COMPOSITE MATERIALS

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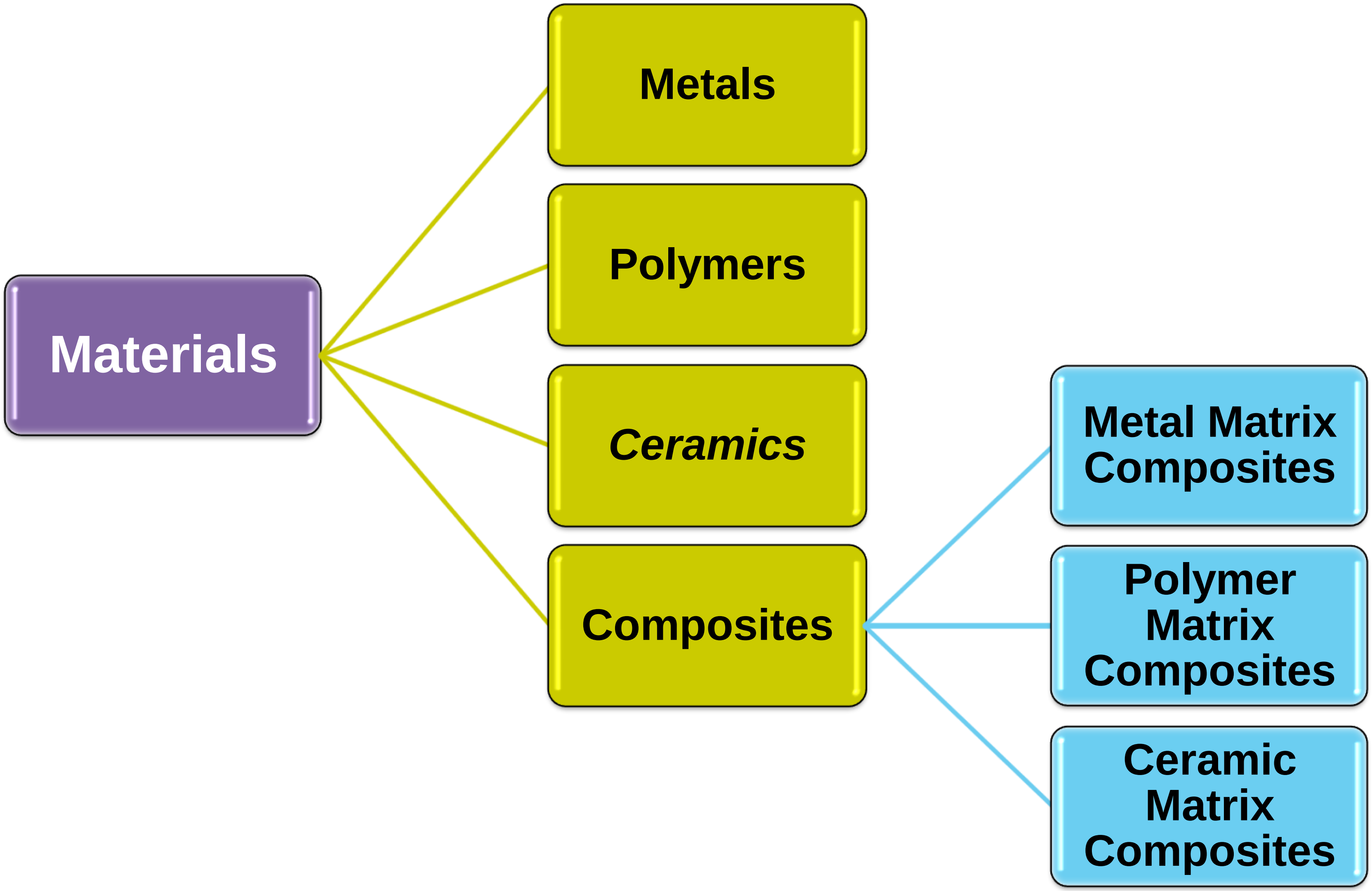
ISSUES TO ADDRESS

- Classification of composites.
- Typical applications of composite materials.

Classifications of Materials



Classifications of Composites

One Possible Classification of Composite Materials

1. *Traditional composites* – composite materials that occur in nature or have been produced by civilizations for many years
   - Examples: wood, concrete, asphalt

2. *Synthetic composites* - modern material systems normally associated with the manufacturing industries, in which the components are first produced separately and then combined in a controlled way to achieve the desired structure, properties, and part geometry

Classifications of Composites

Concrete

The most common large-particle composite is concrete, made of a cement matrix that bonds particles of different size (gravel and sand).

Cement was already known to the Egyptians and the Greek. Romans made cement by mixing lime (CaO) with volcanic ice.

In its general from, cement is a fine mixture of lime, alumina, silica, and water. Portland cement is a fine powder of chalk, clay and lime-bearing minerals fired to 1500 °C (calcinated). It forms a paste when dissolved in water. It sets into a solid in minutes and hardens slowly (takes 4 months for full strength). Properties depend on how well it is mixed, and the amount of water: too little - incomplete bonding, too much - excessive porosity.

