Engineering Composite Materials

Fibers

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Fibers

Fillers and reinforcements

The main reason for which fillers/reinforcement are added to a matrix:

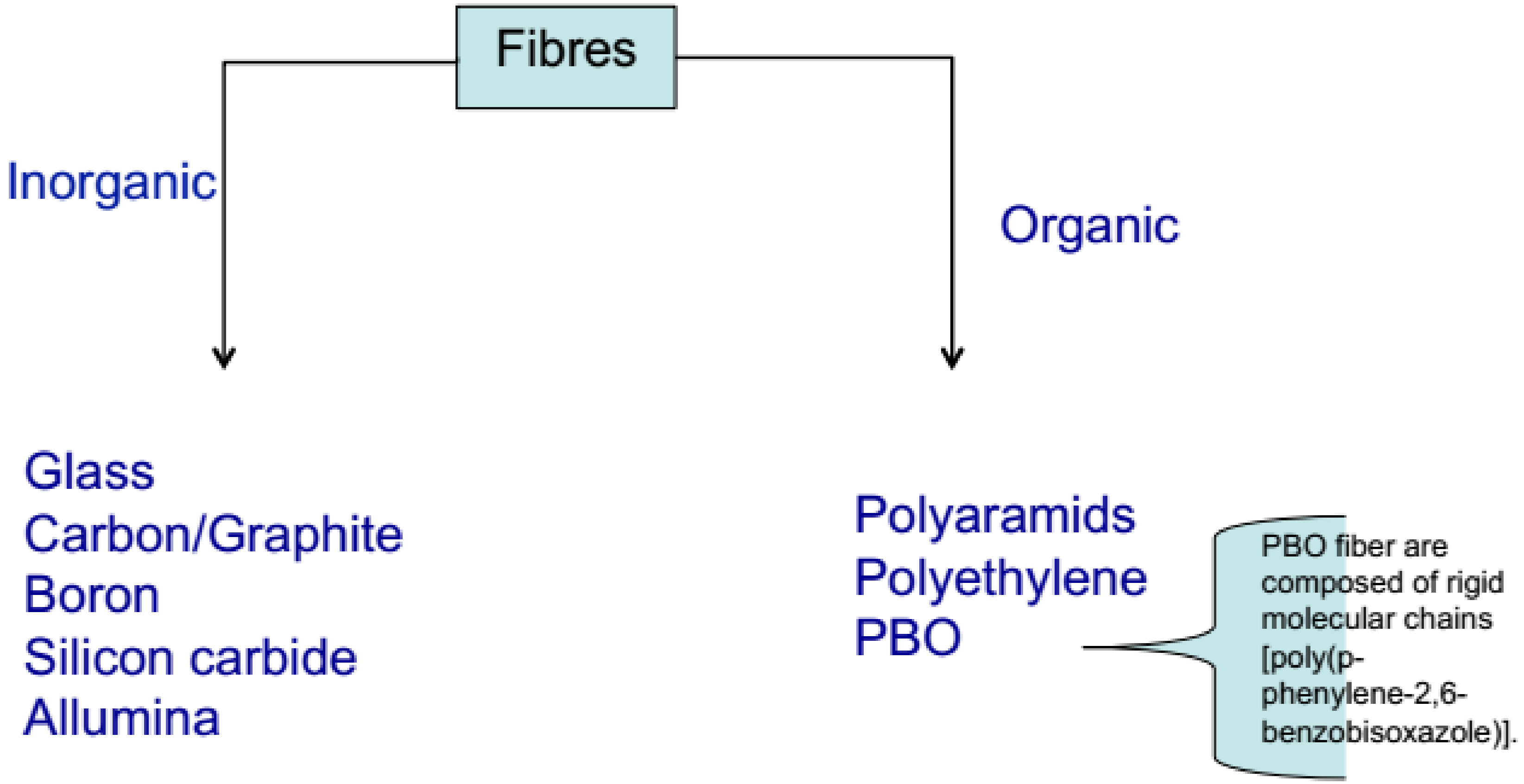
- ✓ Decrease the materials cost (fillers),
- ✓ Reach specific functional properties (e.g., electrical properties)
- ✓ Improve mechanical properties of the matrix material (e.g., stiffness and/or strength)

