Improvement of mechanical properties of bioabsorbable PLLA/PCL polymer blends due to P(LLA-CL) blending

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Introduction

Bioabsorbable thermoplastics poly(L-lactic acid) (PLLA) has widely been used as a biomaterial for bone fixation devices in orthopedic and oral surgeries [1]. Its importance has led to many studies on its mechanical properties and fracture behavior, which found that the fracture behavior of PLLA is relatively brittle in nature. For example, blending with a ductile biodegradable polymer, poly(ϵ -caprolactone) (PCL), has been adopted to improve the fracture resistance; however, the low miscibility between PLLA and PCL causes phase separation [2]. Recently, blending of copolymer of LLA and CL, P(LLA-CL), was discovered to improve the miscibility between PLLA and PCL and hence the mechanical properties [3]. However, details of the associated mechanisms of such improvement are yet to be well understood. In this study, P(LLA-CL) was blended with PLLA and PCL, and the effects of P(LLA-CL) blending on their mechanical properties such as crack initiation toughness, bending strength and modulus were investigated. The study also characterized the fracture mechanisms by field emission scanning electron microscopy (FE-SEM), to provide their correlation with the macroscopic fracture behavior.

Materials and Methods

PLLA/PCL and PLLA/PCL/P(LLA-CL) plates were fabricated by melt-mixing using a conventional melt-mixer and the by hot-pressing at 200°C. The mixing ratio of PLLA and PCL was fixed at 90:10 in weight fraction, and P(LLA-CL) content was fixed at 10phr. Beam and single-edge-notch-bend (SENB) specimens were prepared from the plates for bending and mode I fracture tests. Fracture surface morphologies of SENB specimen were also characterized by FE-SEM.

Results and Discussion

Table 1 shows the mechanical properties of PLLA and the blends. It is seen that both bending properties and fracture toughness effectively increase due to P(LLA-CL) blending. Fig.1 shows FE-SEM micrographs of fracture surfaces. The micrographs showed that ductile deformation increases due to P(LLA-CL) blending, suggesting that the local stress concentration of interface between PLLA and PCL is reduced by the improvement of miscibility between PLLA and PCL. This kind of molecular structure improvement is considered to result in the effective increase of the fracture properties.

Conclusions

Effects of P(LLA-CL) blending on the mechanical properties of PLLA/PCL blend were investigated. The experimental study showed that both bending properties and fracture toughness effectively increase due to P(LLA-CL) blending.

References

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Table 1 Comparison of the mechanical properties.

Material	E (GPa)	σ_f (MPa)	J_{max} (kJ/m ²)
PLLA	3.54	112.6	4.42
PLLA/PCL	3.15	79.7	8.03
PLLA/PCL/P(LLA-CL)	3.24	92.4	9.71

(a) PLLA

(b) PLLA/PCL

(b) PLLA/PCL/P(LLA-CL)

Fig.1 FE-SEM micrographs of fracture surfaces.