Chapter 5

Aircraft Manufacturing Techniques

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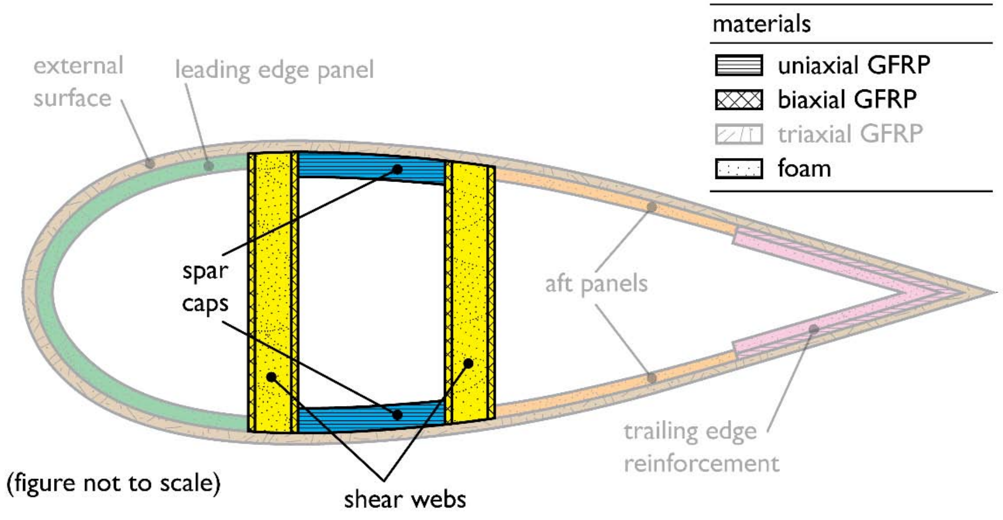
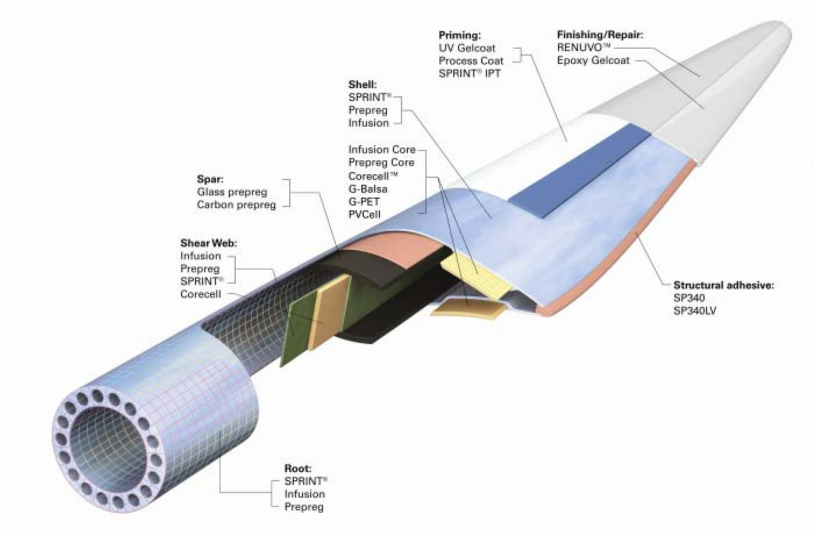
2. Composite Materials in Aerospace Applications

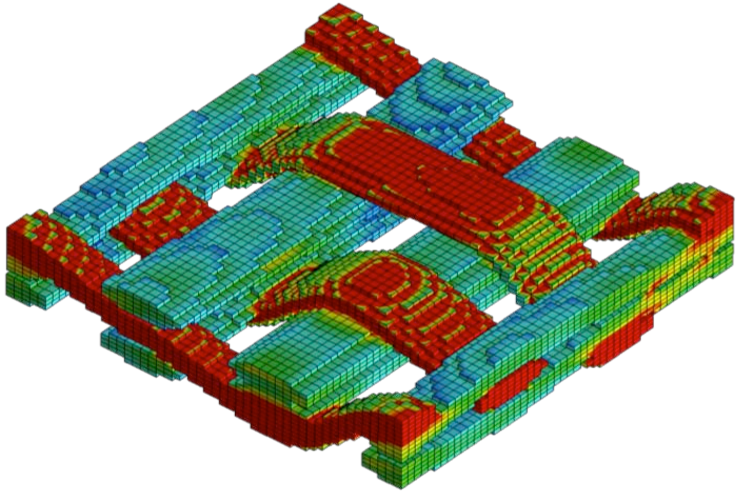
- ➢ Technological development depends on advances in the field of materials.
- ➢ The most advanced turbine or aircraft design is of no use if adequate materials to bear the service loads and conditions are not available.
- ➢ Whatever, the field may be, the final limitation on advancement depends on materials.
- ➢ Composite materials in this regard represent nothing but a giant step in the ever constant endeavor of optimization in materials.
- ➢ The origin of a distinct discipline of composite materials can be marked as the beginning of the 1960s. Approximately 80% of all R&D effort in composite materials has been done since 1965. The percentage has increased since then.





