Carbon Nanofibers (CNF) & Carbon Nanotubes (CNT) Enhanced Micro-Fiber Polymer Composites (Hybrid Nano-/Micro- Fibers Reinforced Polymer Composites)

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Why Hybrid Nano-/Micro- Fibers Reinforced Polymer Composites?

Conventional polymer composite materials reinforced by continuous fibers have excellent in-plane strength, but are usually weak against matrix-dominated failures. The Carbon Nanofibers (CNF) and Carbon Nanotubes (CNT) have extraordinary mechanical, electrical, and thermal properties thus become excellent additive to the polymer matrix for enhancing the matrix-dominated properties of the conventional micro-fiber polymer composites. The expected improvement can be in mechanical, electrical, and thermal performance.

How to Manufacture the Hybrid Nano-/Micro- Fibers Reinforced Polymer Composites?

Since CNF and CNT have very small diameters (from 1 nanometer to 150 nanometers). They can be chemically treated and mixed with resin then followed by infusing the resin-nanoparticle mixture into the micro-fiber preform. This kind of processes is categorized as Liquid Composite Molding (LCM) and two sub-branches of LCM have been customized and used in our group for manufacturing the hybrid nano-/micro- fibers reinforced polymer composites. They are Resin Transfer Molding (RTM) and Vacuum Assisted Resin Transfer Molding (VARTM). The RTM and VARTM procedures to manufacture the hybrid nano-/micro- fibers reinforced polymer composites are illustrated in Figure 1 and Figure 2. More information about processing parameters and chemical treatment procedures can be found in the given references [1-7].

