Measurement 90 (2016) 404–411

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Effect of clay content on the morphological, thermo-mechanical and chemical resistance properties of propionic anhydride treated jute fiber/polyethylene/nanoclay nanocomposites

Md. Faruk Hossen [a,*], Sinin Hamdan [b], Md. Rezaur Rahman [a], Md. Saiful Islam [c], Fui Kiew Liew [b], Josephine Chang hui Lai [a], Md. Mizanur Rahman [b]

[a] Department of Chemical Engineering and Energy Sustainability, Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia
[b] Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia
[c] Department of Chemistry, Faculty of Science, University Putra Malaysia, 43400 Serdang, Selangor, Malaysia

ARTICLE INFO

Article history:
Received 22 June 2015
Received in revised form 3 May 2016
Accepted 5 May 2016
Available online 6 May 2016

Keywords:
Montmorillonite
Jute nanocomposites
Morphology
Thermo-mechanical properties
Chemical resistance

ABSTRACT

Nanoclay is considered potential nanofiller for the manufacturing of natural fiber nanocomposites. The hydrophilic nature of natural fibers affects negatively its adhesion to hydrophobic polymer matrix. In the present study, propionic anhydride (PA) treated jute were used for the manufacturing of jute/polyethylene/nanoclay nanocomposites. Different amount (wt%) of montmorillonite (MMT) were used as nanofiller in order to optimize the nanoclay in the composite system. Finally, the nanocomposites were prepared using hot press machine at 5, 10, 15, and 20 wt% fiber loadings. Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), tensile tests, thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), and chemical resistance test were used to evaluate the morphological, thermo-mechanical and chemical resistance properties of the composites.

1. Introduction

Nowadays, the development of natural fiber reinforced composites is one of the high attractive research fields. Jute performs relatively better properties among the other natural fibers like banana, cotton, coir, sisal, etc., due to the inexpensive and commercial availability in a required form. It can also be substituted for conventional fibers in many applications and has been applied as reinforcement to eco-composites and bio-composites [1]. The hydrophilic nature of natural fibers affects negatively its adhesion to hydrophobic polymeric matrices. To improve the compatibility between both components a surface modification has been proposed. Esterification is a common surface modification technique that has been reported to overcome the incompatible surface polarities between the natural fiber and polymer matrix [2]. Many chemical agents such as acetic anhydride, oleoyl chloride, hexanoic acid, dodecanoic acid, octadecanoic acid and docosanoic acid have been used for esterification to improve dispersion and adhesion [3–5]. During treatment, the chemical agents can react with the OH groups at C-2, C-3 and C6 positions of the cellulose in the fibers. Due to the steric effect, the bulky chemical groups can react either with the hydroxyl group at C-2 or C-3 but cannot react with OH groups in both positions at a time [6]. Thus, in this study, propionic anhydride (PA) has been used as coupling agent for esterification of the jute fibers to improve the interfacial interaction with polymer matrix. The matrix phase plays an important role in the performance of polymer composites. Polyethylene has outstanding properties like low density, low cost, good flex life, excellent surface hardness, scratch resistance and admirable electrical insulating properties [7]. In the case of thermoplastic composites, the dispersion of the fibers in the composites is also an important parameter to achieve consistency in the product. Jute-polyethylene composite has showed remarkable increase in mechanical properties [8]. As jute is abundantly available in South Asia such as Bangladesh, India and China, it is worthwhile to analyze the effect of surface treatments on jute fibers, i.e. on the mechanical, thermal and environmental performance of the composites produced with polyethylene (PE) matrix.

Recently, Nano-materials showed a significant performance into the composite system. It has been reported that the addition of a small amount of nanoparticle into a matrix can improve thermal and mechanical properties considerably without compromising the weight or processability of the composite [9]. Montmorillonite (MMT) incorporated polymer composites and

* Corresponding author.
E-mail address: fhossen.chem@gmail.com (M.F. Hossen).

http://dx.doi.org/10.1016/j.measurement.2016.05.006
0263-2241/

their laminates have excellent characteristics, including improved physical (dielectric, optical, permeability, and shrinkage), thermal (flammability, decomposition, coefficient of thermal expansion, and thermal stability), and mechanical (toughness, strength, and modulus) properties even at a very low filler loading. Thus, higher clay loading above a certain threshold value increases the viscosity of the matrix. A higher clay loading also can be the causes of agglomeration and air bubble during the mixing process [6]. It has been reported that the nanoclay-loaded jute polyester biocomposite showed a substantial improvement in thermomechanical properties [10]. The MMT as nanofiller can also be exhibited a considerable improvement in the morphological and mechanical properties of jute fiber polyethylene nanocomposite [11]. Thus, in this work, different amounts (wt%) of MMT have been used to optimize the nanoclay loading to provide better properties as it is uniformly dispersed into the composite system.

