OPTIMIZING THE FIBER-MATRIX INTERPHASE FOR CONTROLLED ENERGY ABSORPTION AND STRENGTH

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MOTIVATION AND OBJECTIVES

Mechanical performance of fiber reinforced composite can be tailored by varying the interphase between fiber and resin

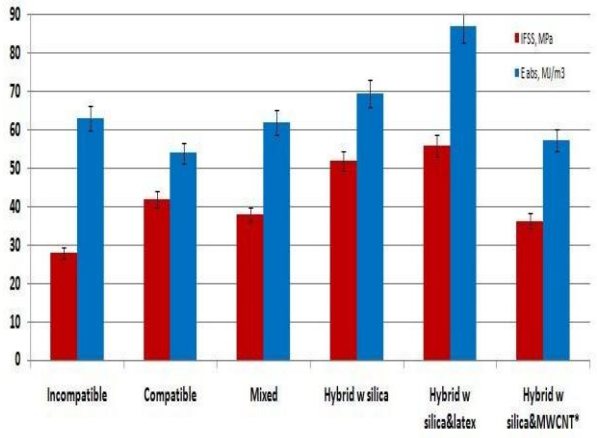
Two targets: higher energy absorption (improvement of antiballistic impact properties) and higher fracture toughness (improvement of mechanical properties).

- There is a delicate balance between energy absorption and fracture toughness properties: strengthening the interphase leads to improved mechanical properties reducing ballistic properties at the same time.
- **Old approach**: try to control the degree of chemical bonding between fiber and resin. **New approach**: try to tailor both adhesion and texture.

Objectives

- Optimize sizing mixture composition for E-glass, Spectra and Kevlar fibers.
- Enhance multifunctionality through nanoparticle hybridization or chemical modification.

E-GLASS FIBER SIZING OVERVIEW



MWCNT* – Multi Wall Carbon Nanotubes oxidized with H_2O_2

MATERIALS USED

Dow Chemical DER 353 low viscosity epoxy resin

Air Products PACM20 curing agent
E-glass fibers

Incompatible sizing: tetraethoxy silane (TES)

Compatible sizing: glycidoxypropyltrimethoxy silane (GPS)

Mixed sizing: mixture of TEOS and GPS (1:1GT, 1 wt %)

Hybrid sizing w silica: 1:1GT (1 wt %) + silica nanoparticles (20 nm, 1 wt %) **optimized sizing**

Hybrid sizing w silica&latex: 1:1GT (1 wt %) + silica nanoparticles (20 nm, 1 wt %) + latex nanoparticles (20 nm, 1 wt %)

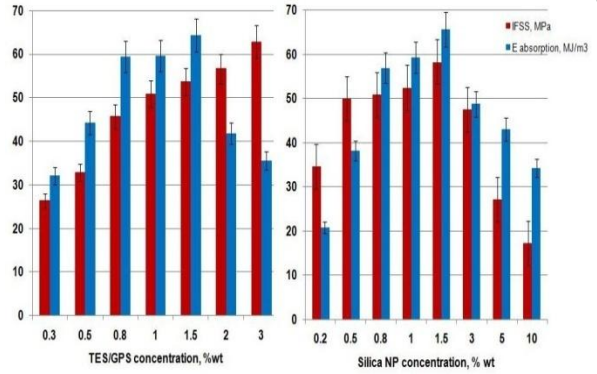
Hybrid sizing w silica&MWCNT: 1:1GT (1 wt %) + silica nanoparticles (20 nm, 1 wt %) + MWCNT*(1 wt %)

Best to date combination of IFSS and energy absorption is observed for hybrid sizing with hard (silica) and soft (latex) nanoparticles

OPTIMIZING THE FIBER-MATRIX INTERPHASE FOR CONTROLLED ENERGY ABSORPTION AND STRENGTH

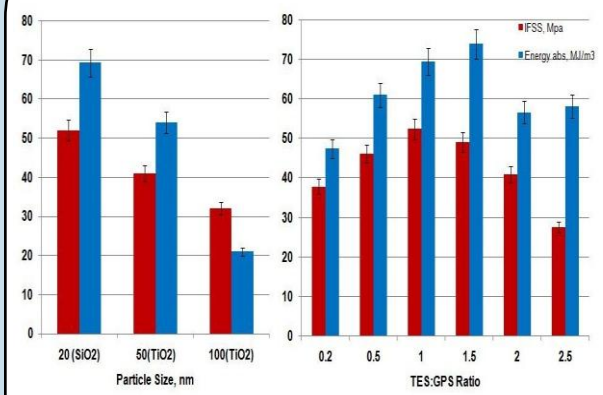
(Continued)

