F0794 2/2013

BORANG FRGS – P3(R)

KEMENTERIAN PENDIDIKAN MALAYSIA

FINAL REPORT
FUNDAMENTAL RESEARCH GRANT SCHEME (FRGS)
Laporan Akhir Skim Geran Penyelidikan Fundamental (FRGS)
Pindaan 1/2015

A

RESEARCH TITLE: Understanding of the structure properties relationship and flame retardancy mechanism of poly(lactic acid) blends containing phosphorus based flame retardant

PHASE & YEAR: Phase 2 Year 2013

START DATE: 1 DECEMBER 2013
END DATE: 30 NOVEMBER 2015
EXTENSION PERIOD (DATE): RMC LEVEL: 31 MAY 2016
KPM LEVEL:

PROJECT LEADER: CHOW WEN SHYANG
I/C / PASSPORT NUMBER: 771226-08-6077

PROJECT MEMBERS: 1. MARIATTI BINTI JAAFAR
(including GRA) 2. TEOH EE LIAN

PROJECT ACHIEVEMENT *(Prestasi Projek)*

B

ACHIEVEMENT PERCENTAGE			
Project progress according to milestones achieved up to this period	**0 - 50%**	**51 - 75%**	**76 - 100%**
Percentage (please state #%)			100%

RESEARCH OUTPUT		
Number of articles/ manuscripts/ books *(Please attach the First Page of Publication)*	**Indexed Journal**	***Non-Indexed Journal***
	2 (1 under-Review)	
Conference Proceeding *(Please attach the First Page of Publication)*	**International**	***National***
	3	
Intellectual Property *(Please specify)*		

HUMAN CAPITAL DEVELOPMENT

Human Capital	Number				Others (please specify)
	On-going		Graduated		
Citizen	Malaysian	Non Malaysian	Malaysian	Non Malaysian	
No. PHD STUDENT					
Student Fullname: IC / Passport No: Student ID:					
No. MASTER STUDENT	1				
Student Fullname: IC / Passport No: Student ID:	Teoh Ee Lian 890622075232 PGM0014/14				
No. UNDERGRADUATE STUDENT			2		
Student Fullname: IC / Passport No: Student ID:			Teo Zu Xian 920202016206 112964 Joyce A/P Micheal Retnasingam 920826065866 117313		
Total	1		2		

EXPENDITURE *(Perbelanjaan) as Borang K1(RMC)*

C

Budget Approved *(Peruntukan diluluskan)* : **RM 85,500.00**
Amount Spent *(Jumlah Perbelanjaan)* : **RM 75,538.31**

Balance *(Baki)* : **RM 9961.69**
Percentage of Amount Spent *(Peratusan Belanja)* : 88.35 %

ADDITIONAL RESEARCH ACTIVITIES THAT CONTRIBUTE TOWARDS DEVELOPING SOFT AND HARD SKILLS
(Aktiviti Penyelidikan Sampingan yang menyumbang kepada pembangunan kemahiran insaniah)

D

International

Activity	Date (Month, Year)	Organizer
1. **Invited speaker.** W.S. Chow, E.L. Teoh, M. Mariatti (2016), "Development of Flame Retarded Poly(lactic acid) Blends and Nanocomposites", International Symposium on Advanced Polymeric Materials (ISAPM 2016), PWTC, Kuala Lumpur, Malaysia.	16 May 2016 – 18 May 2016	Institute of Materials, Malaysia.

	2. **Oral presenter** E.L. Teoh, M. Mariatti, W.S. Chow (2016), "Effect of Phosphorus-based Flame Retardant on the Termal and Flame Resistant Properties of Poly(lactic acid)/Poly(methyl methacrylate) Blend", The 3rd International Conference of Global Network for Innovative Technology 2016 (IGNITE 2016), Evergreen Laurel Hotel, Penang, Malaysia.	27 January 2016 – 29 January 2016	School of Materials and Mineral Resources Engineering (Universiti Sains Malaysia) and Toyohashi University of Technology (Japan).
	3. **Oral presenter** E.L. Teoh, M. Mariatti, W.S. Chow (2015), "Thermal and Flame Resistant Properties of Poly(lactic acid) Blends Containing Halogen-Free Flame Retardant", 5th International Conference on Recent Advances in Materials, Minerals & Environment (RAMM 2015) & 2nd International Postgraduate Conference on Materials, Mineral and Polymer (MAMIP 2015), Vistana Hotel, Penang, Malaysia.	4 August 2015 – 6 August 2015	School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia.