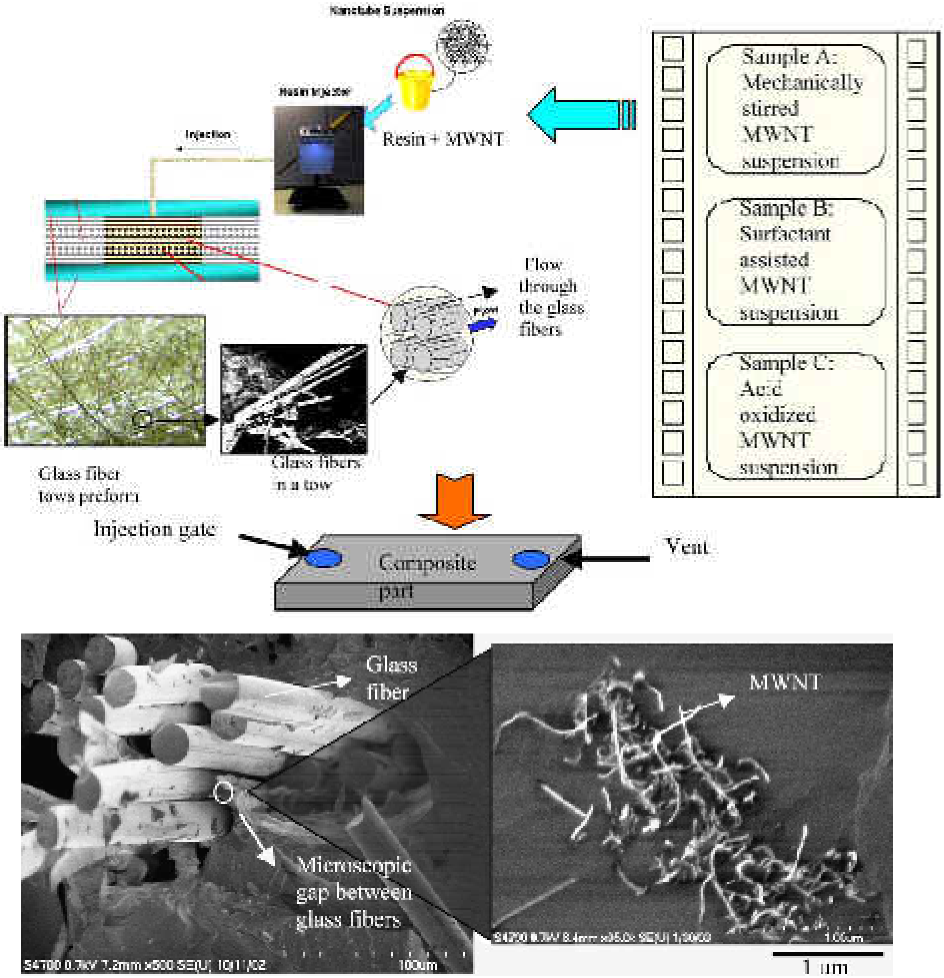


Figure 1. Resin Transfer Molding for Manufacturing Hybrid Nano-/Micro- Fibers Reinforced Polymer Composites [1,2]

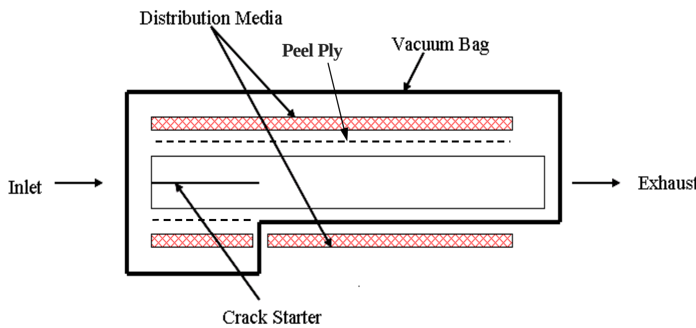


Figure 2. Vacuum Assisted Resin Transfer Molding (VARTM) Process to manufacture Hybrid Nano-/Micro-Fibers Reinforced Polymer Composites [3-6].

Significant Property Improvement?

One of major challenges in using high performance micro-fiber reinforced polymer composites is the "delamination". Delamination of the fiber reinforced composite lamina can significantly weaken the composite structure, particularly during impact loading. Many different approaches have been used to increase the resistance of composites to delamination by composite industry and one of the performance indexes is the critical energy release rate (G_IC) of mode-I delamination (G_IC). Our group has performed mechanical tests to characterize the critical energy release rate (G_IC) of mode-I delamination of the hybrid nano-/micro- fiber reinforced polymer composites and consistently observed about 100% improvement in the delamination performance when 1wt% of CNF were dispersed into the polyester resin matrix and infused into the glass fiber preform (see Figure 3). Figure 4 and Figure 5 show the fracture surfaces of the hybrid composite and the conventional composite specimens after delamination tests and the comparison in G_IC values. Other matrix-dominated property improvements are also experimentally investigated in our group and new results will be updated.

