PAPER • OPEN ACCESS

Mechanical and thermal properties of binary blends poly lactic acid (PLA) and recycled high-density polyethylene (rHDPE)

To cite this article: N Aishah *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **736** 052022

View the article online for updates and enhancements.

This content was downloaded from IP address 103.53.34.15 on 07/04/2021 at 08:59

Mechanical and thermal properties of binary blends poly lactic acid (PLA) and recycled high-density polyethylene (rHDPE)

N Aishah[1], M Bijarimi[1, *], A K M Moshiul[2], M S Z Mat Desa[1], M Norazmi[3], W Alhadadi[1], F Hafizah[1] and M Z M Nor[1]

[1] Faculty of Chemical & Natural Resources Engineering, Universiti Malaysia Pahang, Kuantan, Malaysia
[2] Institute of Radiation and Polymer Technology, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh
[3] Department of Chemistry, Kulliyah of Science, International Islamic University, Kuantan, Malaysia

*bijarimi@ump.edu.my

Abstract. In this work, plastic bottles made of high-density polyethene (HDPE) have been recycled and blended with poly(lactic acid) (PLA). The aim of the work is to prepare a binary blend of PLA and Recycled HDPE (rHDPE) at 90:10 blend ratio by using a twin-screw extruder. The blends were compression moulded and characterized in terms of mechanical and thermal properties. It was found that the rHDPE increased the tensile modulus of the binary blend. Fracture morphology demonstrated that the blend of rHDPE and PLA is immiscible. In terms of thermal property, as measured by Differential Scanning Calorimetry (DSC), the glass transition temperature of the binary blend showed a lower value, whereas the crystallization process was significantly improved.

1. Introduction
Poly(lactic acid) (PLA) is attractive due to its renewable, biodegradable and good mechanical properties. As the demand for the biobased product is increasing yearly, PLA is always preferred compared to other polymers from biomass. However, PLA is very brittle and not suitable for industrial applications. One of the options available is to blend with polyethylene. Usually, blending with natural fibers, plasticization with polyolefins, synthetic and natural rubber is carried out to improve the mechanical properties of PLA. The natural rubber and PLA blend enhanced the ductility of PLA. Additionally, natural rubber enhanced the crystallization rate of PLA [1].

High-density polyethylene (HDPE) is well known and commercially available polyolefin and being used for several practical applications such as blow moulding, injection moulding, shrink wrap, packaging. To date, the development of new material based on biodegradable and non-biodegradable has generated tremendous commercial interests. Recycled HDPE could be utilised to reduce the of cost of pristine biodegradable polymer such as PLA. The aim of this work is to characterize the mechanical and morphological properties of PLA/rHDPE blends.

2. Materials and Methods
In this work, 3251D grade Poly (lactic acid) thermoplastic with a melt index of 5–8 g/10 min (200ºC) and a specific gravity of 1.25. The plastic bottle of high-density polyethylene has been recycled as rHDPE from different locations of Kuantan city, Pahang, Malaysia.

The PLA and 10 wt% recycled high-density polyethylene (rHDPE) were blended through a twin-screw extruder (Thermo Scientific Prism Eurolab-16, Germany). The extrusion was performed at 170-200ºC, extrudates were pelletized and dried at 70ºC. Tests samples were prepared by a compression moulding machine.

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

Stress-strain was conducted according to ASTM 638-08, using a Shimadzu (Model: AG-1) Universal tensile testing machine fitted with a 5 kN load cell and operated at a cross-head speed of 1mm/min. Five samples of each category were repeated for tensile strength (TS) and tensile modulus (TM) measurements.

Field emission scanning electron microscope (FESEM) (JOEL, JSM-7800F, Japan) was used to evaluate fracture morphology of neat PLA and PLA-rHDPE binary blend. The fracture samples were sputter coated with platinum to make them conductive during the investigation.

Differential scanning calorimetry (DSC) was carried out to determine the thermal transitions in the material, using a TA/Q1000 apparatus under a nitrogen atmosphere and heat/cool/heat method. During this analysis, the samples were heated at a temperature in the range of 25–200ºC with a heating rate of 10ºC/ min and cooling rate 5ºC/min.

3. Results and Discussions

Figure 1 demonstrates the tensile strength and tensile modulus of neat PLA and PLA-rHDPE binary blend. It is obvious that the recycled HDPE influenced the mechanical properties of PLA-rHDPE binary blend. The tensile strength of binary blend decreased by 49%, whereas the tensile modulus of this blend increased by12.20%. It is suggested that recycled HDPE sheared load with neat PLA. Therefore, the stiffness of the binary system significantly enhanced due to the incorporation of rHDPE in PLA matrix.

