastics cannot be melted or softened through heating (Islam, Meherier & Islam, 2016). Recently, polymer recycling has received quite some attention as the result of societal pressure to reduce pollution and improve waste management (Castro, Victoria & Latorre, 2014). The easiest way to recycle the plastic waste is by producing polymer blends and composites (Chen, Ahmad & Gan, 2017). Two major processes have been applied in order to recycle post-consumer plastic polymer which are mechanical and chemical recycling. Mechanical way are more favoured compare to chemical recycling as it high cost while mechanical recycling are more simple process and excellent in term of energy saving and gas emission that contribute to global warming. Typically mechanical recycling consists of contamination removal by sorting and washing, drying and melting processing (Castro, Victoria & Latorre, 2014). Mechanical recycling or physical recycling is the process of grounding down, reprocessing and compounding plastics into new component which have either the same function with the original product or not. Whereas chemical recycling is the process where polymer waste were recycled into oil/hydrocarbon component or monomers that can be used as raw materials to produce a new polymer by using suitable chemical solvents and can be used in petrochemical industry (Hamad, Kaseem & Deri, 2013).

Engineering thermoplastics have excellent mechanical and thermal properties as it is often use in structural materials production (Inuwa *et al.*, 2017). The increases in price of the engineering thermoplastics enhance the researcher to find an alternative to get a lower cost (Inuwa *et al.*, 2017). Commodity thermoplastics are relatively lower cost but also have lower performance of mechanical and chemical properties to compare with engineering thermoplastics (Inuwa *et al.*, 2017).

PP is one of the most used polymers in the plastics industry (Wang, Niu & Dong, 2017). It is commonly used as plastic or fibres and its world production has exceeds 35 million tons also predicted to increase in the future (Nonato & Bonse, 2016). PP is used extensively in the industry because of its good process ability and mechanical properties (Hassan, Taimur & Yasin, 2017) besides has relatively high crystallinity, good thermal stability and dielectric properties (Sugano-Segura *et al.*, 2017). The melting point of PP is range from 145 °C to 195 °C (Younis, 2017). However, PP are more likely to degradation by oxygen, heat, light and humidity that will affect the physical, chemical and mechanical properties and reduced service life (Hassan, Taimur & Yasin, 2017), and exhibits poor resistance to aging, weathering and radiation (Sugano-Segura *et al.*, 2017).

PET is thermoplastic polyester that has been used widely in producing many plastic products such as food and drinks container and packaging for pharmaceutical products (Mallakpour & Behranvand, 2017). The concern is that PET takes centuries to degrade. So despite disposing it, new ways to reuse pet is developed (Nonato & Bonse, 2016). Hence, the alternative is to use PET as second raw materials to develop new products (Cazan, Cosnita & Duta, 2017). As example, PET can be used as composite matrix or filler along with plastics (Cazan, Cosnita & Duta, 2017). PET presents good thermal and mechanical properties also it have a slow rate of natural decomposition make it best to undergo recycling process in order to economically reduce PET waste (Castro, Victoria & Latorre, 2014).

PP commonly use as matrix because of its lowest density and price among the polymers while PET have lower resolution but can easily modified (Franciszczak *et al.*, 2017). Besides, during recycling process, PET always get cross contaminated with other polymers especially PP (Itim & Philip, 2015). Thus, blending PP with PET will give a good opportunity to combine the two polymers properties and overcome their individual shortcomings (Inuwa *et al.*, 2017). PP composites containing recycle PET (rPET) fibres are a potential sustainable material and mostly, in a matrix will only contain less than 10wt% of rPET (Nonato & Bonse, 2016).

Methodology

2.1 *Preparation of Materials*

2.1.1 Hopper Dryer

The PET waste have been gathered and cleaned. Then, the recycled PET wastes were shredded first. The shredded recycle PET dried in Hopper Dryer for 24 hours before proceed to the next step. This is to remove the moisture from the shredded PET waste.

2.1.2 Extruder and Palletizer of Polyethylene Terephthalate (PET)

The dried rPET was inserted into a single screw extruder machine. Then, it will produce long and hot chain of recycle PET until the feed is fully consumed. The rPET chain will travel by conveyor belt while being cooled with an industrial fan onto a sack. The cooled solid chain of PET will move to a palletizer. Palletizer cuts the long and cooled chain into pallet to eases the next process involving PP.

Table 1: The Formulation of Polypropylene and rPET

Sample	Polypropylene (kg)	Recycle PET (kg)	Weight percentage (wt%)
1	1.7	0.3	15
2	1.8	0.2	10
3	1.9	0.1	5

Three formulations with different composition of PP and rPET are used in this experiment as shown above. The weight percentage (wt%) of rPET component in each sample are around 5 to 10 wt% are based on the previous research by Nonato and Bonse. PP composites containing recycle PET (rPET) fibres are a potential sustainable material and mostly, in a matrix will only contain less than 10wt% of rPET (Nonato & Bonse, 2016). All the material arc weight by using weighing machine. The total mass for each formulation is 2 kg.

