



AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN: 1991-8178

Journal home page: www.ajbasweb.com



## Poly(L-lactic) acid (PLLA) blends: Melt Flow Indexes and Tensile Properties

<sup>1</sup>Netnapa Eawwiboonthanakit, <sup>1</sup>Mariatti Jaafar, <sup>1</sup>Zuratul Ain Abdul Hamid, <sup>4</sup>Todo Mitsugu and <sup>3</sup>Banhan Lila.

<sup>1</sup>School of Materials and Mineral Resources Engineering, Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Penang, Malaysia.

<sup>2</sup>Fracture Mechanics and Materials Lab, Research Institute for Applied Mechanics, Kyushu University, Japan.

<sup>3</sup>Industrial Engineering, Faculty of Engineering, Burapha University, 20131 Seansuk, Mueang, Chonburi, Thailand.

### ARTICLE INFO

#### Article history:

Received 25 January 2014

Received in revised form 12

March 2014

Accepted 14 April 2014

Available online 25 April 2014

#### Keywords:

Poly(L-lactic) acid, blends, PLA microsphere

### ABSTRACT

Poly(L-lactic) Acid (PLLA) is well known as biodegradable polymer which derived from renewable resources. PLLA is used in many applications. However the brittleness is a drawback of PLLA properties. The blending of PLLA with other polymers to enhance the toughness of PLLA was carried out in this study. Polymers that have been blended with PLLA are acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA) microsphere. The blends were carried out at 98/2 and 94/6 blend ratios. The tensile stress-strain curves of PLLA/PLA microsphere blends at 98/2 and 94/6 blend ratios exhibit slightly higher strain at break and fibril structure which indicate the ductility of the system. No obvious phase separation occurs in PLLA/PLA system. The morphologies of PLLA/PLA microsphere blends which indicate the miscibility exhibit the higher tensile properties and ductility compared to PLLA/ABS blends. PLLA/ABS blends show an obvious droplet and voids in their microstructures. Moreover, melt flow index (MFI) of PLLA/PLA microsphere blends at 98/2 and 94/6 blend ratios are higher than PLLA/ABS blends. It is observed that the MFIs of PLLA/PLA microsphere blends are increased by the content of PLA microsphere.

© 2014 AENSI Publisher All rights reserved.

**To Cite This Article:** Netnapa Eawwiboonthanakit., Poly(L-lactic) acid (PLLA) blends : Melt Flow Indexes and Tensile Properties. *Aust. J. Basic & Appl. Sci.*, 8(5): 336-340, 2014

## INTRODUCTION

Nowadays, the biodegradable polymers are gaining acceptance due to the environmental problem caused by petroleum based polymeric materials (Bitinis *et al.*, 2011). Poly(L-lactic) acid is a biodegradable polymer which derived from renewable resources such as corn and sugar (Hashima *et al.*, 2010; Bitinis *et al.*, 2011). PLLA is used in various applications especially in biomedical application due to the good properties such as high tensile strength, high modulus, biodegradability, resistance and non-toxic to environment (Li and Shimizu, 2009; Alessandra *et al.*, 2012). On the other hand, it was reported that the brittleness and low impact strength are the drawback of PLLA (Ishida *et al.*, 2009). There are many studies investigated on the toughness improvement of PLLA, where various polymers were used for toughening agent such as rubber (Ishida *et al.*, 2009), polyethylene (PE) (Anderson and Hillmyer, 2004), styrene-butadiene-styrene block copolymer (SEBS) (Hashima *et al.*, 2010), poly ( $\epsilon$ -caprolactone) (PCL) (Todo *et al.*, 2007), and acrylonitrile-butadiene-styrene (ABS) (Li and Shimizu, 2009).