National

Activity	Date (Month, Year)	Organizer
(e.g : Course/ Seminar/ Symposium/ Conference/ Workshop/ Site Visit)		

E	**PROBLEMS / CONSTRAINTS IF ANY** *(Masalah/ Kekangan sekiranya ada)*
	-
F	**RECOMMENDATION** *(Cadangan Penambahbaikan)*
	-

G	**RESEARCH ABSTRACT – Not More Than 200 Words** (*Abstrak Penyelidikan – Tidak Melebihi 200 patah perkataan*)
	Poly(lactic acid)/poly(methyl methacrylate) blends were prepared using melt compounding technique in the presence of isopropylated triaryl phosphate ester (FR). The solvent uptake experiment was conducted to estimate the interaction of PLA/PMMA blends based on the calculation of Flory-Huggin interaction parameter (χ). Smallest χ was found on the PLA/PMMA(80/20) blend, indicating good interaction exists between PLA and PMMA at this composition. It is worth to mention that the miscibility of PLA/PMMA still remained even in the presence of FR. This was confirmed by the existence of only one Tg for the PLA/PMMA/FR blends. TGA results proved that FR had enhanced the thermal stability of PLA/PMMA blends at high temperature in both nitrogen and oxygen atmosphere. UL 94 vertical burning test revealed that the presence of FR had imparted PLA/PMMA blend with excellent flame retardant abilities, earning a V-0 rating during the UL-94 vertical burning test. From the FESEM analysis, a cohesive protective char layer was formed on the surface of PLA/PMMA/FR. This further confirmed the role of the phosphorus-based flame retardant (FR) in enhancing flame resistance of PLA/PMMA by promoting the development of char layer on the polymer surface, forming phosphoric and related acid anhydrides that operate as dehydrating agents.
	Date : 14 July 2016 *Tarikh* **Project Leader's Signature:** *Tandatangan Ketua Projek*
H	**COMMENTS, IF ANY/ ENDORSEMENT BY RESEARCH MANAGEMENT CENTER (RMC)** *(Komen, sekiranya ada/ Pengesahan oleh Pusat Pengurusan Penyelidikan)*
	..... Tutup Geran .... **Name:** *Nama:* PROF. DR LEE KEAT TEONG Pengarah Pejabat Pengurusan & Kreativiti Penyelidikan Universiti Sains Malaysia **Signature:** *Tandatangan:* **Date:** *Tarikh:*

JOURNAL OF Applied Polymer SCIENCE

Flexible and Flame Resistant Poly(lactic acid)/Organomontmorillonite Nanocomposites

Wen Shyang Chow, Ee Lian Teoh
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ABSTRACT: The PLA/OMMT nanocomposites were produced using a melt compounding technique with isopropylated triaryl phosphate ester flame retardant (FR; 10–30 parts per 100 resin). The flammability of the PLA/OMMT composites was evaluated with an Underwriter Laboratory (UL-94) vertical burning test, and their char morphology was studied using scanning electron microscopy (SEM). The thermal properties of the PLA/OMMT were characterized with a thermogravimetric analyzer (TGA) and a differential scanning calorimeter (DSC). The thermal analyses showed that adding FR reduced the decomposition onset temperature (T_o) of PLA/OMMT. Both PLA/OMMT/FR20 and PLA/OMMT/FR30 showed excellent flame retardant abilities, earning a V-0 rating during the UL-94 vertical burning test. A compact, coherent and continuous protective char layer was formed in the PLA/OMMT/FR nanocomposites. Additionally, the DSC results indicated that the flexibility of the PLA/OMMT composites increased after adding FR due to the FR-induced plasticization. The impact strength of PLA/OMMT was greatly increased by the addition of FR. Flexible PLA nanocomposites with high flame resistance were successfully produced. © 2014 Wiley Periodicals, Inc. J. Appl. Polym. Sci. 2015, 132, 41253.

