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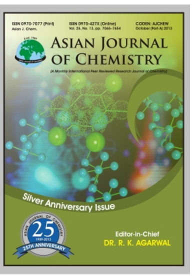

Effect of Talc on Thermal and Mechanical Properties of Poly(L-lactic acid)

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The thermal and mechanical properties of poly(L-lactic acid)/talc composites with different content of talc has been investigated. Non-isothermal crystallization shows that talc can serve as a nucleating agent for the crystallization and increase the overall crystallization rate of poly(L-lactic acid). The scanning electron microscope shows that the addition of talc results in substantially increasing of nucleating density. Thermogravimetric analysis shows that the onset degradation temperature of poly(L-lactic acid)/talc composites significantly decreases. Talc can makes the tensile strength and modulus of poly(L-lactic acid)/talc composites enhance, however, the elongations at break of poly(L-lactic acid)/talc composites steadily decreases with increasing of talc.

Key Words: Poly(L-lactic acid), Crystallization, Talc, Mechanical properties, Thermal degradation.

INTRODUCTION

Poly(lactic acid) has attracted more and more interest in technology due to its potential in new materials, environmental concerns, biomedical applications, *etc*. And there has existed a sharp rise in the development and commercial market of polymer. Because of two optically active isomers: L- and D-lactide, the polymerization of optically pure monomers leads to the formation of stereoregular poly(L-lactic acid) and poly(D-lactic acid). Usually, poly(L-lactic acid) can form crystallization and also is widely investigated. Of course, poly(L-lactic acid) still has some disadvantages that restrict its practical applications, in particular, slow crystallization rate, low crystalline degree is sometimes too weak for practical use compared to the conventional thermoplastic. Usually, the most viable method to increase the overall crystallization rate of poly(L-lactic acid) is the blending with nucleating agent. Talc is often chosen as nucleating agent of poly(L-lactic acid). It was shown that talc nucleates the crystallization of polymers through an epitaxial mechanism[1]. Kolstad[2] studied the crystallization behaviour and the morphology of poly(L-lactide-*co-meso*-lactide) and poly(L-lactide-co-meso-lactide)/talc composites. His work has shown that strong increase in nucleation density with addition of talc was found in poly(L-lactide-co-meso-lactide). Ke and Sun showed that the overall crystallization rate of poly(L-lactic acid) increased with increasing content of talc. To further study effect of thermal and mechanical properties of poly(L-lactic acid) including talc to improve practical use of poly(L-lactic acid)/talc composites. In this paper, poly(L-lactic acid)/talc composites were fabricated by melt blending and hot-press forming process and the thermal and mechanical properties of poly(L-lactic acid)/talc composites were investigated.

EXPERIMENTAL

Poly(L-lactic acid) (2002D) was purchased from Nature Works LLC, USA. The talc was purchased from Shanghai Yuejiang Titanium Chemical Manufacturer Co. Ltd.

Poly(L-lactic acid)/talc composites: Blending of poly(L-lactic acid) and talc was performed on a counter-rotating mixer and the preparation process of poly(L-lactic acid)/talc composites has described in previous paper[4].

Characterization: The non-isothermal crystallization behaviour of poly(L-lactic acid)/talc composites was measured by DSC Q2000 (TA Instruments-Waters LLC, USA). The temperature and heat flow at different heating rate were calibrated using an indium standard. The sample was heated to 190 ºC and maintained at that temperature for 5 min to make sure that the polymer crystals were melted completely. Then the samples were cooled from the melt state to 20 ºC at a cooling rate of 10 ºC/min.

Tensile properties were carried out on an tensile machine (YX-25(D), China) at a crosshead speed of 10 mm/min. The measurement of impact strength was performed on impact testing machine (JJ-20, China).

Freeze-fracture surfaces of neat poly(L-lactic acid) and poly(L-lactic acid)/talc composites were observed by scanning electron microscope (S4800, Hitachi, Ltd. Japan).

TGA analysis was performed using a thermal analysis Q500 from TA Instruments-Waters LLC with a heating ramp of 20 ºC/min under air flow (60 mL/min) from room temperature to 500 ºC.

RESULTS AND DISCUSSION

Non-isothermal crystallization of poly(L-lactic acid)/talc composites: Fig. 1 shows the DSC curves of non-isothermal crystallization from melt of poly(L-lactic acid)/talc composites with different talc content. As seen in Fig. 1, upon cooling rate at 1 ºC/min, the crystallization peak of poly(L-lactic acid) can not be detected. However, with addition of talc, crystallization peak appears in the DSC cooling curve. Compared to the neat poly(L-lactic acid), talc addition leads to the shift of crystallization peak to high temperature indicating the increase of crystallization temperature and the crystallization peak shifts to higher temperature with increasing of talc content, which indicates that 5 % talc makes the crystallization rate of poly(L-lactic acid) become the fastest. On the other hand, crystallization peak for poly(L-lactic acid) containing talc becomes much sharper in the cooling process. This result shows that talc can serve as a nucleating agent for the crystallization and increase the overall crystallization rate of poly(L-lactic acid).