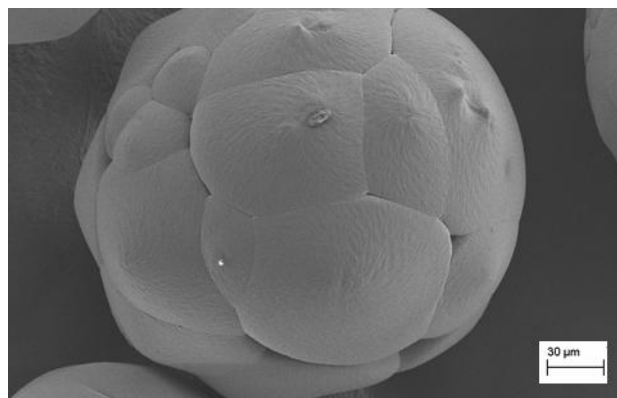
The melt blending is one of the approaches used to improve brittleness of PLLA. It was reported that PLLA blends with rubber or low molecular additives have enhanced the elongation at break (Li and Shimizu, 2009). Thus, blending between PLLA and other polymers can improve the mechanical properties especially the toughness of PLLA. However, it was reported that the mechanical properties and physical properties of polymers blends are depended on the miscibility of polymers blends (Bitinis *et al.*, 2011).

In this study, PLLA was blended with other polymers such as acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA) microsphere at 98/2 and 94/6 blend ratios. The tensile properties and melt flow index (MFI) of PLLA blends system at different blend ratios were investigated and analyzed. The result was supported with microstructure of the polymer blends.

**Corresponding Author:** Mariatti Jaafar, School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia.  
E-mail: mariatti@eng.usm.my

**Experimentation:****Materials:**

PLLA pellets (Lacty®#5000,  $M_w = 1.45 \times 10^5$ ,  $M_n = 0.75 \times 10^5$ , PD = 1.93) were supplied by Toyota Motor Co.,Ltd. PLLA is a thermoplastic which derived from lactic acid. This PLLA indicates a glass transition ( $T_g$ ) of around 60 °C, a crystallization temperature ( $T_c$ ) of around 100 °C and a melting point ( $T_m$ ) of around 175 °C. Acrylonitrile butadiene styrene (ABS) pellets was supplied by Toray Plastics (Malaysia) Sdn. Bhd. PLA microsphere was fabricated by using emulsion solvent evaporation method. Fig. 1 shows the microsphere of PLA microsphere taken at 350x magnification.



**Fig. 1:** SEM morphology of PLA microsphere at 350x magnification.

**Preparation of Blend and Specimens:**

PLLA and polymers consist of ABS and PLA microsphere were blended at 98/2 and 94/6 blend ratios (based on wt.%) by internal mixing machine at 180 °C and 50 rpm for 10 minutes. 5 samples have been used for each blend formulation. Next, pure PLLA and PLLA blends were compressed using hot press machine at 1500 psi and 180 °C for 2 minutes, and followed by cooling process to form sheet specimens (150 mm × 125 mm × 2 mm).