KEYWORDS: clay; composites; flame retardance; thermal properties

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DOI: 10.1002/app.41253

INTRODUCTION

The disposal of petroleum-based plastics and the restricted availability of petrochemical resources is a global concern. In recent years, biopolymers have been a focus of academic and industrial research in the context of sustainable development and reduced impact on the natural environment. Recent developments pertaining to the economical manufacturing of lactic acid from renewable agricultural resources (e.g., corn, potato, sugar beet, sugar cane) have made poly(lactic acid) (PLA) one of the most important biodegradable polymers. PLA offers good mechanical properties (i.e., high strength and modulus), a high degree of transparency, facile processability, good biocompatibility and excellent biodegradability. This material has a high tensile strength (50–70 MPa) and elastic modulus (3–4 GPa), allowing it to replace conventional polymers in numerous applications, such as packaging, extruded products, and thermoformed containers. Moreover, PLA exhibits similar processing characteristics to existing thermoplastic; therefore, PLA can be readily processed using existing production equipment. However, it should be noted that PLA still faces some challenges, e.g., inferior impact performance, low thermal stability and ignitability.[1–3]

Similar to other common petrochemical plastics, the ignitability of PLA and its tendency to drip during combustion limit its applications, especially in the electronic and electrical fields and in the automotive industry. The dripping of flaming melts is a particular problem that hinders the improvement of flame retardant thermoplastics. The flaming drips may lead to a rapidly spreading fire if highly flammable materials are available.[4] Therefore, improving the flame retardant properties of PLA has remained an important task. Polymer/clay nanocomposites have drawn extensive interest due to their improved mechanical, thermal, and flammability properties.[5] Although several studies have reported that polymer/clay nanocomposites can exhibit a decreased heat release rate (HRR), they are unable to impart self-extinguishing properties to the nanocomposites or pass the regulatory tests.[6]

It is known that the impact strength and toughness of PLA could be reduced by the addition of clay. Leu et al.[7] had reported that PLA/OMMT had displayed lower impact strength compare to the neat PLA. There is a need to improve the toughness and flexibility of PLA so that it can complete with commodity thermoplastics (e.g. polyethylene and polypropylene). Thus, various approaches including copolymerization, plasticization, and blending with elastomeric materials have been carried out to enhance the impact properties and toughness of PLA.[8–11] Recently, literatures showed that PLA can be toughened by maleated styrene-ethylene/butylenes-styrene,[7] poly(ethylene glycol),[11] maleic

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5th International Conference on Recent Advances in Materials, Minerals and Environment (RAMM) & 2nd International Postgraduate Conference on Materials, Mineral and Polymer (MAMIP), 4-6 August 2015

Thermal and flame resistant properties of poly (lactic acid)/poly (methyl methacrylate) blends containing halogen-free flame retardant

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[b]*Cluster for Polymer Composites, Science and Engineering Research Centre, Engineering Campus, Universiti Sains Malaysia, Nibong Tebal, 14300 Penang, Malaysia.*

Abstract

Flame retarded poly(lactic acid)/poly(methyl methacrylate) (PLA/PMMA) blend was prepared using melt compounding technique in the presence of isopropylated triaryl phosphate ester flame retardant [FR; 20 parts per hundred resins (phr)]. The effect of FR on the thermal and flame resistant properties of PLA/PMMA blend was studied. The flammability of PLA/PMMA blends was evaluated by UL-94 vertical burning test while the morphology of the residues was analyzed using field emission scanning electron microscope (FESEM). Thermogravimetric analyzer (TGA) was utilized to characterize the thermal decomposition behaviors of PLA/PMMA blends. The UL-94 result revealed that the inclusion of FR has shorten the after-flame time and improved dripping behavior of PLA/PMMA blend, achieving V-0 ranking in the test. An extensive and continuous carbonaceous char-like layer was found on the surface of the PLA/PMMA/FR residue, indicating the existence of condensed phase mechanism by FR. The incorporation of FR has accelerated the thermal degradation of PLA/PMMA blend at low temperature, but enhanced thermal stability of the blend at elevated temperature.

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Peer-review under responsibility of School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia

Keywords: poly(lactic acid); blends; flame retardance; thermal properties

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Peer-review under responsibility of School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia
doi:10.1016/j.proche.2016.03.087

ORAL 8

Thermal and Flame Resistant Properties of Poly(lactic acid) Blends Containing Halogen-Free Flame Retardant

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Keywords: *poly(lactic acid), flammability, thermal properties.*

1 INTRODUCTION

As increasing awareness in developing eco-friendly and renewable versions of petroleum based plastics, poly(lactic acid) (PLA) has emerging as one of the most promising candidate in replacing conventional petroleum based commodity resins. PLA possesses several environmental advantageous such as biodegradability, low emission of greenhouse gas, and low production energy (Jamshidian et. al., 2010; Shukor et. al., 2014). Since it exhibits high degree of transparency and gas permeability, good mechanical properties, low toxic and ability to be process under conventional processing equipments, it holds tremendous potential in packing industries, household and biomedical applications. However, its low heat resistant, slow crystallization rate, and inherent brittleness limit its usefulness in electronic and automotive industries (Jang et. al., 2012; Wang et. al., 2015).

