THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N°. 2 - 2015, ISSN 1453 – 083X

ELECTRICAL PROPERTIES CHARACTERIZATION OF VINYL ESTER RESIN FILLED WITH CARBON NANOTUBES

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ABSTRACT

In this paper the authors have done a characterization of the electrical properties of vinyl ester based nanocomposites containing different percentages of carbon nanomaterials

The carbon fillers used in this study were single wall carbon nanotubes (SWCNTs) and multi-wall carbon nanotubes (MWCNTs). Three weight percentages (0.10, 0.15 and 0.20) of each type of carbon nanotubes used as filler were added into the thermoset polymer matrix of vinyl-ester, resulting six nanocomposite materials.

The electrical properties were measured with TeraOhm 5 kV tester for all six composite materials along with neat vinyl ester resin. The experimental results show that, by the addition of multi-wall carbon nanotubes filler to the vinyl-ester matrix, the electrical properties of the nanocomposite material thus obtained were significantly improved. The electrical percolation threshold concentration for multi-wall carbon nanotubes based vinyl ester nanocomposite was 0.20 wt.%.

KEYWORDS: electrical properties, vinyl-ester resin, conductivity, single wall carbon nanotubes, multi-wall carbon nanotubes

1. Introduction

Due to their superior overall thermal, electrical and mechanical properties, carbon nanotubes filled polymer composites have been of great interest for industrial and research community in the last years [1, 2]. Most polymers are characterized as insulators regarding the electrical properties. This became a challenge for the members of the research community who are studying the way of improving the electrical properties of polymers by adding different materials as reinforcement [3, 4].

Carbon nanotubes are among the most common fillers used in polymer composites that already proved their ability to enhance electrical conductivity, by several orders of magnitude at low percolation threshold [5-7]. Even with very low concentrations, carbon nanotubes are able to form conductive networks mainly due to their capability of high conductivity [8-10].

The main factors that are influencing the electrical conductivity are closely related to the type of polymer matrix. The enhancement of electrical conductivity of the polymer matrix can be achieved by the proper choice of the type of filler and its amount, along with a good dispersion of the filler in the matrix [9, 11].

2. Experimental research

Vinyl ester resin, type Polimal VE-11 M, was used as polymer matrix. Two types of carbon nanotubes: single wall carbon nanotubes (SWCNTs) and multi-wall carbon nanotubes (MWCNTs) provided by Cheap Tubes Inc. Company have been added to vinyl ester thermoset polymer. The main properties of the carbon nanotubes used in this study are presented in Table 1.

For each type of nanocomposite, three weight percentages of nanomaterials (0.10 wt.%, 0.15 wt.% and 0.20 wt.%) were used, obtaining six nanocomposite materials. The procedure of obtaining the nanocomposite materials using the vinyl ester resin as matrix and carbon nanotubes as reinforcement was mechanical stirring. After the addition of carbon nanotubes into polymer matrix, the homogenization of the mixture has been performed by magnetic stirring at 600 rpm for one hour. After the mixture has been degassed using a vacuum pump, the methyl ethyl ketone peroxide has been added as catalyst, to start the polymerization process. The mixture was then homogenized at 600 rpm for 5 minutes and degassed again. The materials thus obtained have been molded and placed into an oven for 8 hours at 80 °C to complete the polymerization process.

Table 1. *Properties of carbon nanotubes*

Carbon nanotubes type	Purity [daN/mm^2]	Density [daN/mm^2]	Outer diameter [nm]	Inner diameter [nm]	Length [μm]	Specific surface [m^2/g]
SWCNTs	>90	2.1	1-2	0.8-1.6	5-30	407
MWCNTs	>95	2.1	8-15	3-5	10-50	233

Three specimens with round cross-section shape with diameter of 5 mm and length of 150 mm have been obtained by this method for all of the composite materials studied. All the nanocomposite materials along with the neat vinyl ester resin were tested with TeraOhm 5 kV tester (Fig. 1). In Figure 2 there is a picture of the position of the tester electrodes during the measurement.

Fig. 1. *TeraOhm 5 kV tester*

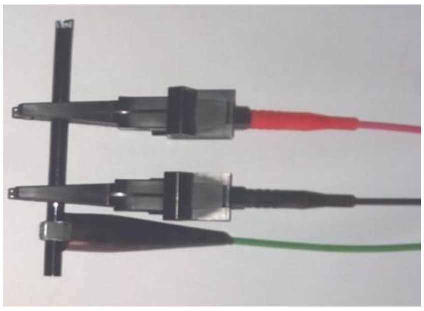

Fig. 2. *The position of electrodes during tests*

3. Results and discussion

The electrical conductivity results for the materials tested in this study are synthesized in the following graphs. The graphs show the calculated mean values of conductivity for the vinyl ester / CNTs composites.

