Evaluation of Constituent and Processing for Advanced Composites

A Survey of Binder Polymers, Fiber/Fabrics, Additives, Lay-Up Issues, Manufacturing & Processing Properties

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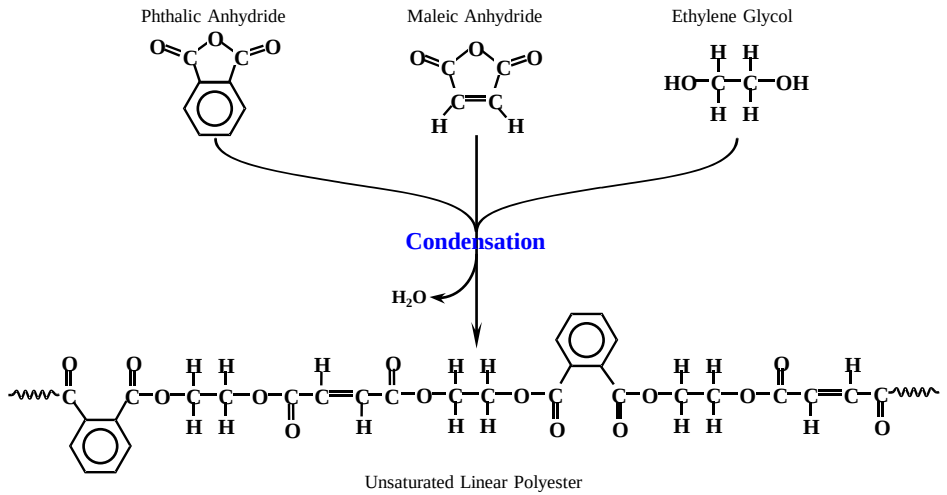
Styrene-Crosslinked Polyesters



Monomers

Stage A Prepolymer

Adhesives,

Binders,

Composites,

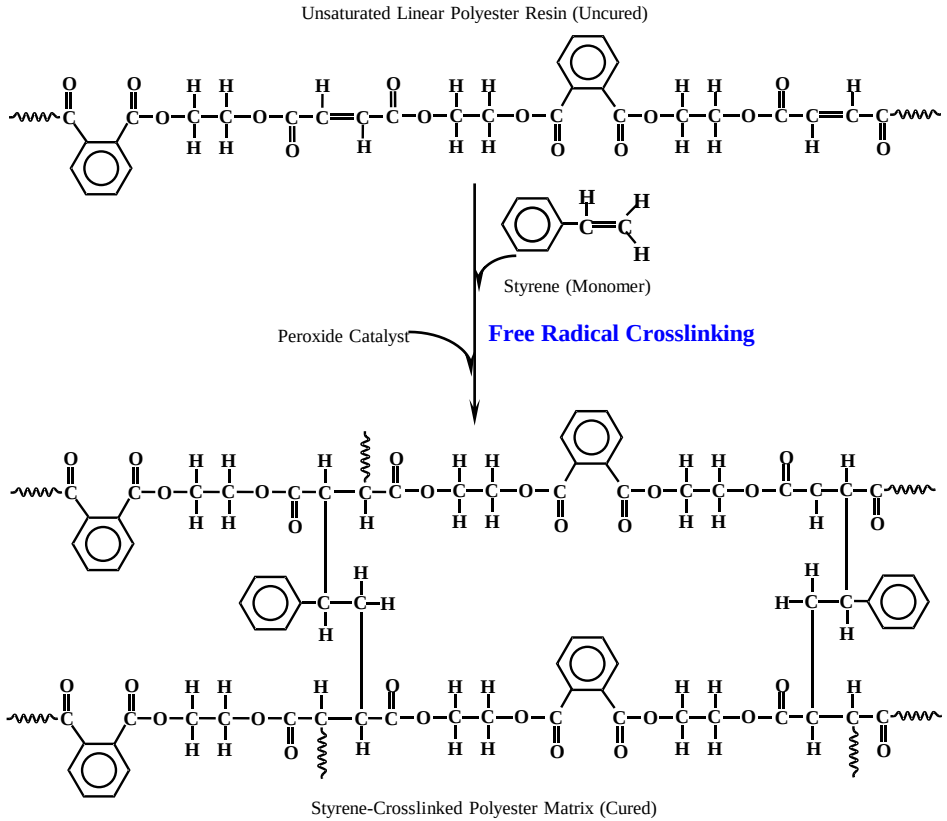
Plastics,

Coatings,

Paints,

Putties,

Compounds



Stage B Polymer Resin

Stage C Crosslinked Thermoset Network

Phenol-Formaldehyde Phenolic Polymers

Adhesives,

Binders,

Composites,

Plastics,

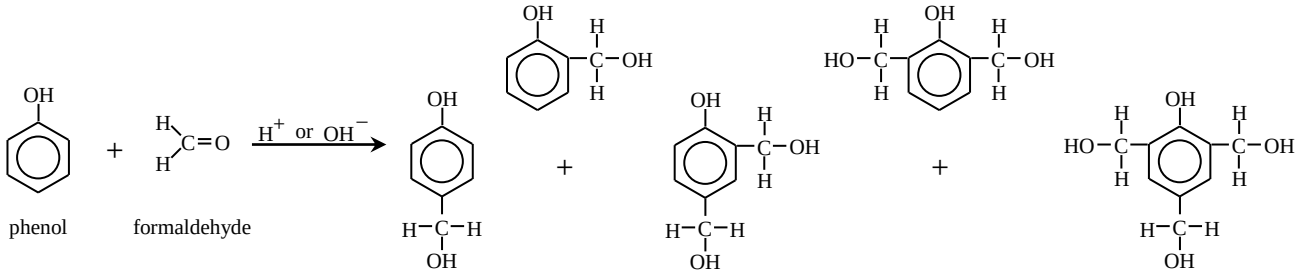
Coatings,

Compounds,

Ablatives,

Ceramics,

Glassy Carbon

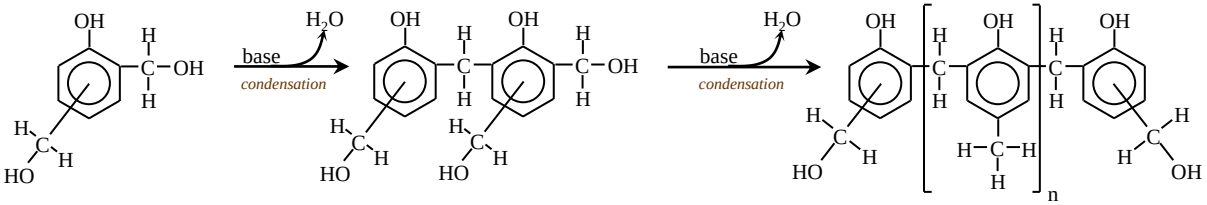


phenol formaldehyde

mixture of ortho and para mono, di and tri methylol phenols

Monomers

Electrolphillic Aromatic Substitution



substituted methylol phenol

substituted diphenol methylene

polymethylene-linked methylol phenols
(an A-stage pre-polymer resol)

