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ORIGINAL PAPER

Morphology and melt rheology of biodegradable poly(lactic acid)/poly(butylene succinate adipate) blends: effect of blend compositions

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Abstract Effect of the blend ratios on the morphology and melt rheology of poly(lactic acid) (PLA)/poly(butylene succinate adipate) (PBSA) blends were investigated using scanning electron microscope, strain-controlled rheometer, and capillary rheometer techniques. The morphological analysis shows that the average radius of the dispersed droplets of PBSA particles increases with change in the blend composition, and a co-continuous structure was generated when PBSA content reached 40%. For the linear viscoelasticity, the increase in the storage modulus at low-frequency region was more distinct in PLA/PBSA blends than in their pure components. A second plateau is clearly observed when the PBSA content was 20% or higher. Weight relaxation spectra showed that there was a longer relaxation time for blend system. These relaxation times were considered to be the shape relaxation periods of the droplets, which increase with change in the blend composition. The interfacial tensions of the PLA/PBSA blends at different compositions were between 5.3 and 6.1 mN/m, calculated from the weighted relaxation spectra and slightly higher than those obtained from Palierne model. These values are relatively high, indicating the poor miscibility of the two polymers. Both pure PLA and PBSA follow the Cox–Merz rule, in good manner. Though, the rule does not satisfy with the PLA/PBSA blends. In addition, PLA/PBSA blends show more non-Newtonian tendencies than their pure components.

Keywords Poly(lactic acid) · Poly(butylene succinate adipate) · Blends · Morphology · Rheology

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Introduction

Biodegradable polymers have attracted considerable attention in the recent years because of urgent environmental concerns. Among these biodegradable polymers, poly(lactic acid) (PLA) has received great interest [1]. PLA is synthesized via either polycondensation of lactic acid or ring-opening polymerization of lactide, the dimer of lactic acid. The monomer, lactic acid, can be produced via bacterial fermentation using sugar or enzyme-thinned cornstarch as carbon sources. PLA shows good processability as well as high-strength, high-modulus, and biocompatible properties. The application of PLA in the fields of industrial packaging and biomedical materials is anticipated [2, 3]. However, the inherent brittleness of PLA limits its large-scale application. Many biodegradable and flexible polymers, such as poly (ε-caprolactone) (PCL) [4–7], poly(butylene adipate terephthalate) [8, 9], poly(ether)urethane [10, 11], and poly(butylene succinate) (PBS) [12–14] are blended with PLA to increase its flexibility.

Melt rheological properties are extremely important for thermal process of material such as film blowing, injection molding, and fiber spinning. A better understanding of rheological properties is helpful in optimizing process conditions and expanding application ranges. Rheological measurements are also effective in determining the molecular structures and morphologies of polymer blend systems. The phase morphologies and rheologies of polymer blends are strongly affected by interfacial characteristics. The Palierne model [15] and relaxation spectrum method [16] based on rheological and morphological measurements are useful in predicting the interfacial tension of polymer blends. Yokohara et al. [17] reported that the Palierne model successfully predicted the linear viscoelastic properties of PLA/PBS blends. The interfacial