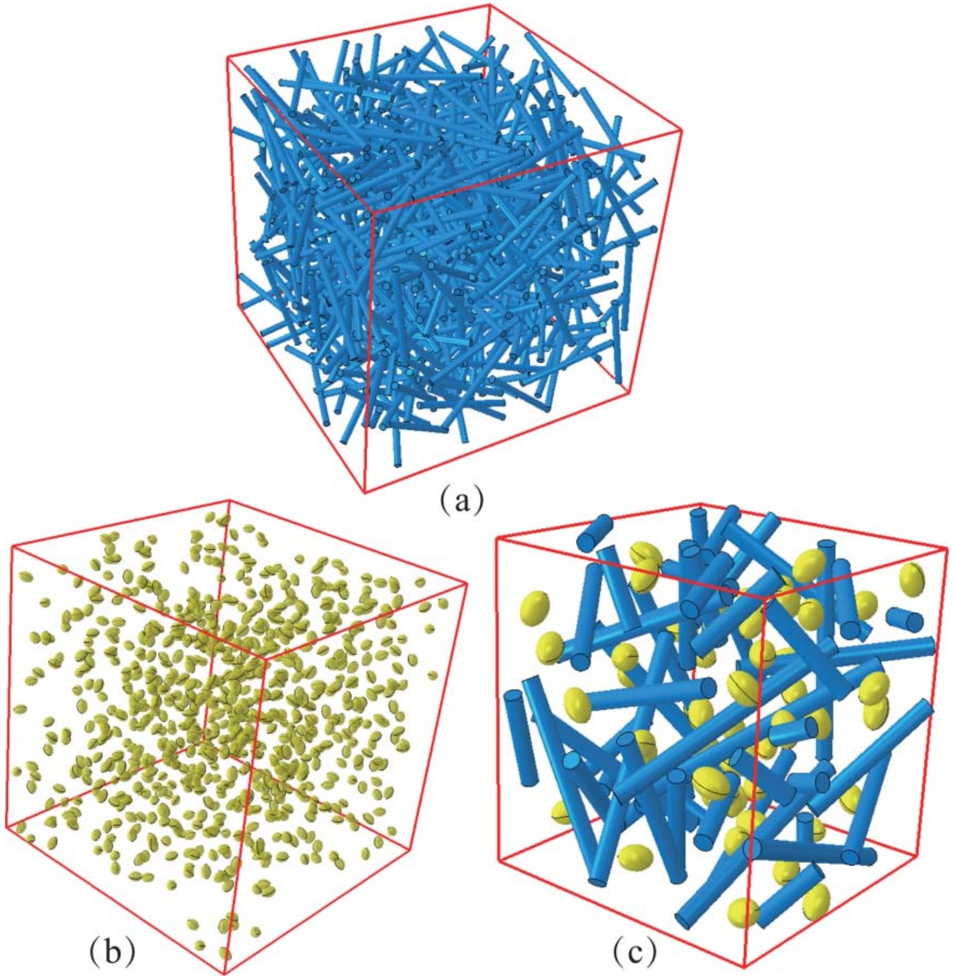
2. Composite Materials in Aerospace Applications

- As a definition, a material that satisfies the following conditions can be called a composite material:
  - It is manufactured (i.e. naturally occurring composites, such as wood, are excluded.)
  - It consists of two or more physically and/or chemically distinct, suitability arranged or disturbed phases with an interface separating them.
  - It has characteristics that are not depicted by any of the components in isolation.
- The great majority of materials is stronger and stiffer in the fibrous form than in any other form.
- Thus there is great attraction of fibrous reinforcements.