2.1.3 Extruder and Palletizer of PP/rPET Blends

Both recycle PET and PP is well mixed, as aforementioned in subsection *2.1.2*, before poured into the feed of the single screw extruder. It is then produce a long and hot semi solid shape which is the PP/rPET blend. After cooled, it becomes a solid shape which then proceeds to shredding process. The palletizer produced pallets of reinforced Polypropylene and recycle PET.

2.1.4 Dry the PP/rPET Blends in Oven

The PP/rPET blends need to be dried in oven for 24 hours before does run the Differential Scanning Calorimetry (DSC) analysis. The oven temperature was set at 80 °C. The blends was stored in oven to remove moisture in the materials to get its constant weight (Luo *et al.*, 2017).

2.2 *Thermal Test*

2.2.1 Differential Scanning Calorimetry (DSC) Analysis

Differential Scanning Calorimetry (DSC) is thermal analysis technique by measuring the temperature and heat flow associated with transitions in materials as a function of temperature and time. This analysis technique provides quantitative and qualitative information about physical and chemical changes including endothermic and exothermic processes or changes in heat capacity. Here, DSC was carried out on Polypropylene and recycled PET polymers blend. The heating process was performed at temperature ranging from 0°C to 190 °C with the rate of 10 °C per minute and samples weighing about 7 mg each time (Michalska-po *et al.*, 2017).

Results and discussion

3.1 *Thermal Properties*

Differential Scanning Calorimetry (DSC) analysis was carried out on the PP and recycled PET blend. A heating process was performed from 0 °C to 190 °C, at rate of 10 °C per minute. The analysis was done to observe the transition glass temperature and melting point of the samples.

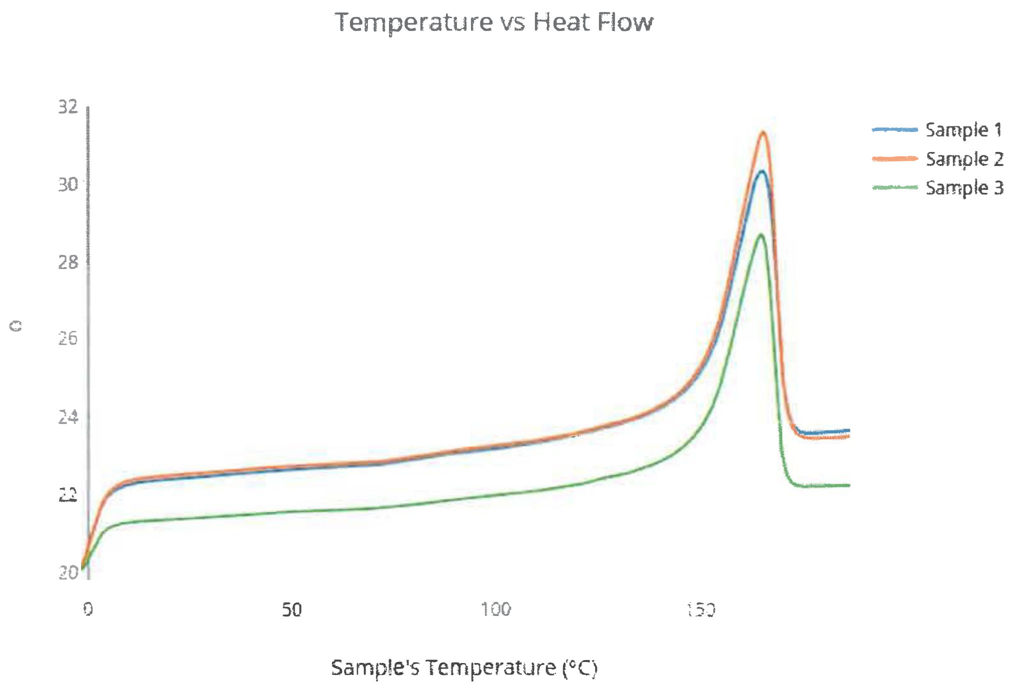

Figure 1: Graph of Heat Flow against Temperature of Sample 1, 2 and 3

DSC test was performed to determine the melting point and transition glass temperature of PP with different concentration of recycled PET. Figure 1 shows the graph of heat flow (m W/g) to temperature (°C) of the PP and recycled PET which are (0.1 kg, 0.2 kg and 0.3 kg) of PET that had been mixed together with PP (1.9 kg, 1.8 kg, 1.7 kg). Sample 1 is referred to 0.3 kg of recycle PET that mixed with 1.7 kg PP producing PP composites with 15 wt% concentration of rPET. Sample 2 refer to 0.2 kg of recycle PET that mixed with 1.8kg PP and sample 3 is referred to 0.1 kg recycle PET mixed with 1.9 kg PP.