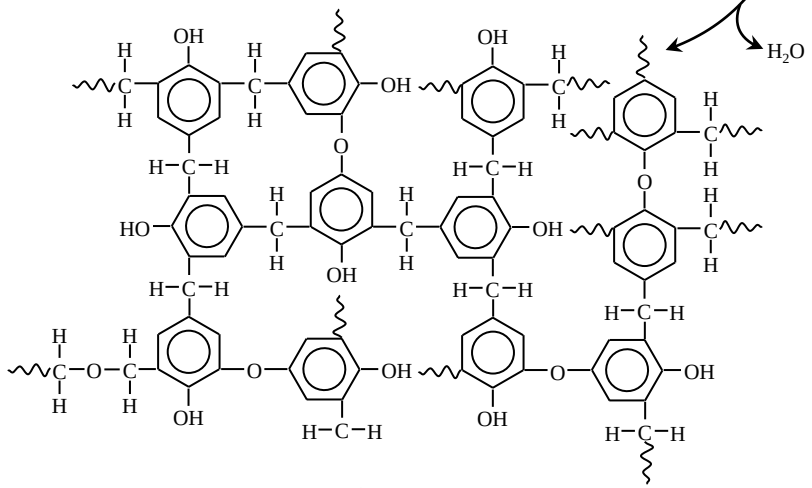
Stage A

Prepolymer

Resol

Stage B

Condensation Crosslinking



Stage C Crosslinked

Thermoset

Network

Figure 1. Suggested representation of an idealized cured phenolic resin structure.