Several approaches have been adopted in order to improve thermal and mechanical performance of PLA. Among of them are: copolymerization, addition of fillers and fibers (Wang et. al., 2015), blending with other polymers (Phuong et. al., 2014). In the PLA blending strategy, it was found that blending PLA with poly(methyl methacrylate) (PMMA) received great attention due to the miscibility of these blends. Zhang et. al. (2002) had successfully prepared miscible blends comprises of amorphous poly(DL-lactide)/PMMA and poly(L-lactide)/PMMA blends by solution/precipitation method. Imre et. al. (2014) also suggested that PMMA had greater miscibility with PLA compared to polystyrene (PS) and polycarbonate (PC).

In this study, PMMA with moderate high glass transition temperature (T_g approximate 105°C) was physical blended with PLA in order to maintain its mechanical intergrity. Although the incorporation of PMMA into PLA able to improve the mechanical and thermal properties, but it is still unable to develop flame retarded PLA. Therefore, phosphorus based flame retardant, triaryl phosphate isopropylated (FR) was incorporated to obtain PLA/PMMA blends with UL94 V-0 rating.

2 CONCLUSION

Phosphorus-based flame-retardant PLA/PMMA blends were successfully prepared through melt compounding technique. The UL-94 vertical burning test revealed that both neat PLA and PLA/PMMA blend burned with flaming drips and bubbling after the flame was applied. The flame resistance of PLA/PMMA was significantly enhanced by the inclusion of FR. The rating of PLA was improved from V-2 to V-0 after adding 20 phr FR. From the FESEM analysis, it was found that a continuous protective char layer was formed in the presence of FR. Addition of FR to the PLA/PMMA was found to affect the thermal stability. FR is readily decomposed at the beginning of combustion to yield phosphoric and polyphosphoric acids that induce char formation in the condensed phase.

improvement in properties of biocomposite from cellulose-based microfiller had shown promising future in application of the water soluble plastic packaging industry.

Keywords: microcrystalline cellulose (MCC), rice straw, polyvinyl alcohol (PVOH)

OR76

EFFECT OF PHOSPHORUS-BASED FLAME RETARDANT ON THE THERMAL AND FLAME RESISTANT PROPERTIES OF POLY(LACTIC ACID)/POLY(METHYL METHACRYLATE) BLEND

Ee Lian Teoh[1], Mustapha Mariatti[1,2], Wen Shyang Chow[1,2*]
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Abstract
Poly(lactic acid)/poly(methyl methacrylate) [PLA/PMMA (80/20)] blends were prepared using melt compounding technique in the presence of isopropylated triaryl phosphate ester (Reofos 50 FR). The thermal properties of the PLA/PMMA blends were characterized by differential scanning calorimeter (DSC) and thermogravimetric analyzer (TGA). Underwriter Laboratory (UL-94) vertical burning test was conducted to determine the flame retardancy of the PLA/PMMA blends while field emission scanning electron microscope (FESEM) was performed to study the morphology of residues after the burning test. It was found that the glass transition temperature (T_g) of PLA/PMMA blends was shifted to lower temperature in the incorporation of FR. TGA results proved that FR had enhanced the thermal stability of PLA/PMMA blends at high temperature in both nitrogen and oxygen atmosphere. UL 94 vertical burning test revealed that the presence of FR had imparted PLA/PMMA blend with excellent flame retardant abilities, earning a V-0 rating during the UL-94 vertical burning test. From the FESEM analysis, a cohesive protective char layer was formed on the surface of PLA/PMMA/FR. This further confirmed the role of the phosphorus-based flame retardant (Reofos 50 FR) in enhancing flame resistance of PLA/PMMA by promoting the development of char layer on the polymer surface, forming polyphosphoric and related acid that operate as dehydrating agents.

