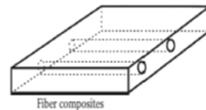
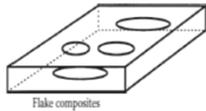
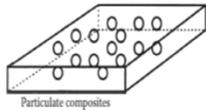


Classification



- **CONCRETE:**
Gravel, sand and cement
- **PAINT:**
Paint and aluminum flakes
- **GRAPHITE/EPOXY:**
Graphite fibers in epoxy matrix

1

Polymer Matrix Composites

- What are the drawbacks of polymer matrix composites?
 - Low operating temperatures
 - High CTE and CMEs
 - Low elastic properties in certain directions

3

Polymer Matrix Composites

- What are the most common advanced composites?
 - Graphite/Epoxy
 - Kevlar/Epoxy
 - Boron/Epoxy

2

Are Carbon and Graphite the Same?

- No
 - Carbon fibers have 93%-95% carbon content and graphite has >99% carbon content
 - Carbon fibers are produced at 2400° F and graphite fibers are produced at 3400° F

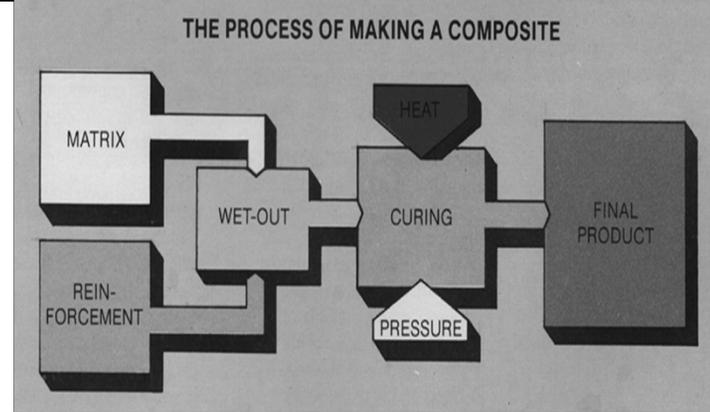
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Table 1.4. Typical mechanical properties of polymer matrix composites and monolithic materials

Property	Units	Graphite /Epoxy	Glass/ Epoxy	Steel	Aluminum
Specific Gravity		1.6	1.8	7.8	2.6
Young's modulus	Msi	26.25	5.598	30.0	10.0
Ultimate Tensile Strength	Ksi	217.6	154.0	94.0	40.0
Coefficient of Thermal Expansion	µin/in/°F	0.01111	4.778	6.5	12.8

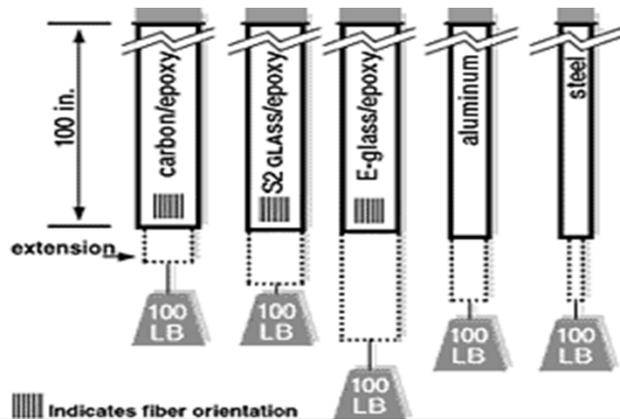
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How to make a PMC



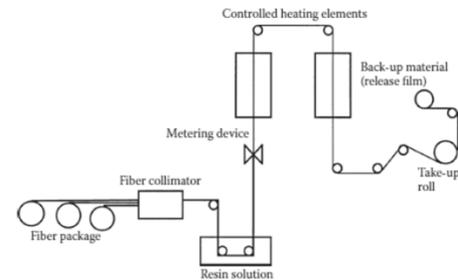
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Comparative Stiffness of PMCs and Metals



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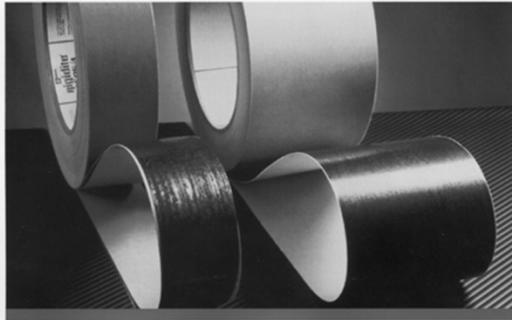
Schematic of Prepreg Manufacturing