Therefore, in this study, the effects of different amount (wt%) of nanoclay on the improvement of different properties of PA treated jute fiber reinforced polyethylene/clay nanocomposites have been investigated. Fourier transform infrared (FTIR) spectroscopy, tensile tests, scanning electron microscopy (SEM), thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), and chemical resistance test were used to evaluate the morphological, thermo-mechanical, and chemical resistance properties of the nanocomposites.

2. Materials and methods

2.1. Materials

Jute fibers (*Corchorus olitorius*) were collected from Bangladesh Jute Research Institute (BJRI), Dhaka, Bangladesh. Polyethylene (PE) granules, used as matrix material, were supplied by Siam Polyethylene Company Limited, Bangkok 10110, Thailand. It had specific gravity of 0.92 and melting temperatures of 105–115 °C. Chemicals used in this study such are NaOH (sodium hydroxide), H_2SO_4 (sulfuric acid) and CH_3COOH (acetic acid) supplied by Merck, Germany. Montmorillonite clay surface modified with 25–30 wt% octadecylamine (MMT-1.30E) and propionic anhydride (PA) were supplied by Sigma–Aldrich (USA).

2.2. Chemical treatment of jute fibers

The reaction of natural fibers with anhydride is known as esterification. The esterification of natural fibers included an alkali treatment followed by esterification [12]. The chopped (middle parts) jute fibers were immersed in 5% NaOH solution and stirred well for 1 h at 27 °C. The fibers were then washed several times by fresh water. Final washings were carried out with distilled water containing acid to remove any NaOH sticking to the fiber surface. The fibers were then air dried. The alkali-treated fibers were soaked in glacial acetic acid for 1 h at 27 °C. Fibers were separated by decanting and soaked in propionic anhydride (PA) containing 2 drops of concentrated H_2SO_4 for 5 min. Then the fibers were taken out, washed well with distilled water and dried in an oven at 80 °C for 12 h. The fibers were then chopped into 3–4 mm in length for composite fabrication. The reaction of jute fiber with propionic anhydride is shown in Fig. 1.

2.3. Fabrication of composites and test specimens

Oven-dried jute fibers, PE granules and MMT were mixed thoroughly in different weight fractions according to Table 1. After mixing, the solid mixture was settled in a mold. The mold is then placed into hot press machine (Fig. 2) performing for 1 h at 180 °C and 7 MPa. The mold was then air cooled at room temperature and the manufactured composites were taken out to prepare the test specimens for characterization.

2.4. Characterization

2.4.1. Fourier transform infrared (FTIR) spectroscopy

The infrared spectra of the prepared composites were recorded on a Shimadzu FTIR 81001 Spectrophotometer using potassium bromide (KBr) as standard. The wave number range was 4000–500 cm^{-1}.

2.4.2. Tensile test

Tensile tests were conducted according to ASTM D 638 using a Universal Testing Machine (Model: MSC-5/500, Shidmadzu Company Limited, Japan) at a crosshead speed of 5 mm/min with the dimension of the specimen 115 mm × 6 mm × 3.1 mm (Fig. 3). In each case, three rectangular specimens were tested and the average value was reported.

2.4.3. Scanning electron microscopy (SEM)

The surface morphology of the prepared composites was examined using a Scanning electron microscopy (TM3030) supplied by JEOL Company Limited, Japan. The micrographs were taken from the fracture surface to study the interfacial adhesion between fiber, clay and polymer matrices. The samples were sputter-coated with gold and observed under the SEM. The micrographs were taken at a magnification of 500×.

2.4.4. Thermogravimetric analysis (TGA)

TGA was conducted with a TGA/DSC1 STAR System, Mettler Toledo thermal analyzer according to ASTM E1131. The thermal analyses were done in a nitrogen gas atmosphere with flow rate of 30 mL min^{-1} at the heating rate of 10 °C min^{-1} from 50 °C to 800 °C. The weight of the samples was maintained about 10 mg.

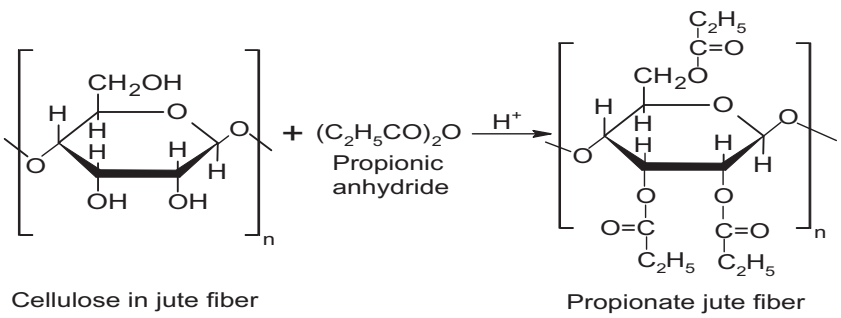

Fig. 1. The reaction of jute fiber with propionic anhydride (PA).