COLLEGE OF ENGINEERING AND COMPUTER SCIENCE
FLORIDA ATLANTIC UNIVERSITY

Announces the Ph.D. Dissertation Defense of

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for the degree of Doctor of Philosophy (Ph.D.)

"Enhancing Fracture Toughness and Thermo-Mechanical Properties of Vinyl-Ester Composites Using a Hybrid Inclusion of Both CNT and GNP"

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777 Glades Rd., Engineering West (EW), 187
Boca Raton, FL

DEPARTMENT: Ocean and Mechanical Engineering

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ABSTRACT OF DISSERTATION

Enhancing Fracture Toughness and Thermo-Mechanical Properties of Vinyl-Ester Composites Using a Hybrid Inclusion of Both CNT and GNP

We report a method of increasing fracture toughness (K_{IC}) and strain energy release rate (G_{IC}) of vinyl-ester (VE) matrix by adopting a hybrid (dual) reinforcement strategy. The idea of using this strategy was to trigger intrinsic polymer-nanoparticle interaction such as carbon nanotube (CNT) pull-out and interface sliding to enhance energy absorption during fracture. Additionally, we included a second reinforcement, graphene nanoplatelets (GNP), to promote crack-deflection, crack bridging and cross-linking density. Both reinforcements were dispersed into the polymer in three states: non-functionalized (nf>); functionalized with COOH (f>); surface-treated with Triton X-100 (TX100). We embarked on numerous experiments with many combinations of these variables.We measured K_{IC} and G_{IC} using ASTM D5045-14. We conducted an exhaustive iterative investigation with three systems (f>CNT-VE; f>GNP-VE; f>CNT-f>GNP-VE) to determine the best weight-percentage for the nanocomposite system that produced the highest K_{IC} and G_{IC} values when compared to neat-VE. We found that 0.5wt% f>CNT with 0.25wt% f>GNP in the VE matrix resulted in the highest fracture toughness values and was termed the optimized hybrid nanocomposites (OHN) system. Subsequently, we explored further increasing the K_{IC} and G_{IC} of OHN through altering the nanoparticle surface characteristics, which led to four OHN groups: f>CNT-f>GNP-VE; f>CNT-f>GNP-TX100-VE; nf>CNT-nf>GNP-TX100-VE; nf>CNT-nf>GNP-VE. We discovered that the OHN group with non-functionalized nanofillers that were TX100 surface treated (0.5wt%nf>CNT-0.25wt%nf>GNP-TX100-VE) generated the greatest improvements in K_{IC} and G_{IC}. Ultimately, we observed that the K_{IC} of neat-VE increased by 65%, from 1.14 to 1.88 MPa*($m^{½}$). The improvement in G_{IC} was even greater with an increase of 166%, from 370 to 985 J/(m^2). Differential scanning calorimetry (DSC) and dynamic mechanical analysis (DMA) studies showed a minor shift in glass transition temperature (T_g) by up to 8°C when comparing neat-VE specimens to OHN specimens. A similar increase in maximum thermal decomposition temperature (T_p) of up to 8°C was observed through thermogravimetric analysis (TGA) and derivative TGA (DTG). Scanning electron microscope (SEM) studies revealed that the source of improvements in fracture toughness and thermal properties was primarily the three-dimensional hybrid nanostructures (3DHN) that formed by binding CNT and GNP together, which caused an increase in nanoparticle surface area and inhibited agglomerations.

BIOGRAPHICAL SKETCH
Born in West Palm Beach, Florida
B.S., University of Florida, Gainesville, Florida, 2007
M.E., University of Florida, Gainesville, Florida, 2010
Ph.D., Florida Atlantic University, Boca Raton, Florida, 2018

CONCERNING PERIOD OF PREPARATION & QUALIFYING EXAMINATION
Time in Preparation: 2013 – 2018

Qualifying Examination Passed: Fall 2013

Published Papers:

Gapstur, C., Mahfuz, H., Hashemi, J., & Terentis, A. (2018). Enhancing Fracture Toughness and Stress Energy Release Rate of Vinyl Ester Matrix Using Dual Reinforcement of CNT and GNP. *MRS Advances,* 1-7. doi:10.1557/adv.2018.330.

C. Gapstur, H. Mahfuz, J. Hashemi and A.C. Terentis, "Enhancing Fracture Toughness and Stress Energy Release Rate of Vinyl-ester Matrix Using Dual Reinforcement of CNT and GNP", *2017 MRS Fall Meeting and Exhibit*, Nov. 26–Dec. 1, 2017, Boston, MA, USA, Poster Presented at the Conference.

C. Gapstur, H. Mahfuz and A.C. Terentis, "Investigating Fracture Toughness Behavior of CNT and GNP Reinforced Vinyl-ester Resin by Altering Surface Characteristics of the Nanoparticles", *2018 TechConnect World Innovation Conference and Expo*, May 13-16, 2018, Anaheim, CA, USA, Oral Presentation at the Conference.

Gapstur, C.M. & Mahfuz, H. (2018). Investigating Fracture Toughness Behavior of CNT and GNP Reinforced Vinyl-ester Resin by Altering Surface Characteristics of the Nanoparticles. *TechConnect Briefs*, Advanced Materials, (1), 120-124.