

Structure and properties of composites of highly crystalline cellulose with polypropylene: Effects of polypropylene molecular weight

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Abstract

Composite of highly crystalline fibrous cellulose (CE) and polypropylene (PP) of different molecular weights (\overline{M}_w) was prepared via melting–mixing, maleic anhydride grafted polypropylene (MAPP) was used as a compatibilizer. And the effects of molecular weight of PP on the properties of the composites were investigated. Through the studying of mechanical properties, dynamic mechanical properties, melting and crystallization behaviors, thermo-oxidative properties, water absorption behaviors, and the morphology of the composites, it was found that PP with higher molecular weight revealed stronger interfacial interaction with cellulose in the composites. Compared with the lower molecular weight, the composites derived from higher molecular weight of PP exhibited stronger tensile strength at the same cellulose content.

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Keywords: Polypropylene (PP); Cellulose; Molecular weight; Composites; Mechanical properties

1. Introduction

Polypropylene as one of the most popular versatile thermo-plastic polymers, provides many advantages with regard to its low cost, recyclability, and high thermal stability, and has yielded many kinds of composites. The reinforcing materials have been extensively used in plastics industry are mineral fill-

ers and fibers. Considering the serious environmental problems caused by the growing consumption of synthetic polymers, it is potentiated to minimize the use of the synthetic polymers derived from petroleum and also to maximize the use of renewable resources. So the considerable attention has been picked up momentum to the natural fibers both in the literature and in industry in recent years [1–8]. Advantages of natural fibers over conventional reinforcement such as glass or carbon fibers are lower cost, low density, biodegradability, as well as high specific properties. The natural fibers can be grouped into bast (jute, banana, flax, hemp, kenaf, mesta), leaf (pineapple, sisal, screw pine), and seed or fruit fibers (coir, cotton, oil palm) [9]. For some

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natural fibers of plants origin, cellulose is the main component. Cellulose-reinforced polymer composites are characterized by low cost, low density, high stiffness, biodegradability, and good mechanical properties as well as availability of renewable natural resources. The main disadvantage of cellulose-reinforced polymer composites is the inherent incompatibility between the hydrophilic cellulose fibers and the hydrophobic thermo-plastic matrix, particularly, the polyolefin such as polypropylene (PP). As a result, lack of interfacial adhesion between cellulose and polypropylene results in the unsatisfactory properties of the resultant composites. To overcome the disadvantage, many efforts have been carried out to improve the interfacial adhesion between fibers and matrix [1,2,9–24]. Among these methods, maleic anhydride grafted polypropylene (MAPP) was proved to be very efficient in improving interfacial adhesion of fibers and polypropylene matrix.

A lot of works have been done in the cellulosic composites, such as making use of various cellulosic materials and different matrixes, surface treatment of cellulosic materials, modification of matrixes, processing conditions, characterization of the composites, and so on [1]. We reported elsewhere [25,26] that MAPP is a good compatibilizer for cellulose and PP, and the effects of MAPP content as well as the cellulose content on the properties of the composites were investigated. Recently, we found that the enhanced interfacial esterification between MAPP and activated cellulose had much effect on the properties of the cellulose composites, the resultant composites show a greater improvement in tensile strength, and the evidence of the esterification were observed directly in the melt-mixed composites [27–29]. The un-grafted free MA monomers remained in the matrix gives a slight positive effect to PP composite while a negative effect to MAPP composite [30]. The graft degree of MAPP on the properties of cellulose composites was studied, too, results showed that even an amount of grafted MA as small as 0.2 wt.% is sufficient to impart satisfactory tensile strength to the resulting composites [29,30]. However, the relationship between molecular weight of PP matrix and properties of the composites is not clear yet. In this work, we concentrated upon the effect of molecular weight of polypropylene on the properties of composites of PP and the highly crystalline fibrous cellulose compatibilized by MAPP.

2. Experimental

2.1. Materials

Three kinds of isotactic polypropylene pellets were obtained commercially from Aldrich (Milwaukee, WI). They were notated as PP1, PP2, and PP3, of which the molecular weights given by the supplier are $\overline{M}_w \approx 250,000$ [melt flow index (MFI) 12 g/10 min, density 0.900 g/cm³], $\overline{M}_w \approx 340,000$ (MFI 4 g/10 min, density 0.900 g/cm³), and $\overline{M}_w \approx 580,000$ (MFI 0.5 g/10 min, density 0.900 g/cm³), respectively. Polypropylene-graft-maleic anhydride (MAPP pellets, ≈ 0.6 wt.% MA; melt index 115; density 0.950 g/cm³, as reported by the supplier) was also obtained from Aldrich. Fibrous cellulose {CF11, 50–350 μ m in length, about 20 μ m in diameter; crystallinity 93% (cellulose I type) [31]} was supplied by Whatman Int. Ltd. (Maidstone, England).

2.2. Preparation of composites and samples

PP and CF11 were dried in vacuo at 70 °C for 3 days, and MAPP was pretreated in vacuo at 120 °C for 15 h before preparing composites. All composites with a 30 wt.% cellulose content were prepared by a melt-mixing method with a Toyoseiki Labo Plastomill 30C150 Rheomix (the volume of the mixing chamber: 60 cm³). The mixing was carried out in air at 190 °C at 55 rpm for 20 min.

Sheets of 1 mm thickness were obtained by using the resulting composites and compression molding in a Shinto press (Shinto Metal Ind. Ltd.) at 200 °C, under a pressure of 3 MPa for 6 min, followed by cooling under a pressure of 8 MPa to room temperature at 2 °C/min. Teflon films were used to avoid the adhesion of MAPP to the stainless surface of the mold. The sheet sample was then placed between two stainless steel plates, maintained in vacuo at 60 °C for 24 h in an oven, then switched off the power of the oven, and continued the vacuo at room temperature over night. Standard specimens were cut from the sheets for the measuring of properties.

For comparing, pure PP as well as pure MAPP sample was melt-mixed and thermal pressed under the same conditions, as described above. And all the samples for the property measurements were obtained in the same conditions.

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