Silanes, Siloxanes and Ureasilazanes

Adhesives,

Sealants,

Binders,

Composites,

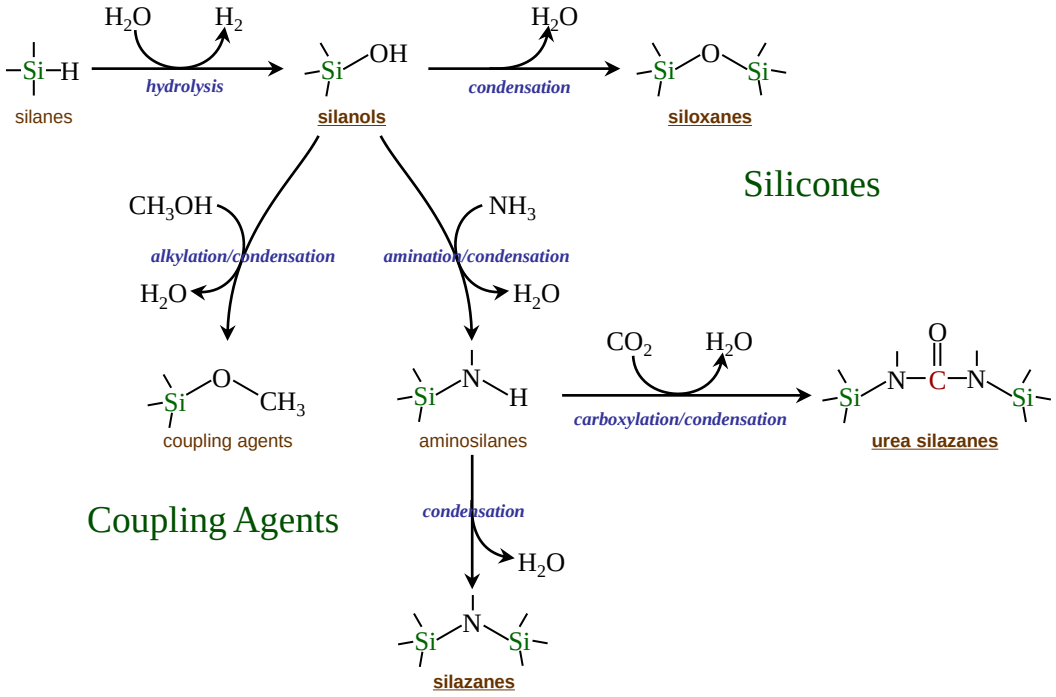
Plastics,

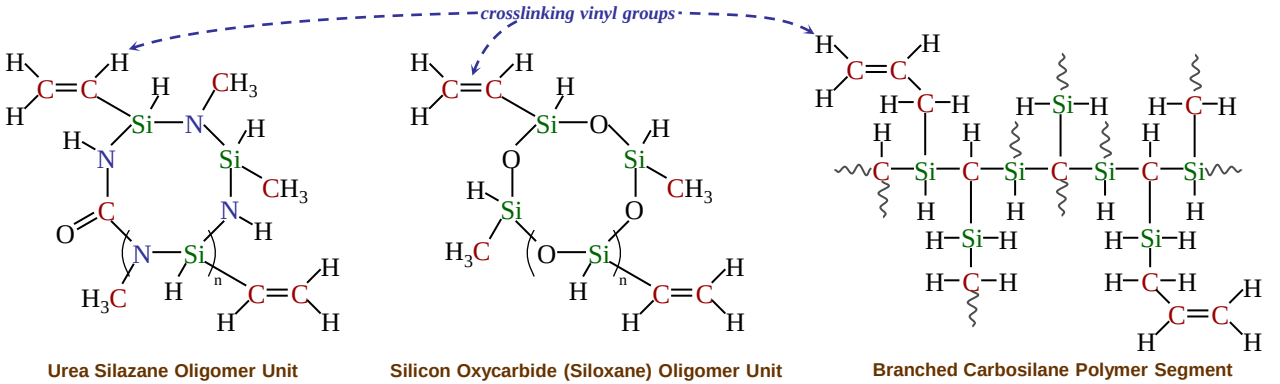
Coatings,

Compounds,

Ablatives,

Ceramics





Preceramic Polymers

Polymer-Derived Ceramics

Polyimides & Liquid Crystal Polymers

Adhesives,

Binders,

Composites,

Plastics,

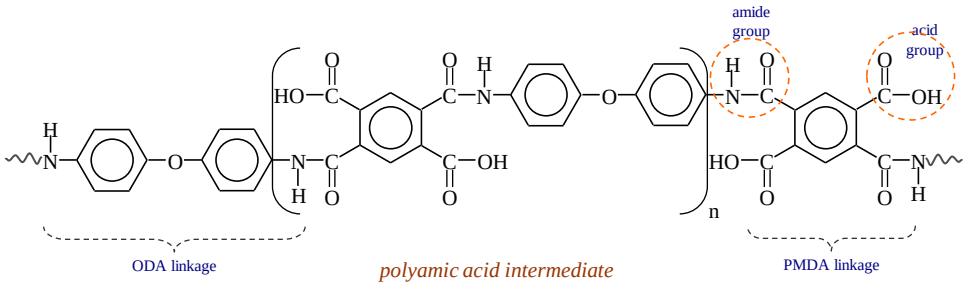
Coatings,

Ablatives,

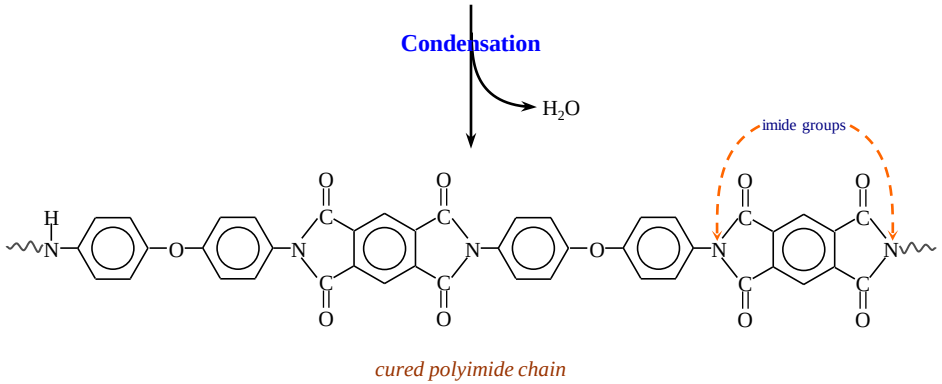
Fibers,

Armor,

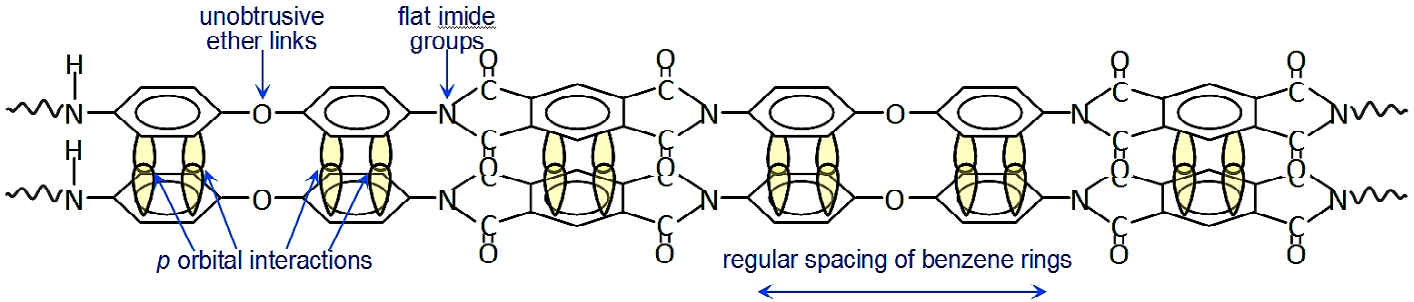
Fire Suits



Polyimide Resin Precusor



Cured Polyimide Thermoplastic



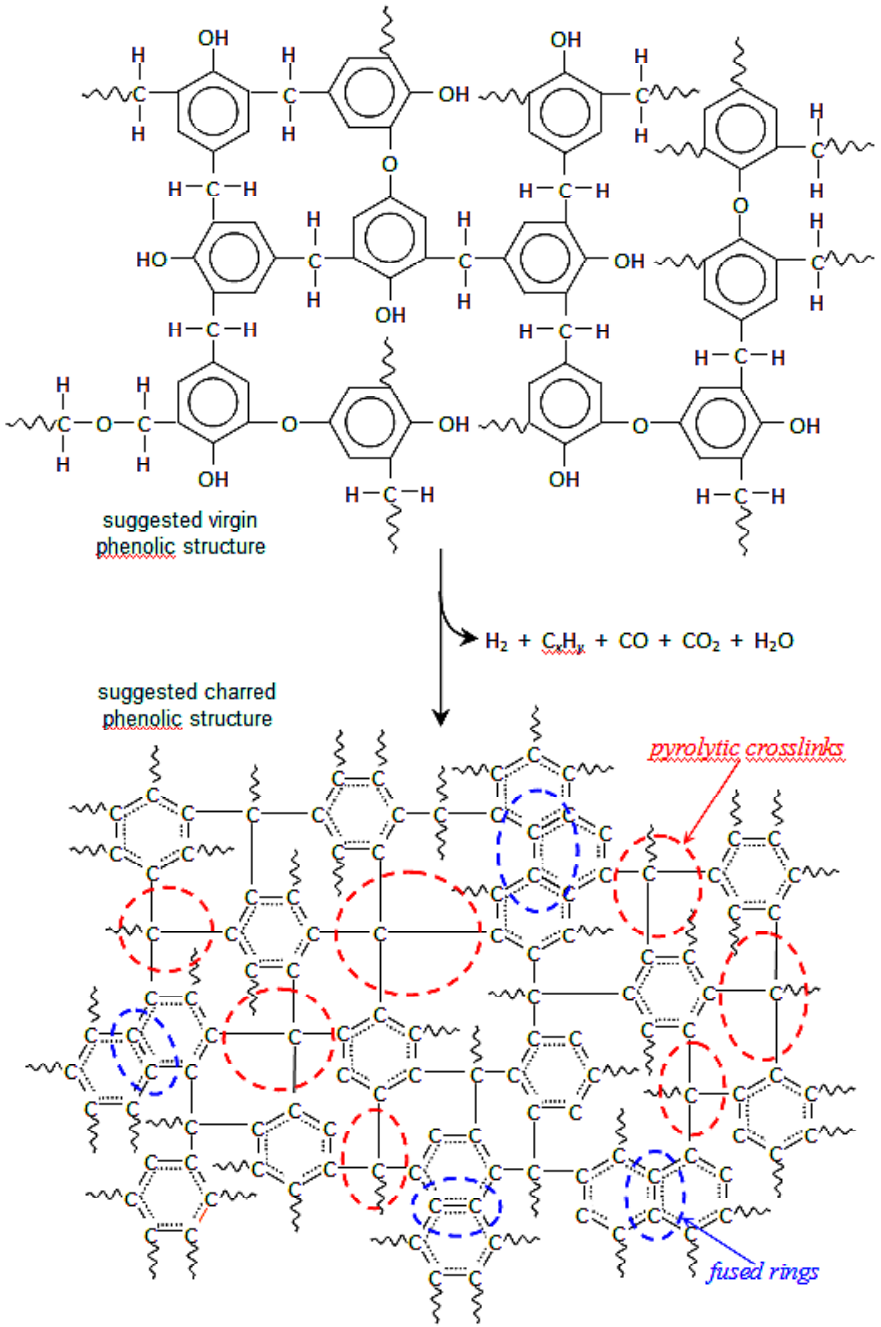
Mesogenic Interactions

Thermal Degradation & Pyrolysis of Polymers

a) Thermosets form non-graphitzable glassy carbon char

b) Common thermo-plastics melt and volatilize away

c) Mesogenic polymers form graphitizable amorphous carbon char

