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Orientation and Dispersion of Carbon Nanotubes in Unsaturated Polyester Matrix

Sun Chang
Associate Professor, School of Material Science and Engineering, Shandong Jianzu University, Jinan, China

Abstract:
In this paper, the dispersion and orientaton of Carbon nanotubes (CNTs) in unsaturated polyester matrix were studied with reciprocating injection process. The Orientation state of carbon nanotubes in unsaturated polyester matrix was characterized using scanning electron microscope (SEM). The experimental results show that multi-wall carbon nanotubes (MWNTs) in the composites are well dispersed and orientated along the reciprocating motion direction of the mold. The process proposed here for dispersion and orientaton of CNTs in a polyester matrix has a good application foreground.

Keywords: *multi-wall carbon nanotubes, Dispersion, Alignment, reciprocating injection process*

1. Introduction

Carbon nanotubes (CNTs) have attracted considerable scientific attention since their discovery in 1991{Iijima, 1991 #29}, because of their exceptional electrical, magnetic, mechanical, and thermal properties{Hone, 2000 #30;Xie, 2000 #31}. As a result, this molecular scale wires have a number of application, such as energy storage and energy conversion devices; field emission displays and radiation sources, hydrogen storage media, nano-sized semiconductor devices, nanoprobes, and interconnects, molecular computers, as well as ideal additives for structural and functional composites{Lahiri, 2012 #32;De Volder, 2013 #33;Roxbury, 2012 #34;Sathiya, 2011 #35;Lota, 2011 #37}. Composites of carbon nanotubes in polymeric matrices are considered as very promising materials in the research and industrial communities{Hewitt, 2012 #36}. CNTs polymer nanocomposites possess high stiffness, high strength, and good electrical conductivity at relatively low concentrations of CNTs filler{Kim, 2014 #38}. Compared to other fiber reinforced composites, these enhancements ultimately stem from the distinct properties of the CNTs themselves. For example, CNTs exhibit modul and tensile strength level in the rang of 200-1000GPa and 200-900MPa, respectively{Salvetat-Delmotte, 2002 #39}. CNTs have diverse electrical properties, capable of acting as metallic-like conductors or having characteristics of a semiconductor from the distortion or chirality of the graphite littice. On the side, CNTs have very large aspect ratios, as high as 100-1000{Pötschke, 2002 #40}. Such special properties make CNTs excellent additives for polymer and other matrices in order to achieve the superior properties. CNTs have been dispersed in more than 20 polymer matrix system, including semi-crystalline, and amorphous thermoplastics, thermosetting polymers, water soluble polymers, liquid crystalline polymers, and conjugated polymers to form various composites. Because of the unique one-dimensional structure of carbon nanotubes, a high anisotropy is expected for carbon nanotubes-polymer composites. Similar to short fiber-reinforced composites, CNT orientation state determines the anisotropic functionality of CNTs composites. Thostenson et al. found if MWNTs are orientated in one direction, storage modulus improved by 49%, compared to 10% in random orientated MWNT/PS composite{Thostenson, 2002 #41}. Liang et al. also found much higher electrical conductivity in aligned SWNTs buckypaper than for the random case{Fan, 2005 #42;Wang, 2008 #43}. In addition, due to small size and large surface area, CNTs are strongly affected by Van de Waal's forces which give rise to the formation of aggregates, which in turn, make dispersion of CNTs difficult in matrix. Therefore, preparation of high performance CNTs composites should take into consideration the alignment of CNTs in a certain direction, addition to the dispersion of them in the matrix. Hence, CNTs orientation state and fine dispersion play a crucial role in defining the internal microstructure that will influence the composite physical and mechanical properties.

In the present study, the oriented MWNTs/unsaturated polyester composites were successfully prepared by reciprocating injection process using a set-up designed to disperse and align multi-wall carbon nanotubes (MWNTs) in polymer or another matrix. The Orientation state of MWNTs in the unsaturated polyester matrix was characterized using scanning electron microscope (SEM). Currently, we are carrying out tests to characterize the electromagnetic, electrical, and mechanical properties of the oriented MWNTS/unsaturated polyester composites, and the results will be reported separately.

