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Research paper

Effect of annealing on the mechanical properties of PLA/PCL and PLA/PCL/LTI polymer blends

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ARTICLE INFO

Article history:
Received 7 June 2010
Received in revised form
4 October 2010
Accepted 9 October 2010
Published online 16 October 2010

Keywords:
Biodegradable polymer
Polymer blend
Fracture mechanism

ABSTRACT

The effects of annealing on the mechanical properties of polymer blends of poly(lactic acid) (PLA) and poly(ε-caprolactone) (PCL) were investigated. The bending strength and modulus of PLA/PCL tend to increase due to crystallization of the PLA phase by annealing. The mode I fracture energy, J_{in}, of PLA/PCL decreases dramatically due to the suppression of the ductile deformation of the spherical PCL phase by annealing. The immiscibility of PLA and PCL can be improved by adding lysine triisocyanate (LTI) as a result of additional polymerization. The phase transformation due to LTI addition reduces the size of the spherical PCL phase, resulting in higher fracture energy. An annealing process applied to PLA/PCL/LTI further strengthens the microstructure, resulting in effective improvement of the fracture energy.

1. Introduction

The biodegradable thermoplastic poly(lactic acid) (PLA) has been used in a variety of industrial fields including automotive, computer, food and electric appliances. PLA has also been used in medical fields as a bioabsorbable material in orthopedics and oral surgery (Mohanty et al., 2000; Higashi et al., 1986). The fracture behavior and properties of PLA have been investigated, and it was found that PLA exhibits a relatively brittle fracture manner in which crack growth is initiated by multiple craze formation in the crack-tip region, similarly to the fracture behavior of brittle polymers such as polypropylene (PP) and polystyrene (PS) (Todo et al., 2002, 2003; Park et al., 2004a,b, 2005, 2006). An improvement of the toughness of such brittle polymers can generally be achieved by blending a ductile secondary phase into the base polymer. Recently, poly(ε-caprolactone) (PCL), a ductile biodegradable thermoplastic, has been chosen to be a promising blend partner for PLA (Tsuji and Ikada, 1996; Tsuji et al., 2003; Todo et al., 2007; Wang et al., 1998; Hiljanen et al., 1996; Meredith and Amis, 2000; Dell' Erba et al., 2001), and the fracture energy of the PLA/PCL blend was found to be much greater than that of neat PLA (Todo et al., 2007). It was, however, also found that the immiscibility of PLA and PCL causes a phase separation in PLA/PCL blend, and this tends to suppress the toughness improvement, especially when the PCL content increases. Just recently, it was found that this immiscibility can be decreased by adding lysine triisocyanate (LTI) as a compatibilizer, and as a result, the toughness of the PLA/PCL blend is effectively improved due to the LTI addition (Takayama et al., 2006a,b,c,d,e). However, blending of ductile PCL with PLA degrades the mechanical properties such as the strength and elastic modulus of the base polymer PLA.

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doi:10.1016/j.jmbbm.2010.10.003