Depending on geometry, fillers can be divided in

- Particulate fillers(e.g., $CaCO_3$, silica, metallic powder,….)
- Short fibers (e.g., glass, C, organic fibers, vegetal/plant fibers, ceramic whiskers , …)
- Long fibers (e.g. , glass, C, organic fibers)

Fibers

Fibers used for composites, depending on their composition



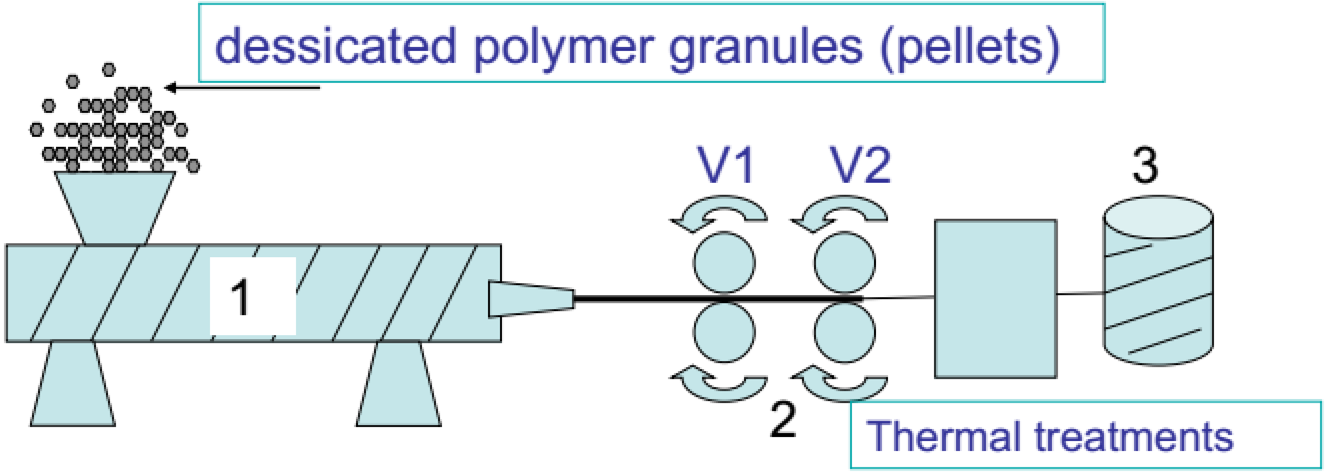
Fibers

Fabrication of Fibers

Synthetic fibers are made by:

- Melt spinning (spinning of a melt)
- Solution Dry spinning (spinning from a solution in a gas)
- Solution Wet spinning (spinning from a solution in liquid)

