

Epoxy/Carbon Nanotubes Nanocomposites – Enhanced Stiffness & Fracture Toughness at Low Nanotube Content

Content

- Methodology
- Manufacturing – Materials, Methods
- Dispersion
- Tensile Properties
- Fracture Toughness
- Micro-mechanical Mechanisms
- ILSS of FRPs with CNT-modified epoxy

Objectives

Evaluation of the reinforcing effect of CNTs in an epoxy matrix:

- Interfacial bonding (functionalisation)
- Dispersion
- Characterization (properties, dispersion, adhesion)

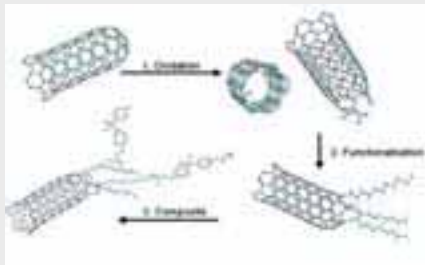
Methodology

Interfacial bonding:

- CNT/Polymer-Interface is weak
- Functionalisation
- Reaction with matrix-polymer
- Formation of covalent bonds
- Improved Interface

Dispersion:

- Sonication (Ultra-sound)
- Shear-mixing
- Functionalisation improves dispersibility of CNTs



Manufacturing

Materials:

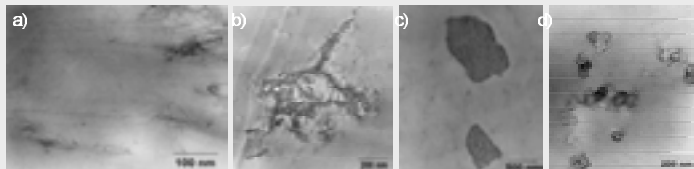
- CVD-Nanotubes from Nanocyl®(B)
- Carbon Black Printex XE2 Degussa (D)
- Epoxy L135i/H137i MGS GmbH (D)

Manufacturing:

- Calendering - Exakt 120 S
- Sonication - Bandelin Sonoplus HD2200
- Resin Transfer Moulding



Dispersion

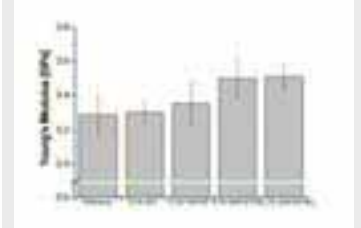
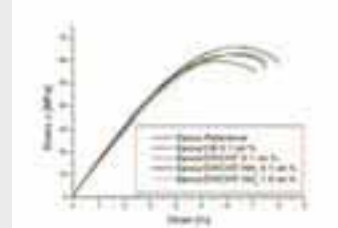


TEM-Images (Philips EM 400):

- Observed dispersion of DWCNTs in epoxy (Calendering) – isolated DWCNTs
- Small agglomerates show exfoliated structure (Calendering)
- Larger and condensed agglomerates (Sonication)
- Carbon black dispersed into aggregate structure and primary particles (~30 nm)

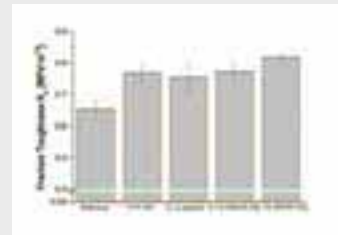
- Calendering: More efficient and up-scalable
Exfoliation of agglomerates ⇒ Impregnation of CNTs with epoxy matrix
- Sonication: Energy input locally ⇒ Damaging and rupture of CNTs

Tensile Properties



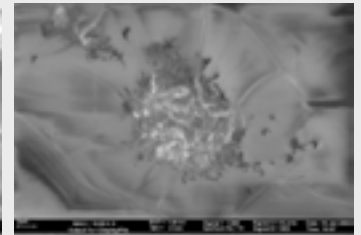
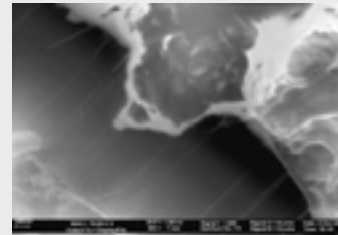
- Increased stiffness already at 0.1 wt.% DWCNT-NH₂ content
- Carbon black do not affect stiffness at this content

Fracture Toughness



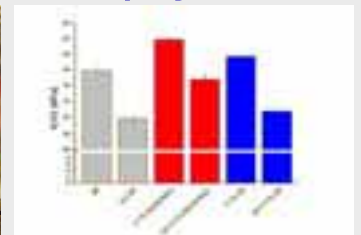
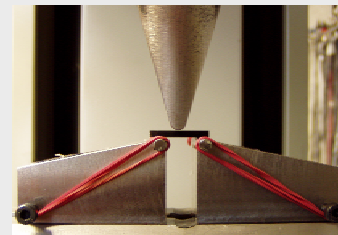
- Increased fracture toughness observed for all nano-fillers

Micro-mechanical Mechanisms



- Crack deflection at agglomerates is dominating mechanism
- Bridging-mechanism observed – stronger influence at higher CNT-contents?

ILSS of FRPs with CNT-modified epoxy



- 0.1 wt.% DWCNTNH₂ increases ILSS by 16%

Summary

- Effective dispersion of CNTs using a mini-calander
- Method applicable to technical demands
- Increased Young's Modulus at 0.1 wt.% DWCNT-NH₂
- Fracture toughness increased for all nano-fillers
- Improved ILSS in FRPs with CNT-modified epoxy

Acknowledgement

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