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ORIGINAL RESEARCH

Poly(lactic acid)/opal-methacryloylpropyltrimethoxysilane-polystyrene graft polymer composites: preparation, characterization, and performance

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Abstract
Opal-methacryloylpropyltrimethoxysilane-polystyrene graft polymer (opal-MPS-PS) was synthesized using coupling method and solution polymerization. The results of orthogonal experiments showed optimum reaction conditions including: polymerization time of 4 h, catalyst at 0.03 g, reaction temperature of 80 °C, and styrene volume of 4 mL. Moreover, the structure of opal-MPS-PS was characterized by Fourier transform infrared spectroscopy, X-ray photoelectron spectroscopy, and scanning electron microscopy. The results demonstrated that PS was grafted onto opal-MPS. Furthermore, poly(lactic acid) composites (PLA/opal-MPS-PS) were prepared using opal-MPS-PS as filler by melt blending. The results of mechanical testing showed that the impact toughness of PLA/opal-MPS-PS composites was increased by 50.5%. The rheological behavior and morphological analysis showed that PLA displayed high interfacial compatibility with opal-MPS-PS. The polarized optical microscopic and differential scanning calorimetric results showed that opal-MPS-PS with heterogeneous nucleation effect improved the crystallization properties of PLA, and enhanced toughness of PLA. The flame retardancy test showed that the thermal stability and flame retardancy of the PLA composites material were improved compared with PLA. Enzymatic degradation tests showed that opal-MPS-PS had an inhibitory effect on the degradation of PLA. In all, this study provides a promising method to improve the comprehensive performance of PLA through organic modification using opal as filler.

Keywords Poly(lactic acid) · Poly(styrene) · Opal · Performance · Heterogeneous nucleation effect · Crystallization

Introduction

Poly(lactic acid) (PLA) is a biodegradable polymer [1], having poor impact toughness and crystallization properties, which greatly limit its application scope [2]. Therefore, there is an urgent need to explore methods to improve the toughness and heat resistance of PLA resin.

Addition of inorganic minerals in plastics as fillers is economical and widely used to modify plastics [3]. Zhang et al. [4] proposed that the properties of a powdered mineral particles-filled composite were affected by the state of bonding of the polymer matrix with its surface and its state of dispersion in the polymer. Amjadi et al. [5] reported that the surface of a non-metallic mineral filler with hydrophilic functional groups is non-polar, whereas the surface of the organic polymer had hydrophobic groups with polarity; therefore, they display poor compatibility. The agglomeration of mineral powders is a problem when mineral powders are used as additives by blending with plastics. The most effective way to improve the interfacial compatibility between fillers and polymer is to modify the fillers' surface [6]. Surface modification of inorganic fillers promotes the dispersion of fillers in the polymer, thus enhancing the effect of the filler and the comprehensive performance of polymer.

High performance of organic/inorganic hybrid composites can be achieved by modifying the surface of micro or nanoscale inorganic particles [7]. This is the combined advantages of two substances. Especially the grafting of polymer on the surface of inorganic particles can endow the particles with many new properties, such as amphiphilicity

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