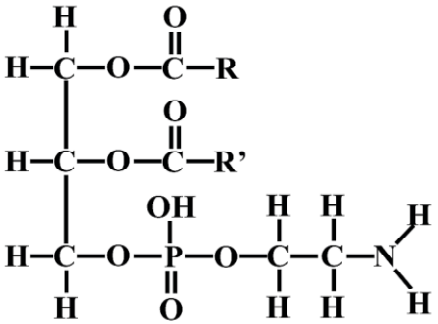


Cured Polymer Thermoset

Charred Glassy Carbon

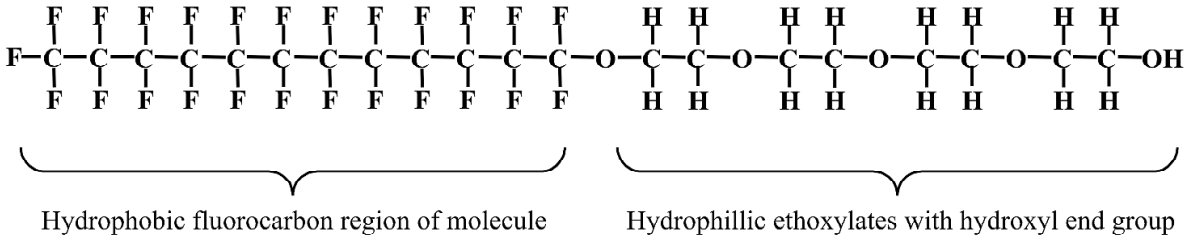
Surfactants & Unique Formulation Compounds

Phospholipid Wetting Agents



Typical lecithin complex showing simplified glycerol-type structure with phosphatidyl-amine functionality.

Fluorosurfactants



Representative structure of a typical fluorosurfactant showing the water soluble (hydrophilic) end opposite to the particle (or surface) attractive end.

Silane Coupling Agents

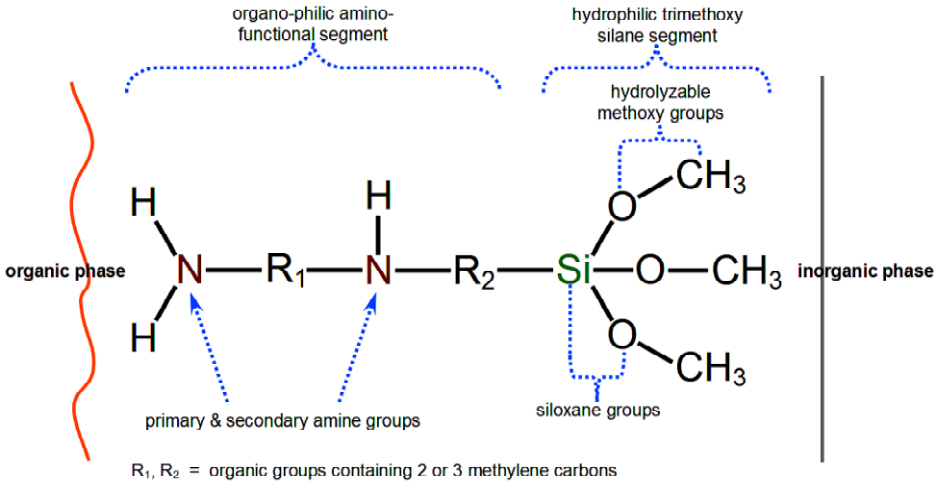
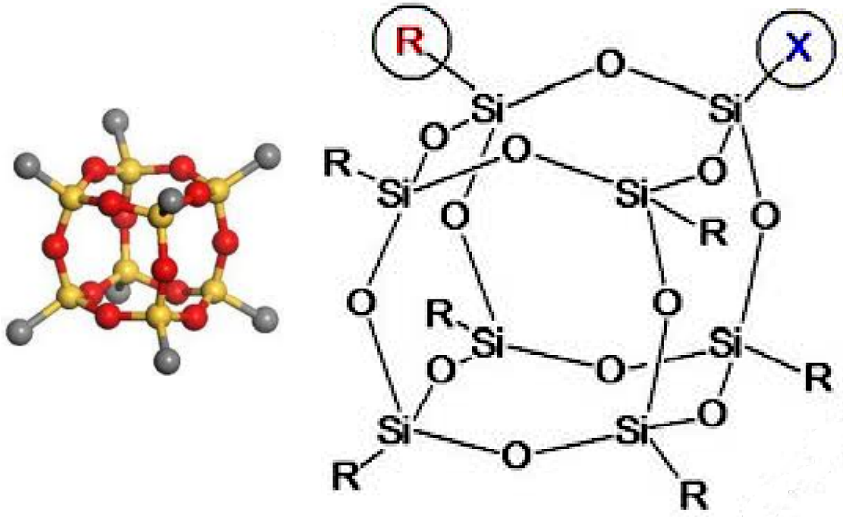
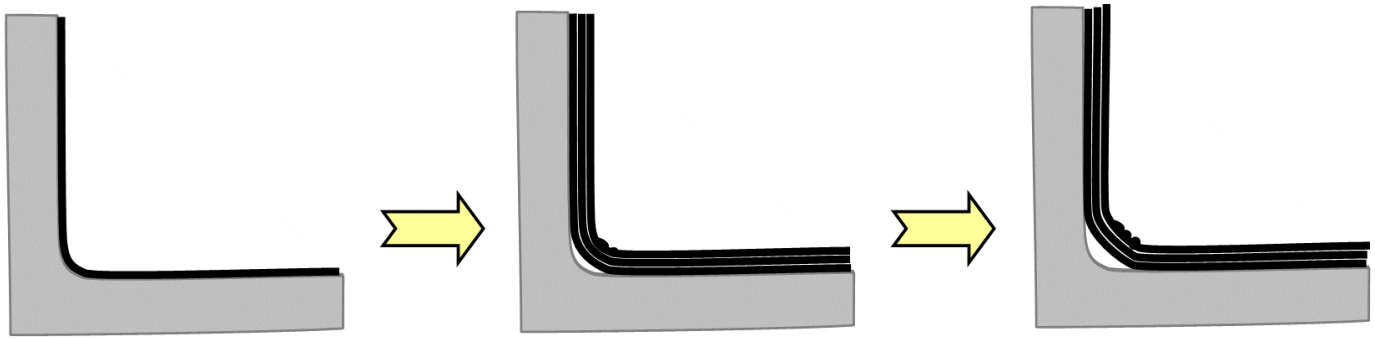


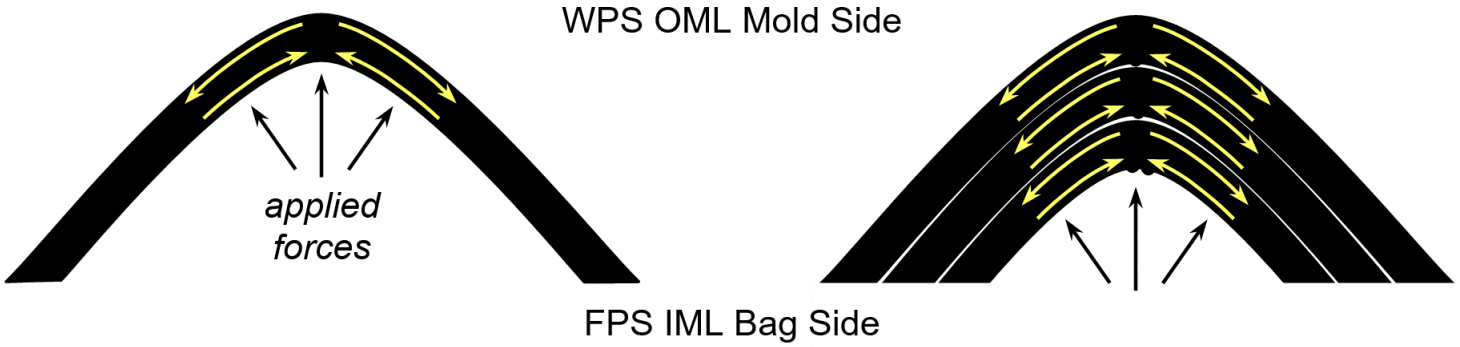
Figure 1. Representative structure for the amino-type coupling agent used in the SCP/GCP systems (before bonding with the organic matrix or inorganic substrate).