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Prepreg Boron/Epoxy

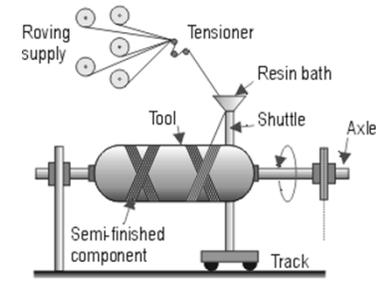
BORON EPOXY PREPREG TAPE-5521



■ 250°F Cure Resin System

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Filament Winding



[Filament Winding Video](#)

Azom.com™

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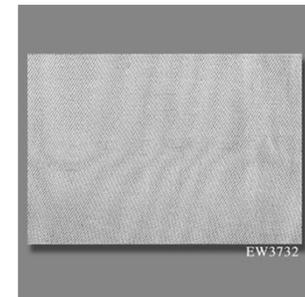
Autoclave Lamination



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Common PMC Fibers & Matrices

- Fibers
 - Graphite
 - Glass
 - Kevlar
- Matrices
 - Epoxy
 - Phenolic
 - Polyester



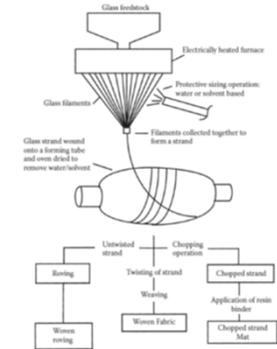
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Table 1.5 Typical mechanical properties of fibers used in polymer matrix composites

Property	Units	Graphite	Aramid	Glass	Steel	Aluminum
Specific Gravity		18.	1.4	2.5	7.8	2.6
Young's modulus	Msi	33.35	17.98	12.33	30	10
Ultimate Tensile Strength	Ksi	299.8	200.0	224.8	94	40
Axial Coefficient of Thermal Expansion	$\mu\text{in/in}^{\circ}\text{F}$	-0.722	-2.778	2.778	6.5	12.8

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Manufacturing of Glass Fibers



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Cost Comparison of PMC fibers

Type of fiber	Cost (\$ per pound)
A-glass	0.65 - .90
C-glass	0.75 - 1.00
E-glass	0.75 - 1.00
S-2 Glass	6.00 - 8.00
Heavy Tow	9.00 - 12.00
Medium Tow	15.00 - 20.00
Low Tow	40.00 - 70.00+
Kev29	12.00 - 14.00
Kev149	25.00 - 30.00

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Glass Fiber Types

- E-glass (fiberglass) - electrical applications
- S-glass - strength applications
- C-glass - Corrosion resistant
- D-glass - Low dielectric applications
- A-glass - Appearance applications
- AR-glass - Alkali resistant

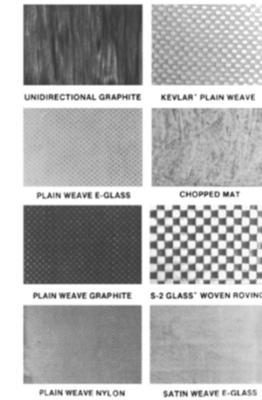
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Table 1.6 Comparison of properties of E-glass and S-glass

Property	Units	E-glass	S-glass
Specific Gravity		2.54	2.49
Young's modulus	Msi	10.5	12.4
Ultimate Tensile Strength	Ksi	500	665
Coefficient of Thermal Expansion	$\mu\text{in/in}/^\circ\text{F}$	2.8	3.1

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Fig 1.10 Forms of Fibers



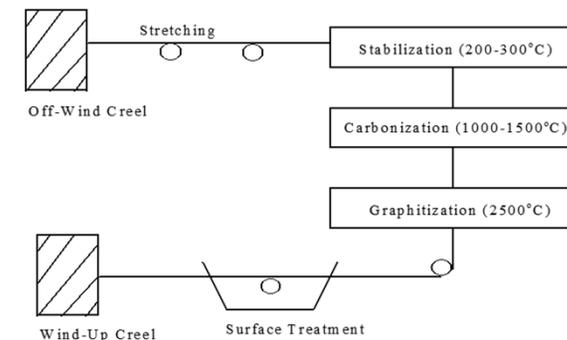
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Table 1.7 Chemical Composition of E-Glass and S-Glass Fibers

