Thermal analysis of IZO-Kenaf/Polyaniline/Polylactic Acid (PLA) hybrid composite

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ABSTRACT – Indium doped zinc oxide (IZO) coated kenaf fiber and polyaniline (PANI) as filler in polylactic acid (PLA) can be seen as a potential approach for green-conductive composite. The composite samples were developed based on these combinations of S1 (PLA), S2 (PLA/PANI), S3 (PLA/IZO-Kenaf) and S4 (PLA/IZO-Kenaf/PANI). Their thermal stabilities were studied by analysing and comparing the decomposition temperature obtained from thermogravimetric analysis (TGA). The results have confirmed that the addition of kenaf fiber in PLA composite has lowered the endurance of higher temperature due to the content of hemicellulose and cellulose in the fiber. However, thermal decomposition of this hybrid was improved up to 20.43% upon the addition of PANI, which is strongly assisted by the high decomposition temperature of oxidized PANI.

1. INTRODUCTION

Natural fiber or plant fiber and polymers are usually known as non-conductive materials. Its broad potential usage has taken much attention amongst researchers in various studies including electrical and electronics. Previously, most studies were focusing on incorporating conductive filler like carbon, metals, intrinsic conductive polymers etc. to develop electrical-conductive green composites. There are very limited studies concentrating on inducing a conductive material on kenaf fiber to make it conductive filler. Indium doped zinc oxide (IZO) is known as a transparent conductive oxide which has a practical synthesis method for kenaf fiber and also promising electrical properties. Hence, the idea of integrating IZO-coated kenaf has a huge potential in the development of green-conductive hybrid composite as electromagnetic interference shielding material [1,2]. However, the thermal aspect on the application of natural fiber had often been a huge limitation due to its low thermal resistance compared to the synthetic fibers. Thus, this study intends to evaluate and compare the synergistic effects on the thermal stability in the hybrid composite consists of PLA, IZO-coated kenaf and polyaniline.

2. METHODOLOGY

2.1 Development of IZO-coated kenaf

Firstly, the non-woven kenaf was chemically treated by 6% of sodium hydroxide (NaOH) for 24 hours and dried for 24 hours at 70ºC. Then, the solution was prepared by diluting 0.1M zinc acetate dihydrate in ethanol and stirred on magnetic stirrer for 1 hour. Then, 5.0 wt.% of indium (III) chloride was added into the solution and continued stirring at 75ºC for another hour while deionized water was dripped into the solution until it turned to clear solution. The IZO coated kenaf fiber was produced through a set of dipping process in indium doped zinc oxide solution for 10 minutes. After that, the fiber was pad-dried under constant load to obtain 30-40% uptake of excessive solution. Finally, it was cured at 150ºC for 4 hours.

2.2 Synthesis of polyaniline

Polyaniline was synthesised via chemical oxidative polymerization. In this process, the 0.2M aniline chloride and 0.25M of ammonium peroxydisulfate were dissolved in 100ml of distilled water, then both solutions were precooled at around 9.0ºC for 12 hours. After that, both solutions were mixed together and briefly stirred for 1 hour and then left for 24 hours in the chiller at temperature of 2.0-9.0ºC. The resulted precipitate was filtered and washed thoroughly with 0.2M hydrochloric acid and acetone. Lastly, it was dried at 60ºC for 24 hours in vacuum oven.

2.3 Fabrication of composite

The hybrid composite was produced by mixing IZO coated kenaf fiber, polyaniline and PLA in the HAAKE Rheomix 600 mixer at 170ºC for 12 minutes. The amounts were set according to Table 1 which are represented as S1 (PLA), S2 (PLA/PANI), S3 (PLA/IZO-Kenaf) and S4 (PLA/IZO-Kenaf/PANI). The final samples were prepared accordingly to be analysed.