2. Composite Materials in Aerospace Applications

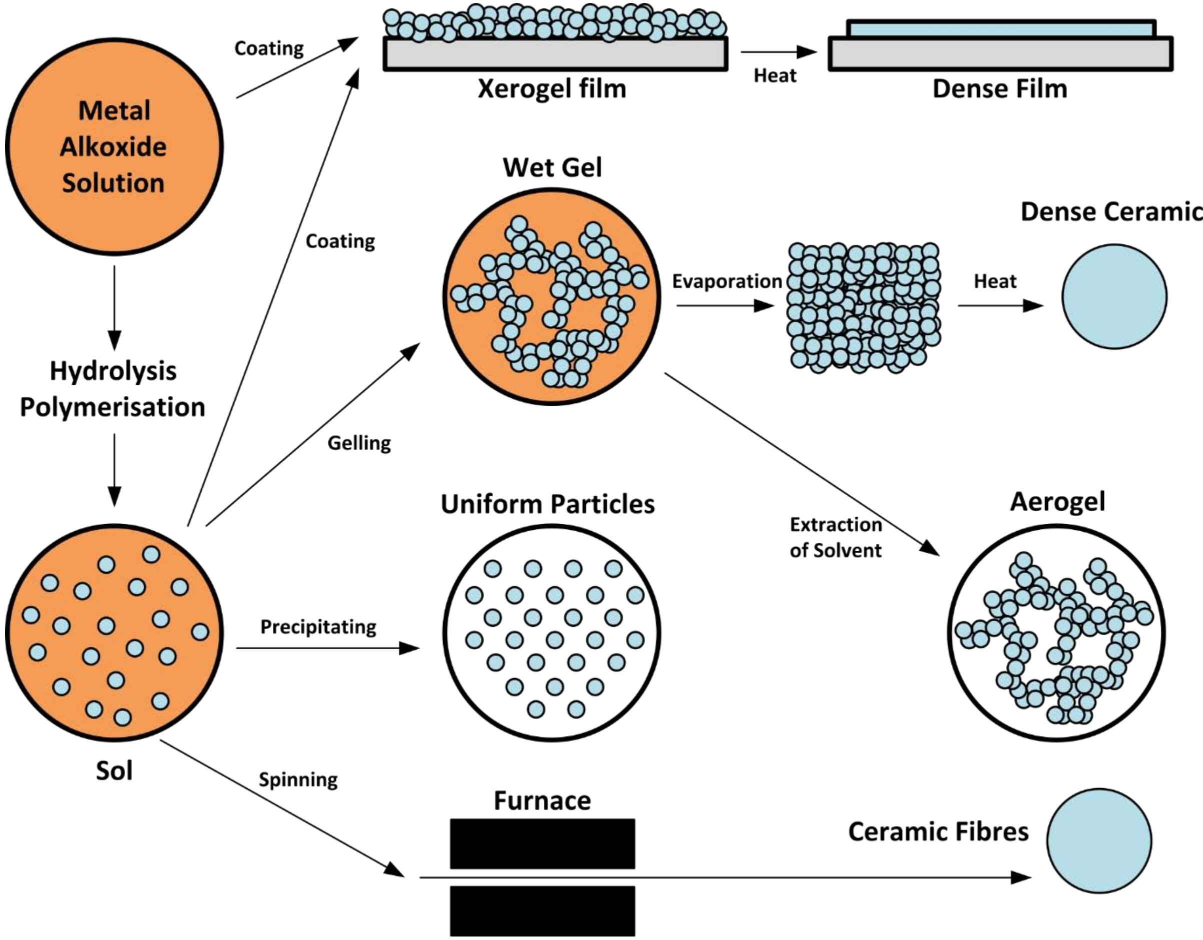
- The use of high-performance engineering materials is based on three important characteristics:
- A small diameter with respect to it's grain size or other microstructural unit. This allows a higher fraction of the theoretical strength to be attained than that possible in bulk form. This is a direct result of the so-called **size effect**; that is, the smaller the size, the lower the probability of having imperfections in the material.
- A high aspect ratio (length/diameter) that allows a very large fraction of the applied load to be transferred via the matrix to the stiffs and strong fiber.
- A very high degree of flexibility that is really a characteristic of a material having a high modulus and a small diameter. This flexibility permits a variety of techniques to be employed for making composites with these fibers.



2. Composite Materials in Aerospace Applications

Glass Fibers

- Glass fiber is a generic name like carbon fiber or steel.
- Common glass fibers are silica based (~50%-60% SiO_2) and contain a host of other oxides of calcium, boron, sodium, aluminum, and iron, for example.
- A common modern method of fabrication of glass fibers, as well as a host of other fibers, is the **sol-gel technique**.
- A **sol** is a colloidal suspension in which the individual particles are so small that they show no sedimentation. A **gel** is a suspension in which the liquid medium has become viscous enough to behave more or less as a solid.
- The sol-gel process involves a conversion of fibrous gels, drawn from a solution at near room temperatures, into glass or ceramic fibers at several hundred degrees Celsius.



