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Material properties

Influence of pineapple leaf fiber and it's surface treatment on molecular orientation in, and mechanical properties of, injection molded nylon composites

Ajjima Nopparut [a], Taweechai Amornsakchai [a, b, c, *]

[a] Polymer Science and Technology Program, Department of Chemistry and Center of Excellence for Innovation in Chemistry, Faculty of Science, Mahidol University, Phuttamonthon 4 Road, Salaya, Phuttamonthon District, Nakhon Pathom 73170, Thailand
[b] Center of Sustainable Energy and Green Materials, Faculty of Science, Mahidol University, Phuttamonthon 4 Road, Salaya, Phuttamonthon District, Nakhon Pathom 73170, Thailand
[c] Center of Excellence for Innovation in Chemistry, Faculty of Science, Mahidol University, Phuttamonthon 4 Road, Salaya, Phuttamonthon District, Nakhon Pathom 73170, Thailand

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ABSTRACT

The objective of his work is to show that pineapple leaf fiber (PALF) can be used successfully to reinforce a high melting polymer such as nylon. One of the most important barriers to the utilization of lignocellulosic materials in polymer matrix composites is their limited temperature resistance. As a consequence, they are mostly used to reinforce low melting temperature polymers such as polyethylene and polypropylene as well as polystyrene. However, this work reveals that PALF can be used to reinforce nylon. This is because of its very low lignin content. Nylon 6/66 composites containing a fixed amount of 20 wt % PALF in the form of short and fine fibers were prepared with a laboratory twin screw extruder and then injection molded. The mechanical properties of three types of PALF, i.e. untreated, alkaline- and silane-treated, were studied. Significant improvements in modulus and heat distortion temperature were obtained. The crystalline structure and orientation in the injected composites were investigated with synchrotron wide angle x-ray scattering (WAXS). It was found that both PALF and nylon crystallites oriented well along the flow direction and this is the key factor for the improvements observed.

1. Introduction

The utilization of lignocellulosic materials, either as a general filler or as a reinforcement for petroleum based polymers, although long studied, has become a very active research topic over recent decades. Materials from numerous sources have been studied ranging from different common agricultural waste [1,2] to industrial by-products [3–5] and from cultivated plants to grasses and weeds [6–8]. These various materials differ in composition, form, physical properties and, especially, mechanical properties. Most of the works so far have studied polymers with low processing temperatures such as polyethylene, polypropylene [9–13] and even polystyrene [14]. This is due to the limited thermal stability of material containing high amounts of lignin such as wood flour and sawdust. There are only very limited reports of studies on high melting polymers like nylon [1,15–17]. Indeed, only in some cases has good reinforcement been obtained [16,17].

Nylons are a family of common engineering plastics with a high melting point. They are used in various engineering applications. They can be used in either unfilled or filled forms. The range of fillers for nylons is not as wide as of those used for polyolefins since at the higher processing temperatures their good properties would be degraded. Among many types of fillers, glass fiber [18] is the most common, while clay has shown promising results [19–21], although it is still not in wide use. A recent report has shown that recycled carbon fiber can also be used to effectively reinforce nylon [22]. Particulate fillers such as glass beads, wood flour and wheat straw provide improvement in modulus only, but cause a reduction in tensile strength and impact resistance [1,15,23].

Recently, our research group has reported a method to produce

* Corresponding author. Polymer Science and Technology Program, Department of Chemistry and Center of Excellence for Innovation in Chemistry, Faculty of Science, Mahidol University, Phuttamonthon 4 Road, Salaya, Phuttamonthon District, Nakhon Pathom 73170, Thailand.
E-mail address: taweechai.amo@mahidol.ac.th (T. Amornsakchai).