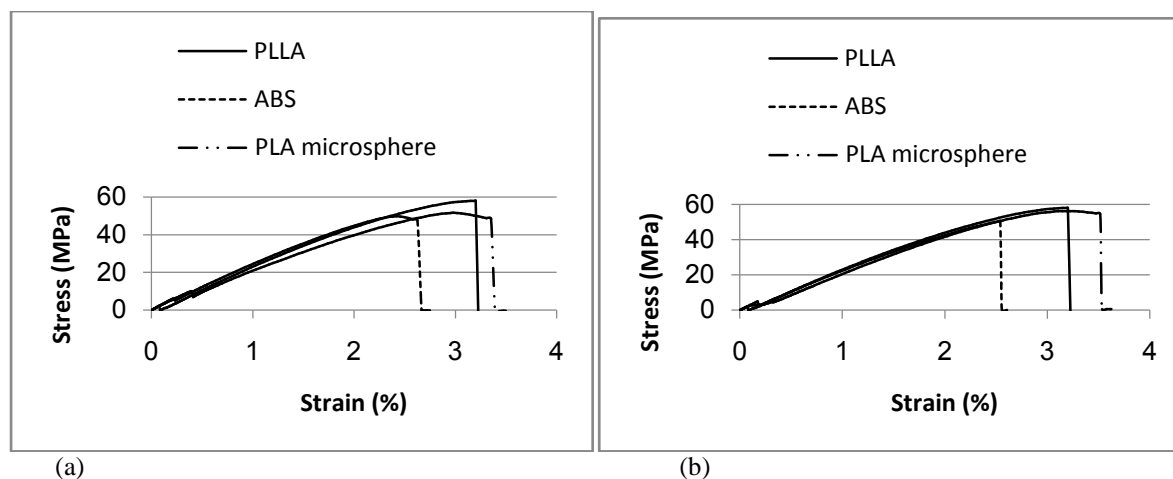
**Characterization:**

Tensile test was carried out by Instron-3366 universal mechanical testing machine according to ASTM-D882. Tensile test was performed at a cross-head speed of 5 mm/min. Melt Flow Index (MFI) was carried out by Dynisco Polymer Test (mode D4004) according to ASTM D1238-04 (procedure A, 190°C/2.16 kg). The outcome of melt flow index (MFI) is the molten polymer flow through an orifice in g/10 minutes from a standard cylinder die (Ø 2.1 mm × 8.0 mm). Field emission scanning electron microscopy (FE-SEM) of the cryo-fracture surfaces was performed to characterize the morphology of pure PLLA and PLLA blends system by Leo Supra 35VP. The fracture surfaces from tensile test were immersed in liquid nitrogen ( $N_2$ ) for 30 minutes, next samples were coated by gold sputter.

**RESULT AND DISCUSSION****Tensile Stress-Strain Curves;**

Figure 2 shows the tensile stress-strain curves of pure PLLA, PLLA/ABS blends and PLLA/PLA microsphere blends at 98/2 and 94/6 blend ratios. Tensile stress-strain curves of PLLA/ABS blends show the brittle fracture which indicated by low strain at break. In Fig.2 (a), tensile stress-strain curve of PLLA/PLA microsphere blend at 98/2 blend ratio shows slightly lower tensile stress and higher strain at break compared to pure PLLA (control sample) whereas tensile stress and strain at break of PLLA/ABS blend are lower than those of pure PLLA and PLLA/PLA microsphere blend. At 94/6 blend ratio, tensile stress-strain curve of PLLA/PLA microsphere blend shows higher strain at break, which is illustrated in Fig.2 (b). The tensile stress and strain at break of PLLA/PLA microsphere blend at 94/6 are higher than PLLA/PLA microsphere blend at 98/2 blend ratio.

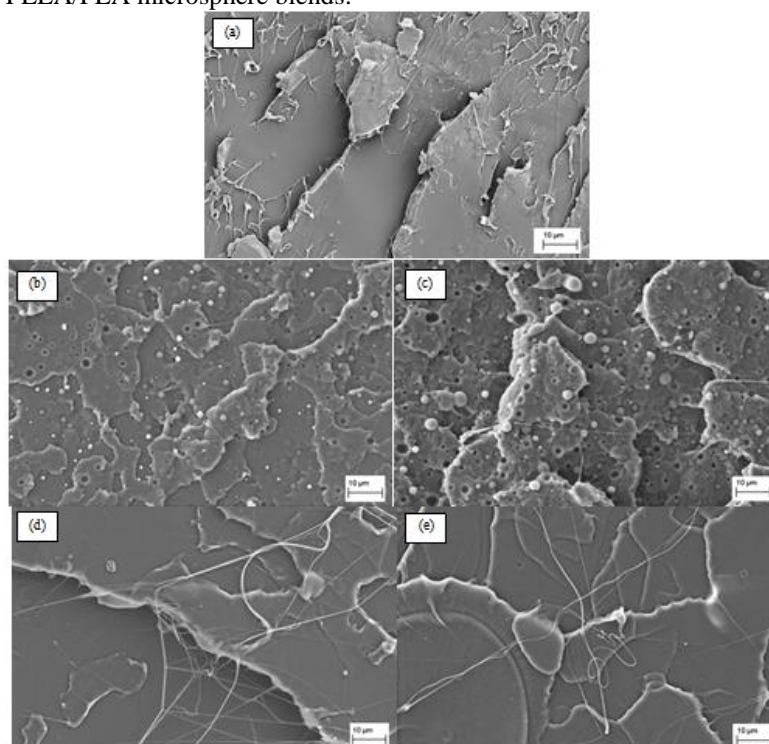
This is might be due to the fibril structure that exists within morphology as shown in Fig.3. It is noted that the tensile stress and strain at break of PLLA/PLA microsphere blends are increased when the content of PLA microsphere is increasing. Area under stress-strain curve refers to the toughness of materials. It is found that the toughness of PLLA/PLA microsphere blend at 94/6 blend ratio is slightly higher than pure PLLA (control sample).