Sol-gel Process

2. Composite Materials in Aerospace Applications

Glass Fibers

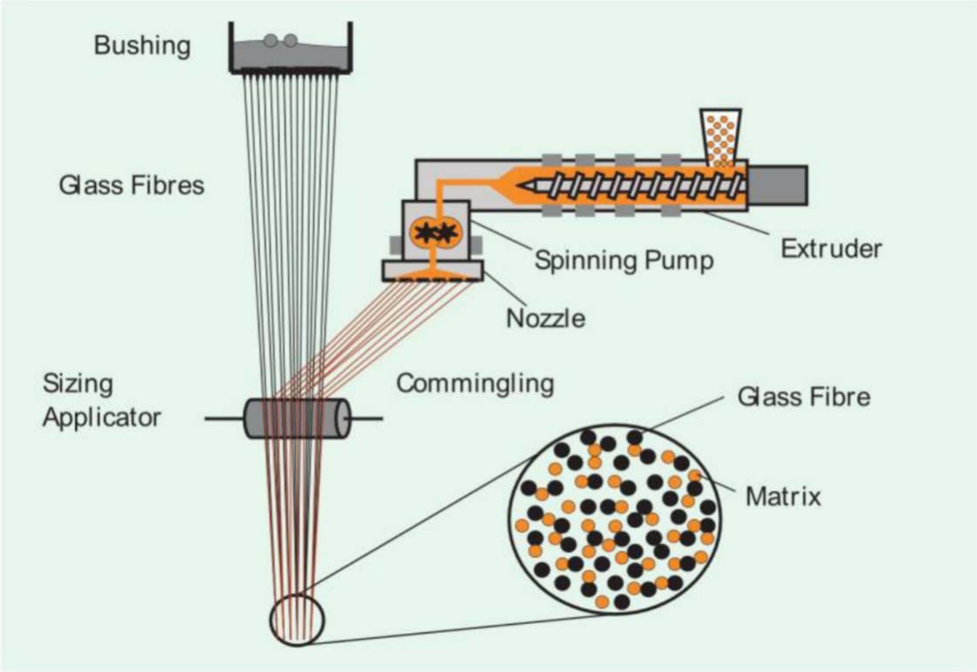
Glass fiber spool

Glass reinforced concrete mixture

White Glass fiber composite

Glass Fibers

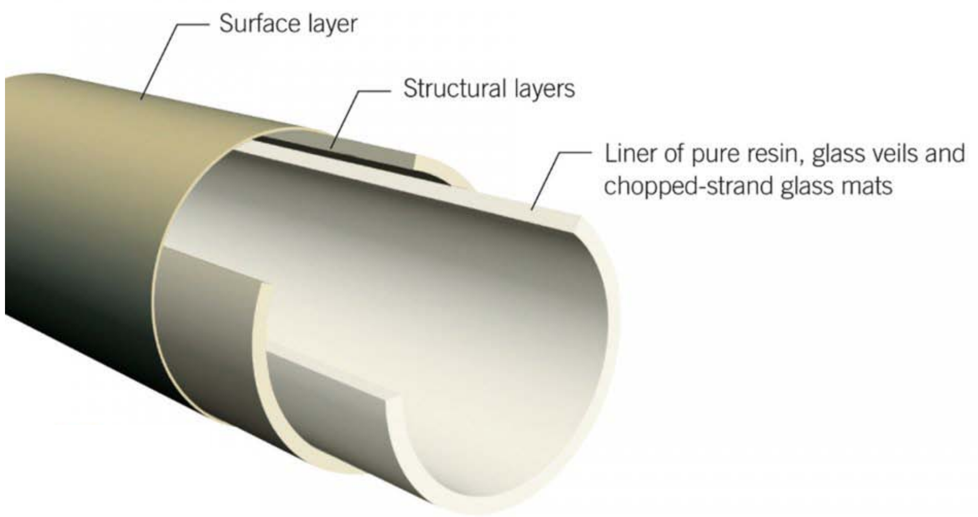
- Glass fibers are easily damaged by the introduction of surface defects. To minimize this and make handling of these fibers easy, a sizing treatment is given. Sizing protects as well as binds the filaments into a strand.
- For reinforcement purposes, a size based on polyvinyl acetate and containing a resin coupling agent is used; the latter is compatible with polyester, epoxy, and phenolic matrix resins. The coupling agent is used to bond the sized glass fiber and the resin matrix.
- Glass fibers continue to be used for reinforcement of epoxy, polyester, and phenolic resins.
- Moisture decreases glass fiber strength and are susceptible to static fatigue.



2. Composite Materials in Aerospace Applications

Glass Fibers

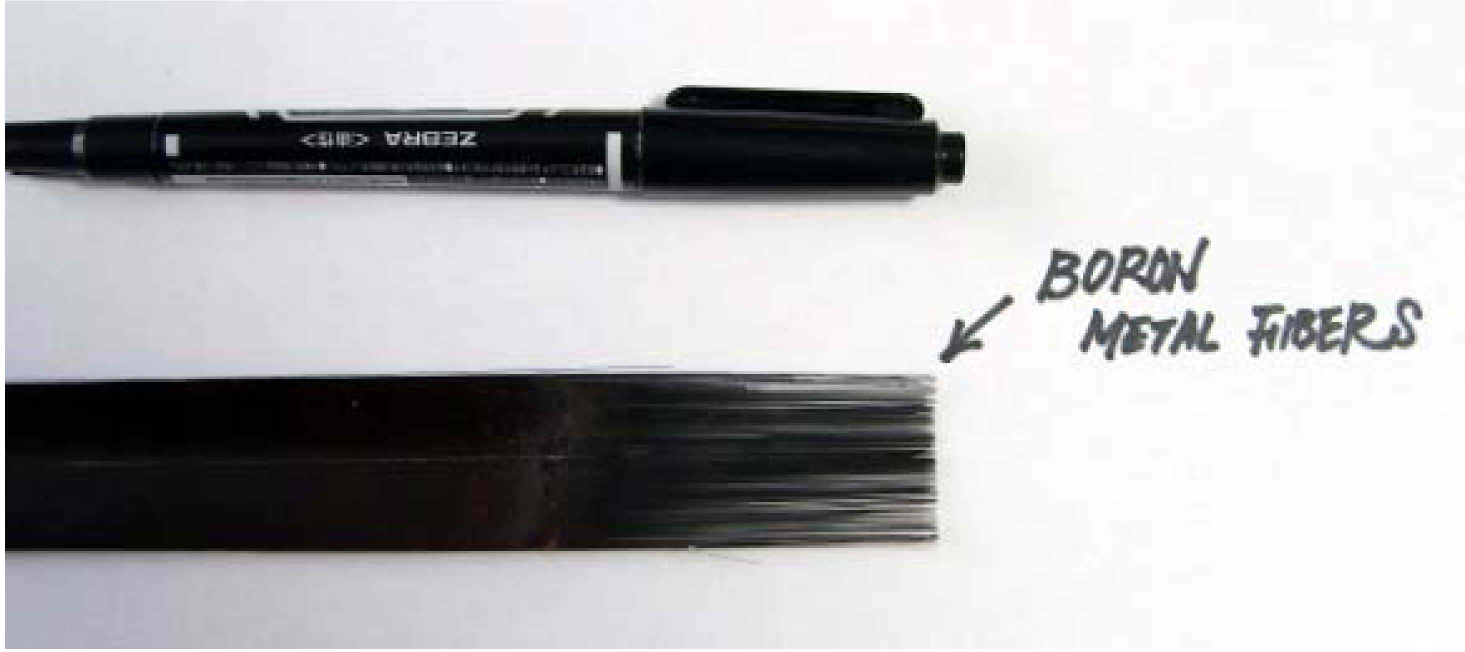
- Glass fibers reinforced resins are used widely in the building and construction industry. Commonly, these are called glass reinforced plastics or GRP.
- They are used in the form of cladding for other structural materials or as an integral part of structural or non-load bearing wall panel.
- Window frames, tanks, bathroom units, pipes, and ducts are common examples.
- Boat hulls have primarily been made out of GRP.
- The rail and road transportation industry as well as the aerospace industry are other big users of GRPs.