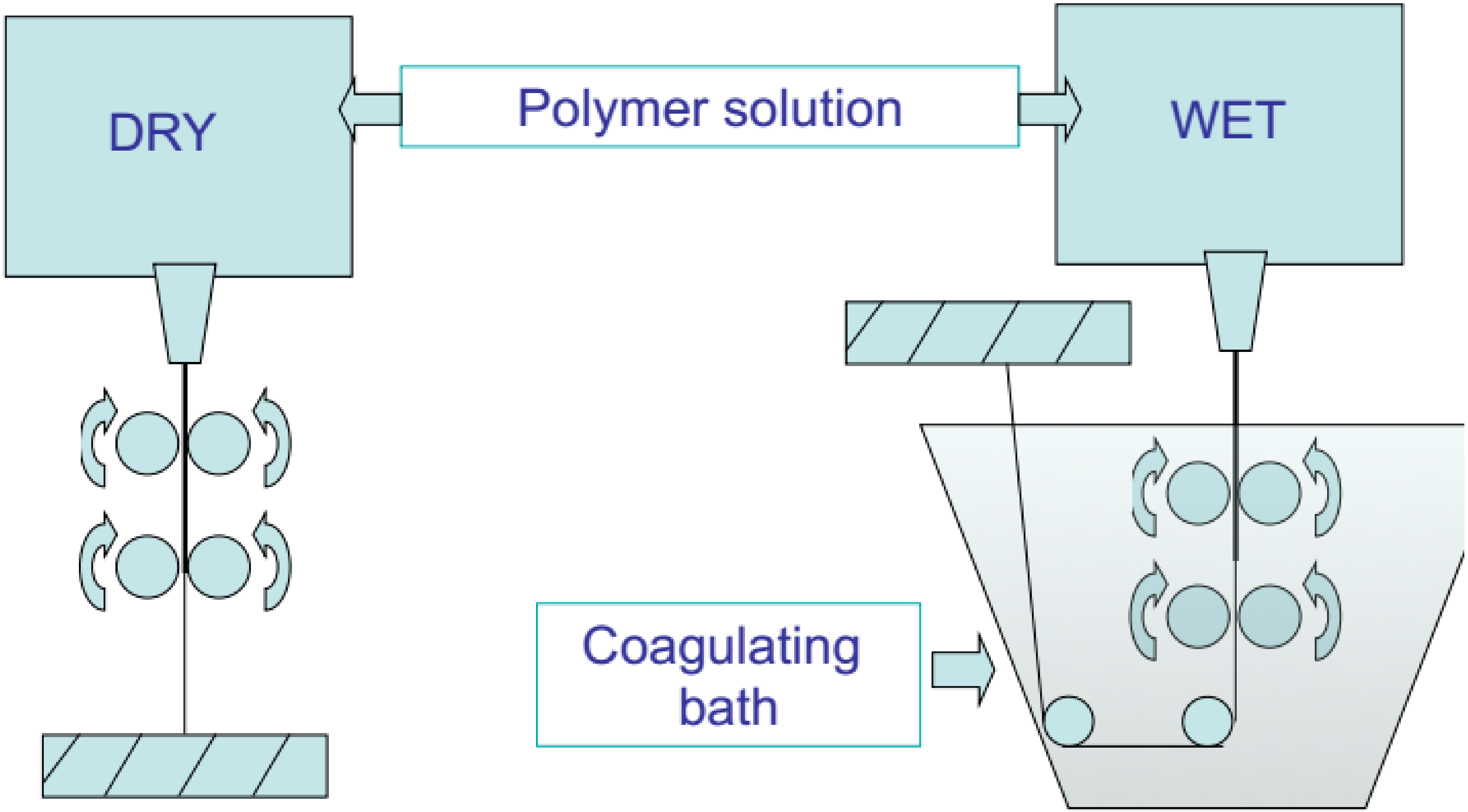
Melt Spinning



1. Extruder
2. Drawing system (V2>V1)
3. Collecting reel

Fabrication of Fibers

Solution Spinning



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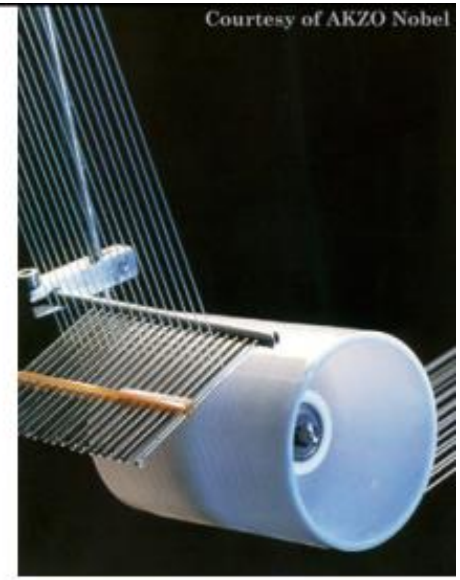
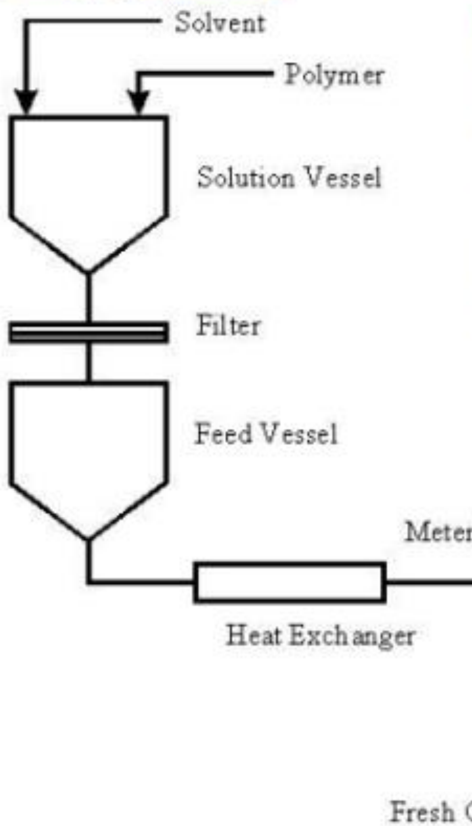
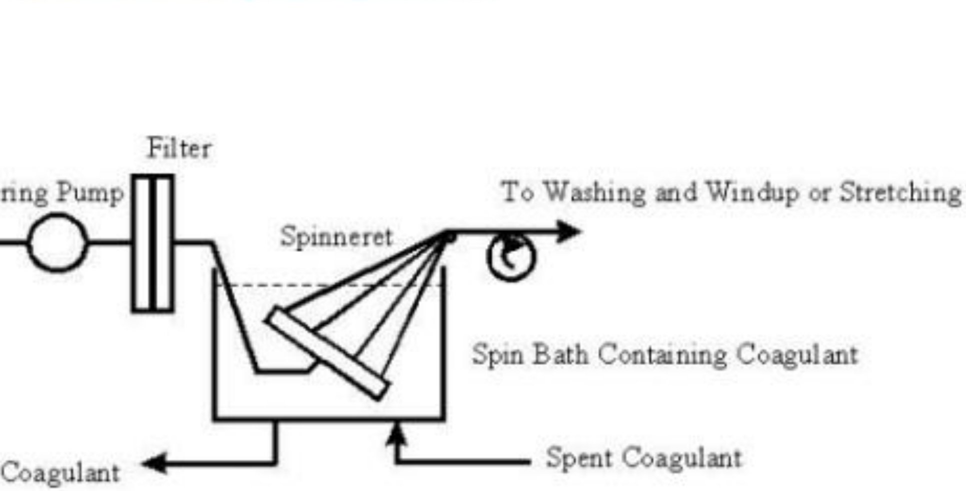
Fabrication of Fibers

