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Photodegradation behavior of poly(butylene succinate-co-butylene adipate)/ZnO nanocomposites

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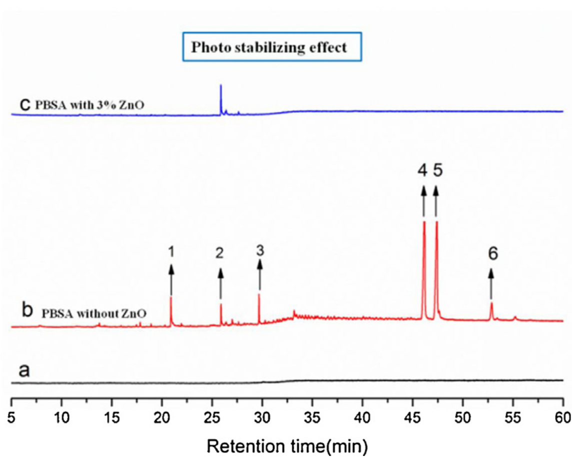
HIGHLIGHTS

- ZnO nanoparticles are well distributed and dispersed in PBSA matrix.
- FT-IR, PGC-MS, DSC and SEM are used to characterize the photodegradation behavior.
- ZnO can stabilize the PBSA matrix during photodegradation.
- The possible structure of degradation products are analyzed using PGC-MS.

GRAPHICAL ABSTRACT



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ABSTRACT

The photodegradation of PBSA and PBSA/ZnO nanocomposites with different ZnO loadings were studied in this paper. The PBSA/ZnO nanocomposites were prepared by melt-compounding process and the ZnO dispersion state within the PBSA matrix was analyzed by TEM. The reduction of molecular weight of PBSA nanocomposites is lower than that of the neat PBSA, which indicates more chain scission occured in neat PBSA. The chemical structure changes characterized by FTIR and PGC-MS showed that ZnO nanoparticles can stabilize the PBSA matrix. Carbonyl index and hydroxyl index of PBSA grew more significantly than PBSA nanocomposites. More degradation products accumulated in PBSA samples than in the PBSA nanocomposite samples. Thermal properties analyzed by DSC revealed a decrease of crystallization temperature in all samples, which is due to the formation of short chains after irradiation. In addition, the small fragments could recrystallize and increase the crystallinity. SEM images of sample surfaces revealed that PBSA sample had severer damages on surface than PBSA/ZnO nanocomposites. These results demonstrate that ZnO nanoparticles can hinder the photodegradation of PBSA.

1. Introduction

In recent years, biodegradable polymers gained wide attention because of their potential to minimize the environmental

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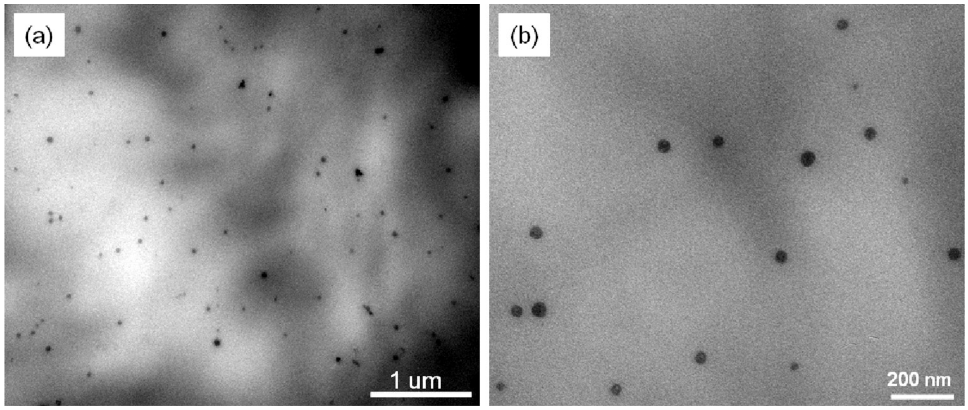
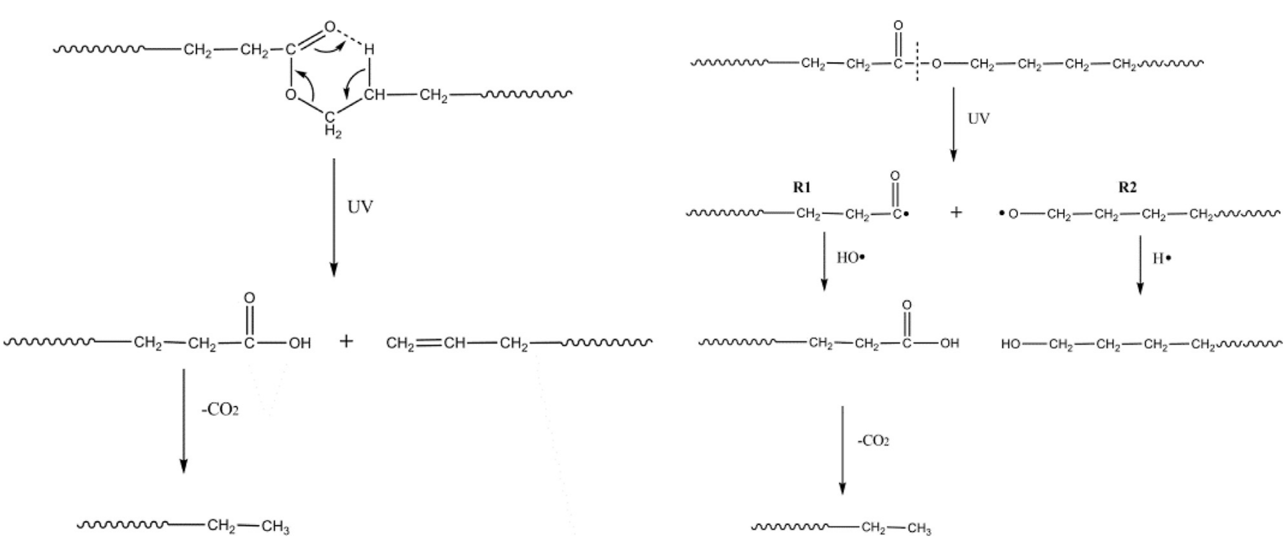