2. Composite Materials in Aerospace Applications

Boron Fibers

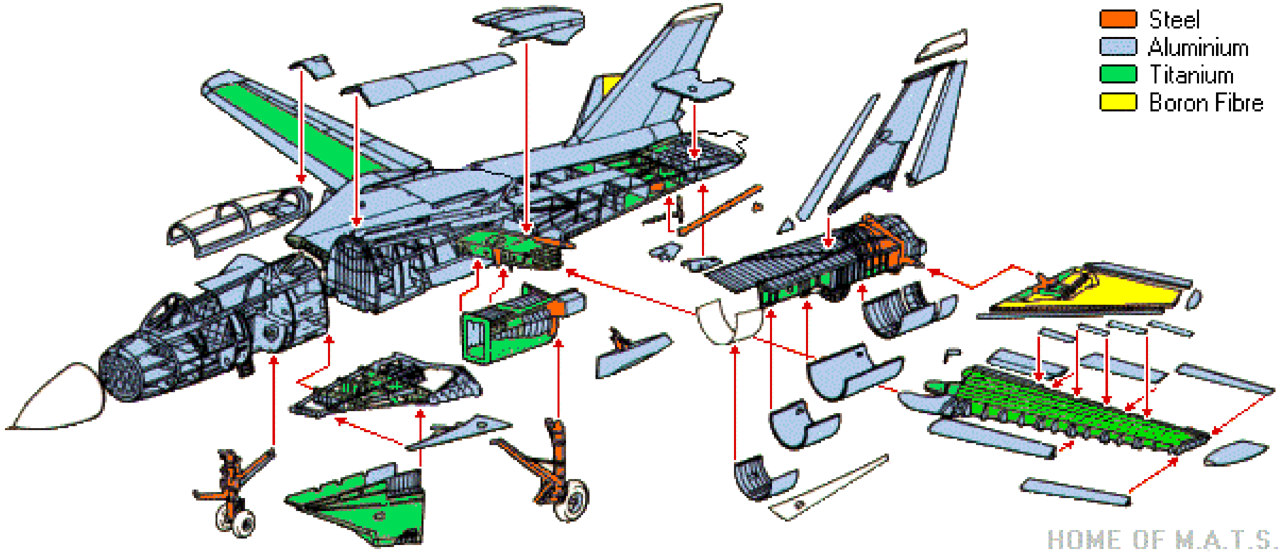
- Boron is an inherently brittle material. It is commercially made by chemical vapor decomposition of boron on a substrate, that is, boron fiber as produced is itself a composite fiber.



2. Composite Materials in Aerospace Applications

Boron Fibers

- Boron fiber is a very brittle material and cracks originate at preexisting defects located at the boron-core interface or at the surface.
- Boron fiber composites are in use in a number of U.S. military aircraft, notably F-14 and F-15, and in the U.S. Space Shuttle.
- Increasingly, boron fibers are being used for stiffening golf shafts, tennis racks, and bicycle frames.
- One big obstacle to the widespread use of boron fiber is its **high cost** compared to that of other fibers.