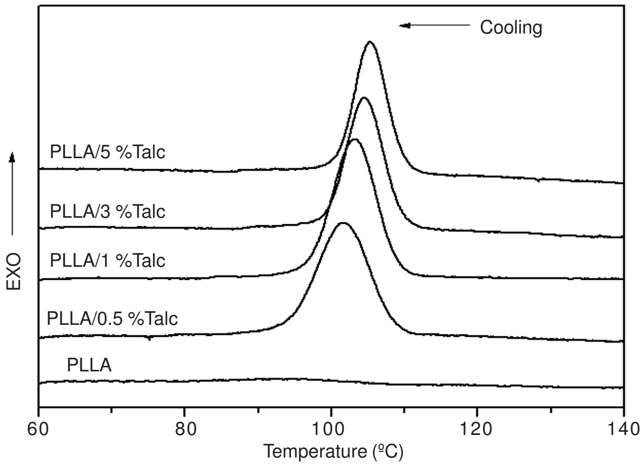

Fig. 1. DSC curves of non-isothermal crystallization from melt of poly(L-lactic acid)/talc composites with different talc content

The dispersion of talc in poly(L-lactic acid) matrix also affects poly(L-lactic acid) crystallization, Fig. 2 shows the SEM images of the freeze-fracture surfaces of neat poly(L-lactic acid) and poly(L-lactic acid)/5 % talc As shown in Fig. 2, neat poly(L-lactic acid) shows a smooth freeze-fracture surface. Image of poly(L-lactic acid)/5 % talc composites shows that there exist many small particles talc and addition of talc result in substantially increasing of nucleating density, then crystallization of poly(L-lactic acid) also is improved. However, excessive talc also tend to aggregate seriously and it is difficult to disperse them homogeneously in poly(L-lactic acid) matrix, this may reduce nucleating effect of talc.

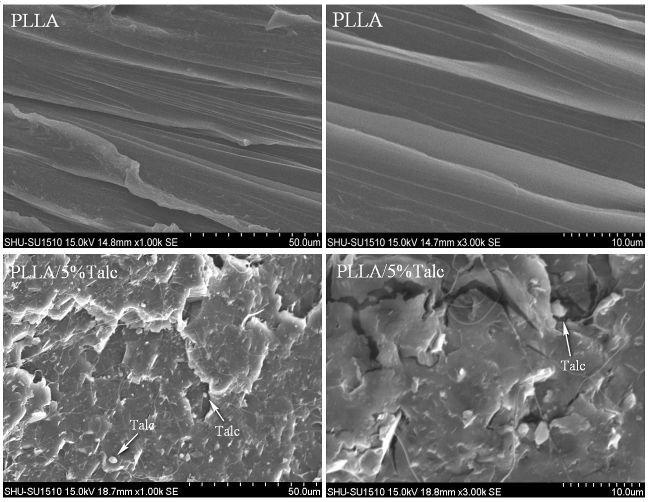

Fig. 2. SEM micrographs of neat poly(L-lactic acid) and poly(L-lactic acid)/5 % talc composites

Thermogravimetric analysis: Thermogravimetric curves of pure poly(L-lactic acid) and poly(L-lactic acid)/talc composites at heating rates of 10 ºC/min are presented in Fig. 3, poly(L-lactic acid) decomposes fast and completely in one stage above 300 ºC, the main degradation products of poly(L-lactic acid) are oligomers together with some lactide, but there are also other volatile products such as acetaldehyde, carbon dioxide, carbon monoxide and ketene[5]. However, compared to the neat poly(L-lactic acid), the onset degradation temperature of poly(L-lactic acid)/talc samples significantly decreases and the degradation temperature of poly(L-lactic acid)/talc composites is lower, the content of talc is higher. The reason may be that the compatibility decreases by mixing of poly(L-lactic acid) and filler[6].

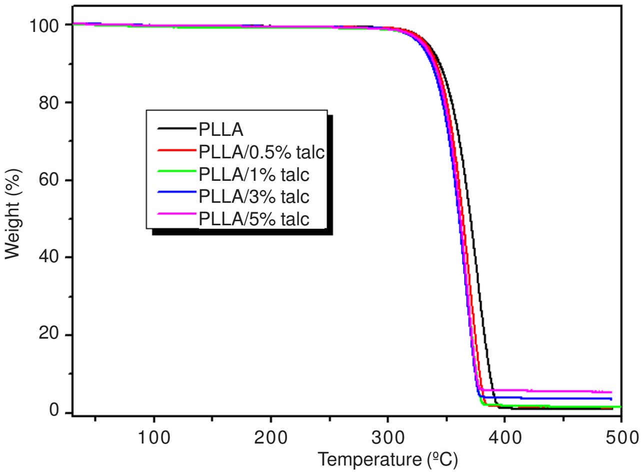

Fig. 3. TGA of poly(L-lactic acid) and poly(L-lactic acid)/talc decomposition at heating rate of 10 ºC/min