E-GLASS FIBER POLYSILOXANE SIZING OPTIMIZATION



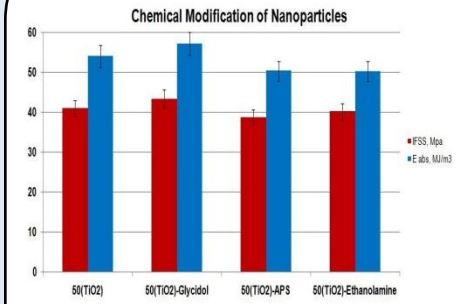
Optimized concentration range for TES/GPS and silica nanoparticles is between 0.8-1.5 wt%

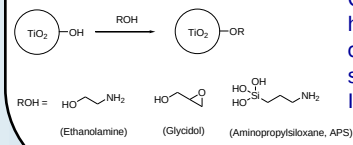
E-GLASS FIBER POLYSILOXANE SIZING OPTIMIZATION (CONT.)



Optimized TES:GPS ratio is in the range1-1.5. Increase of the nanoparticle size leads to a gradual decline in both IFSS and energy absorption

E-GLASS FIBER POLYSILOXANE SIZING OPTIMIZATION (CONT.)

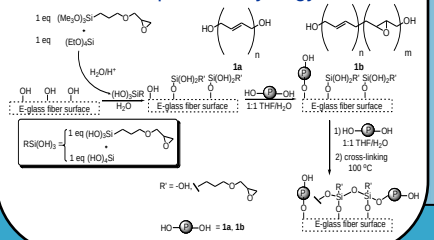




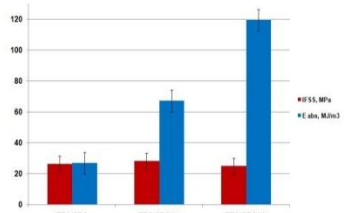
Chemical modification of hard nanoparticles surface doesn't lead to statistically significant change in either IFSS or energy absorption

HARD-SOFT NANOPARTICLES SYNERGY INVESTIGATION

The combination of hard-soft nanoparticles is the best for strength and energy absorption improvement. What is the mechanism of hard-soft nanoparticles synergy?



ENERGY ABSORPTION AND STRENGTH FOR PBD-SIZED FIBERS



Sample	IFSS, MPa	E^{sl}_{deb}, kJ/m²	E^{sl}_{do}, MJ/m³	E^{sl}_{do}, MJ/m³	E^{l}_{abs}, MJ/m³
TES/GPS	26.52 ± 2.85	1.20 ± 0.41	16.52 ± 2.56	3.52 ± 0.77	26.90 ± 2.61
TES/GPS/1a	28.39 ± 2.90	1.13 ± 0.37	57.25 ± 5.29	3.91 ± 0.84	67.37 ± 5.46
TES/GPS/1b	25.10 ± 3.01	1.11 ± 0.49	108.97 ± 8.46	3.98 ± 0.86	119.37 ± 8.76

Rubber species contribute to enhanced energy absorption

CONCLUSIONS

The combination of hard (silica) and soft (latex) nanoparticles works best for strength and energy absorption in E-glass fibers. The study shows that hard particles contribute to the surface roughness increase and interfacial strength, whereas rubber particles contribute to improved energy absorption.

The best mechanical performance of E-glass/Epoxy composite was observed in the following concentrations' range: 0.8-1.5 wt% tetraethoxysilane (TES)/3-glycidoxypropyltrimethoxy silane (GPS) mixture, and 0.8-1.5 wt% Ludox® silica nanoparticles; 1-1.5 TES/GPS ratio, and 20 nm silica nanoparticles size. Increase of nanoparticles sizes leads the decline in both strength and energy absorption.

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