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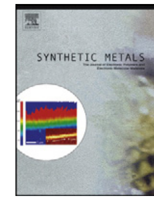

Electro-conductive composite fibers by melt spinning of polypropylene/polyamide/carbon nanotubes

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ABSTRACT

In this study, the blends of polypropylene/polyamide with carbon nanotubes (CNTs) have been prepared and melt spun to as-spun and drawn fibers. Thermal analysis showed that increasing the polyamide content, decreased the degree of crystallinity in the blends. Characterization of fibers showed that both conductivity and tensile strength have been improved by increasing the amount of polyamide in the blends as well as the melt blending temperature; furthermore, the morphology, electrical and mechanical properties of the blends were significantly influenced by adding 1 phr compatibilizer to the blend. The comparison between as-spun fibers and drawn fibers proved that although mechanical properties were improved after drawing, the electrical conductivity was decreased from the order of E−02 to E−06 (S/cm), due to applied draw-ratio of three.

1. Introduction

Creating new materials with unique properties and applicable in special fields as well as finding out the physical processes, which can provide the desired properties is the main goal of materials researchers. Nowadays, the needs for conductive polymer composites (CPCs) with higher conductivity and better mechanical properties have been increased [1].

The conductive polymer composites (CPCs) have some special properties such as good electrical conductivity, corrosion resistance, light weight and good mechanical properties. So, they are used in wide variety of technical application such as conductive and semi-conductive polymer fibers, corrosion resistant coatings, electrostatic dissipative materials (ESD), electronics, solar collectors and low temperature heaters [2–4]. CPCs usually consist of an insulating polymer matrix and conductive fillers. The conductive filler should pass the certain threshold concentration for transition and making the composite conductive by percolation phenomena [2]. This transition happens when the conductive filler flow through polymeric matrix pores slowly [5,6].

Different conductive filler types can be added to the matrix to obtain conductivity. Three most important conductive fillers are mentioned below:

a) Carbon based materials such as carbon black (CB) and carbon nanotubes (CNTs) [4,7,8].
b) Metal powders and their compounds like indium tin oxide (ITO) and aluminum zinc oxide (AZO) [4,9].
c) Inherently conductive polymers (ICPs) e.g. polypyrrole (PPy) and polyaniline (PANI) [10,11].

As mentioned above, carbon nanotubes (CNTs) can be used as conductive filler. CNTs are allotropes of carbon with a cylindrical nanostructure that firstly was discovered by Iijima [12]. Since then, CNT usages have been increased extremely in both academic and industrial applications [13]. These multifunctional materials have some unique characteristics that make them applicable for manufacturing different types of products such as nano-electronic and photo-voltaic devices, superconductors, electromechanical actuators, electrochemical capacitors, nano-wires, and nano-composite materials [3,7,14–21]. Electrical conductivity, thermal conductivity, low mass density and large aspect ratio (>1000) as well as high tensile modulus and strengths are some CNTs properties [7,8,22].

One target in conductive polymer composites production is decreasing the conducting percolation threshold to get a better conductivity at lower filler content. Many parameters such as type of CNTs, synthesis method, treatment and dimensionality as well as polymer type and dispersion method can affect on the percolation threshold [23]. On way to obtain better conductivity at lower filler content is using ternary polymer composites. These composites consist two immiscible polymer blends mixed with CNTs, which lead to decrease in percolation threshold and consequently improve the conductivity of the composite due to double percolation phenomena. The double percolation phenom-

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Table 1
Average electrical conductivity values for extruded rods.

Composition% (PP–COPA–CNT)	Conductivity (S/cm)					
	200 °C		220 °C		240 °C	
	0 phr Compat.	1 phr Compat.	0 phr Compat.	1 phr Compat.	0 phr Compat.	1 phr Compat.
65-30-5	0.000834	0.002544	0.004379	0.006839	0.003666	0.005444
55-40-5	0.001131	0.001491	0.007081	0.011022	0.005206	0.020287
47.5-47.5-5	0.000696	0.00124	0.002379	0.011726	0.009670	0.020818
40-55-5	0.001311	0.001355	0.005982	0.010563	0.013443	0.025925
30-65-5	0.000938	0.001404	0.006464	0.019755	0.028333	0.039234

ena refer to percolation of CNTs in one phase of matrix, which also percolates in another phase [2,7].

