CARBON NANOTUBE – BASED DAMAGE SENSING FOR COMPOSITE MATERIALS

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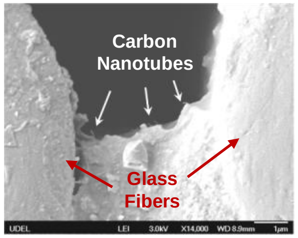
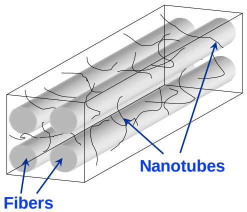
INTRODUCTION

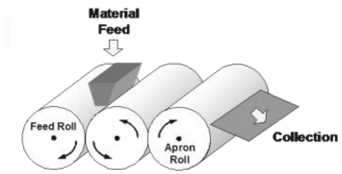
The mechanical deformation of carbon nanotubes and their composites is coupled with changes in electrical resistivity. Thus, carbon nanotubes are excellent candidates for sensors



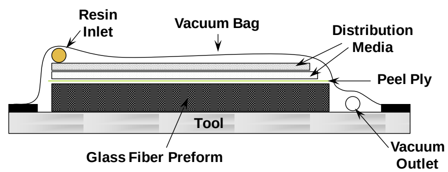


The change in reinforcement scale from conventional micron-sized fibers to carbon nanotubes with nanometer sized diameters enables unique opportunity for the creation of multifunctional *in situ* sensors

PROCESSING OF NANOTUBE / FIBER HYBRID COMPOSITES



Carbon nanotubes were dispersed into epoxy resin using a high-precision calendering approach and controlling the gap between the rollers from 50μm to 5μm.

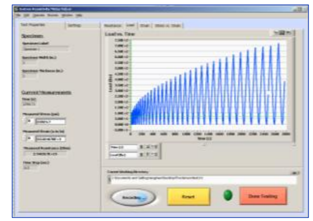


Composite laminates were manufactured with ply layups of $[0/90_n/0]$ using a conventional vacuum-assisted resin transfer molding technique

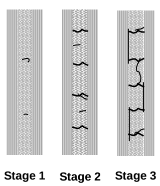
MECHANICAL / ELECTRICAL CHARACTERIZATION

- Quasi-static monotonic and progressively increasing cyclic loading conditions
- Specimen edge replicas taken to view microstructural damage accumulation at each cycle
- Acoustic emission monitored to validate damage sensing

- Simultaneous resistance, strain and load data integrated in a customized LabView® data acquisition system

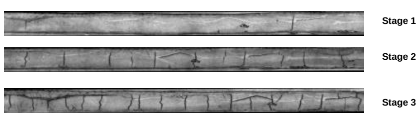


DAMAGE ACCUMULATION

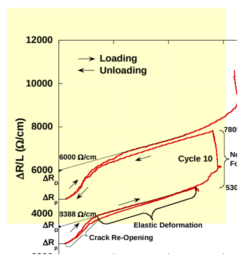


- Damage accumulation in cross-ply laminates has been widely studied and grouped into specific stages: crack initiation, transverse cracking and delamination.

Optical Micrographs of Edge Replicas

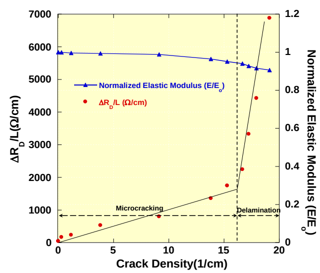


CYCLIC LOADING TESTS



- There is substantial hysteresis in the post-damage resistance-strain curves
- Opening and closing of cracks result in nonlinearity at low strain
- Damaged resistance ($\Delta R_D/L$) is proposed as a quantitative measure of damage

RESISTANCE BEHAVIOR



- $\Delta R_D/L$ increases linearly with increasing crack density
- Delamination results in large changes in resistance with little increased accumulation of transverse cracks.

JOURNAL PUBLICATIONS

1. LM Gao, ET Thostenson, ZG Zhang, TW Chou, "Sensing of Damage Mechanisms in Fiber-Reinforced Composites under Cyclic Loading Using Carbon Nanotubes," *Advanced Functional Materials*, 19(1) 123-130 (2009).
2. LM Gao, ET Thostenson, ZG Zhang, TW Chou, "Coupled Carbon Nanotube Network and Acoustic Emission Monitoring for Sensing of Damage Development in Composites," *Carbon*, 47(5) 1381-1388 (2009).

ACKNOWLEDGEMENTS

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