

Influence of Nanoclay on the Physical Properties of Recycled High-Density Polyethylene/Bagasse Nanocomposite

¹Amir Hooman Hemmasi, ²Ismail Ghasemi, ¹Behzad Bazyar and ¹Ahmad Samariha

¹Department of Wood and Paper Science,

Science and Research Branch, Islamic Azad University, Tehran, Iran

²Department of Processing, Iran Polymer and Petrochemical Institute (IPPI),

P.O. Box 14965-115, Tehran, Iran

Abstract: In this study, the influence of nanoclay (0, 2 and 4 wt, phc) loading on the physical properties of nanocomposites is investigated. Composites based on the recycled high-density polyethylene (rHDPE), bagasse flour and nanoclay was made by using a counter-rotating twin-screw extruder and then injection molding. When 2 and 4 (phr) nanoclay were added, the water absorption decreased significantly, finally, the thickness swelling of rHDPE/bagasse nanocomposites was lowered with the increase in nanoclay content. Furthermore, we can conclude that addition of nanoclay enables to achieve better physical properties in conventional composites.

Key words: Nanoclay • High-density polyethylene • Water absorption • Thickness swelling

INTRODUCTION

During the last decade, wood-plastic composites (WPCs) have emerged as an important family of engineering materials. They have become prevalent in many building applications, such as decking, docks, landscaping timbers, fencing, etc [1]. Generation of solid and industrial wastes is increasing at an alarming rate [2]. The worldwide production of plastics is approximately 100 million tonnes per annum [3], resulting in a significant proportion in municipal solid waste (MSW). For example, waste plastics account for 11.8% of the 246 million tonnes of MSW generated in the United States in 2005 [4]; 9,400 tonnes (11.2% of total imported virgin plastics) in Tehran (capital of Iran) [5]. About 54 million tons of bagasse is produced annually throughout the world. In general, sugar factories generate approximately 270 kg of bagasse (50% moisture) per metric ton of sugarcane [6]. Commonly used nanoclays include montmorillonite, hectorite and saponite, all of which belong to the same general family of 2:1 layered or phyllosilicates (Fig. 1). The combination of clays and functional polymers interacting at the atomic level constitutes the basis for preparing an important class of inorganic-organic nanostructured materials. Polymer-layered silicate nanocomposites containing low

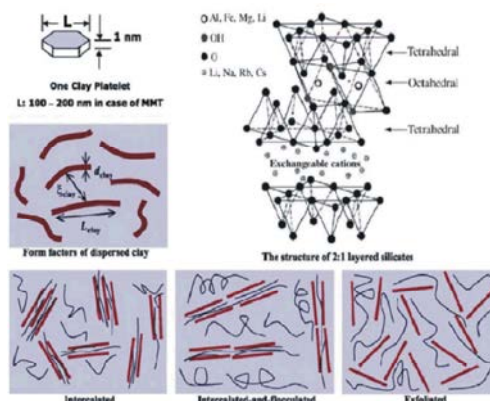


Fig. 1: Schematically illustration of three different types of thermodynamically achievable polymer/layered silicate nanocomposite [7]

levels of exfoliated clays such as montmorillonite and vermiculite have a structure consisting of platelets with at least one dimension in the nanometer range (Fig. 1). Nanocomposite technology with layered silicate clays as in situ reinforcement has been intensively investigated. Essential improvements of physical and mechanical properties, thermal stability, flame resistance and barrier resistance have been observed for various thermoplastic

Table 1: Composition of the studied formulations

Formulation Code	Recycled polyethylene Content (Wt. %)	Bagasse Flour Content (Wt. %)	Nanoclay (phc)	MAPE Content (phc)
A	50	50	0	3
B	50	50	2	3
C	50	50	4	3

and thermoset nanocomposites at low silicate content [8, 9]. Using nanoclay filler in WPC composite has been reported in the literatures (Hemmasi *et al.* 2010; Kord 2010; Han *et al.* 2008; Wu *et al.* 2007) [10-13]. Many efforts have been made in the formation of wood polymer composite to improve such properties so as to meet specific end-use requirements. The aim of this study was to investigate the influence of nanoclay on the physical properties of recycled high-density polyethylene/bagasse nanocomposite.

Experimental

Materials: Recycled high-density polyethylene (rHDPE) was provided as granules by Arak Petrochemical Company. The rHDPE has melt flow indices of 23.037 g/10 min at 190°C and density of 0.956 g cm⁻³. Flour from bagasse (70-mesh size) supplied by Choob Plastic DEZ Co. was used as filler. Maleic anhydride grafted polypropylene (PP-g-MA) provided by Solvay with trade name of Priex 20070 (MFI=7 g/10min, grafted maleic anhydride 0.1 Wt. %) was used as coupling agent. Montmorillonite modified with a methyl, tallow, bis-2-hydroxyethyl, quaternary ammonium (CEC = 90 meq/100 g clay, $\text{doo}_1 = 18.5 \text{ \AA}$) was obtained from Southern Clay Products Co. USA, with trade name of cloisite 30B.