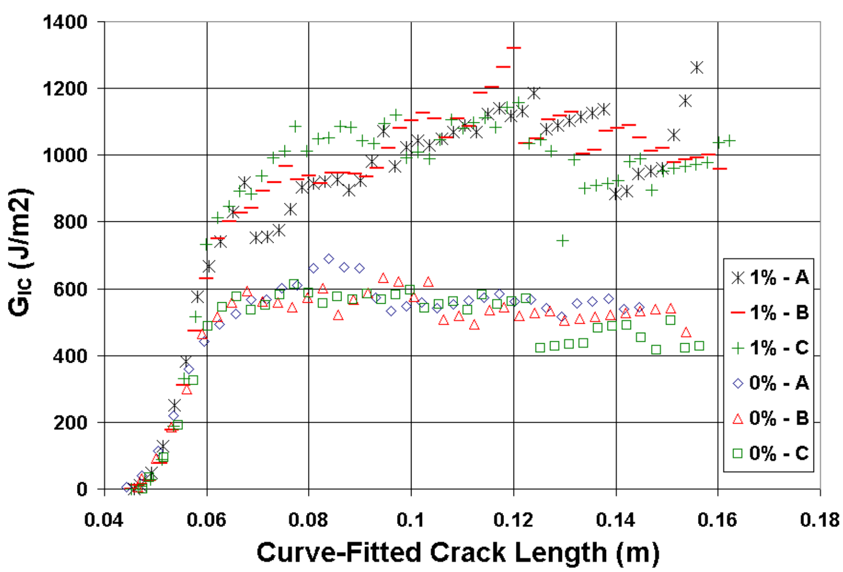
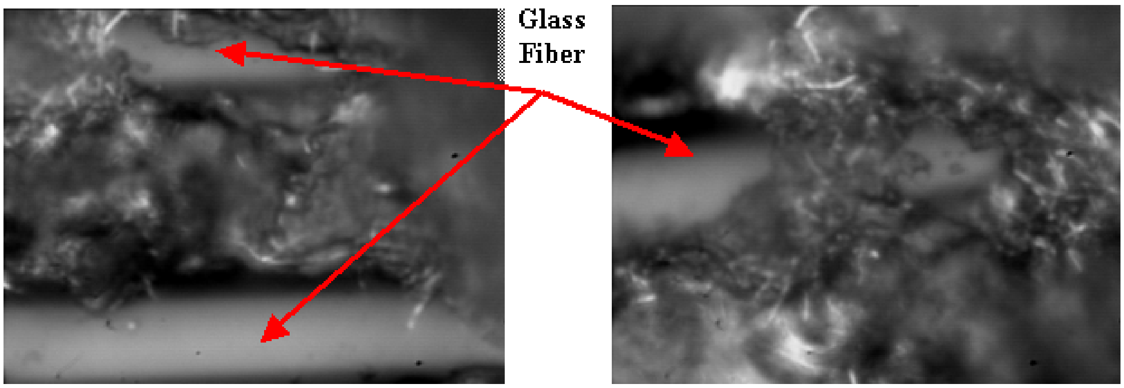


Figure 3. Mode-I delamination resistance curve. [3-6]



(a) (b)

Figure 4. Delamination surfaces of 1wt% CNF toughened glass fiber/polyester composite (a) near the injection gate; (b) near the vacuum gate. [3-6]

Figure 5. Fracture surface of the pure glass fiber/polyester composite specimen. [3-6]

Another significant property improvement is in the dimensional accuracy of the composites part. A L-shaped part has been manufactured with the original mold cavity angle 90° will change its angle to less than 90° after the part is de-molded as shown in the below figure. Such phenomenon is called "spring-in" and the angle change is called "spring-in angle" as define in Figure 6. We have conduct experiments and successfully reduced the spring-in angle by adding CNF into the resin as shown in Figure 7 [7]. Currently, we are using finite element analysis to model the spring-in phenomena so we can predict the spring-in angle.

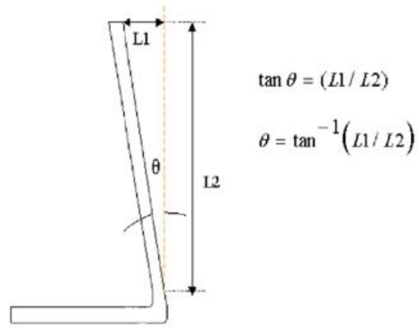


Figure 6. Calculation of spring-in angle. [7]

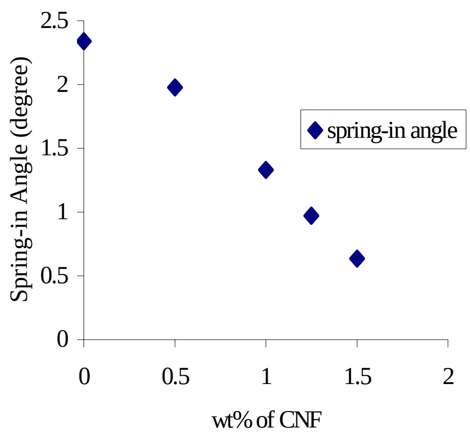


Figure 7. CNF load vs. spring-in angle. [7]

References

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