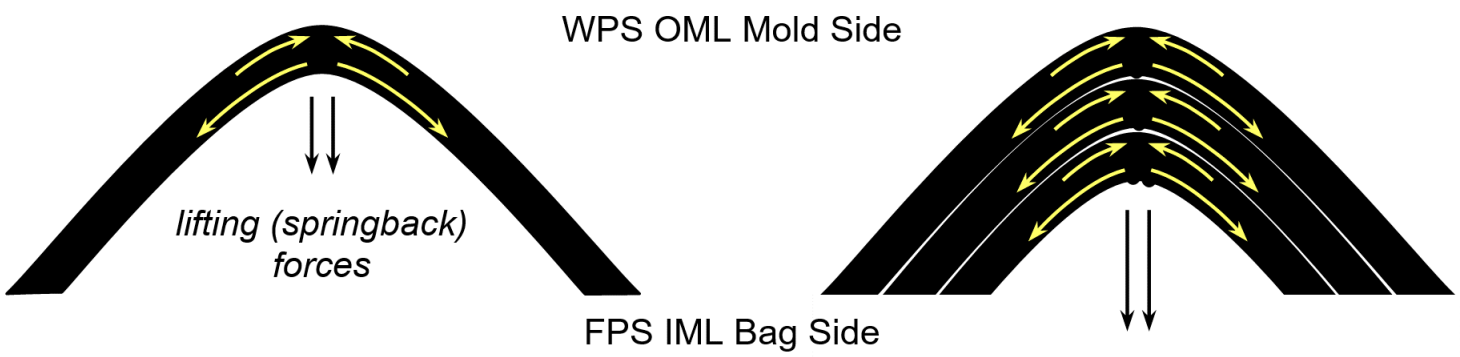
POSS Compounds (Polyhedral Oligomeric Silsesqueoxane)



Lay-Up & Molding Issues on Contours & Radii

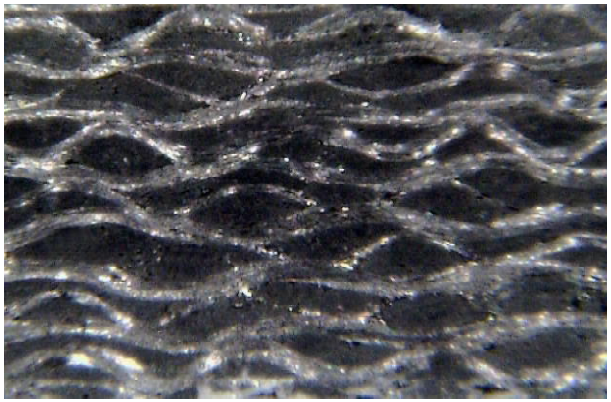




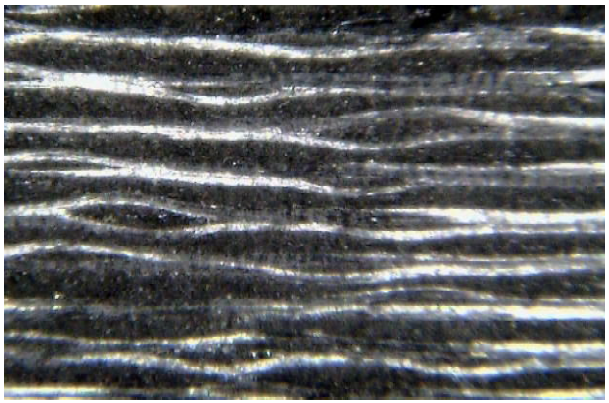


Interlaminar Interactions & Carbon Fiber Processing

Good Interlaminar Nesting



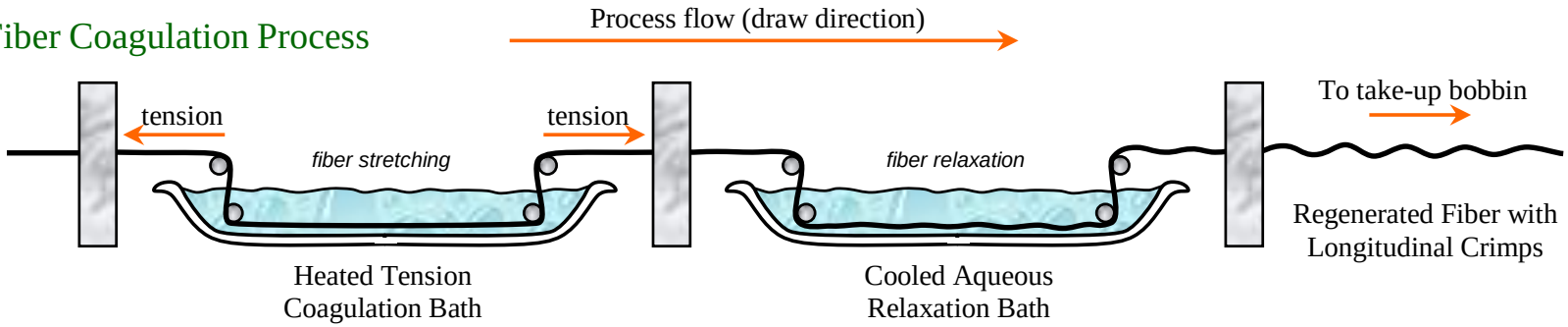
Cross-sectional thickness image of carbonized ***rayon*** fabric-reinforced / charred phenolic-matrix laminate