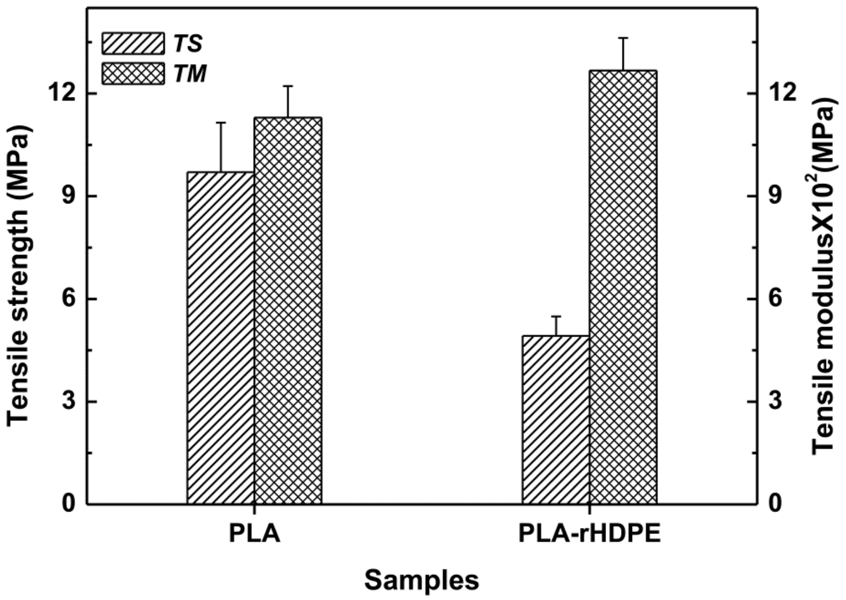

Figure 1. Tensile strength and tensile modulus of neat PLA and PLA-rHDPE binary blend.

Figure 2 illustrates the fracture morphology of neat PLA (a) and PLA-rHDPE (b) binary blend. The fracture surface of neat PLA is a smooth and brittle fracture in nature; on the other hand, the fracture surface of the binary blend appears to be a rough surface. Usually, the fracture surface of the stiff material exhibits a rough surface rather than the smooth surface of brittle material suggested elsewhere [3-5]. Additionally, the micrograph of binary blend reveals that there are a number of tiny droplets of rHDPE are shown by white arrows, are visible on the fracture surface. It is obvious that rHDPE does not completely compatible with neat PLA; as a consequence, the tensile strength of the binary system was decreased in spite of increasing the stiffness.

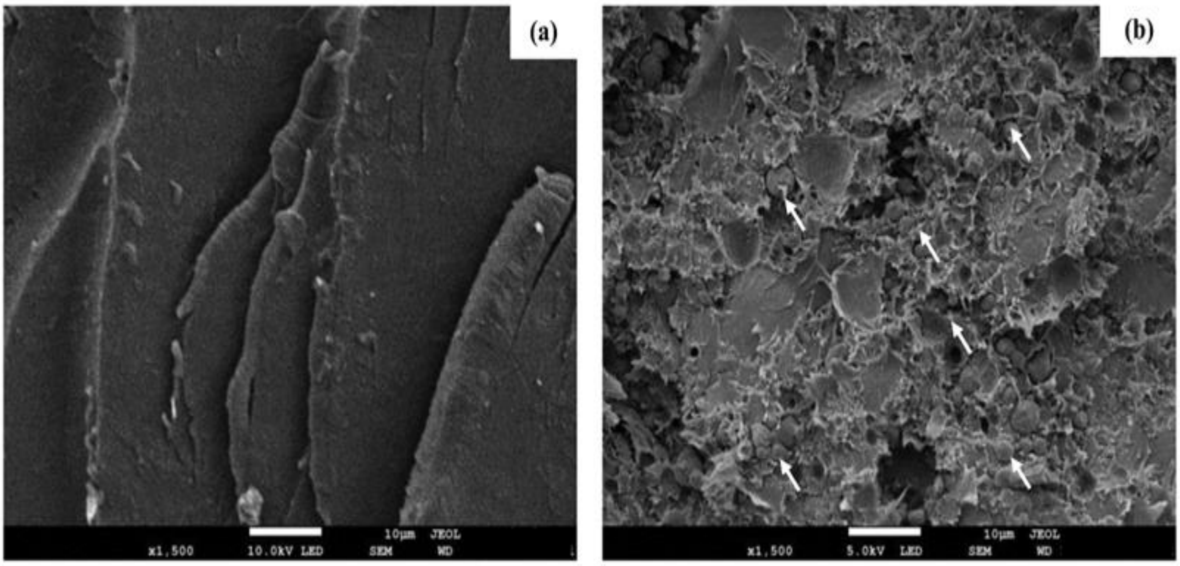

Figure 2. FESEM micrograph of neat (a) PLA and (b) PLA-rHDPE binary blend.