Solution Spinning

Wet Spinning



Composite Materials

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Fiber - Glass

Glass is an amorphous material that consists of a silica (SiO_2) backbone with various oxide components to give specific compositions and properties.

Types: E-glass, S-glass, C-glass, quartz

E-glass: calcium aluminoborosilicate with 2 % alkali; good strength and electrical resistivity; the least expensive one

S-glass: 40 % higher than E-glass; high temp application

C-glass: soda lime borosilicate; use in corrosive environments

Quartz: low dielectric; use for protecting antennas

Composite Materials

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Fiber - Glass

Most widely used fiber

- **Uses**: Piping, tanks, boats, sporting goods
- **Advantages:-**Low cost (relative to others)

  -corrosion resistance

- **Disadvantages:-**High elongation,

  -moderate strength and weight

- **Types**: -E-Glass - electrical, cheaper

  -S-Glass - high strength

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Fibers - Carbon

A carbon fiber is a long, thin strand of material about 0.005-0.010 mm in diameter and composed mostly of C atoms.

The C atoms are bonded together in microscopic crystals that are more or less aligned parallel to the long axis of the fiber.

The crystal alignment makes the fiber incredibly strong for its size.

Several thousand carbon fibers are twisted together to form a yarn, which may be used by itself or woven into a fabric.

Composite Materials

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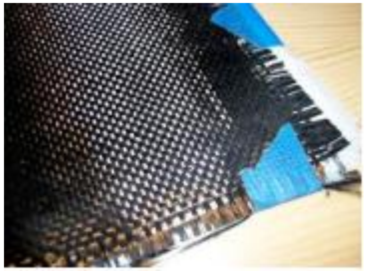
Fibers - Carbon

2nd most widely used fiber

- **Applications**: aerospace, sporting goods

- **Advantages**: – High stiffness and strength
  – Low density
  – Intermediate cost



- **Properties**:
  - Standard modulus: 207-240 Gpa
  - Intermediate modulus: 240-340 GPa
  - High modulus: 340-960 GPa
  - Diameter: 5-8 microns, smaller than human hair