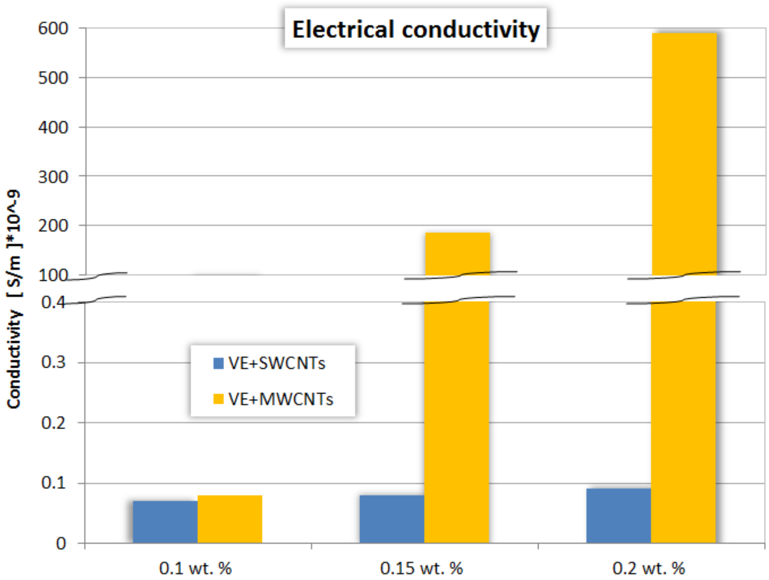

Fig. 3. *Electrical conductivity of vinyl ester/CNTs composites*

In Figure 3 the results of electrical conductivity for the two types of carbon filler based vinyl ester nanocomposite are represented together. For the 0.10 weight percentage of filler content, the conductivity is almost the same for the single and multi-wall carbon nanotubes / vinyl ester composite. In the case of 0.15 wt.% filler content, the value of the conductivity increases by about 200% for the multi-wall nanocomposite compared to the single wall / vinyl ester composite. The difference is of several orders of magnitude for 0.20 wt.% filler content.

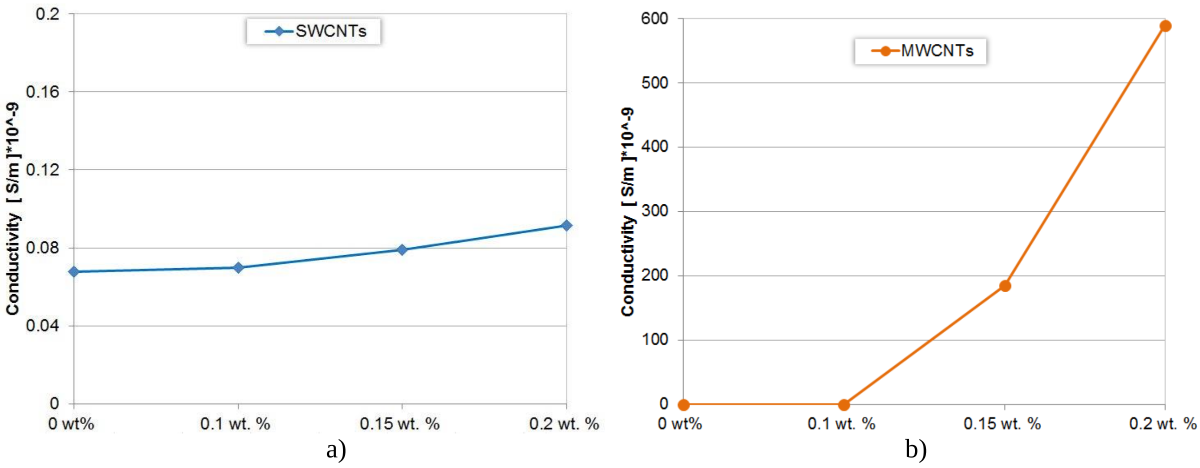

Fig. 4. *The tendency of electrical conductivity of nanocomposite of vinyl ester filled with different weight percentage (0 wt.%, 0.10 wt.%, 0.15 wt.% and 0.20 wt.%) of: a) single wall carbon nanotubes and b) multi-wall carbon nanotubes*

The filler content influence over the electrical properties for vinyl ester polymer matrix is represented in Figure 4. There is almost no difference between the 0.10 wt. % SWCNTs filler content nanocomposite and the neat vinyl ester (0 wt.% filler) electrical conductivity results. The addition of 0.15wt% and 0.20 wt.% of single wall carbon nanotube increases the electrical conductivity by approximately 14% and 27 % respectively. The increasing of electrical conductivity for addition of SWCNTs up to 0.20 wt.% content brings almost no changes in the insulating characteristics of the vinyl ester polymer matrix. In the case of multi-wall carbon nanotubes, an increase of 18% in electrical conductivity has been achieved for 0.10 wt.% of content, compared to 0 wt.% of filler. The enhancement of several orders of magnitude of electrical conductivity has been obtained for the above 0.15% weight percentage level content of multi-wall carbon nanotubes / vinyl ester composite.

4. Conclusions

Carbon nanotubes have already proved their capability as fillers in multiple multifunctional nanocomposites. In terms of electrical properties, an important factor is the percolation threshold linked closely by the dispersion of the nanoparticle in vinyl ester matrix.

According to the experimental results, multi-wall carbon nanotubes can be successfully used as fillers along with vinyl ester polymer as matrix. The observation of an improvement of electrical conductivity by several orders of magnitude at very low percolation threshold could be observed mainly on multi-wall carbon nanotubes for more than 0.15 wt.%. For single wall carbon nanotubes fillers, the results show a slight increase by 0.15 wt.% and 0.20 wt.%, leading to the conclusion that the percolation threshold for this case was not achieved. The electrical percolation threshold concentration was obtained for MWCNTs/vinyl ester for 0.20 wt. % content of carbon nanotubes.

Acknowledgement

The work of Georgel Chirita was supported by Project SOP HRD /159/1.5/S/138963 – PERFORM.

The work of Alina Cantaragiu has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/132397.

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