




# HYBTONITE®

## Research Summary – Science Behind HYBTONITE®

Several studies [1–4] have shown considerable enhancements in mechanical and electrical properties in CNT-epoxy nanocomposites compared to neat epoxy. For example, dispersing of 0.2—10 wt % CNTs into epoxy resin results in modulus increase up to 50 % [5] and strength increase up to 18 %. [6] However, in many studies even better results have been suggested with proper dispersion of CNTs. [7–18] Amroy Europe Ltd has solved the difficulties of dispersing CNTs into resins by proper mechano-chemical treatment of carbon nanotubes.

With our patented HYBTONITE®-technology we are dispersing CNTs into several resins and curing agents with scalable and cost effective processes.

## What is the difference between HYBTONITE® and other CNT dispersions?

Not only that our mechano-chemical process makes CNT dispersion easy, it also attaches functional chemical groups covalently to the CNTs. When epoxy resin is cured, these functional groups take part in the polymerization process creating a strong hybrid structure between matrix and CNTs.

*Figure 1. Schematic picture of polymerization of carbon nanotubes inside epoxy matrix*

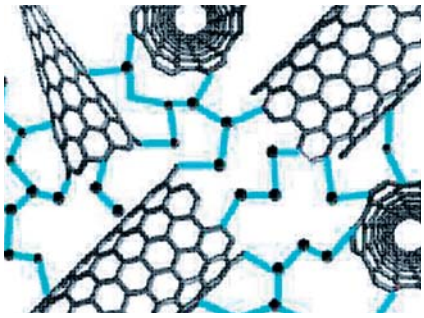

*Figure 1*

## How does it work?

Dynamic stress creates microcracks inside epoxy matrix. These microcracks are starting points of matrix failure. Bridging the cracks with strong nanofibers like CNTs, failure can be avoided or it can be slowed down significantly.

*Figure 2. SEM Micrograph of CNTs stretched across crack observed in CNT-epoxy nanocomposite.* [19]

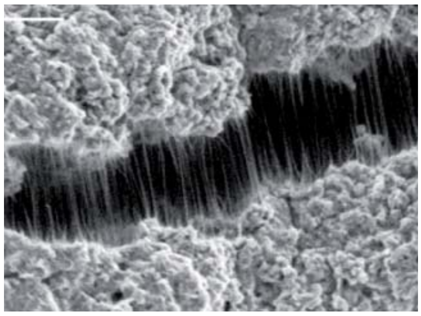

*Figure 2*

## SCIENTIFIC RESEARCH: EXAMPLES

### Miktech Mikkeli, Finland

MIKTECH studied fatigue properties of glassfiber-epoxy laminates (60/40) with and without CNTs. Results show that laminates with HYBTONITE® G4LV matrix gave 13 % better test result in max stress compared to the reference matrix, 30 % better result after 50000 cycles and 68 % better results after 100000 cycles.

MICTECH used Jeffamine D-230 as a curing agent, laminate was 60 % glass and amplitude of fatigue test was 80 % of the max stress of each laminate.

*Figure 3. Fatigue test HYBTONITE® G4LV vs reference Epoxy*

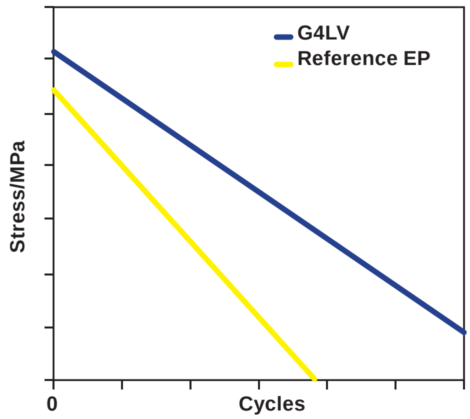


*Figure 3*

# HYBTONITE® SCIENTIFIC RESEARCH: EXAMPLES

## Technical University of Tampere, Finland

Technical University of Tampere, Finland studied effects of different nanofillers in epoxy matrices of carbon fiber laminates on compressive strength. In the study they compared commercial nano-sized $SiO_2$, nano-NBR and functionalized CNTs (HYBTONITE®).

A result was that with only 0.05 wt % of CNTs the compressive strength and modulus increased by 12 % and 15 % respectively. On the other hand they noticed that nano-$SiO_2$ and NBR decreased both properties.

| Composition of matrix in carbon fiber laminate | Compressive strength, MPa | | Compressive modulus, GPa | |
|---|---|---|---|---|
| | 0° | 90° | 0° | 90° |
| Reference epoxy, EP | 507,0 | 68,5 | 106,0 | 8,3 |
| EP + 0,05 wt % CNT | 586,0 | 77,0 | 108,0 | 8,7 |
| Reference epoxy, EP | 507,0 | 64,9 | 106,0 | 8,6 |
| EP + 0,2 wt % $SiO_2$ | 461,0 | 64,1 | 105,0 | 7,0 |
| EP + 1,0 wt % $SiO_2$ | 411,0 | 63,1 | 92,9 | 6,4 |
| EP + 3,5 wt % $SiO_2$ | 365,0 | 42,4 | 77,9 | 5,1 |
| Reference epoxy, EP | 507,0 | 64,9 | 106,0 | 8,6 |
| EP + 0,2 wt % NBR | 373,0 | 56,7 | 90,5 | 6,0 |
| EP + 1,0 wt % NBR | 474,0 | 63,2 | 103,0 | 6,5 |
| EP + 3,5 wt % NBR | 388,0 | 56,9 | 81,9 | 5,8 |