Composite Materials

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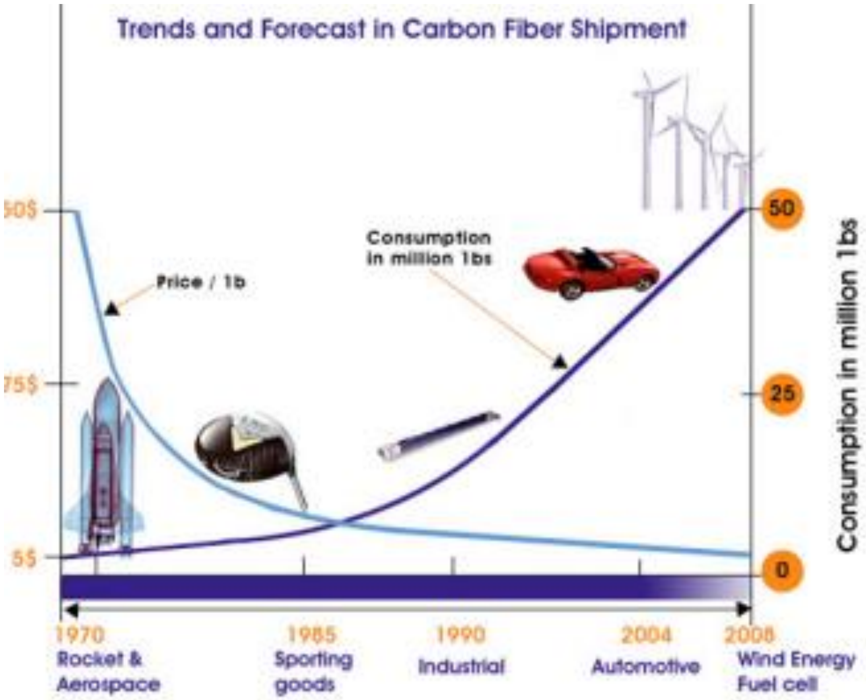
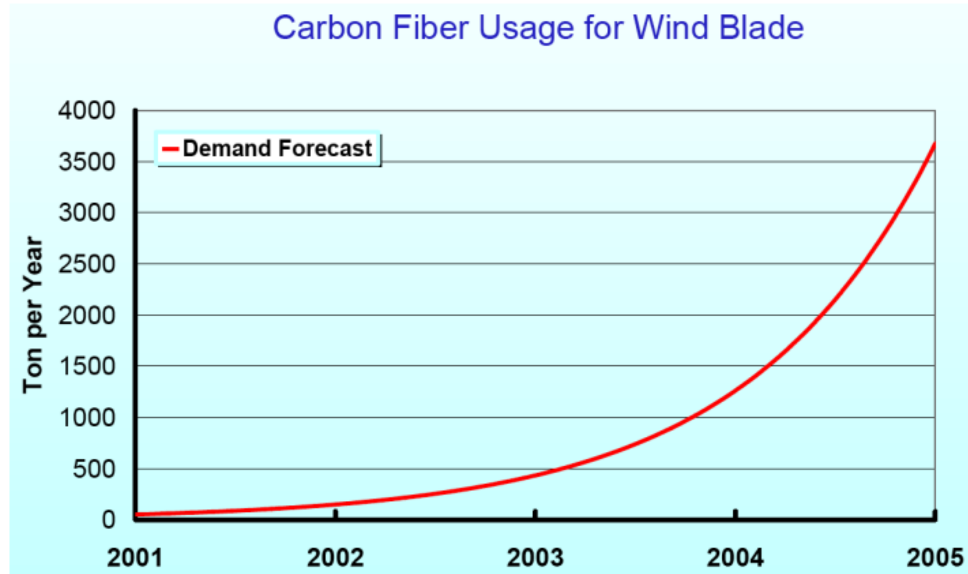
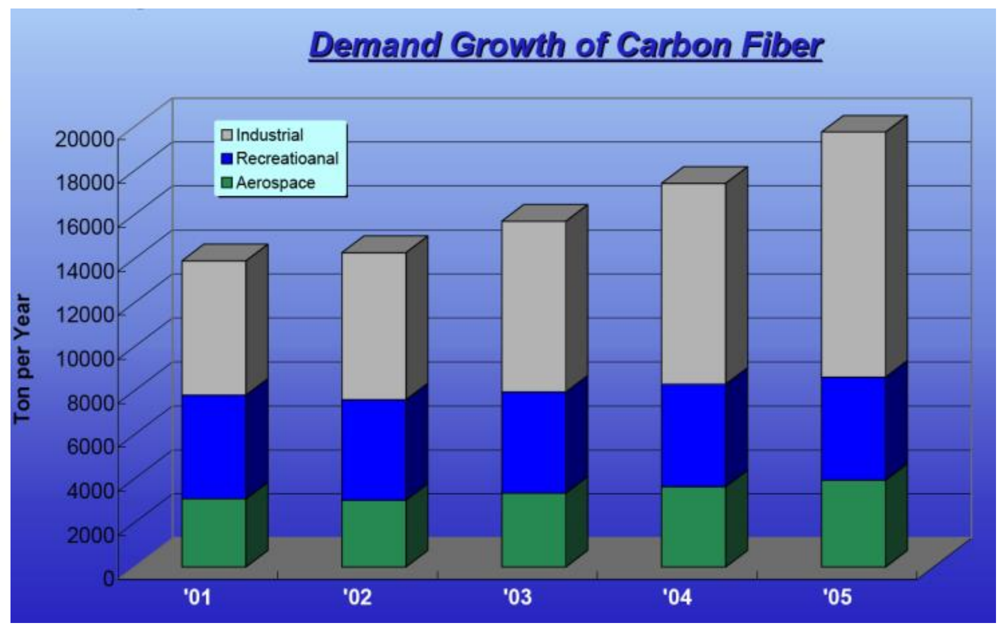
Fibers - Carbon