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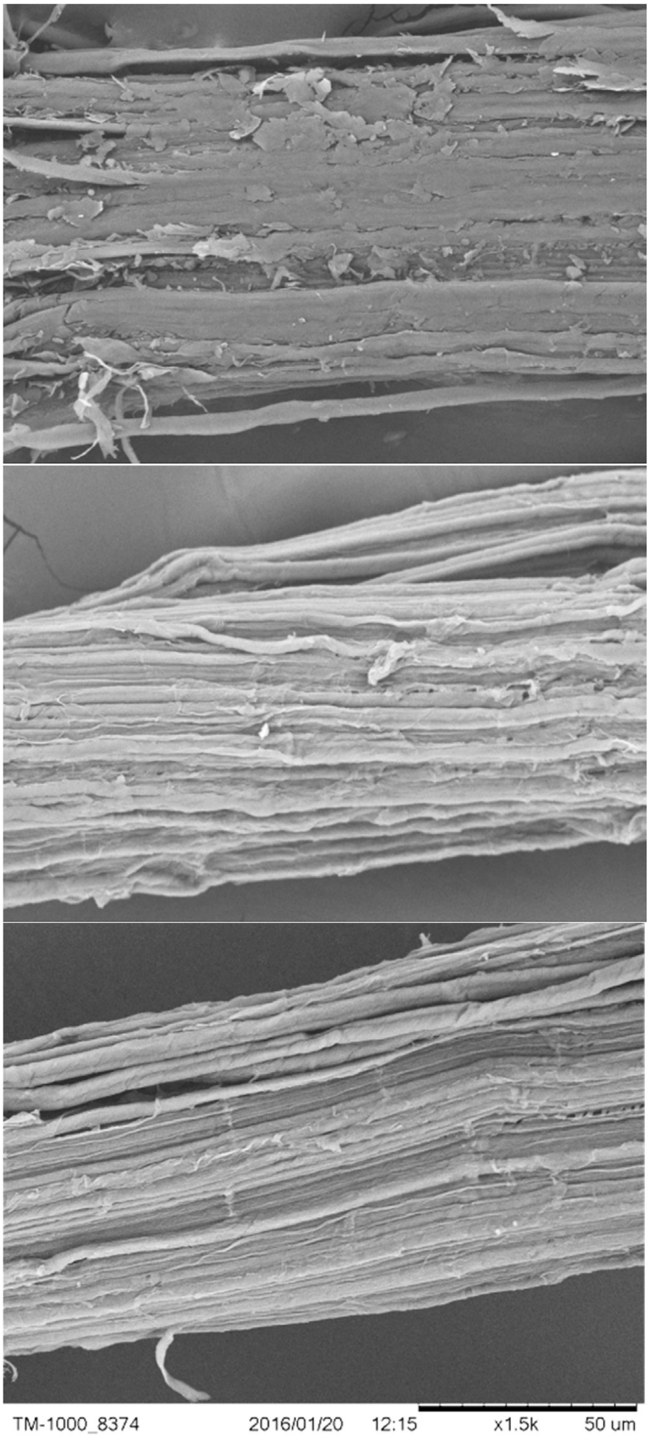

Fig. 1. Scanning electron micrographs of UPALF, TPALF and SiPALF.

short and fine pineapple leaf fiber (PALF) and has demonstrated its uses in polypropylene [24,25] and different rubbers [26–29]. This PALF contains a very low amount of lignin [30–33]. Thus it should be a good candidate for reinforcing nylon. It is the objective of this paper to demonstrate that PALF can, indeed, be used effectively to reinforce nylon.

Nylon/PALF composites containing 20% by weight of PALF samples having experienced different pre-treatments were prepared. Injection molded specimens were tested for their flexural and tensile properties as well as the heat distortion temperature

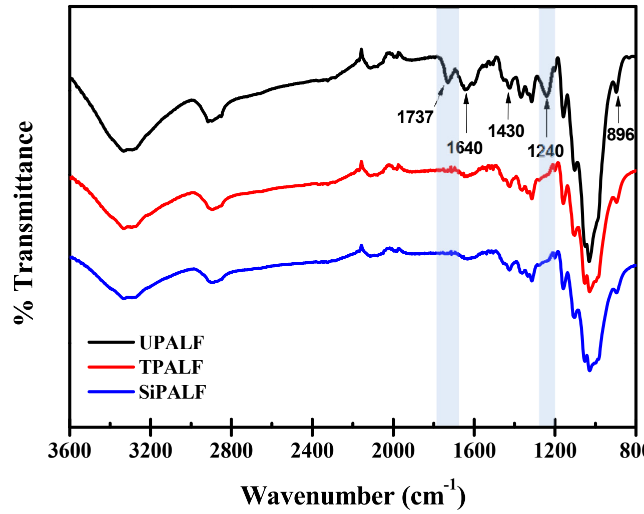

Fig. 2. FTIR spectra of UPALF, TPALF and SiPALF.

(HDT). Synchrotron wide angle x-ray scattering (WAXS) was used to investigate the molecular orientation in the composites.

2. Experimental

2.1. Materials

2.1.1. PALF

The fiber was prepared from fresh pineapple leaves according to a milling technique developed in our laboratory [24]. Pineapple leaves were collected from the Ban Yang District, Amphor Nakhonthai, Phitsanulok Province, Thailand. Fresh leaves were cut into 6 mm lengths and then crushed into paste with a stone grinder. The paste was then dried, ground and sieved in order to separate PALF from non-fibrous materials. General characteristics of PALF obtained in this way have been reported elsewhere [24].

2.1.2. Matrix

Nylon 6/66 copolymer (grade 5021T, medium viscosity) manufactured by UBE Nylon (Rayong, Thailand). It was pulverized by a local compounder before used.

2.1.3. Chemicals

Sodium hydroxide was commercial grade from local supply and (3-Aminipropyl) trimethoxysilane was purchased from Sigma-Aldrich.

2.2. Fiber treatment

2.2.1. Alkaline treatment

PALF was soaked in 10% NaOH aqueous solution for 30 min. The solution was drained and the PALF was washed with water until neutral. The fiber was dried at 80 °C.

2.2.2. Silane treatment

Alkaline treated PALF was soaked in a solution of 1% w/w (3-Aminipropyl) trimethoxysilane (based on fiber weight) in 80:20 ethanol-water for 12 h. The pH of the solution was adjusted to 5 using acetic acid. Treated PALF was then washed several times with an ethanol-water mixture and dried at 80 °C. That the silane-caused alteration of functional groups on the fiber was determined with a Nicolet 6700 FTIR spectrometer (Thermo Scientific) operating in ATR mode.