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Dielectric Breakdown Strength and Flammability Properties of Flame Retardant Filler/PLLA-PLA microsphere/Kenaf fiber Composites

Netnapa E.[a], Mariatti M.[b,*] , Hamid Z.A.A.[c], Todo M.[d], and Banhan L.[e]

[a-c]*School of Materials and Mineral Resources Engineering, Engineering Campus, Universiti Sains Malaysia, Nibong Tebal, Penang 14300, Malaysia*

[d]*Fracture Mechanics and Materials Lab, Research Institute for Applied Mechanics, Kyushu University, Japan*

Abstract

Poly(L-lactic acid) (PLLA) is well known as biodegradable polymer and it is used in many applications since its strength and modulus are comparable with another commercial polymers. However, PLLA exhibits brittle fracture, thus blending of PLLA with other polymer is carried out to improve the toughness of PLLA. In addition, Kenaf fiber is a natural fiber which commonly been used to reinforce the biodegradable composites. However, uses of biodegradable composites is limited in some applications for example appliances, textile, and fabric applications due to low compatibility, low thermal stability at blending temperature and flammability. Therefore, addition of flame retardant filler in PLLA-PLA microsphere/KF composite is to prevent or slow down the ignition of composites which are used in many application such as consumer applications and appliances. A phosphorus-based non-halogenated flame retardant or trade name of NP-100 is used in this study to reduce the flammability of the biocomposites. Generally, this flame retardant filler will react with hydrogen and form water, and reduces the rate of combustion. The dielectric breakdown strength of PLLA-PLA microsphere/KF/NP-100 composites at 0, 2 and 4 wt% of NP-100 loading was investigated in this study. It was observed that addition of NP-100 loading at 2 and 4 wt% in composites improved dielectric breakdown strength from 21.09 kV/mm to 23.71 kV/mm and 21.60 kV/mm, respectively.

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* Corresponding author. Tel.: 04 - 5995262; fax: +604-594-1011. +6-045-995-262
E-mail address: mariatti@usm.my

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Nomenclature

wt%	weight percent
kV/mm	kilovolt/millimetre
β	failure rate
α	scale or spread of data distribution

1. Introduction

Poly(L-lactic acid) (PLLA) is a thermoplastic produced from the renewable resources, one type of biodegradable polymer which mostly used for bioplastics. PLLA is used in many applications such as biomedical and automobile applications due to its properties i.e. good mechanical properties, thermal stability, biocompatibility and low toxicity. However, PLLA is brittle and rigid with very low elongation at break[1-3]. Natural fibers are ecofriendly alternatives for conventional fibers. Addition of natural fiber in polymer can be considered as possible engineering materials due to advantages of natural fibers such as low densities, low cost and high specific modulus (modulus/specific gravity), but the mechanical properties of natural fibers are lower than synthetic fibers[4-6]. Kenaf fiber (KF) is mostly used for reinforcement of composites because it can grow under a wide range of weather condition which can harvest twice a year[7-9]. According to reinforcement of KF in biocomposites, KF offers the low cost, lightweight, renewability, degradability, and high specific properties such as stiffness, impact resistance[10].

Biocomposites are gaining popularity due to their biodegradability. However, they have main limitations for some applications such as low compatibility and flammability[11, 12]. Applications of natural fiber polymer composites for flame retardant applications have attracted attention from researchers due to the environmental friendly characteristic of the materials[11, 13]. Addition of halogen-free flame retardant filler with containing phosphorus/nitrogen in biocomposites exhibited low toxicity materials and does not generate additional quantities of smoke[13, 14]. The most common method used for adding flame retardant filler is blending flame retardant filler compound into composites during processing[15].

In this project, effect of addition of phosphorus-based non-halogenated flame retardant filler or trade name of NP-100 in PLLA-PLA microsphere/KF composites with 2 wt,% and 4 wt% of NP-100 content was investigated. The flexural property, thermal stability, flammability and dielectric breakdown strength of the composites were observed and analyzed. Microstructure of PLLA-PLA microsphere/KF/NP-100 composites were observed by FE-SEM.

2. Experimental

2.1. Materials

PLLA pellet (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 (Tg) of around 60 °C, a crystallization temperature (T_c) of around 100 °C, and a melting point (T_m) of around 175 °C. PLA microsphere was fabricated by using emulsion solvent evaporation method[16]. Bast kenaf fibers (KF) were supplied by Forestry Research Institute Malaysia (FRIM). A phosphorus-based non-halogenated flame retardant filler or trade name of NP-100 was used in the study. NP-100 in white powder with particle size of 1.31 µm was supplied by Topchem Technology Co. Ltd, China.