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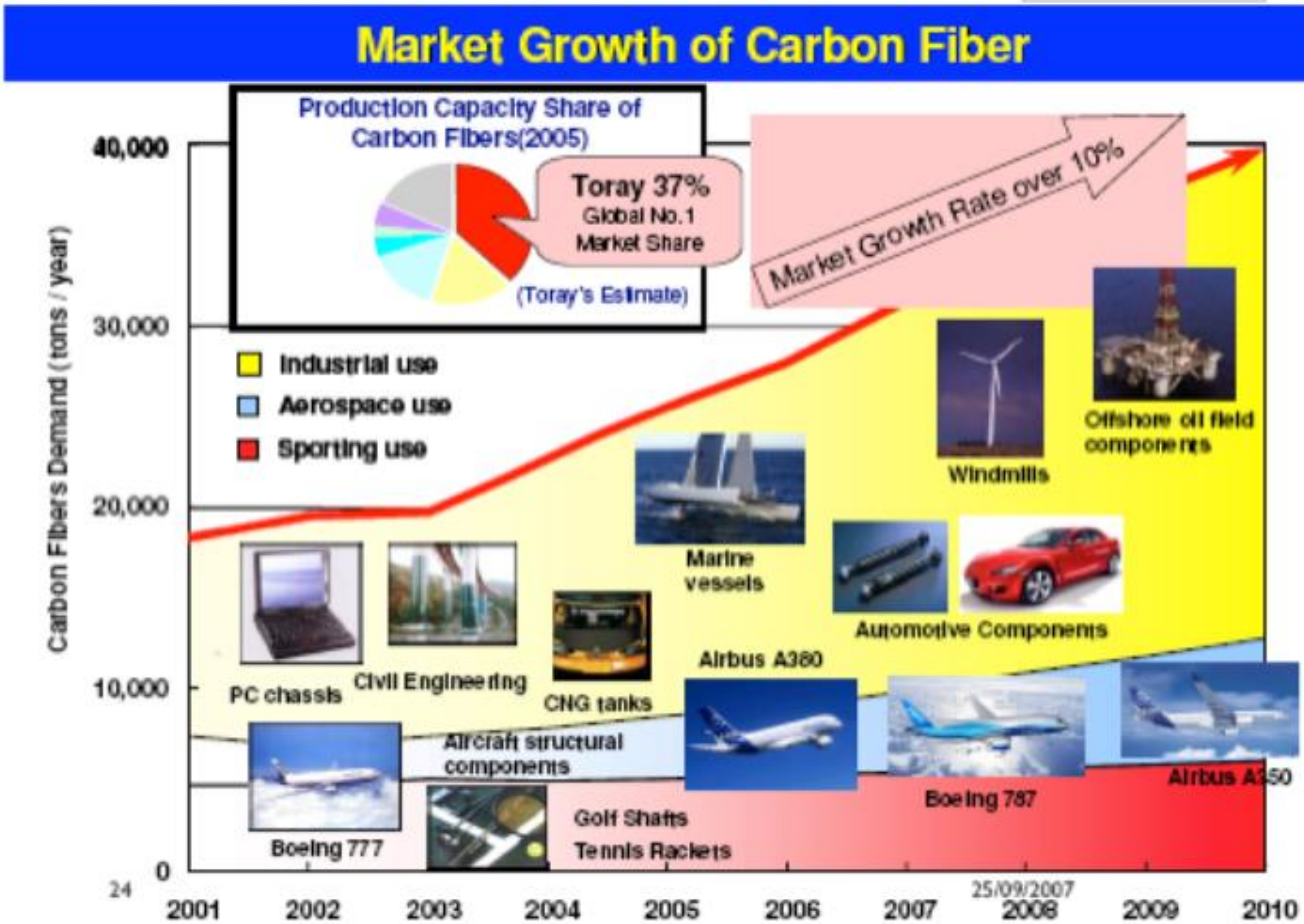
Fibers - Carbon



