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ORIGINAL PAPER

Treatment of ramie fiber with different techniques: the influence of diammonium phosphate on interfacial adhesion properties of ramie fiber-reinforced polylactic acid composite

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Abstract Ramie fiber-reinforced polylactic acid (PLA) composites were successfully prepared by hot compression molding. Different treatment techniques were used to modify the surface of ramie fiber. The influence of diammonium phosphate (DAP) on the interfacial adhesion between ramie fiber and PLA composites was investigated by the contact angle measurements, FTIR and SEM analyses. The contact angle measurement results showed that alkali treatment combined with DAP was very efficient in decreasing the hydrophilicity of fibers. After treatment, the hydrophilicity of untreated ramie fiber from 5.9 ± 1.3 decreased to 2.0 ± 0.8 mJ/m^2. The wettability of alkali/silane/DAP-treated ramie fiber/PLA composite was higher (95.4° ± 1.3°) than that of pure ramie fiber/PLA composite (87.3° ± 1.9°). The FTIR results were consistent with the wetting measurements as the increment of hydrophilicity. Thermal analysis indicated that DAP-modified ramie fiber/PLA composites exhibited a lower thermal decomposition temperature, unique decomposition behavior and more residual char formation at decomposition temperature. The tensile, flexural and impact properties of DAP-modified ramie fiber composites were comparable to those of untreated ramie fiber composite. Moreover, proper alignment and uniform distribution of ramie fibers within the PLA matrix were found to be excellent. The morphological structures observed by SEM showed that well-modified ramie fibers enhanced the failure of the PLA composites in tensile, flexural and impact tests.

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Introduction

The utilization of natural fibers in composite manufacturing has rapidly increased in the last two decades in automotive parts, construction and sound absorption materials for their outstanding properties. Natural fibers composites are comparable in mechanical properties to synthetic fibers composites. The use of natural fibers in composites gives a number of benefits including better environmental safety and lower costs. In addition, in some applications, natural fibers can replace glass fibers in polymer composite [1, 2]. However, the mechanical properties of natural fibers depend on the type of fibers, the orientation of fibers in composite and nature of matrix used. The properties of natural fiber-reinforced composites are highly influenced by the adhesion forces at the fibers/matrix interfaces [3]. Therefore, adhesion at the fiber/matrix interface is a critical property in natural fibers composite that must be understood, controlled and measured. Essential properties of a composite such as tensile, flexural, and inter-laminar shear strength can be achieved by designing interfacial bond strength at the fiber/matrix interface. Usually, the interface can be engineered by modifying the fiber surface to optimize the adhesion between fiber and matrix. Adhesion at the fiber/matrix interface is often obtained from the surface energy of a reinforced fiber, which is an indicator for adhesive properties of the fiber. All natural plant fibers contain hydroxyl groups (–OH), which are highly hydrophilic [4–6]. Unfortunately, the fibers are covered with waxes, pectin and other impurities in their raw form. Unless the waxes and pectin are completely removed, it is unlikely to obtain