Material	% Weight	
	E-glass	S-glass
Silicon Oxide	54	64
Aluminum Oxide	15	25
Calcium Oxide	17	0.01
Magnesium Oxide	4.5	10
Boron Oxide	8	0.01
Others	1.5	.8

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Fig 1.11 Manufacturing Graphite Fibers



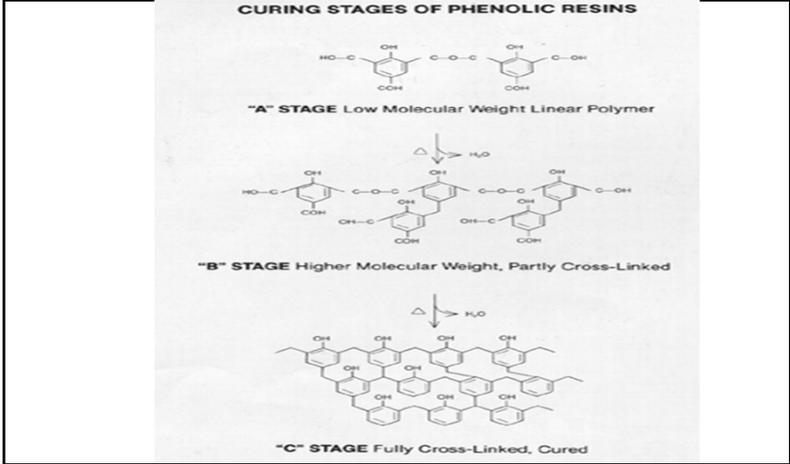
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Resin Systems

- Polyester
- Phenolics
- Epoxy
- Silicone
- Polyimide

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Curing Stages of Epoxy



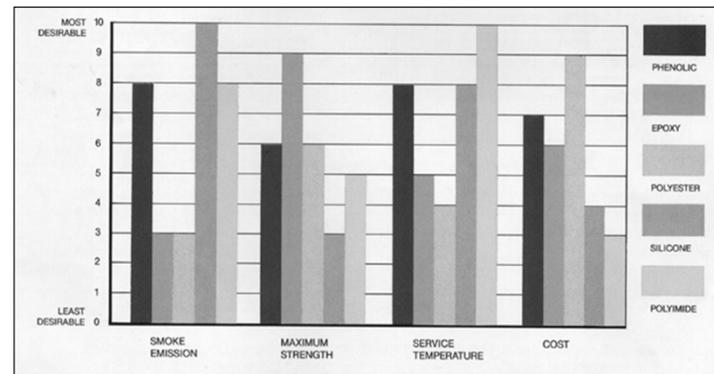
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Properties of epoxy

PROPERTY	UNITS	EPOXY
Specific gravity	-	1.28
Young's modulus	Msi	0.55
UTS	Ksi	12.0

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Comparison of Resins



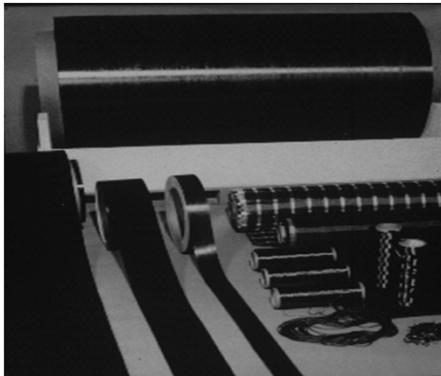
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Difference between thermosets and thermoplastics

THERMOPLASTICS	THERMOSET
Soften on heating and pressure, and hence easy to repair	Decompose on heating
High strains to failure	Low strains to failure
Indefinite shelf life	Definite shelf life
Can be reprocessed	Cannot be reprocessed
Not tacky and easy to handle	Tacky
Short cure cycles	Long cure cycles
Higher fabrication temperature and viscosities have made it difficult to process	Lower fabrication temperature
Excellent solvent resistance	Fair solvent resistance

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Pre-Preg Graphite/Epoxy



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