**Fig. 2:** Tensile stress strain curves of pure PLLA, PLLA/ABS blend and PLLA/PLA microsphere blend (a) at 98/2 and (b) 94/6 blend ratios.

### Phase Morphology:

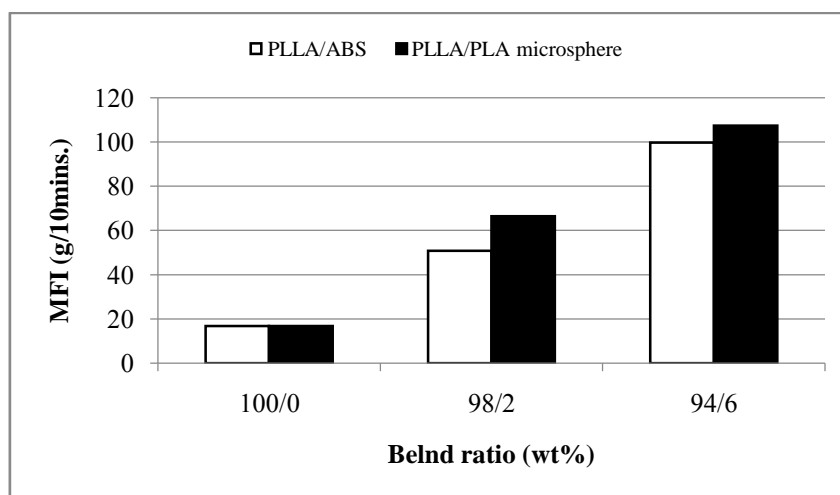
The microstructures of the pure PLLA, PLLA/ABS blend and PLLA/PLA microsphere blend are shown in Fig. 3. In Fig. 3 (a), tensile fracture surface is flat and smooth which indicated to the brittleness of pure PLLA. The same PLLA microstructure was reported by Vannaladsaysy *et al.*, (2010a). Fig. 3 (b-c) exhibit to PLLA/ABS blends at 98/2 blend and 94/6 blend ratios, it is observed the ABS droplets and voids present in the microstructure which indicate to the immiscibility of the blends. These ABS droplets and voids are increased when the quantity of ABS is increased. In other words, generally PLLA/ABS system at 98/2 and 94/6 blend ratios indicate the immiscibility and macro-phase separation of two components. As known, these immiscibility and phase separation affect to physical property and mechanical property of polymers blend (Vannaladsaysy *et al.*, 2010b). In Fig. 3 (d-e), the microstructures of PLLA/PLA microsphere blends at 98/2 and 94/6 blend ratios indicate the presence of the fibril structures. It was reported that these fibril structures and the stretched edge of fracture surface exhibit the ductility of blends (Meng *et al.*, 2012). It is observed that there is no phase separation exists in PLLA/PLA microsphere blends.



**Fig. 3:** SEM morphology of tensile fracture surface of (a) pure PLLA, (b) PLLA/ABS blend and (c) PLLA/PLA microsphere blend at 98/2 blend ratio, (d) PLLA/ABS blend and (e) PLLA/PLA microsphere blend at 94/6 blend ratio (at 1,000x magnification).

**Melt Flow Index (MFI):**

Melt flow index (MFI) is a parameter which important in plastics industry, it fulfills requirement for processability which the flow properties of materials are important considered for processability (Guerreiro *et al.*, 2012; Chui *et al.*, 2007). MFI was calculated from the weight of molten polymers blends that flow through the orifice of standard cylinder die under the controlled temperature in 10 minutes. MFI of pure PLLA, PLLA/ABS blends and PLLA/PLA microsphere blends are shown in Fig. 4. It is observed that the MFI of PLLA/ABS blends and PLLA/PLA microsphere blends at 98/2 and 94/6 blend ratios are higher than pure PLLA. It is found that the MFI increased with the content of ABS and PLA microsphere. PLLA/PLA microsphere blends indicate the higher MFI compared those of PLLA/ABS blends. According to Liang and Ness (1997), the miscibility of polymer blends might increase the flow rate of the polymer melt. As shown in Fig. 3 (d and e), there is no obvious phase separation occurs in PLLA/PLA microsphere blends this indirectly indicate the miscibility of the blend, hence slightly increase the MFI.



