POLYMER/CNT COMPOSITES AND FILAMENTS FOR SMART TEXTILES: MELT MIXING OF COMPOSITES

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ABSTRACT

Textile products are of great importance in the dissemination of newly developed communication devices and flexible electronics in conjunction with the advantages of covering the entire human body and being used all day long by all individuals in society.
Our research deals with melt spinning of carbon nanomaterial-based composites (CNCs) into electrically conductive filaments. By combining the various composite structures and property profiles with a conductive filler at high concentration, specific morphological structures can be achieved that offer a much higher potential for the development of new functional fibers for different smart textile applications.
This study aims to produce nanocomposites from polyamide (PA6) and polyethylene (PE) matrices with single-walled CNTs (SWCNTs) and multi-walled CNTs (MWCNTs) by using a small-scale mixing device that provides short mixing time, and material savings in the first stage of the research.

MATERIALS AND METHODS

The polymers as matrices used were PA6 and PE. The carbon-based nanofillers used were MWCNTs, SWCNT (pure), and an SWCNT matrix provided as a masterbatch with 90 wt% PE and 10 wt% SWCNTs. The polymer matrices and nanofillers used in this study are shown in Table 1.

Table 1. Polymer matrices and nanofillers used in this study

Material	Trade Name	Company
PA6	B27E	BASF AG, Ludwigshafen, Germany
PE	Evolue-H	Prime Polymer Co. Ltd., Tokyo, Japan
MWCNT	NC7000	Nanocyl S.A., Sambreville, Belgium
SWCNT	Tuball™	OCSiAl Ltd., Novosibirsk, Russia
SWCNT masterbatch	Tuball matrix 816 Beta	OCSiAl Ltd., Novosibirsk, Russia

Melt compounding of PA6/CNTs [1] was performed at a mixing temperature of 260 °C, a rotation speed of 250 rpm, and a mixing time of 5 min using a conical twin-screw micro-compounder DSM15 having a capacity of 15 ccm (Xplore Instruments BV, Sittard, Netherland). The extruded strands were cut into pieces of some millimeters length and compression molded into plates.
Melt compounding of PE/SWCNT was performed using micro-compounder DSM15 at a mixing temperature of 180 °C, a rotation speed of 20 rpm, and a mixing time of 5 min. After mixing, the material was led out as a strand using a 1 mm nozzle. Melt spinning ability was evaluated using a micro-scale winder (“Micro Fiber Spin Device” - Xplore Instruments BV, Sittard, Netherland) set up directly after the extruder nozzle and by drawing a monofilament of PE/SWCNT of at least 50 m. Fiber diameters ranged from 0.4 to 0.9 mm depending on SWCNT content.
To measure the electrical volume resistivity of PA6/CNT compression-molded plates a Keithley 6517a electrometer (Keithley Instruments, USA) combined with a self-constructed

4-point device was used. The electrical resistance of PE/SWCNT was measured directly on single filaments with a length of about 100 mm using a DT-61 digital multimeter from MASTECH (Multimeter Warehouse, Walnut, CA, USA).

RESULTS AND DISCUSSION

The electrical volume resistivity of polymer/CNT composites and filaments at a filler content of 0.1-10 wt % is given in Table 2.

Table 2: Electrical volume resistivity of polymer nanocomposites containing different CNTs

	Electrical Volume Resistivity (Ω cm)		
CNT Content (wt %)	**PA6/MWCNT***	**PA6/SWCNT***	**PE/SWCNT⁺**
0.1	-	3.89E+05	-
0.25	-	1.65E+04	-
0.5	2.95E+14	1.32E+03	-
1.0	1.07E+14	2.10E+02	-
2.0	9.15E+07	1.30E+02	-
3.0	1.35E+06	1.09E+02	-
4.0	1.66E+05	1.07E+02	-
5.0	9.43E+03	2.51E+01	-
8.0	-	-	1.1E+02
10	-	-	1.7E+03

*Measured on plates ⁺ measured on filaments.

The results of volume resistivity measurements show the significantly lower electrical percolation threshold of the PA6/SWCNT as compared to the PA6/MWCNT composites. The resistivity value of PA6/SWCNT achieved at the loading of 0.1 wt % already lower than 10^6 Ohm cm and at 0.25 wt % addition, values lower than 10^4 Ohm cm are reached. Similar resistivity values were achieved for PA/MWCNT loadings of 4-5 wt %. However, characterization of the state of macrodispersion has shown that the area of agglomerates is much larger in PA6/SWCNT composites compared to PA6/MWCNT composites.

The results of volume resistivity of PE/SWCNT filaments which loading was less than 8 wt % could not be measured because the percolation threshold has not been exceeded. This may be due to the worse CNT dispersion in PE even when using a masterbatch combined with the elongation of the network during the drawing of filaments, resulting in resistivity increase above the measuring range of the equipment.

CONCLUSION

PA6/SWCNT composites show lower electrical volume resistivity than PA6/MWCNT composites at the same loading. The PE composites, measured directly as filaments, need much higher SWCNT contents to reach similar resistivity values. The focus of futures studies will be to also investigate PA6 based filaments, to analyse the nanocomposite materials in more detail, and to systematically analyse the influencing parameters (compounding, melt-spinning, filtering, drawing) of the melt spinning process chain.

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REFERENCES

[1] Krause, B., Barbier, C., Levente, J., Klaus, M., & Pötschke, P. (2019). Screening of different carbon nanotubes in melt-mixed polymer composites with different polymer matrices for their thermoelectrical properties. Journal of Composites Science, 3(4), 106.