The advantage of cement is that it can be poured in place, it hardens at room temperature and even under water, and it is very cheap. The disadvantages are that it is weak and brittle, and that water in the pores can produce crack when it freezes in cold weather.

Classifications of Composites

Concrete

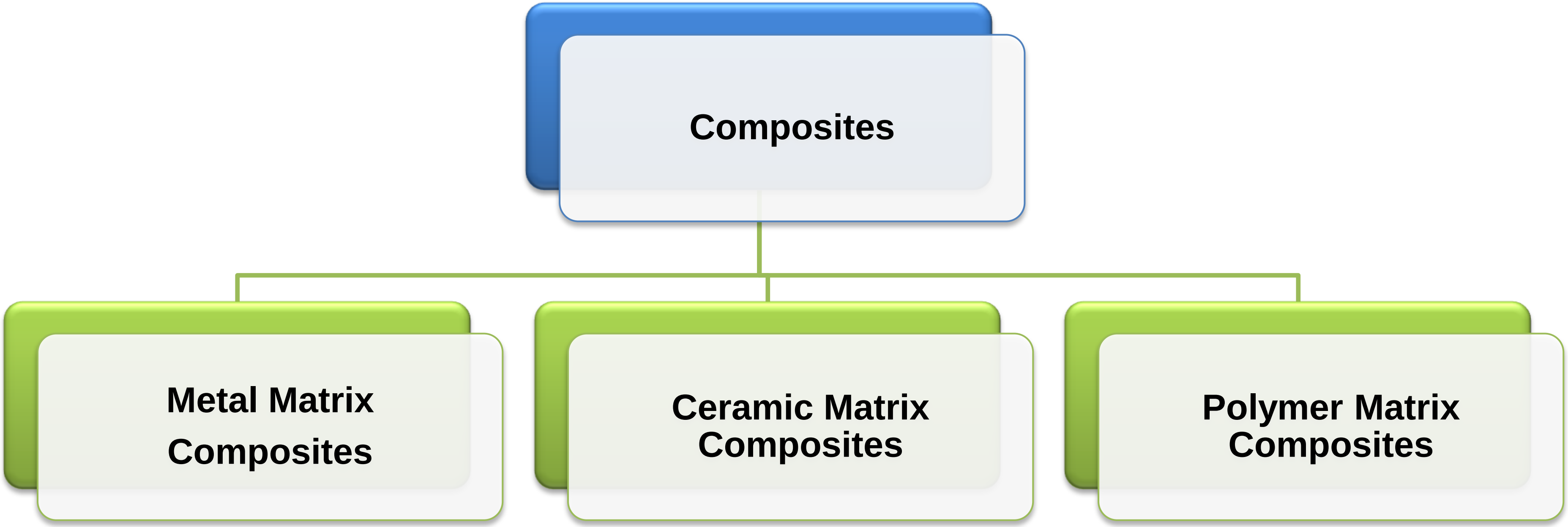
Concrete is cement strengthened by adding particulates. The use of different size (stone and sand) allows better packing factor than when using particles of similar size.

Concrete is improved by making the pores smaller (using finer powder, adding polymeric lubricants, and applying pressure during hardening.

Reinforced concrete is obtained by adding steel rods, wires, mesh. Steel has the advantage of a similar thermal expansion coefficient, so there is reduced danger of cracking due to thermal stresses. *Pre-stressed concrete* is obtained by applying tensile stress to the steel rods while the cement is setting and hardening. When the tensile stress is removed, the concrete is left under compressive stress, enabling it to sustain tensile loads without fracturing. Pre-stressed concrete shapes are usually prefabricated. A common use is in railroad or highway bridges.

Classifications of Composites

According to matrix



Classifications of Composites

Reinforcement: Function depends on matrix

- **Metal matrix;** to increase the hardness and creep resistance at high temperature
- **Polymer matrix;** to improve stiffness, strength and toughness
- **Ceramic matrix;** to improve toughness

Types of Composites

Primary Phase, Matrix

Secondary Phase, Reinforcement

	Metal	Ceramic	Polymer
Metal	Powder metallurgy parts – combining immiscible metals	Cermets (ceramic-metal composite)	Brake pads
Ceramic	Cermets, TiC, TiCN Cemented carbides – used in tools Fiber-reinforced metals	SiC reinforced Al_2O_3 Tool materials	Fiberglass
Polymer	Fiber reinforced metals Auto parts Aerospace		Kevlar fibers in an epoxy matrix
Elemental (C, B, etc.)	Fiber reinforced metals		Rubber with carbon (tires) Boron, Carbon reinforced plastics

Classifications of Composites

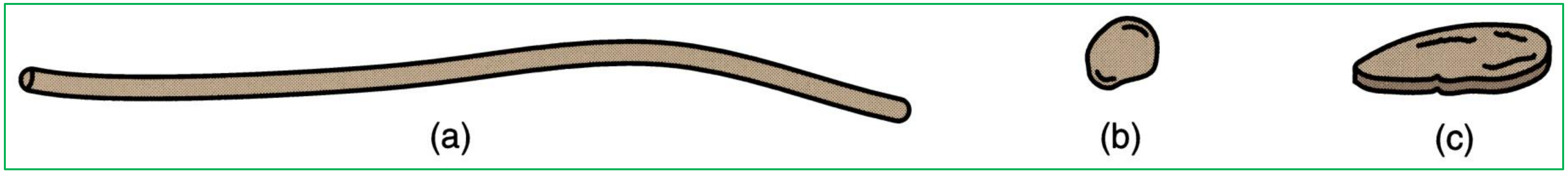
According to reinforcement

- continuous (fibrous, laminar, etc)
- discontinuous (particulate, short fibre, platelet, etc)