In this study, MWNTs were used as conductive filler and blended with polypropylene (PP) and polyamide (PA) using different blending temperatures. Then the blends were extruded into fibers using melt spinning technology to prepare as-spun and drawn fibers. Afterward, the extruded rods, as-spun and drawn fibers were investigated regarding conductivity and the fibers were examined regarding the mechanical strength. Moreover, thermal properties (using TGA and DSC) and morphology (using scanning electron microscopy, SEM) of extruded rods were studied. The goal of this study is to determine thermal, mechanical and electrical characteristics of conductive melt spun fibers prepared in different conditions and compositions.

Table 2
Average electrical conductivity values for as-spun fibers.

Composition% (PP–COPA–CNT)	Conductivity (S/cm)	
	0 phr Compat.	1 phr Compat.
65-30-5	0.003303[a]	0.003388[a]
55-40-5	0.013957[a]	0.014624
47.5-47.5-5	0.043062	0.040836
40-55-5	0.056581	0.067473
30-65-5	0.071958	0.080201

[a] These samples were melt blended at 220 °C due to their better conductivity than samples prepared at 240 °C, the melt blending temperature for other samples was 240 °C.

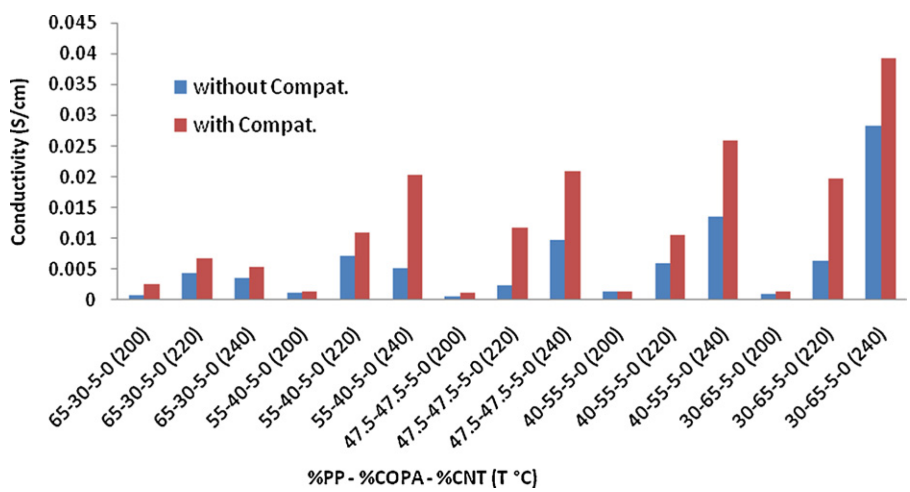

Fig. 1. Electrical conductivity of extruded rods made in different compositions.

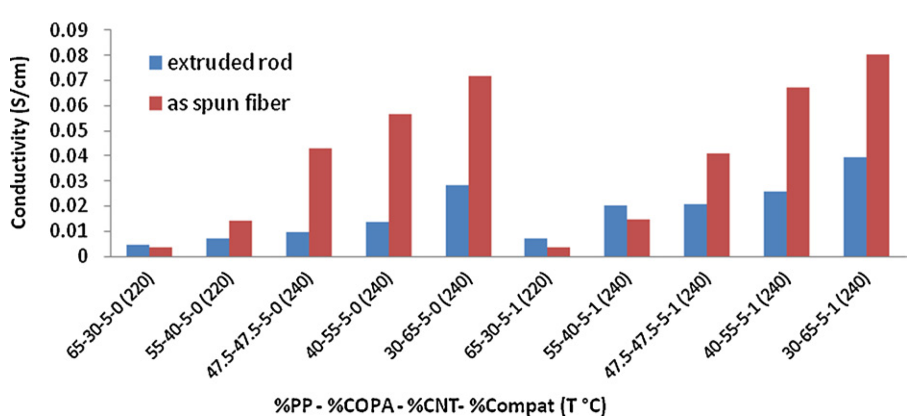

Fig. 2. Conductivity comparison between extruded rods and as-spun fibers.