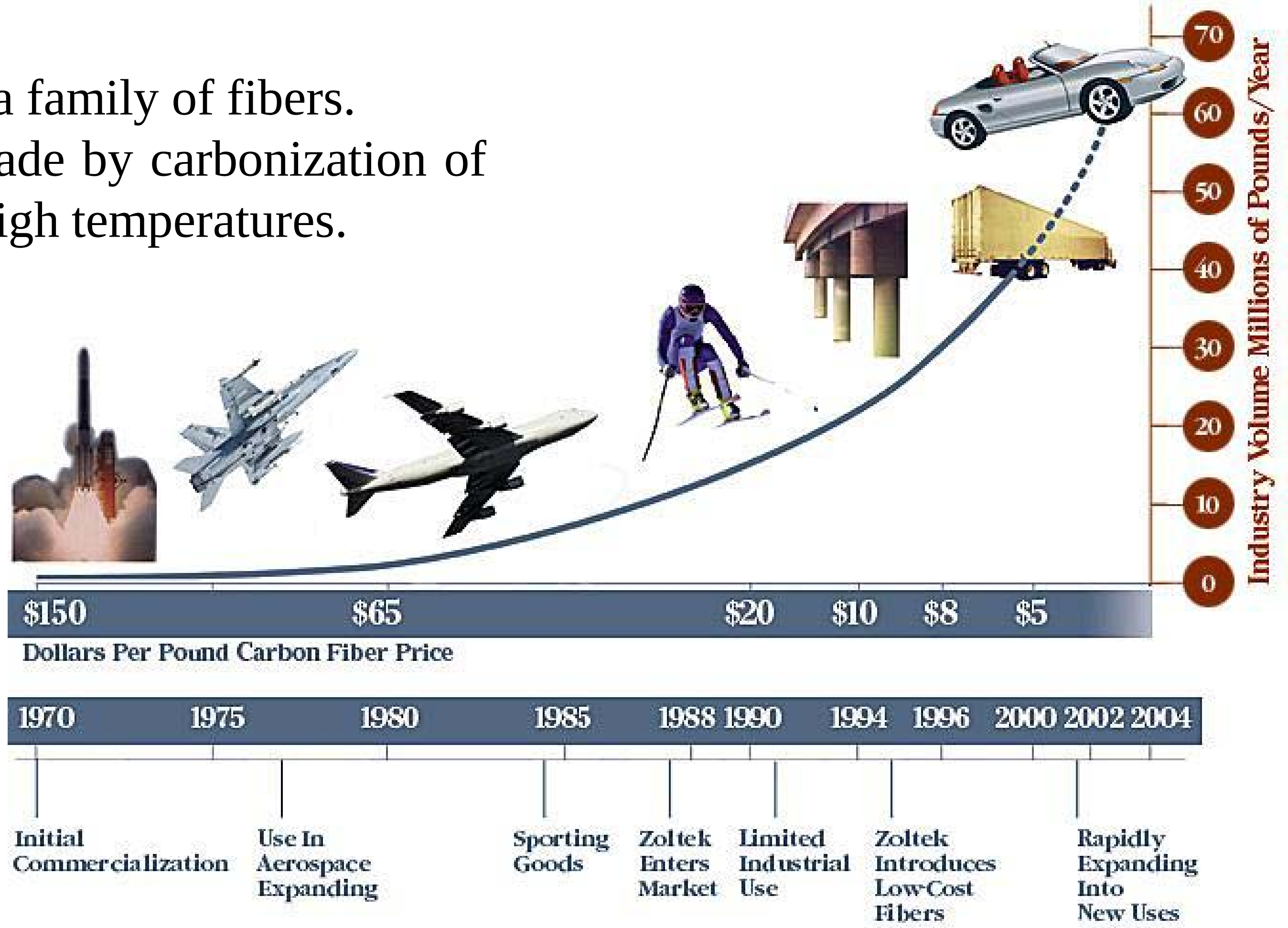


2. Composite Materials in Aerospace Applications

Carbon Fibers

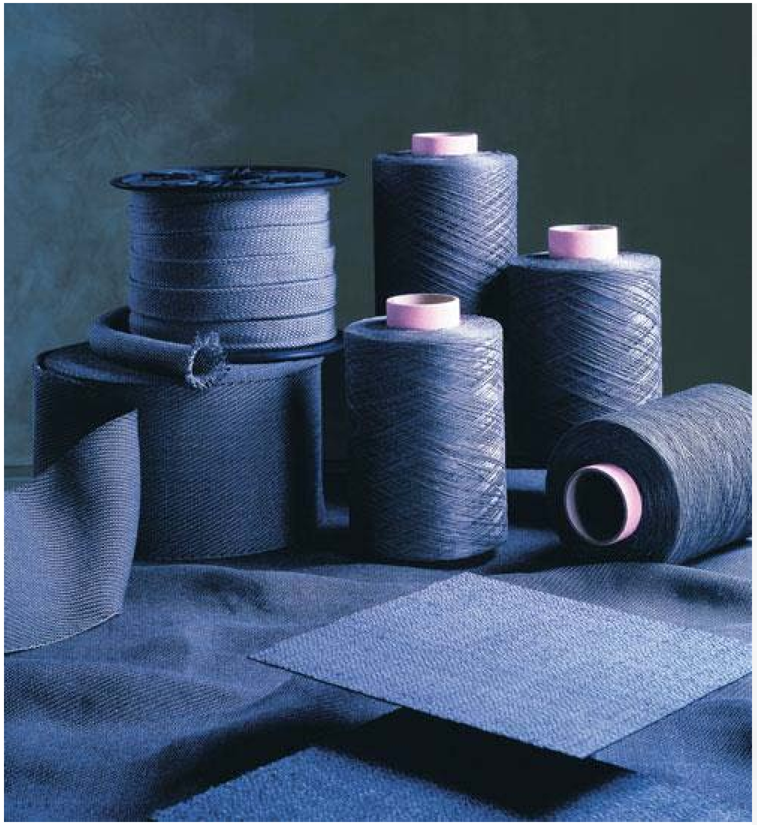
- The name carbon fiber is a generic one representing a family of fibers.
- Carbon fibers of extremely high modulus can be made by carbonization of organic precursor fibers followed by graphitization at high temperatures.