Method

Composite Preparation: Before preparation of sample, bagasse flour was dried in an oven at $65 \pm 2^\circ\text{C}$ for 24 h. Then the components of each sample (rHDPE, MAPE, nanoclay and bagasse flour) were pre-mixed to prepare homogeneous compounds according to formulations given in Table 1 and were blended in a counter-rotating twin-screw extruder (Dr. Collin System) at a screw speed of 80 rpm at 175°C . The compounded materials were then grinded to prepare the granules using a pilot-scale grinder (WIESER, WGLS 200/200 model). The mix was removed from the mixing bowl, cooled in water and granulated into pellets. The pellets were dried at 105°C for 24 h before injection molding. Test specimens were prepared by an injection molding machine (Imen Machine, IRAN) at 190°C and a pressure of 10 MPa according to standard ASTM D638. The specimens were stored under controlled conditions (50% relative humidity and 23°C) for at least 40 h before testing.

Measurements: Water absorption tests were carried out according to ASTM D-7031-04. Five specimens of each formulation were selected and dried in an oven for 24 h at $102 \pm 3^\circ\text{C}$. The weight and thickness of dried specimens were measured to a precision of 0.001 g and 0.001 mm, respectively. The specimens were then placed in distilled water and kept at room temperature. For each measurement, specimens were removed from the water and the surface water was wiped off using blotting paper. Weight and thicknesses of the specimens were measured after 24-hours immersions. The values of the water absorption in percentage were calculated using the following equation 1.

$$W_{a_t}(\%) = (W_t - W_o) / W_o * 100 \quad (1)$$

Where W_t and W_o , are the weights of the specimen before and after immersion in water, respectively.

The values of the thickness swelling in percentage were calculated using equation. 2.

$$T_{s_t}(\%) = (T_t - T_o) / T_o * 100 \quad (2)$$

Where T_{s_t} is the thickness swelling at time t , T_o is the initial thickness of specimens and T_t is the thickness at time t .

The statistical analysis was conducted using SPSS programming (Version 11.5) method in conjunction with the analysis of variance (ANOVA) techniques. Duncan multiply range test (DMRT) was used to test the statistical significance at $\alpha = 0.05$ level.

RESULT AND DISCUSSION

The results of an ANOVA indicated that the nanoclay content had significant effects ($p < 0.05$) on the physical properties of composites. The effect of nanoclay content on the water absorption and thickness swelling of wood plastic composites is shown in Figures 2 and 3. Figure 2 and 3 shows the values of the water absorption and thickness swelling for the composites, which vary depending upon the nanoclay loading. Figure 2 also shows that the water absorption decreased with of nanoclay loading. It seems the barrier properties of

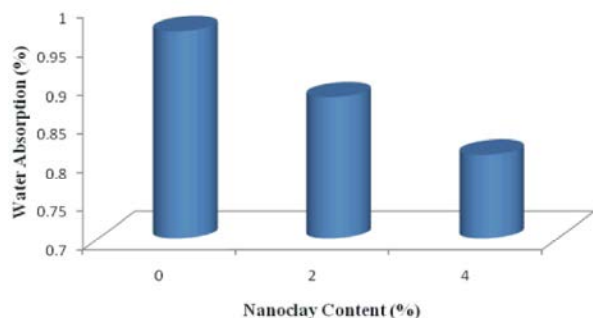


Fig. 2: Effect of nanoclay content on water absorption (24h)

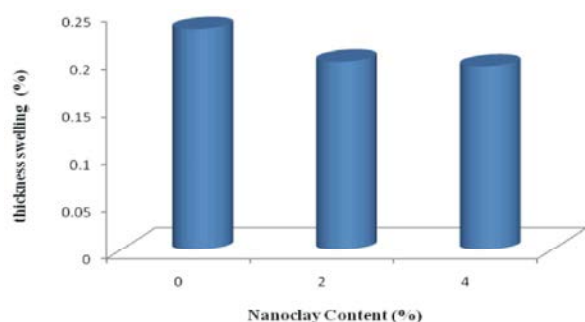


Fig. 3: Effect of nanoclay content on the thickness swelling (24h)

nanoclay fillers inhibit the water permeation in the polymer matrix. Two mechanisms have been reported for this phenomenon. The first is based on the hydrophilic nature of the clay surface that tends to immobilize some of the moisture [14], second, surfactant-covered clay platelets form a tortuous path for water transport [15, 16]. This barrier property hinders water from going into the inner part of the nanocomposite. It seems that both of aforesaid mechanisms could be more efficient when the morphology is exfoliated. In other words, in the exfoliated morphology there is more available surface of organoclay (with hydrophilic nature) and surfactant (tortuous path), so the water transport goes down under the severe conditions. The reason for less water uptake could be existence of nanoclay as a nucleating agent [17]. Due to such as nucleation, the crystallinity of the hybrid composite can be improved by the presence of the nanofiller as a nucleating agent. As the crystalline regions are impermeable, but water absorption is less in the composites.

CONCLUSION

The experimental results of our study indicate the water absorption and thickness swelling of composites

was lowered with the increase in nanoclay content. Also, from these results, we can conclude the addition of nanoclay improves its water absorption and thickness swelling property. As a consequence, it is possible to conclude that nanoclay enables to achieve better physical properties than conventional composites.

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