Characterizing the reinforcement mechanisms in multiwall nanotube/polycarbonate composites across different length and time scales

by

Renée Kelly Duncan

An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

In Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Engineering Science

The original of the complete thesis is on file

in the Rensselaer Polytechnic Institute Library

Examining Committee:

____

Linda S. Schadler, Thesis Adviser

____

Thierry A. Blanchet, Member

____

Rahmi Ozisik, Member

____

Nikhil A. Koratkar, Member

Rensselaer Polytechnic Institute

Troy, New York

December 2008

Abstract

Characterizing the reinforcement mechanisms in multiwall nanotube/polycarbonate composites across different length and time scales

Renée Kelly Duncan

Engineering Science Department

Rensselaer Polytechnic Institute

The enthusiasm and interest in the potential properties of nanotube (NT)/polymer composites are based on several factors, including the potential for unsurpassed enhancements in mechanical properties together with electrical, thermal and optical properties. Using multiwall nanotubes (MWNTs) grown to a long aspect ratio, the study found that fragmentation tests can be completed in a similar manner to traditional fiber composites. It was found that the fragmentation length does not depend on the angle of the nanotube to the loading direction hence the ISS does not change with the orientation angle of the nanotube in the composite. A critical aspect ratio of 100 and 300 for untreated nanotubes (ARNT) and treated nanotubes (EPNT), respectively was also measured. For nanotubes that are well dispersed in the polycarbonate, it was observed at a critical angle of 60° that there was a change in failure mechanism from pullout to fracture of the nanotubes due to bending shear. Because the tensile strength of a MWNT is

unknown a cumulative distribution was used to characterize the relative interfacial shear strength as a function of nanotube chemical modification.

The second goal of this thesis is to use Dynamic Mechanical Thermal Analysis (DMTA) with controlled aspect ratios of multiwall nanotubes (MWNT) to isolate and quantify the effects of the interfacial region on modulus enhancements in nanotube-reinforced composites. One major finding of this study was that the shortest aspect ratio showed a significantly broadened relaxation spectrum than the longer aspect ratio nanotubes, despite the longer aspect ratio nanotubes being more percolated at the given weight percent. There is also a direct correlation between the free space parameter of the short aspect ratio nantoubes network and broadening of the relaxation spectrum, concluded to be a result of increased interaction of the interfacial polymer. The study found agreement with the premise that at a constant filler weight percent, as the aspect ratio changes there is similarity in the volume of interfacial polymer and broadening of the relaxation spectrum was due to the critical inter-nanotube distance. Thus, interaction of the interfacial polymer regions where nanotubes were in close proximity lead to an effective larger interfacial polymer.