2. Experimental

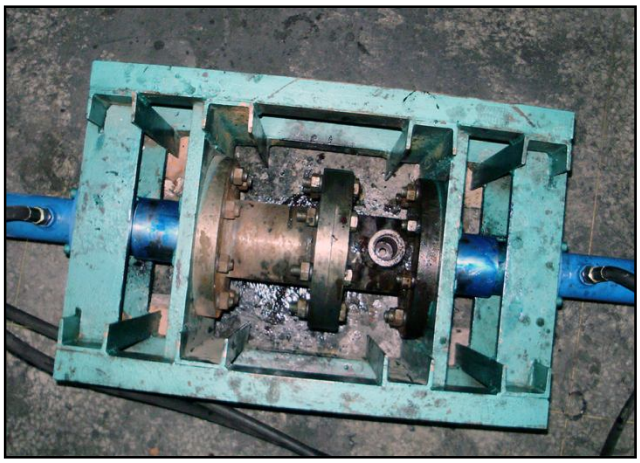

Figure 1: The photo of equipment for the reciprocating injection process

The oriented MWNTs/unsaturated polyester composites were prepared by reciprocating injection process using a set-up designed to disperse and align multi-wall carbon nanotubes (MWNTs) in polymer or another matrix. Figure 1 is the photo of equipment for the reciprocating injection process. MWNTs were purchased from Shenzhen Nanoport Company, China, and the purity was claimed to be 95% by producer. Fig. 2 shows a TEM image of MWNTs, which was supplied by producer. An unsaturated polyester resin (UPR 191#) used in this study contains 35% styrene and 65% unsaturated polyester prepolymer by weight. Cobalt octoate (CoOct, a mineral spirit solution containing 6.0 wt% active cobalt) was employed as the promoter to decompose the initiator at low temperatures. The initiators used in this study were methyl ethyl ketone peroxide (a single component initiator). UPR, its curing agent and the promoter are purchased commercial reagents. All materials were used as received without further purification in order to mimic the industrial applications.

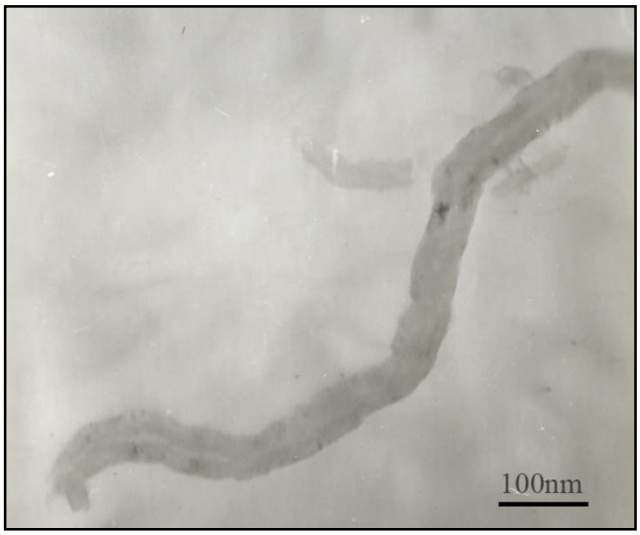

Figure 2: TEM image of the as received MWNTs

A weighed amount of MWNs, Cobalt octoate and methyl ethyl ketone peroxide were added into a weighed amount of UPR to form a viscous mixture under stirring. The weighed ratio between PUR, MWNs, Cobalt octoate and methyl ethyl ketone peroxide used was 100:4:2:5. The mixture was quickly poured into a syringe pump of the set-up made of two biconnected pistons. In order to form a homogeneous mixture where MWNTs was dispersed and straightened the mixture in the syringe pump was injected into the other one, and then injected back into the original pump, as shown schematically in fig. 3(1). After reciprocating motion was perform for 50 times, the mixture then was injected slowly through a thin tube into a mold that was in the state of reciprocating motion at the speed that was more or the same as the flow speed of the mixture at the tip of thin tubes, as shown schematically in fig. 3(2). The composite was obtained after the UPR cured.

