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Effect of Nanoclay on Thermal Properties of Polylacticacid-Kenaf Hybrid Bio-composite.

***M. R. Kaiser and Hazleen Anuar.**
Department of Manufacturing and Materials Engineering, Kulliyyah of Engineering, International Islamic University Malaysia, P.O. Box 10, 50728 Kuala Lumpur, Malaysia.

An alternative composite material which is a mixture of bio-fiber with nano filler and polymer known as hybrid bio-composite has become a state of the art in composite research and development. The hybrid bio-composite has been widely studied with different combinations for the application of secondary structure in automotive industry, packaging, aerospace, sports, armour proucts and others. The availability of natural fiber (such as kenaf fiber) makes the hybrid bio-composite competetively lower cost and feasible to be produced industrially for wide range of applications. The main objectives of this paper are to fabricate and the effect of nanoclay on thermal properties of hybrid bio-composite. A comprehensive database was developed to determine the thermal property of PLA, PLA-20KF-3Clay, PLA-20KF-5Clay and PLA-20KF-7Clay. Three point bend Dynamic mechanical analysis (DMA) tests were carried out on standard specimens at temperature ranging from -90^{0}C to 100^{0}C whereas frequency was 1Hz. The result revealed that with addition of nanoclay glass transition temperature (T_g) increased 5^{0}C. The storage modulus (E'), loss modulus (E") and damping (tanδ) also increased with addition of nanoclay which is an indication of better thermal properties.
Keywords: *Nanoclay, Hybrid Bio-composite, Thermal properties, Glass transition temperature, DMA.*

1. INTRODUCTION

In the UN millennium development goals from 2000, it was agreed to work for eradication of extreme poverty and hunger and to ensure environmental sustainability (Jeffrey et. el., 2005). These two goals are not easily met simultaneously. The fast economical growth in some developing countries that is seen lately will hopefully continue and spread. But there are some quite alarming obstacles for this positive development to persist: i) the demand for all kinds of products increases when economical welfare is increased but the world's resources remain limited, ii) world population is growing rapidly thus demand will continue to raise in all kinds of sectors and iii) this is all happening in a time when we experience climate changes which most likely are triggered by human activities, mainly the use of fossil resources, which will escalate due to the increased consumption, if it is not acted mankind has a large challenge to deal with (Chandra et. al., 1998). Parts of the solution are a major redirection of our consumption habits in the Western world and an alteration from using fossil to renewable resources for energy production as well as in our products. Among lots of products plastic and plastic base materials are responsible for depletion of fossil and environment pollution for their diversified usage (Bogaert et. el., 2000).

The increased use of plastics all over the world has resulted in an increase in plastic waste. For this reason the development of biodegradable polymers has been a subject of great interest in materials science for both ecological and biomedical perspectives. Bio-based plastics are sustainable, largely biodegradable and biocompatible (Drumright et. al., 2000). They reduce our dependency on depleting fossil fuels and are CO_2 neutral (Hill et. al., 1997).

Different biodegradable polymer materials like polycaprolactone (PCL), polyesteramide (PEA), aliphatic copolyesters (PBSA), aromatic copolyesters (PBAT), polyhydroxyalkanoate (PHA), polylacticacid (PLA) were used to replace the comventional polymer (Mohanty et. al., 2002). Among them PHA and PLA are agro based polyester, which are the most promising to replace the conventional one. Between PLA & PHA, PLA shows better mechanical and thermal property (Averous et. al., 2004). Extensive researches are done with different natural fiber reinforcement and nano filler materials are also used to produce bio-composite and nanocomposite respectively. Both

* Corresponding Author: M.R.Kaiser,
E-mail: rejaul.kaiser@gmail.com

biocomposite and nanocomposite has some merits and demerits. As for example kenaf/PLA biocomposite shows better strength, stiffness, lower cost and easy to fabricate. However this biocomposite shows higher moisture absorption, less flame retardancy and low impact strength. On the other hand nanoclay/PLA nanocomposite shows higher flame retardency, less moisture absorption and higher impact strength. Again the main drawback of nanocomposite is higher cost and difficult to process (Le, 1999, Miyagawa et. al., 2006)

This paper tries to investigate the addition of both kenaf fiber and nano filler in a PLA with different percentage. This is necessary in order to fabricate an environmental friendly biocomposite and as well to replace the conventional polymer in terms of cost, availability and property.

2. EXPERIMENTAL

2.1 Materials

PLA and three PLA based composites were considered under observation. All the composites were made by using PLA, Kenaf and Nanoclay.

(1) **PLA:** 3051D graded PLA was used that is produced by NatureWorks® from USA. It was in pellet form. Its specific gravity is 1.24g/cm^3, crystalline melt temperature and glass transition temperature is 145-155ºC & 55-65 ºC respectively.

(2) **Nanoclay:** Nanomers® I.31PS was used as reinforcement was manufactured by Nanocor, Inc from st. Louis USA. It comes in powder form with a mean size of 15-25 microns. It is an onium ion modified montmorillonite, designed for maximum compatibility and dispersion in a polyolefin matrix. In addition to the typical onium treatment, Nanomer I.31PS contains a silane-coupling agent to promote higher tensile properties. It contains 0.5-5 wt. % aminopropyltriethoxysilane and 15-35 wt. % octadecylamine.

(3) **Kenaf Fiber:** Kenaf fiber that was used obtained from Kenaf Natural Fibre Industries Sdn. Bhd., Kelantan, Malaysia. The stalk of the kenaf plant consists of two distinct fiber types. The outer fiber is called bast and the inner fiber is called core.

