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Modification of flax fiber surface and its compatibilization in polylactic acid/flax composites

Xuelian Xia[1] · Wentao Liu[1] · Liyong Zhou[1] · Zhengxia Hua[1] · Hao Liu[1] · Suqin He[1]

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Abstract Fiber–matrix interaction plays a key role in the development of high-performance polymer/fiber composites. Flax fiber surface was modified by alkali treatment, corona discharge, maleic anhydride (MA) grafting and aminopropyltriethoxysilane treatment. Chemical structure of the treated fibers was characterized by FTIR, and the results revealed that alkali treatment removed hemicelluloses, lignin, waxes and oils. In addition, MA and silane reacted with the fiber to form –OCO–CH=CH–COOH and $–(CH_2)_3–NH_2$ groups. Oil/water test was carried out on the treated fiber, and the results indicated that MA grafting and silane treatment changed the wettability of fiber from hydrophilic to hydrophobic. The morphology of fibers was observed by scanning electron microscope (SEM). It was obvious that the surface of alkali-treated fiber was very rough, and the surface of MA-grafted fiber and silane-treated fiber was covered by a coating layer. High toughness polylactic acid (PLA)/flax composites were fabricated by blending the modified fibers with PLA. The mechanical properties of PLA/flax composites were evaluated. The results showed that the impact strength and elongation-at-break of PLA/treated fiber composites were higher than those of PLA/untreated fiber composites. The compatibilizing mechanism between the fibers and PLA was discussed according to experimental phenomena and their corresponding results. Alkali treatment led to a rougher fiber surface, and formed more contacting points to enhance mechanical interlocking between PLA and fiber. The –OCO–CH=CH–COOH group of MA-grafted fiber and the $–(CH_2)_3–NH_2$ group of silane-treated fiber acted as adhesive agents to hook the fiber to the matrix, and increased the fiber–matrix interaction.

Keywords Surface modification · Interfacial interaction · Compatibilizing mechanism · PLA/flax composites

Introduction

Recently, eco-friendly and renewable materials have gained increasing interest because of environmental concern and energy crisis. Polylactic acid (PLA) has attracted much more attention because of its inherent biodegradability, biocompatibility and very low or no toxicity. Moreover, high tensile strength, high Young's modulus and good transparency have made PLA successful in many applications such as packaging and household products. However, big markets of PLA are still prohibited due to its brittleness. To toughen PLA, many fillers were employed, such as rubber, silkworm silk [1], and wool [2]. As impact modifier, plant fiber is one of the most competitive candidates. First, plant fiber is derived from annual renewable sources, which are biodegradable, environmentally friendly and safe [3], as it is revealed by life cycle analysis [4]. Second, plant fiber has a similar strength and stiffness compared to glass fiber (GF), for example, flax fibers have stiffness 50–100 GPa versus 72 GPa for E-glass fibers [5, 6]. In addition, a great interest has been focused on the plant fiber due to easy processability, reduced wear on the processing equipments, and the low density and transparency of polymer/plant fiber composites [7, 8].

However, the interface adhesion is usually poor between inherently hydrophilic plant fiber and hydrophobic polymeric matrices [9]. The mechanical properties of polymer/

✉ Wentao Liu
wtliu@zzu.edu.cn

1 School of Materials Science and Engineering, Zhengzhou University, Zhengzhou 450052, China