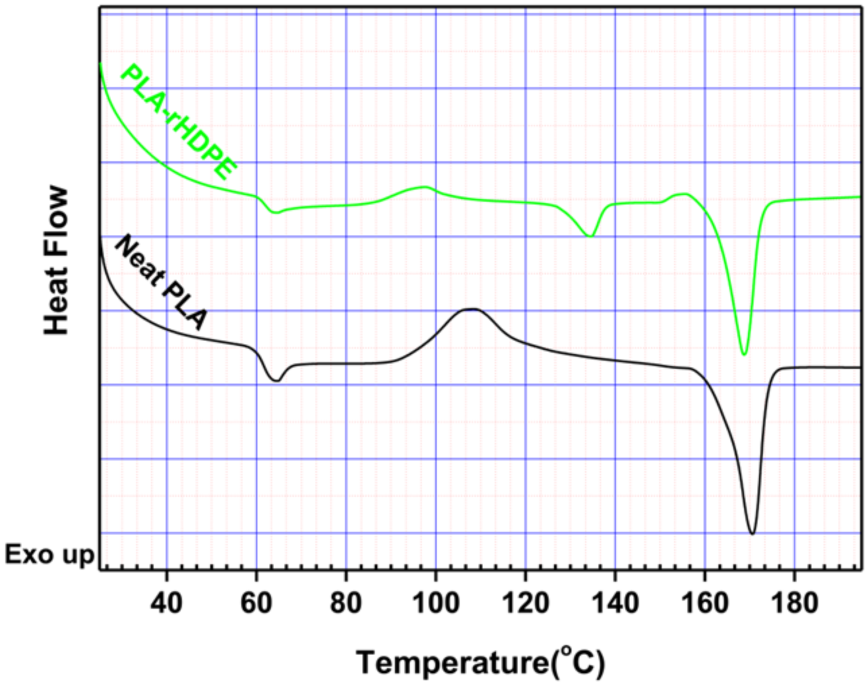

Figure 3. represents the DSC thermograms of neat PLA and PLA-rHDPE binary blend with glass transition (T_g), crystallization transition (T_c) and melt transition (T_m).

The glass transition endotherm and the crystallization exothermic peaks appeared at a lower temperature as compared to the neat PLA. Additionally, the crystallization temperature of blend signifies that rHDPE enhanced the crystallization ability of PLA in the binary system. It perhaps due to easy molecular motion and suggests that rHDPE molecules reduced the rigidity of PLA molecular chains. Therefore, the glass transition temperature, as well as crystallization temperature was decreased. Table 1 shows the summery of the values of glass transition (T_g), crystallization transition (T_c) and melt transition (T_m).

IOP Conf. Series: Materials Science and Engineering **736** (2020) 052022 doi:10.1088/1757-899X/736/5/052022

Table 1. T_g, T_c and T_m of PLA and PLA/rHDPE.

Sample	T_g (ºC)	T_c (ºC)	T_m (ºC)
PLA	65.03	108.33	170.1
PLA/rHDPE	64.36	97.68	168.01

4. Conclusion

In this work, we have studied the mechanical and thermal properties of recycled high-density polyethene with poly (lactic acid). The binary polymers were blended through a twin-screw extruder and characterized using tensile, field emission scanning electron microscope and Differential scanning calorimetry. The result shows tensile strength of binary blend decreased by 49%, whereas the tensile modulus of this blend increased by12.20%. The of FESEM micrograph blend reveals that there are a number of tiny droplets of rHDPE are visible on the fracture surface. The melt transition temperature slightly reduced of PLA/rHDPE as compared to the neat PLA by 2 degrees.

Acknowledgement

This study was supported by the Universiti Malaysia Pahang internal research grant (RDU180351) and FRGS/1/2019/TK05/UMP/02/1.

References

[1] Bijarimi M, Ahmad S and Rasid R 2014 *J. Elastom. Plast.* **46**(4) 338
[2] Lee H J, Won J S, Lim S C and Lee S G 2016 *Polym. Bull*. **73** 2639
[3] Alam A K M M, Beg M D H and Yunus A R M 2016 *Polym. Comp.* **38** E462
[4] Bijarimi M, Ahmad S and Alam A K M M 2016 *Polym. Bull.* **74**(8) 3301
[5] Bijarimi M, Ahmad S and Rasid R 2013 *J Reinf. Plast. Comp*. **32**(21) 1656