Table 1 Composition of composites

Sample	IZO-Kenaf (wt%)	PLA (wt%)	Polyaniline (phr)
S1	-	100	-
S2	-	100	10
S3	20	80	-
S4	20	80	10

2.4 Thermogravimetric analysis (TGA)

The thermal characteristic was examined by using thermogravimetric analysis (TGA) to investigate the decomposition temperature of hybrid composite and its comparison to the control sample.

3. RESULT AND DISCUSSION

3.1 Thermal stability analysis by TGA

The thermogravimetric curves for all four samples (S1, S2, S3 and S4) is figuratively illustrated by the graph in Figure 1. Initially, the samples exhibit thermally stable up to 220-300ºC and starts to degrade above these temperatures, which demonstrates the decomposition of kenaf fiber, PANI and PLA. Before degradation, the composites average mass was sustained at 98% of its original mass, which clarifies that the 2% of mass loss from initial moisture vaporization in the materials. It is shown that sample S3 (PLA/IZO-Kenaf) starts degrading at the lowest temperature and exhibits two step degradation at 200-210ºC and 310-320ºC which represents kenaf fiber and PLA decomposition respectively. Meanwhile, sample S1 (PLA) gives the highest thermal stability among the composite samples.

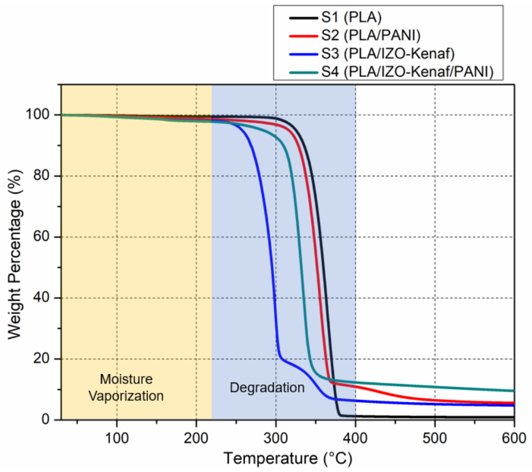

Figure 1 Thermogravimetric curves of composites

Detail data from Table 2 shows the decomposition temperature of S1 (PLA) and S2 (PLA/PANI) by 332.42ºC and 312.68ºC respectively. The addition of PANI in PLA indicates a very minimal decrease of its thermal stability. On further observation, the results also demonstrate the decomposition temperature of sample S3 (PLA/IZO-Kenaf) and S4 (PLA/IZO-Kenaf/PANI) which is at 253.21ºC and 304.98ºC respectively which explains the rapid decomposition upon the addition of kenaf fiber. This finding confirms the reduction of thermal stability of the composite due to the hemicellulose and cellulose content in kenaf fiber which usually degrades above 220ºC [3]. However, as the polyaniline is added in the composite S4 (PLA+IZO-Kenaf+PANI), the resulted hybrid had improved thermal resistance by 20.43% compared to the sample without polyaniline. This phenomenon is attributed by the crosslinking and large molecular weight of oxidized PANI in the hybrid composites which may increase the thermal stability [4]. Additional data from the thermogravimetric has also shown that hybrid composite sample (S4) yields the highest residue at 600ºC. This phenomenon describes the undecomposed carbon or char yielded from the polymer with crosslinking and aromatic rings structure like polyaniline in natural fiber [5].

Table 2 Results of TGA

Sample	Onset decomposition temperature (ºC)	Residual weight at 600ºC (%)
S1	332.42	0.91
S2	312.68	5.40
S3	253.21	4.36
S4	304.98	8.54

4. CONCLUSIONS

At the end of the experiment, it can be concluded that the addition of kenaf fiber in PLA composite decreases the thermal stability at which it decomposes at low temperature associated with the low thermal resistance of natural fiber. However, the hybrid sample of S4 (PLA/IZO-Kenaf/PANI) has shown an improved thermal resistance by 20.43% with the addition of PANI which contributed by its crosslinking and large molecular weight in the hybrid composites.

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