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Carbon Fiber Effects on the Interphase

Slade Gardner - BP Amoco Chemicals

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Interphase: Fiber/Matrix Interactions

wettability

- surface energy (dispersive, polar)

adhesion

- chemical adhesion (functional groups)
- mechanical adhesion (surface morphology)

Carbon fiber manufacturing

- precursor composition
- fiber spinning
- oxidation
- carbonization
- surface treatments
- post treatments

Precursor composition

- rayon cellulose
- pitch
- polyimide
- polyacrylonitrile (93-99% PAN)
  - methyl methacrylate
  - methacrylic acid
  - methyl vinyl pyridine
  - itaconic acid
  - methyl acrylate
  - vinyl acetate

Fiber spinning

melt spinning

solution spinning

- dry spinning
- wet spinning
- dry jet wet spinning

fiber morphology

solvent diffusion	pores/micropores
orientation (extent of draw)	topography (ridged, smooth)
process conditions	cross sectional uniformity

fiber shape

round	oval
bean	dogbone
trilobal	

surface finish oil

- handling, processing

Oxidation

thermal stabilization of PAN precursor

- up to 300 °C
- air or oxyen containing atmosphere
- tension

aliphatic polymer converted to aromatic structure

crosslinks fomed w/ addition of oxygen

adds thermal stabilization for subsequent thermal processing

increase in density

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Carbonization

process

- inert atmosphere
- 1000°C +
- tension

effects

- carbon fiber surface funcionalities

COOH	C=O
C-OH	C-O-C
$C-NH_2$	C-NH-C

- oxygen, nitrogen & hydrogen decrease w/ temperature
- carbon concentration increases w/ temperature
- dT/dt effects morphology (voids, micropores)
- formation of graphene morphology
  - edge planes
  - layer planes
  - skin/core morphology

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Surface Treatment

increase surface area
remove weaker surface material
increase surface functional groups
balance btwn ILSS & TS

gaseous

air or oxygen treatment (temperatures up to 700°C, long durations)

plasma treatment (low pressure, oxygen, nitrogen or organic plasma)

solution

milder than gas phase oxidation
long durations
high concentrations of oxidizing solvents

electrolytic

CF: anode
electrolye: strong acid or base in dilute solution

continuous processing
short treatment duration

Post treatements

surface coatings

- CVD carbon
- silicon carbide, alumina, titanium nitride
- organometallic coatings

sizing

- solvent application of thin polymer coating
- typcially epoxy
- less than 2 wt %
- improves handling & wettablity
- bonding???

moisture adsorption

Conclusions

Many opportunities in manufacturing steps to alter the surface chemistry and surface morphology of carbon fibers

Most probable modifications of surface chemistry and surface morphology are through carbonization, surface treatment and sizing steps

Variety of materials, techniques and processing variables available