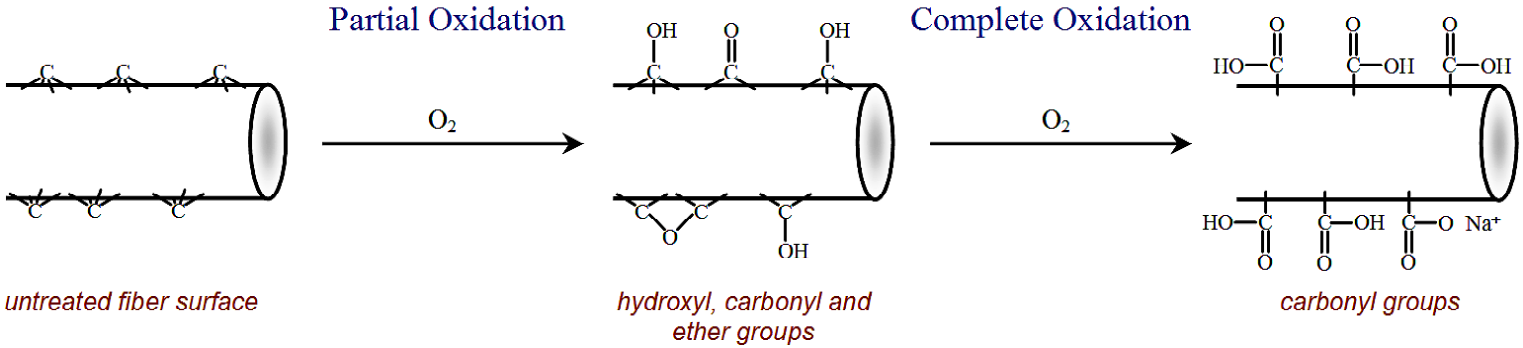
Cross-sectional thickness image of carbonized ***PAN*** fabric-reinforced / charred phenolic-matrix laminate

Poor Interlaminar Nesting

Rayon Fiber Coagulation Process



Fiber Surface Functionalization



3-D Woven Preforms for C-C and CMC Composites

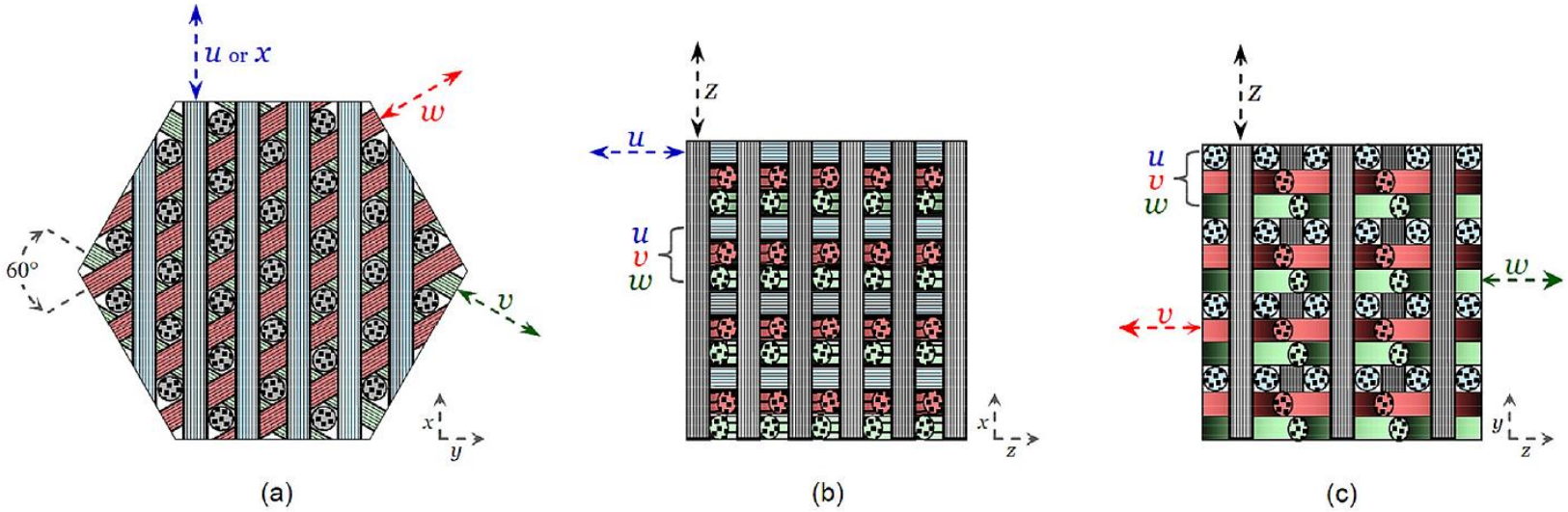
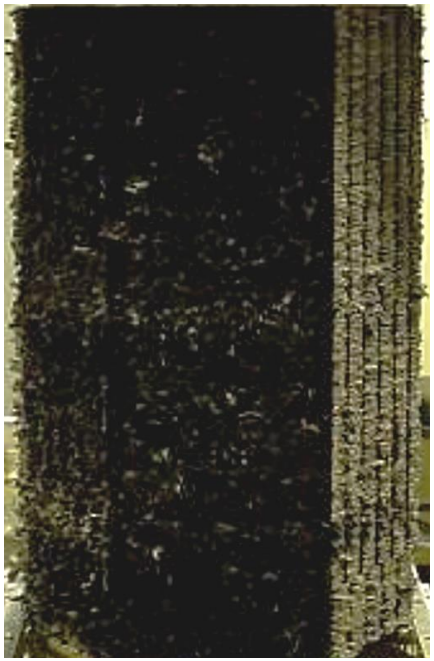
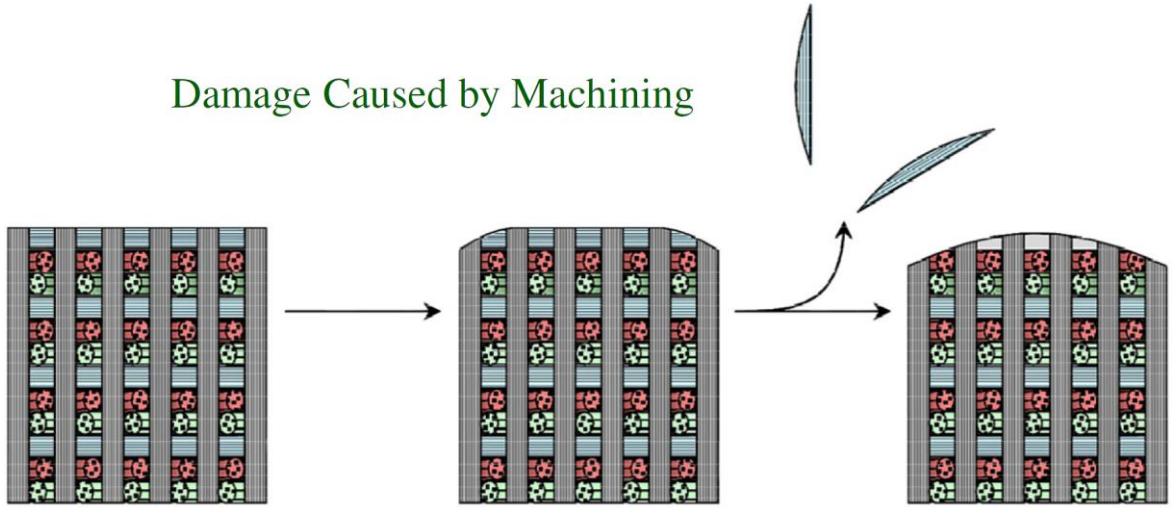


Figure 1. Cross-sectional views of the 4-directional preform weave architecture utilized by FMI for the HT-7 components[1] . . . (a) Perspective looking down the z axis onto the x-y plane; (b) Perspective looking along the u + 90 direction (the y direction) onto the x-z plane (recall there are no bundles parallel to y; u bundles are perpendicular); (c) Perspective looking down the u direction (the arbitrary x axis) onto the y-z plane (v bundles come in from the right, w bundles come in from the left at 120° apart).