Fig. 1. (a, b) TEM images at different magnifications of PBSA-1 nanocomposite.

problems caused by the disposal of non-biodegradable polymers [1,2]. A variety of biodegradable polymers have been studied such as poly(butylene succinate) (PBS) [3], poly(lactic acid) (PLA) [4], poly(ϵ-caprolactone) (PCL) [5], polyhydroxyalkanoates (PHA) [6] and poly(butylene adipate-co-butylene terephthalate) (PBAT) [7]. Among the biodegradable polymers, poly(butylene succinate-co-butylene adipate) (PBSA), chemically synthesized by the polycondensation of 1,4-butanediol, succinic acid and adipic acid, plays an important role in the biodegradable polymer field for its biomass-based resource, appropriate degradation rate, thermal stability, mechanical property and good processability [2,5,7]. As a result, it has found applications in biodegradable fibers, packaging materials, injection molded products and mulch films. For some outdoor applications of PBSA-based materials (e.g., mulch films), photodegradation stability is a crucial property in its practical use. So, studies associated with photodegradation of PBSA and its composite are vital in order to predict their life-time and behavior in outdoor applications.

The utilization of nanoscale materials is an emerging area for many applications. Various nanosized materials have been used to prepare biodegradable polymer nanocomposite to improve physical properties of polymer composites [8–12]. Nanoparitlces such as titanium dioxide (TiO_2), silicon oxide (SiO_2), aluminium oxide (Al_2O_3), and zinc oxide (ZnO) can act as inorganic UV-screen agents and have influences on the photodegradation behavior of polymer matrix. Yang et al. [13] compared the impact of different nanoparticles (SiO_2, Al_2O_3, ZnO) on linear low density polyethylenes (LLDPE) and found that all the three nanopartilces can improve the photo stability of the composites. Miyauchi et al. [14] revealed that photo decomposition of PBS depended on the size and dispersibility of TiO_2 and would enhance the degradation of PBS/TiO_2 composite under sunlight. The similar conclusion was drawn in PLA/TiO_2 composite by Nakayama and Hayashi [15]. It has been reported that ZnO is not only a UV-screen agent but also an antibacterial multifunctional material. Several works [16–19] have reported the photodegradation behavior of polyolefin and polyester when ZnO was incorporated into polymer matrix. However, only a few papers noted ZnO filled biodegradable polymers. Liu et al. [20] showed the effect surface modification of ZnO on mechanical and crystallization performances of PBS/ZnO composite. Therias et al. [21] studied the photochemical behavior of PLA/ZnO nanocomposite films.

In this work, PBSA/ZnO nanocomposites were prepared by melt-compounding process and the effect of ZnO nanoparticles on the photodegradation behavior of PBSA/ZnO nanocomposites was investigated and compared to the behavior of pristine PBSA. Chemical, thermal and morphological property changes were evaluated on the composites and discussed as a function of irradiation time.



Scheme 1. Route of PBSA photodegradation.