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Effects of Nanographene Addition on Tensile and Electrical Properties of Nylon 6,6 Nanocomposite

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ABSTRACT – The effects of nanographene (NG) filler on tensile and electrical properties of nylon 6,6 nanocomposite were analyzed. The samples were fabricated by blending nylon 6,6/NG in Sino compounder twin screw machine which subsequently injected into standard size specimens for tensile and electrical conductivity test. An addition of small percentages of NG filler, i.e., 0.3, 0.5 and 1.0 wt% significantly affected the tensile performance and electrical conductivity of nylon 6,6 nanocomposite, in which tensile properties and electric conductivity improved with increasing nanographene filler loading.

1. INTRODUCTION

In recent years, there have been an increasing number of literatures on graphene incorporated polymer composite in pursuit of enhancement on mechanical, thermal and electrical properties. Up to present, graphene is emerging to be a promising material in range of application from construction, transportation, sensors, thermal conductor and electromagnetic interference due to its superior intrinsic properties. Graphene is a new class of monolayer carbon atoms that are arranged into 2D hexagonal pattern and has various advantages [1]. Comparison on mechanical, thermal and electrical properties of graphene has proven its outstanding performance against CNT, steel, Kevlar, HDPE and rubber [2]. Nanographene addition holds the potential to boost electrical conductivity and mechanical by creating electrical path and providing stress transfer advantage in the composite, respectively [3,4]. There have been many studies examining the effects of nanographene filler addition on composites [4-7], however only few studies on nanographene reinforced nylon 6,6 based material have been reported. Hence, the goal of this study is to explore the effects of nanographene addition on tensile and electrical properties of nylon 6,6 nanocomposite.

2. METHODOLOGY

2.1 Materials

Composite samples were fabricated by using nylon 6,6 and nanographene filler of different weight percentage (0.3, 0.5 and 1.0 wt%). They were both supplied by Terra Techno Engineering. Initially, nanographene and nylon 6,6 were dry-mixed using high speed mixer at 50 rpm to form 3 kg of homogenous mixture which then dehumidified at 70 °C for 3 hours. After that, the mixture was compounded using Sino PSM 30 co-rotating twin screw extruder and crushed into pallet form before injected into standard specimen shape (ASTM D638 Type 4) by using table top injection molding (Ray Ran–Plunger Type).

2.2 Testing

Tensile properties of nylon 6,6/NG nanocomposite were performed in accordance to ASTM D638 using Universal Testing Machine (UTM). The results of tensile strength, Young's modulus and elongation at break were reported. Meanwhile, electrical conductivity test was performed using LCR meter (Agilent Precision LCR meter - E4980A) on disc samples (d = 25 mm), to study the effect of nanographene addition to the electrical conductivity of nylon 6,6/NG nanocomposite.

3. RESULTS AND DISCUSSION

3.1 Tensile properties

Table 1 shows the average results of tensile strength, Young's modulus and elongation (%) at break. The results demonstrate a significant contribution of nanographene filler to the composite, where the tensile strength and Young's modulus increase as nanographene filler increases. Addition of merely 1.0 wt% of nanographene, gives an increase of 5.5% and 10.2% in tensile strength and Young's modulus, respectively. An efficient mixing process that resulted in uniformly dispersed filler contributed to sufficient matrix-filler adhesion, hence improved the material's strength. As the reinforcing material, nanographene provides favorable stress transfer within the composite which leads to higher tensile strength and Young's modulus compared to non-reinforced sample.

Table 1: Tensile properties of nylon 6,6/NG

Sample (NG%)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation (%)
NG(0.0)	50.5	1.67	3.46
NG(0.3)	51.8	1.74	1.67
NG(0.5)	52.8	1.76	2.35
NG(1.0)	53.3	1.84	2.59

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However, the maximum elongation of composite decreases as nanographene filler content increases, indicating an increase in stiffness. The result shows that a small amount of NG filler could restrict the molecular mobility of composite, hence decreases its maximum elongation [8]. This is consistent with the increase of Young's Modulus with increasing filler content, indicating more resistance towards elastic deformation. The difference in fracture surface after the addition of 1.0 wt% of NG is shown in Figure 1.

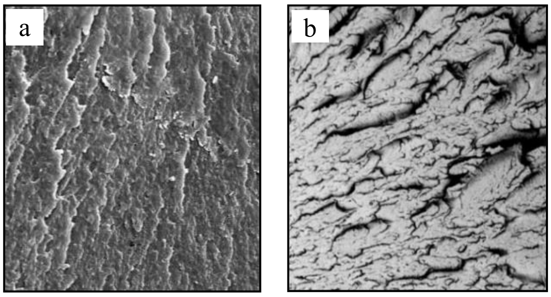

Figure 1 SEM micrograph of (a) nylon 6,6 and (b) nylon 6,6 added with 1.0 wt% NG.

3.2 Electrical Conductivity

Figure 2 clearly shows the electrical conductivity of nylon 6,6/NG nanocomposite increases drastically even with a minimal (0.3 wt%) nanographene filler addition. Like most polymers, nylon 6,6 behaves more as electric insulator. But with the presence as little as 0.3 wt% of conductive nanographene filler, its electric conductivity improved significantly due to formation of conductive path by nanographene through the material [3]. As the concentration of conductive filler increases, the filler nanoparticle generates closer contact to each other and spread the electric charge efficiently resulting in higher conductivity as reflected by the result of filler content addition from 0.3 to 1.0 wt%. As reported elsewhere, the electrical conductivity of the nanocomposite is strongly influenced by the synthesis method, type of nanofiller, type of polymer, disantaglement of filler agglomerates and dispersion of nanoparticle [2].

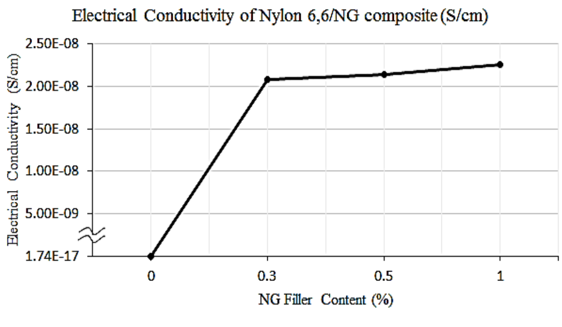

Figure 2 Electrical conductivity versus NG content.

4. CONCLUSIONS

The significant effects of nanographene filler to the tensile properties and electrical conductivity of nylon 6,6/NG composite have been observed in this study. Regarding tensile properties, increased content of nanographene filler resulted in higher tensile strength and Young's modulus, but lower % elongation at break of the composite sample. This finding shows that as the filler content increases, the resistance of elastic deformation increase due to restriction of its molecular mobility that creates stiffer material. Meanwhile, the electrical conductivity of the composite shows a linear increase with the addition of nanographene filler due to the conductive charge mobility of nanographene that transfers the charge from one particle to another.

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