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Fibers - Others

Boron

-High stiffness, very high cost

-Large diameter - 200 microns

-Good compressive strength

Polyethylene - trade name: Spectra fiber

-Textile industry

-High strength

-Extremely light weight

-Low range of temperature usage

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Fibers - Others

Ceramic Fibers (and matrices)

-Very high temperature applications (e.g. engine components)

-Silicon carbide fiber - in whisker form

-Ceramic matrix so temperature resistance is not compromised

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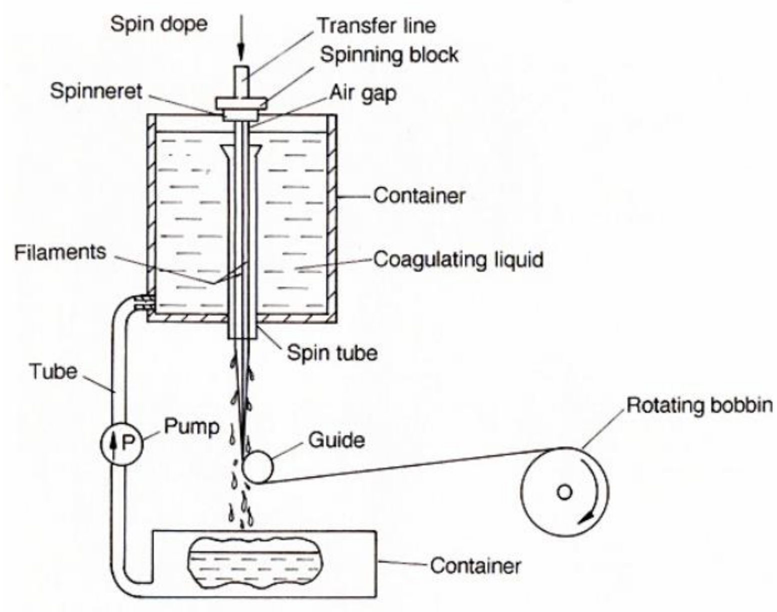
Fibers - Others

Aramid Fiber (Kevlar)

- Thermoplastic material: poly paraphenylene terephthalamide (PPTA)
- High tensile properties and weak compressive properties
- Mechanically stable between –200 and 200°C
- Chemically weak to degradation by strong acids and bases

Producing Kevlar fibers



Major applications of AFRPs

Bullet-proof vests, sporting goods, ropes, missile cases, pressure vessels, automobile brakes and clutch linings

Fibers

Fibers Material Properties

Table 1.1 Mechanical Properties of Typical Fibers

Fiber	Fiber Diameter (μm)	Fiber Density (lb/in³)	Fiber Density (g/cc)	Tensile Strength (ksi)	Tensile Strength (GPa)	Tensile Modulus (Msi)	Tensile Modulus (GPa)
E-glass	8–14	0.092	2.54	500	3.45	10.5	72.4
S-glass	8–14	0.090	2.49	665	4.58	12.5	86.2
Polyethylene	10–12	0.035	0.97	392	2.70	12.6	87.0
Aramid (Kevlar 49)	12	0.052	1.44	525	3.62	19.0	130.0
HS Carbon, T300	7	0.063	1.76	514	3.53	33.6	230
AS4 Carbon	7	0.065	1.80	580	4.00	33.0	228
IM7 Carbon	5	0.065	1.80	785	5.41	40.0	276
XUHM Carbon	—	0.068	1.88	550	3.79	62.0	428
GY80 Carbon	8.4	0.071	1.96	270	1.86	83.0	572
Boron	50–203	0.094	2.60	500	3.44	59.0	407
Silicon Carbide		0.115	3.19	220	1.52	70.0	483

Steel: density (Fe) = 7.87 g/cc; TS=0.380 GPa; Modulus=207 GPa

Al: density=2.71 g/cc; TS=0.035 GPa; Modulus=69 GPa