Keywords: poly(lactic acid), flame retardant, thermal properties

OR77

A NOBLE ELECTROACTIVE POLYELECTROLYTE COMPLEX FOR ELECTROLYTIC RELEASE DEVICE OF CALCIUM ION

Toshiaki Hattori[1],* Kenji Hirota[1], Ryo Kato[2], Kazuaki Sawada[1]
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Abstract
We developed a noble electroactive polyelectrolyte complex to fabricate a new electrochemical device of Ca^{2+} releasing. A controlled local release of Ca^{2+} is useful for experiments on the contraction of muscle cells and Vorticella because the increase in Ca^{2+} concentration brings the shrinkage of muscles. The electroactive material was ternary complex consisted of poly(vinyl sulfate) (PVS), 11-ferrocenyltrimethylundecyl ammonium ion (FeTMA), and calcium ion. FeTMA is bi-functional material having electroactive and long-alkyl-chain cationic elements. The long-alkyl-chain cationic material, so called cationic surfactant, forms polyion complex with anionic polyelectrolyte by electrostatic interaction and hydrophobic interaction. The kind of anionic polyelectrolyte affects the feature of the Ca polyelectrolyte complex. Ca-PVS complex formed the precipitation in water, while Ca-poly(styrene sulfonate) complex did not precipitate in water. Ca-heparin complex slightly dissolved in water. Carbon paste (CP) with Ca-PVS complex was evaluated by voltammetry, and the amounts of Ca^{2+} released from the CP was measured by atomic absorption spectroscopy (AAS). The cyclic voltammogram indicated redox waves of FeTMA. The measurement of AAS revealed that Ca^{2+} concentration increased in the sample solution of CV after a long-time electrolysis applied with a constant voltage beyond the oxidation potential. The increased concentration of Ca^{2+} was proportional to the quantity of Ca-PVS complex in the CP. As a pinpoint releasing device of Ca^{2+}, a micro CP device with a tip of 500 μm of diameter

ISAPM-027-IS-NT-CHOW (INVITED SPEAKER)

DEVELOPMENT OF FLAME RETARDED POLY(LACTIC ACID) BLENDS AND NANOCOMPOSITES

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ABSTRACT

This paper presents the development of flame retarded poly(lactic acid) blends and nanocomposites by using non-halogenated flame retardant. The ignitability of PLA and its tendency to drip during combustion limit its applications, especially in the electronic and electrical fields and in the automotive industry. Since PLA is highly flammable and severe melt dripping when exposed to fire, improvement of the flame retardance performance has remaining as an upmost and important task. Poly(lactic acid)/poly(methyl methacrylate) blends and poly(lactic acid)/organoclay nanocomposites were prepared using melt compounding technique in the presence of isopropylated triaryl phosphate ester (Reofos 50 FR). The thermal properties of the PLA/PMMA blends were characterized by thermogravimetric analyzer (TGA). Underwriter Laboratory (UL-94) vertical burning test was conducted to determine the flame retardancy of the PLA/PMMA blends and PLA/organoclay nanocomposites while field emission scanning electron microscope (FESEM) was performed to study the morphology of residues after the burning test. The thermal analyses showed that adding FR reduced the decomposition onset temperature (To) of PLA/PMMA blends and PLA/OMMT nanocomposites. The UL 94 vertical burning test revealed that the both PLA/PMMA/FR blends and PLA/organoclay/FR nanocomposites demonstrated excellent flame retardant abilities, earning a V-0 rating. From the FESEM analysis, a cohesive protective char layer was formed in the PLA blends and nanocomposites. This proved the potential of phosphorus-based flame retardant in enhancing flame resistance of PLA/PMMA blends and PLA/organoclay nanocomposites.

Purchase Requisition ▸ Purchase Order ▸ Suppliers ▸ Maintenance ▸ Financials ▸ Coda Info ▸ Reports ▸ Admin ▸

UserCode: ASMAH / USMKCTLIVE / PBAHAN | Program Code: Votebook9100 | Current Program : Votebook (Header)

Current Date : 14/07/2016 10:43:32 AM | Version: 15.124, Last Updated at 01/07/2016 | DB: 13.00, 9/18/2010 VB: 13.01, 3/14/2011 | Switch Language : English /Malay