Mechanical properties of poly(L-lactic acid)/talc composites: The tensile strengths, tensile modulus and elongation at break of poly(L-lactic acid) with different talc contents are presented in Fig. 4(a)-(c), respectively. The figures show that talc can improve the tensile strength and modulus of poly(L-lactic acid) and the tensile strengths and tensile modulus increase with the increase of talc contents. Upon addition of 3 % talc, the tensile strength of poly(L-lactic acid)/3 % talc composites has a maximum value. comparing with the neat poly(L-lactic acid), the tensile strength of poly(L-lactic acid)/

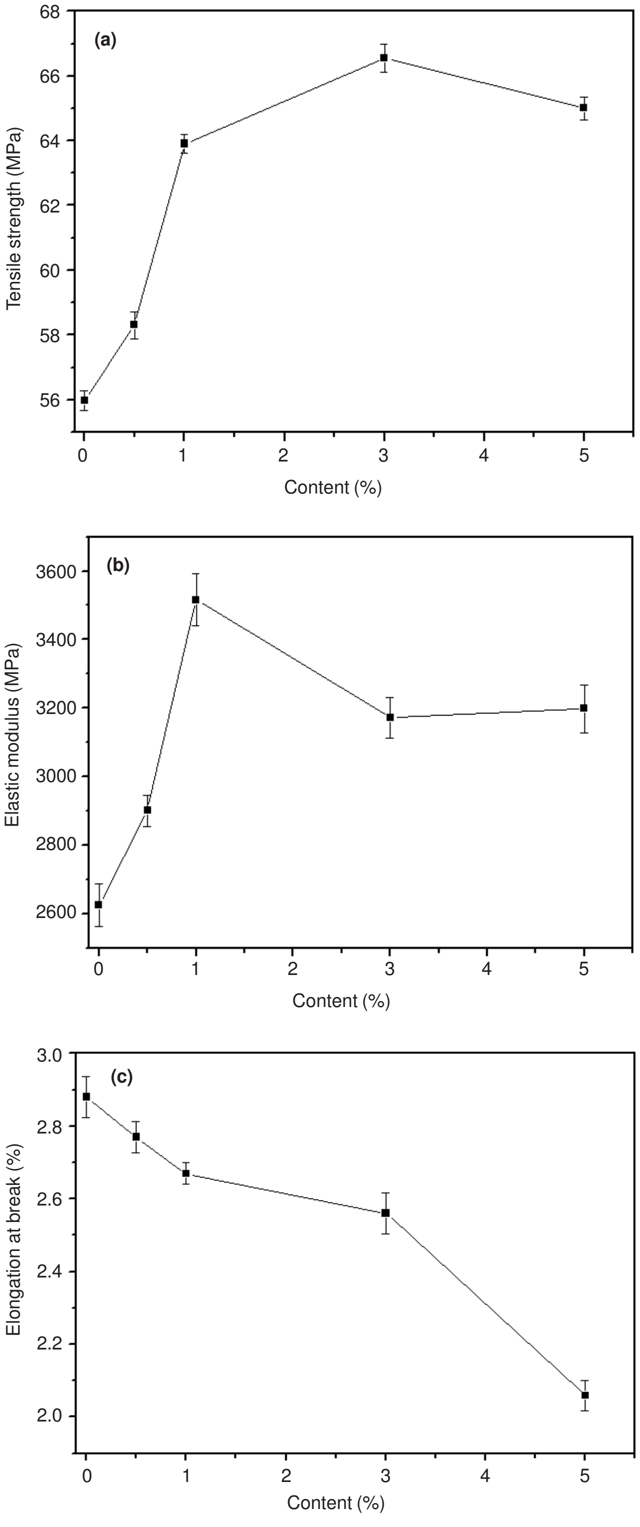

Fig. 4. Mechanical properties of poly(L-lactic acid) with different talc contents

3 % talc composites increases from 55.9 MPa to 66.5 Mpa. The tensile modulus increases from 2625.9 Mpa to 3515.6 Mpa with the content of 1 % talc. The enhancement of the tensile strength and modulus of poly(L-lactic acid)/talc is due to the increasing of crystallization degree of poly(L-lactic acid) with talc. The elongations at break of the samples are shown in Fig. 1(c). From this figure the effect of adding talc can be seen clearly and directly. Talc can make poly(L-lactic acid) become brittle and the elongations at break of poly(L-lactic acid)/talc composites steadily decreases with increasing of talc.

Conclusion

The thermal and mechanical properties of poly(L-lactic acid)/talc composites were investigated. Talc can increase the overall crystallization rate of poly(L-lactic acid) and can results in substantially increasing of nucleating density in poly(L-lactic acid) matrix. The onset degradation temperature of poly(L-lactic acid)/talc composites significantly decreases. However, talc can makes the tensile strength and modulus of poly(L-lactic acid)/talc composites enhance.

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