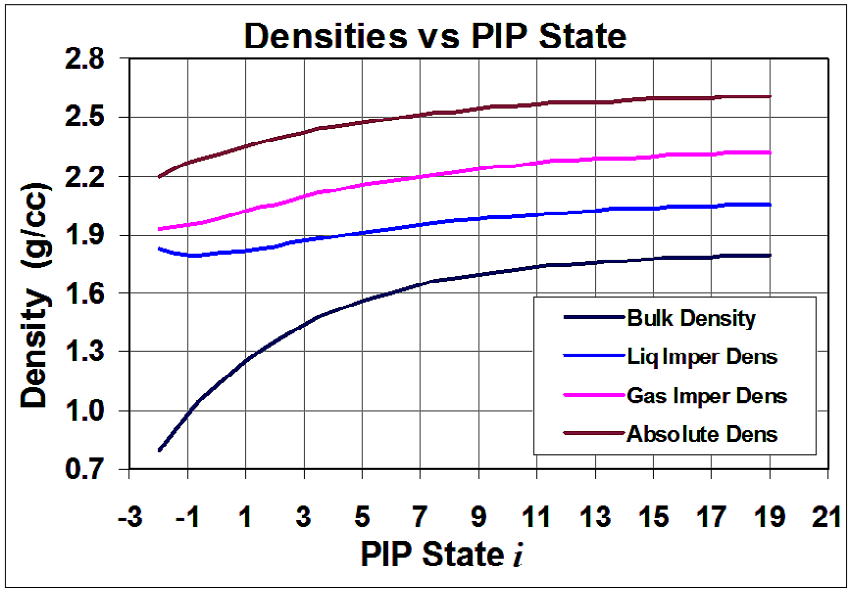
Multi-Directional Preform Billet

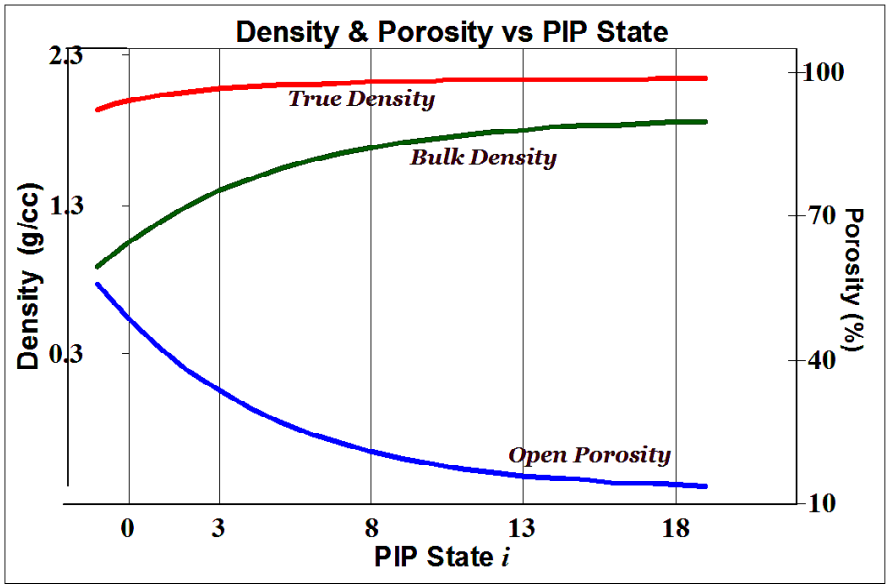


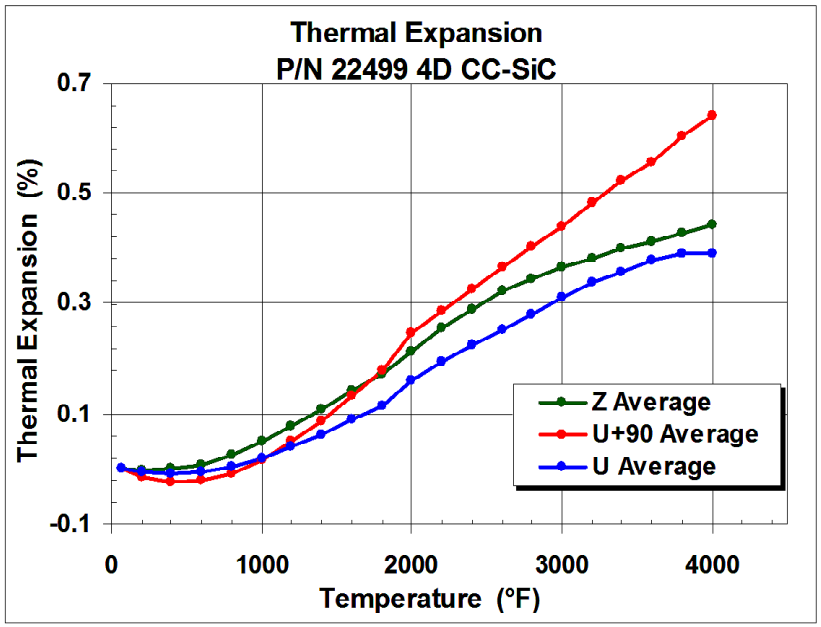
Damage Caused by Machining

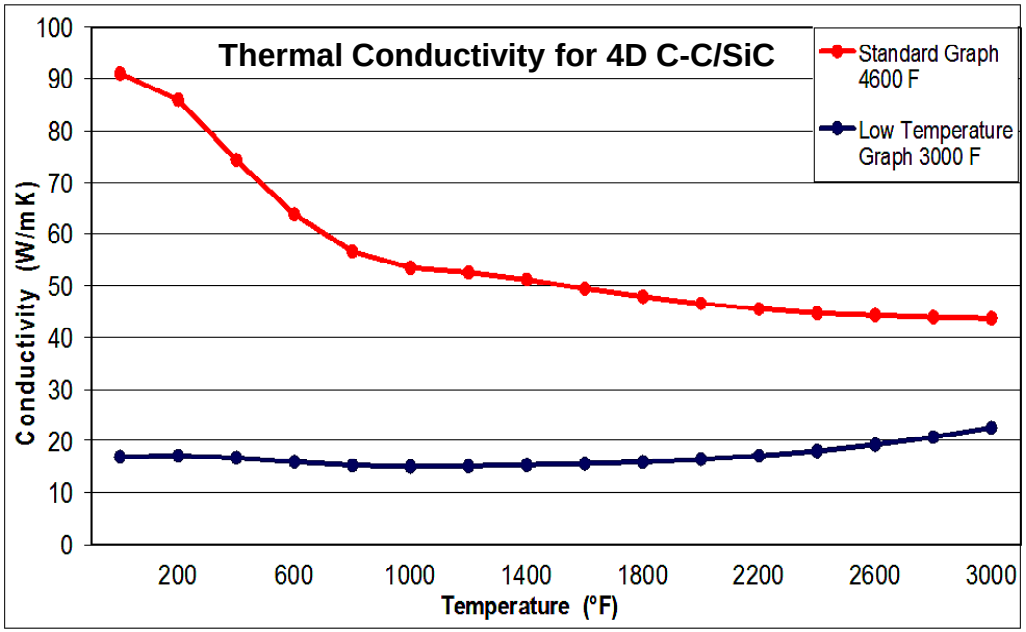


Processing & Thermal Data For C-C/SiC Composite

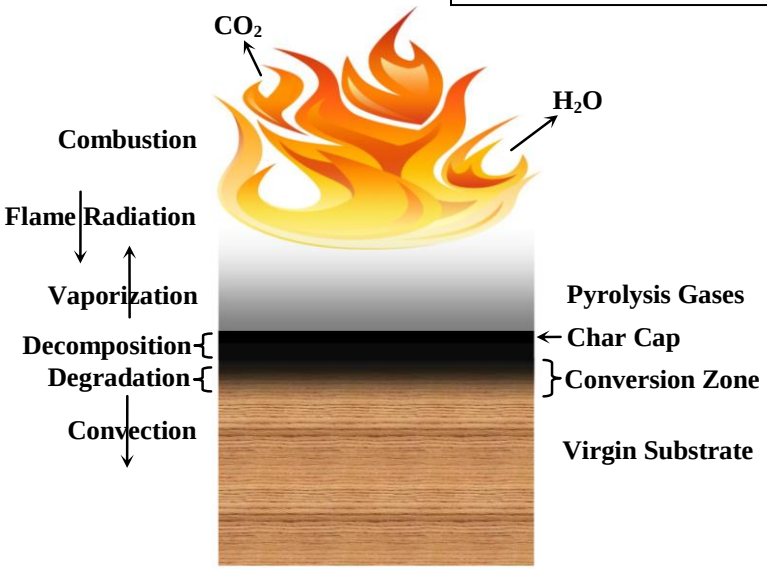




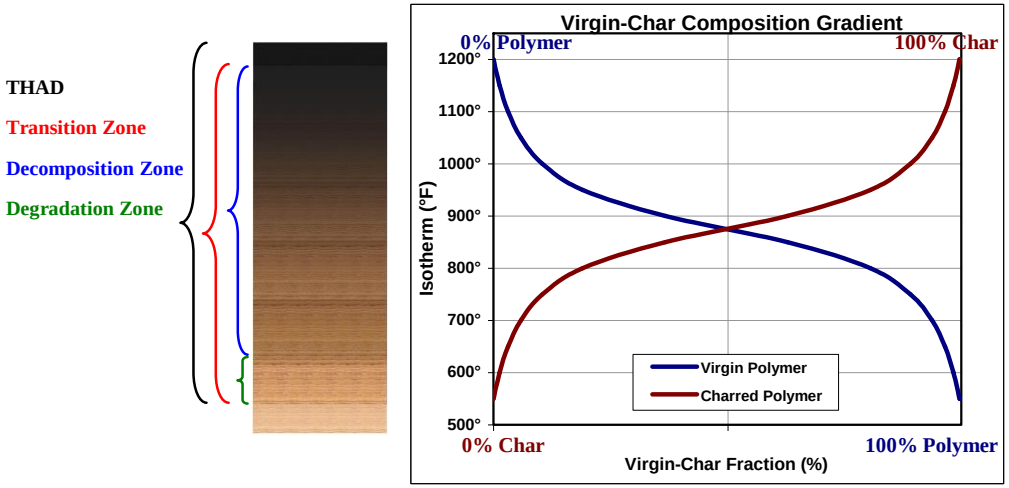