*Table 1. Summarization of compression test results.*

## Tuskegee University, USA

Zhou et al. [19] performed mechanical tests on unfilled and CNT-filled epoxy resins. They used different loadings in order to see a tendency of how CNT content changes properties.

| | Modulus, GPa | Strength, MPa | Failure strain, % |
|---|---|---|---|
| Neat epoxy | 2,46 | 93,5 | 4,02 |
| 0,1 % CNT | 2,54 | 109 | 6,06 |
| 0,2 % CNT | 2,60 | 115 | 6,80 |
| 0,3 % CNT | 2,65 | 121 | 7,58 |
| 0,4 % CNT | 2,75 | 113 | 5,12 |

*Table 2. Mechanical properties of neat and nanofilled epoxy.*

## Literature


[1] Gojny FH, Wichmann MHG, Kopke U, Fiedler B, Schulte K. Carbon nanotube-reinforced epoxy-composites: enhanced stiffness and fracture toughness at low nanotube content. Compos Sci Technol 2004;64(15):2363–71.

[2] Breton Y, Delpeux S, Benoit R, Sallvetat J, Sinturel C, Beguin F. Functionalization of multiwall carbon nanotubes properties of nanotubes–epoxy composites. Mol Cryst Liq Cryst 2002;387:135–40.

[3] Breton Y, Desarmot G, Salvetat JP, Delpeux S, Sinturel C, Beguin F, et al. Mechanical properties of multiwall carbon nanotubes/epoxy composites: influence of network morphology. Carbon 2004;42(5–6):1027–30.

[4] Song YS, Youn JR. Influence of dispersion states of carbon nanotubes on physical properties of epoxy nanocomposites. Carbon 2005;43(7):1378–85.

[5] Liao Y, Marietta-Tondin O, Liang Z, Zhang C, Wang B. Investigation of the dispersion process of SWNTs/SC-15 epoxy resin nanocomposites. Mater Sci Eng A 2004;385(1–2):175–81.

[6] Zhu J, Peng H, Rodriguez-Macias F, Margrave JL, Khabashesku VN, Imam AM, et al. Reinforcing epoxy polymer composites through covalent integration of functionalized nanotubes. Adv Funct Mater 2004;14(7):643–8.

[7] Moniruzzaman M, Winey KI. Polymer nanocomposites containing carbon nanotubes. Macromolecules 2006;39(16):5194–205.

[8] Coleman JN, Khan U, Gun'ko YK. Mechanical reinforcement of polymers using carbon nanotubes. Adv Mater 2006;18(6):689–706.

[9] Zhu J, Kim J, Peng H, Margrave JL, Khabashesku VN, Barrera EV. Improving the dispersion and integration of single-walled carbon nanotubes in epoxy composites through functionalization. Nano Lett 2003;3(8):1107–13.

[10] Song YS, Youn JR. Influence of dispersion states of carbon nanotubes on physical properties of epoxy nanocomposites. Carbon 2005;43(7):1378–85.

[11] Wang Z, Liang Z, Wang B, Zhang C, Kramer L. Processing and property investigation of single-walled carbon nanotube (SWNT) buckypaper/epoxy resin matrix nanocomposites. Composites Part A Appl Sci Manuf 2004;35(10): 1225–32.

[12] Schadler LS, Giannaris SC, Ajayan PM. Load transfer in carbon nanotube epoxy composites. Appl Phys Lett 1998;73(26):3842–4.

[13] Coleman JN, Khan U, Blau WJ, Gun'ko YK. Small but strong: a review of the mechanical properties of carbon nanotube–polymer composites. Carbon 2006;44(9):1624–52.

[14] Hussain F, Hojjati M, Okamoto M, Gorga RE. Review article: polymer–matrix nanocomposites, processing, manufacturing, and application: an overview. J Compos Mater 2006;40(17):1511–75.

[15] Liu TX, Phang IY, Shen L, Chow SY, Zhang WD. Morphology and mechanical properties of multiwalled carbon nanotubes reinforced nylon-6 composites. Macromolecules 2004;37(19):7214–22.

[16] Shofner ML, Khabashesku VN, Barrera EV. Processing and mechanical prop-erties of fluorinated single-wall carbon nanotube–polyethylene composites. Chem Mater 2006;18(4):906–13.

[17] Liu L, Wagner HD. Rubbery and glassy epoxy resins reinforced with carbon nanotubes. Compos Sci Technol 2005;65(11–12):1861–8.

[18] Wang S, Liang Z, Liu T, Wang B, Zhang C. Effective amino-functionalization of carbon nanotubes for reinforcing epoxy polymer composites. Nanotechnology 2006;17(6):1551–7.

[19] Y. X. Zhou1, P. X. Wu, Z-Y. Cheng, J. Ingram1, S. Jeelani1. Improvement in electrical, thermal and mechanical properties of epoxy by filling carbon nanotube . eXPRESS Polymer Letters Vol.2, No.1 (2008) 40–48



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