2.2 Preparation and Processing:

All the composites that were produced went through extrusion process at 180^{0}C followed by injection molding at 200^{0}C. Before this a rigorous manual mixing was occurred. 100PLA was the only materials that directly gone for injection molding without following extrusion process. BATTENFELD HM 600/850 injection molding machine was used for injection whereas Brabender twin screw extruder was used for extrusion. After completing the extrusion process four different composite was obtained. They are stated in the table-1.

Table-1: Compositions and names of composite

Sample	Denotation	Matrix (wt%)	Fiber (wt%)	Filler (wt%)
PLA	S1	100	0	0
PLA-20KF	S2	80	20	0
PLA-20KF-3clay	S3	77	20	3
PLA-20KF-5Clay	S4	75	20	5
PLA-20KF-7clay	S5	73	20	7

3. RESULTS AND DISCUSSION

At present polymer hybrid biocomposite takes the attention of researcher and polymer companies because of its better mechanical properties than conventional polymer. Besides mechanical properties, thermal properties are also important factor to make them commercially viable. DMA, one of the very important and common thermal testing was done to know the effect of nanoclay on thermal properties of PLA and PLA-based hybrid biocomposites.

From the DMA curves showing in Fig. 1 & Fig. 2, it is clearly seen T_g is increased about 3 to 4^{0}C with addition of nanoclay. T_g value for S1 is about 53^{0}C whereas S2 shows 55^{0}C and S3, S4 and S5 shows almost 58^{0}C. The main reason of higher T_g for S2, S3, S4 and S5 is the uniform dispersion of fiber and nanoclay throughout the matrix which restrict the movement of the side group of polymer chain that occurred at T_g.

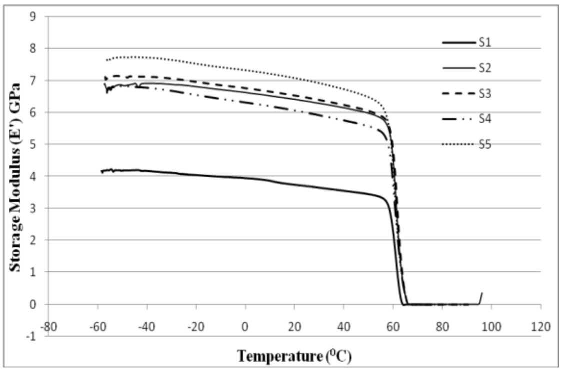

Fig. 1: Storage Modulus curves for S1, S2, S3, S4 and S5.

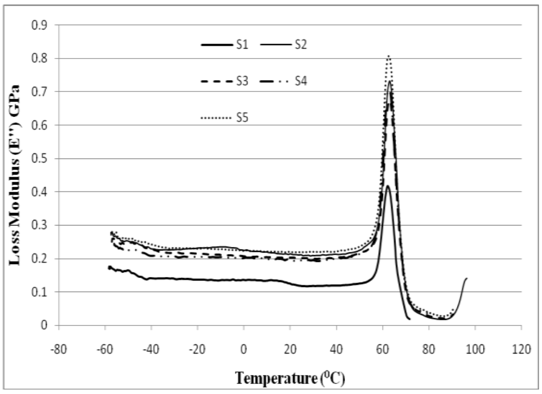

Fig. 2: Loss Modulus curves for S1, S2, S3, S4 and S5.

Generally the working temperature range of polymer and their composites is from β-transition (T_β) temperature to T_g. Thus a small increment of T_g is very significant. It can be seen also in Fig. 5 that the T_β of S1 is about -20^{0}C which is a small decrement of curve whereas S2 and S3 do not show any T_β therefore it can be inferred that S2, S3, S4 and S5 can be applied at lower than -20^{0}C which is also a significant effect of nanoclay as a filler. It should be mention here that, thermal properties of unfilled PLA have been reported in our previous work (Anuar et. al., 2011).

Fig. 1 and Fig. 2 also clearly exhibit that storage modulus and loss modulus are increased with the amount of nanoclay. The increment of loss modulus is however less than storage modulus which indicates higher damping (tan δ). Higher storage modulus and damping is an indication of higher toughness (Ray et. al., 2003). These statements are also supported by flexural test curve showing in Fig. 3. It showing that with addition of nanoclay flexural modulus is increased significantly but S4 shows comparatively lower modulus than S3 this due to agglomeration of clay particle in S4 another sense it can be said that S3 shows better dispersion of clay throughout the matrix.

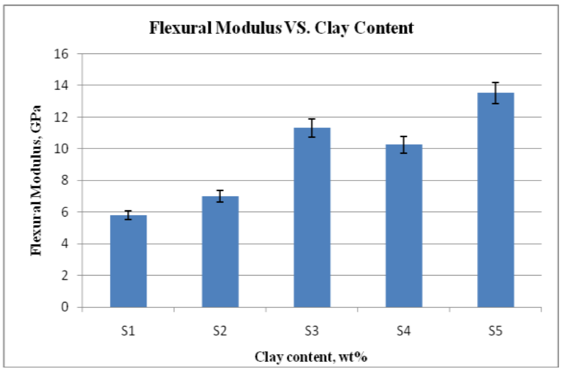

Fig. 3: Flexural modulus curves for S1, S2, S3, S4 and S5.

4. CONCLUSION

From the results it can be concluded that nanoclay has a very significant effect on thermal properties specifically glass transition temperature, storage modulus, and damping property. It can be infered from the results that PLA-20KF-3Clay hybrid biocomposite is a strong competitor to replace conventional one because of its better properties than other compositions. It should be noted, however the availability, price are also very important aspects for commercial purposes. Further research is needed for advancement of PLA-based hybrid biocomposite.

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