- Unlike rigid diamond structure, graphitic carbon has a lamellar structure. (hexagonal lattice structure with van der Waals force holding the layers together).
- Thus depending on the size of the lamellar packets, their stacking heights, and the resulting crystalline orientations, one can obtain a range of properties.
- For high modulus carbon fiber, the orientation of graphitic crystals or lamellas need to be improved, obtained at a varying degree.



2. Composite Materials in Aerospace Applications

Carbon Fibers

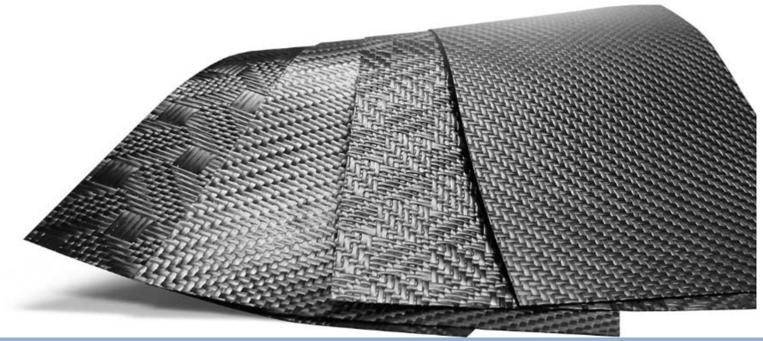



Carbon fiber spools and fabric

2. Composite Materials in Aerospace Applications

Carbon Fibers

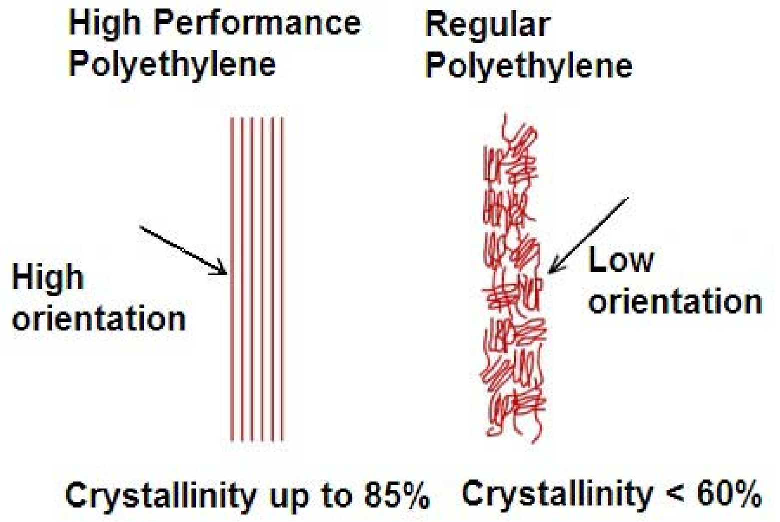
- Carbon fibers have a variety of applications in the aerospace and sporting goods industries.
- Cargo bay doors and booster rocket casings in the U.S. Shuttle are made of carbon fiber reinforced epoxy composites. Modern commercial aircrafts also use carbon fiber reinforced composites.
- Among other areas of application of carbon fibers are machinery items such as turbine, compressor and windmill blades and flywheels.
- Other machine applications include both equipment as well as implant materials (e.g., ligament replacement in knees and hip joint replacement).



2. Composite Materials in Aerospace Applications

Organic (Polymer) Fibers

- Owing to the strong covalent carbon-carbon bond, linear chain polymers such as polyethylene are expected to be potentially very strong and stiff.
- The orientation of these polymer chains with respect to the fiber axis and the manner in which they fit together (i.e. the order of crystallinity) are controller by their chemical nature and the processing route.
- **Spectra**- an extended chain ultrahigh molecular weight (UHMW) polyethylene (PE) fiber (Allied corporation).
- **Kevlar**- trade name for the highly successful aramid fiber commercialized by Du Pont (also, noncommercially by Monsanto).
- Aramid fiber is a generic name for a class of synthetic fibers called **aramatic polyamide fibers**.