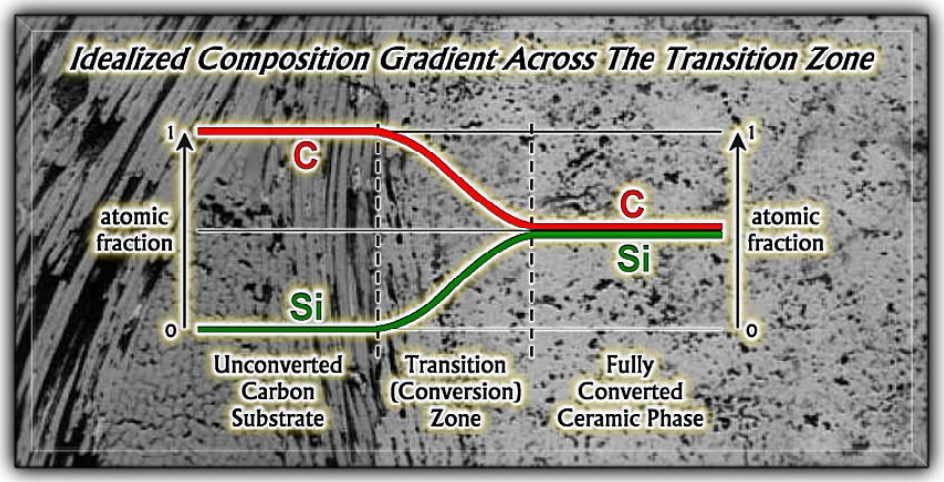
Graded Materials & Gradient Transition Zones



Combustion of Organic Material

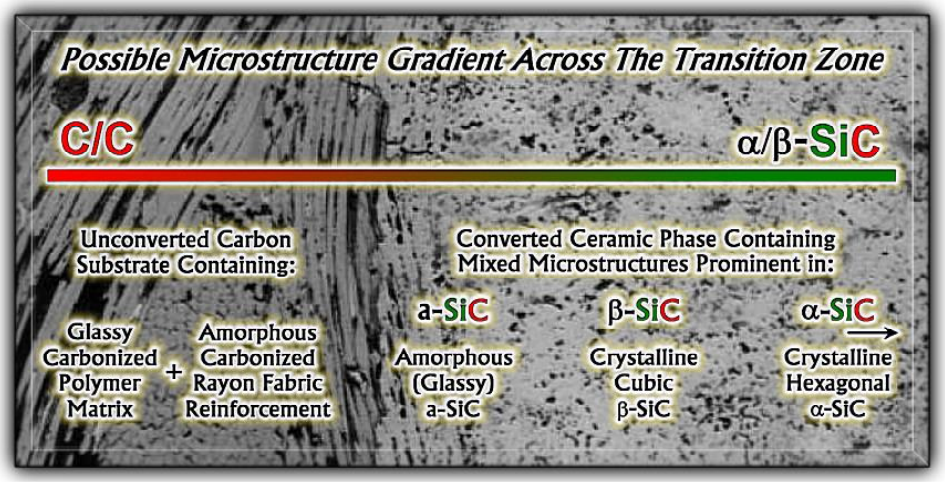


Virgin Polymer-To-Char Gradient



Carbon Composite-To-Ceramic Compositional Gradient

(via EDX line scan analysis)



Carbon Composite-To-Ceramic Microstructural Gradient

(via XRD line scan analysis)