3.1.1 *Transition Glass Temperature*

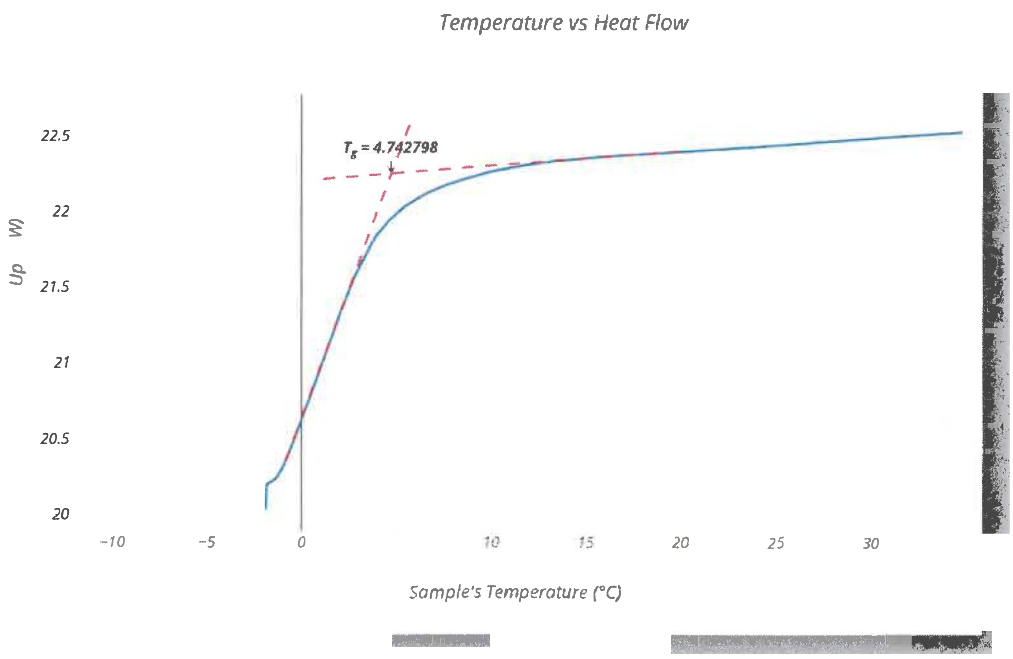

Figure 2: Transition-glass Temperature of Sample 1

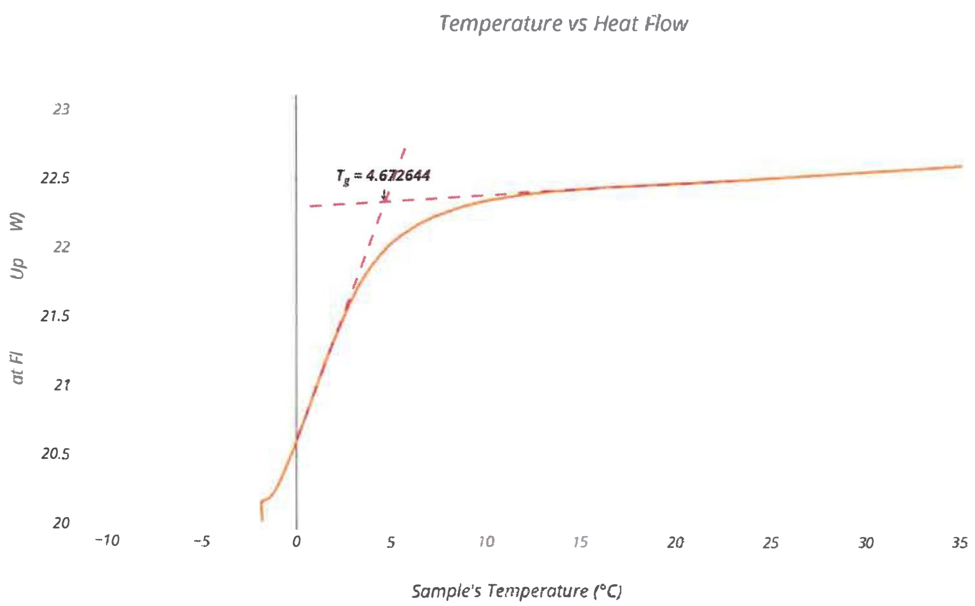

Figure 3: Transition-glass Temperature of Sample 2