2. Composite Materials in Aerospace Applications

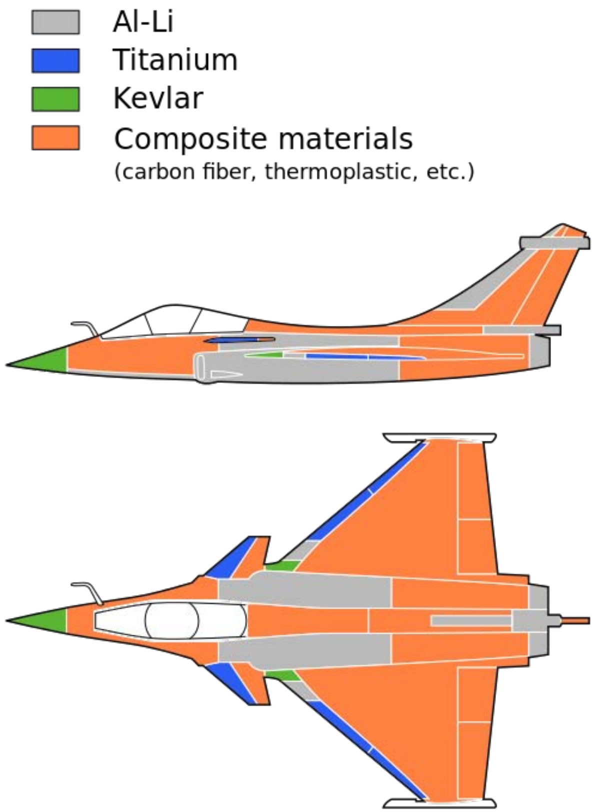
Organic (Polymer) Fibers

- Nylon is a generic name for any long-chain polyamide.
- Aramid fibers like Nomex and Kevlar, however, are ring compounds based on the structure of benzene as opposed to compounds used to make nylon.
- Kevlar's aromatic rings impart the rigid rod-like characteristics. These chains are highly oriented and extended along the fiber axis with the resultant high longitudinal modulus.
- The fibers available in three types:
  - **Kevlar-** Meant mainly for use as rubber reinforcement for tires (belts or radial tires of cars and carcasses of radial tires for trucks) and, in general, for mechanical rubber goods.

2. Composite Materials in Aerospace Applications

Organic (Polymer) Fibers

- …
  - **Kevlar 29-** Meant for ropes, cables, coated fabrics for inflatable, architectural fabrics, and ballistic protection fabrics. Vests made of Kevlar 29 have been used by law enforcement agencies in many countries.
  - **Kevlar 49-** Meant for reinforcement of epoxy, polyester, and other resins for use in aerospace, marine, automotive, and sports industries.



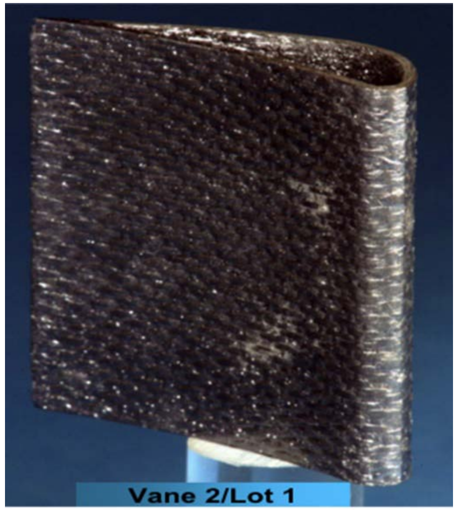
2. Composite Materials in Aerospace Applications

Organic (Polymer) Fibers

2. Composite Materials in Aerospace Applications

Ceramic Fibers

- Ceramic fibers combine rather high strength and elastic modulus with high-temperature capability and a general freedom from environmental attack. These characteristics make them attractive as reinforcements in high-temperature structural materials.
- Some important ceramic fibers are as follows:
    - **Alumina fibers**- may be composed of 70-100% Al_2O_3 and 30-0% SiO_2. They can have excellent strength retention at high temperatures.
    - **Silicon Carbide fibers (SiC)**- Attractive for low density and low thermal expansion. Available cheaply and abundantly in particulate/whisker form.

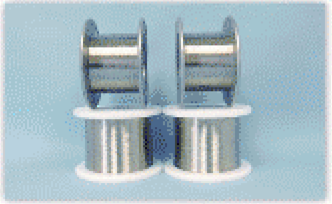


2. Composite Materials in Aerospace Applications

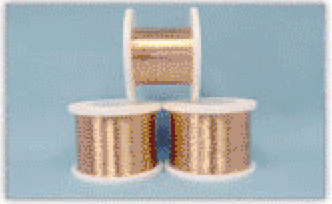
Metallic Fibers

- Metals in the form of wires show rather high strength levels.
- The wires of **beryllium** (low density and high modulus), **steel** (high strength and low cost), and **tungsten** (high modulus and refractory) are among the most important ones.
- One great advantage of metallic wires is that they show very consistent strength values, more so than any of the ceramic fibers.
- Steel wire is a common commercial reinforcement material, more for concrete than for metals or polymers. They are also commonly used as reinforcement in tires.


Beryllium Copper Wire


Nickel Wire


Phosphor Bronze Wire


Copper Wire


Brass Wire