Wildcard : eg. Like 100%, Like 10%1, Like %1

Element 1: 203 Element 2: % Element 4: PBAHAN

Element 5: 6071260 Year: 2016

Detail	Excel	Budget Rule	Budget Control	Account Description	Budget Account Code	Roll over	Budget	Cash Received	Advanced	Commit	Actual	Available	Percentage
Detail	Excel	205	T	Penyelidikan Fundamentals (FGRS)	203.111.0.PBAHAN.6071260	18,400.00	0.00	0.00	0.00	0.00	8,941.94	9,458.06	0.00%
		205	T	SubTotal		18,400.00	0.00	0.00	0.00	0.00	8,941.94	9,458.06	0.00%
Detail	Excel	206	T	Penyelidikan Fundamentals (FGRS)	203.221.0.PBAHAN.6071260	8,946.60	-700.00	0.00	0.00	0.00	2,479.51	5,767.09	-823.87%
Detail	Excel	206	T	Penyelidikan Fundamentals (FGRS)	203.224.0.PBAHAN.6071260	-70.00	0.00	0.00	0.00	0.00	56.00	-126.00	0.00%
Detail	Excel	206	T	Penyelidikan Fundamentals (FGRS)	203.227.0.PBAHAN.6071260	6,864.35	0.00	0.00	0.00	1,415.00	9,662.20	-4,212.85	0.00%
Detail	Excel	206	T	Penyelidikan Fundamentals (FGRS)	203.228.0.PBAHAN.6071260	1,500.00	0.00	0.00	0.00	0.00	0.00	1,500.00	0.00%
Detail	Excel	206	T	Penyelidikan Fundamentals (FGRS)	203.229.0.PBAHAN.6071260	2,239.94	0.00	0.00	0.00	800.00	3,764.61	-2,324.67	0.00%
		206	T	SubTotal		19,480.89	-700.00	0.00	0.00	2,215.00	15,962.32	603.57	-86.22%
Detail	Excel	209	T	Penyelidikan Fundamentals (FGRS)	203.552.0.PBAHAN.6071260	0.00	700.00	0.00	0.00	72.26	727.68	-99.94	-14.28%
		209	T	SubTotal		0.00	700.00	0.00	0.00	72.26	727.68	-99.94	-14.28%
		9999		GrandTotal		37,880.89	0.00	0.00	0.00	2,287.26	25,631.94	9,961.69	0.00%

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SPE Journal of Vinyl & Additive Technology

Poly(lactic acid)/Poly(methyl methacrylate) Blends with Self-extinguishing Properties

Journal:	*Journal of Vinyl and Additive Technology*
Manuscript ID	VNL-16-040.R1
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Date Submitted by the Author:	n/a
Complete List of Authors:	Teoh, Ee Lian; Universiti Sains Malaysia - Kampus Kejuruteraan Seri Ampangan, School of Materials and Mineral Resources Engineering Chow, Wen Shyang; Universiti Sains Malaysia, School of Materials and Mineral Resources Engineering Mustapha, Mariatti; Universiti Sains Malaysia, School of Materials and Mineral Resources Engineering;
Keywords:	poly(lactic acid), poly(methyl methacrylate), blends, thermal properties, flame retardant

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Poly(lactic acid)/poly(methyl methacrylate) blends with self-extinguishing properties

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Abstract

This work focuses on the evaluation of the effectiveness of isopropylated triaryl phosphate ester flame retardant (FR) in improving flame resistance of poly(lactic acid)/poly(methyl methacrylate) (PLA/PMMA) blend with two different blending ratios (i.e., PLA/PMMA = 80:20 and PLA/PMMA = 60:40). The properties of the PLA/PMMA/FR blends were characterized by limiting oxygen index (LOI), UL-94 vertical burning test, thermogravimetric analysis (TGA) and field emission scanning electron microscopy (FESEM). It was found that the LOI value of PLA/PMMA was increase significantly by the addition of FR. Both PLA/PMMA blends (regardless of blending ratio) achieved UL-94 V-0 rating in the presence of FR. TGA results showed that the onset degradation temperature (T_o) of PLA/PMMA/FR blends was shifted to lower temperature due to the faster decomposition of FR. FESEM analysis revealed that there is more char formation in the PLA/PMMA40/FR compare to PLA/PMMA20/FR.

Keywords: Poly(lactic acid); poly(methyl methacrylate); blends; thermal properties; flame retardant

in PLA. As a result, PLA/PMMA40/FR blends gave slightly higher residue amount than PLA/PMMA20/FR in TGA analysis.

Acknowledgements

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