**Fig. 4:** The Melt Flow Index (MFI) values of pure PLLA, PLLA/synthetic rubber and PLLA/PLA microsphere.

**Conclusion:**

PLLA/PLA microsphere blend at 98/2 and 94/6 blend ratios exhibit the higher strain at break and Melt flow index (MFI) compared to PLLA/ABS blends. This is might be due to the miscibility of PLLA/PLA microsphere blend since no phase separation occurs in the microstructure of PLLA/PLA microsphere blend. However, PLLA/ABS blends exhibit the lower tensile stress and strain at break compared to PLLA/PLA microsphere blends due to the ABS droplets and voids are observed in the morphology which indirectly related immiscibility of PLLA/ABS blends.

**ACKNOWLEDGEMENT**

The author is grateful to AUN-Seed Net Project (Grant no.6050200) for financial support and gratefully acknowledges School of Materials and Mineral Resources Engineering, Universiti Sins Malaysia for providing the facilities to carry out the research.

**REFERENCES**

- Alessandra, d.S.A., I.B.T. Maria, O.d.S. Emerson, P.C.N. Roberto, A.M. Leonardo, 2012. Development of hybrid nanocomposites based on PLLA and low-field NMR characterization. *Polymer Testing*, 31: 267-275.
- Anderson, K.S., M.A. Hillmyer, 2004. The influence of block copolymer microstructure on the toughness of compatibilized polylactide/polyethylene blends. *Polymer*, 45: 8809-8823.
- Bitinis, N., R. Verdejo, P. Cassagnau, M.A. Lopez-Manchado, 2011. Structure and properties of polylactide/natural rubber blends. *Materials Chemistry and Physics*, 129: 823-831.
- Chui, Q.S.H., C. Franciscone, J.A.F. Baptista, D.S. Rosa, 2007. An interlaboratory comparison of the melt flow index: Relevant aspects for the participant laboratories. *Polymer Testing*, 26: 576-586.
- Guerreiro, S.D.C., I.M. João, L.E. Pimentel Real, 2012. Evaluation of the influence of testing parameters on the melt flow index of thermoplastics. *Polymer Testing*, 31: 1026-1030.
- Hashima, K., S. Nishitsuji, T. Inoue, 2010. Structure-properties of super-tough PLA alloy with excellent heat resistance. *Polymer*, 51: 3934-3939.

Ishida, S., R. Nagasaki, K. Chino, T. Dong, Y. Inoue, 2009. Toughening of poly(L-lactide) by melt blending with rubbers. *Journal of Applied Polymer Science*, 113: 558-566.

Li, Y., H. Shimizu, 2009. Improvement in toughness of poly(l-lactide) (PLLA) through reactive blending with acrylonitrile–butadiene–styrene copolymer (ABS): Morphology and properties. *European Polymer Journal*, 45: 738-746.

Liang, J.Z., J.N. Ness, 1997. Studies on melt flow properties of low density and linear low density polyethylene blends in capillary extrusion. *Polymer Testing*, 16: 173-184.

Meng, B., J. Deng, Q. Liu, Z. Wu, W. Yang, 2012. Transparent and ductile poly(lactic acid)/poly(butyl acrylate) (PBA) blends: Structure and properties. *European Polymer Journal*, 48: 127-135.

Todo, M., S.D. Park, T. Takayama, K. Arakawa, 2007. Fracture micromechanisms of bioabsorbable PLLA/PCL polymer blends. *Engineering Fracture Mechanics*, 74: 1872-1883.

Vannaladsaysy, V., M. Jaafar, Z. Ahmad, K. Pasomsouk, M. Todo, 2010a. Improvement of microstructures and properties of biodegradable PLLA and PCL blends compatibilized with a triblock copolymer. *Materials Science and Engineering*, 527: 6930-6937.

Vannaladsaysy, V., M. Todo, M. Jaafar, Z. Ahmad, K. Pasomsouk, 2010b. Characterization of microstructure and mechanical properties of biodegradable polymer blends of poly(L-lactic acid) and poly(butylene succinate-co- $\epsilon$ -caprolactone) with lysine triisocyanate. *Polymer Engineering & Science*, 50: 1485-1491.