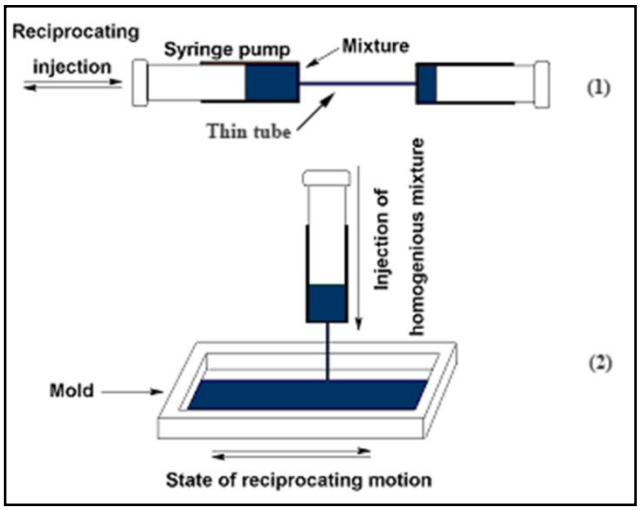

Figure 3: Schematic representation of (1) dispersion of MWNTs, and (2) oriention of MWNTs and moulding by casting

The orientation state of carbon nanotubes in unsaturated polyester matrix was characterized using scanning electron microscope (SEM, JSM-6700F). The sample taken from directly from the as prepared composite was investigated by cutting film with a razor blade which causes a fracture. SEM images were taken of the fractured region along the direction of the mold motion.

3. Results and Discussion

It was interest to explore the morphology of the oriented MWNTs/unsaturated polyester composite. Figure 4 shows SEM photomicrograph of fracture surface of the oriented MWNTs/unsaturated polyester composite along the direction of the mold motion. The image shows that the MWNTs are oriented preferably and exhibits a good dispersion. As could be expected, MWNTs in the matrix had a tendency to orientate in the direction of the flow, which was confirmed by the image of SEM. The orientation of MWNTs occurred as a result of the extrusion process, and meanwhile the aggregation or entanglement of MWNTs were destroyed by the shearing force from flow of the mixture. We suppose that factors that effect on the orientation and dispersion of MWNTs in the matrix include the diameter and length of the thin tube formed shear flow, the matrix viscosity, etc.

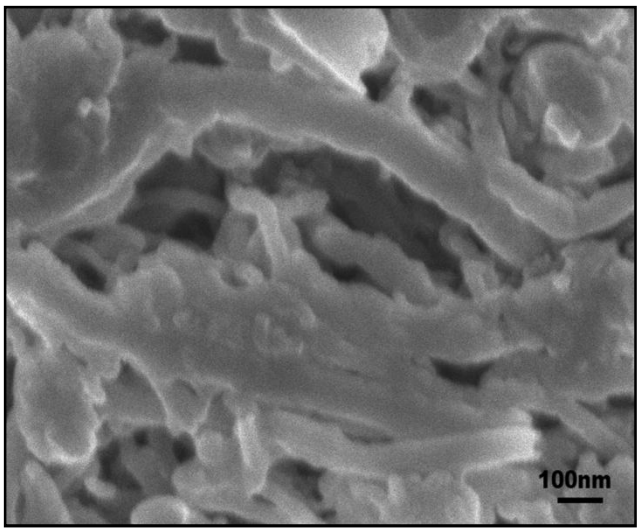

Figure 4: SEM photomicrograph of fracture surface of the oriented MWNT-unsaturated polyester composite along the direction of the mold motion.

4. Conclusion

MWNTs/unsaturated polyester composite has been successfully prepared by reciprocating injection process using a set-up designed to disperse and orient MWNTs in the polymer matrix. The orientation dispersion of MWNTs was characterized by scanning electron microscope (SEM). From the SEM image it can be seen that MWNTs in the composite are well orientated along the reciprocating motion direction of the mold. The process proposed here for dispersion and orientation of CNTs in a polyester matrix shows practicality for the preparation of oriented-CNTs composites.

5. Acknowledgements
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