Classifications of Composites

The reinforcement is usually a ceramic and/or glass. If it is similar in all dimensions, it is a **particulate reinforced composite**; if needle-shaped single crystals, it is **whisker-reinforced**; if cut continuous filament, chopped **fiber-reinforced**; and if continuous fiber, **fiber composite**.

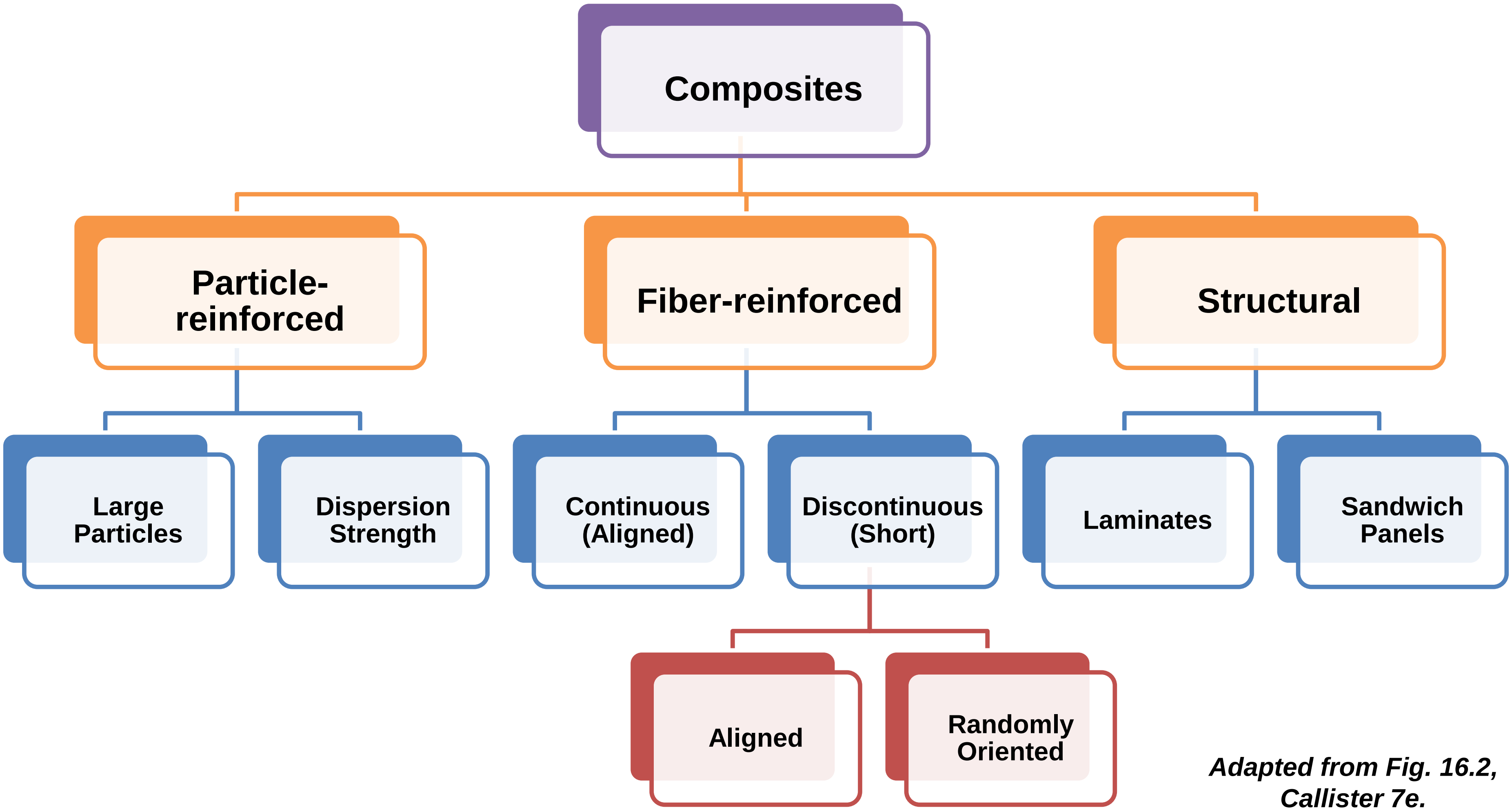
For fiber composites configuration gives a further category. If fibers are aligned in one direction, it is a **uniaxial fiber composite**; if arranged in layers, it is a **laminar composite**; if a three-dimensional arrangement, it is a 3D weave composite.



Possible physical shapes of imbedded phases in composite materials: (a) fiber, (b) particle, and (c) flake

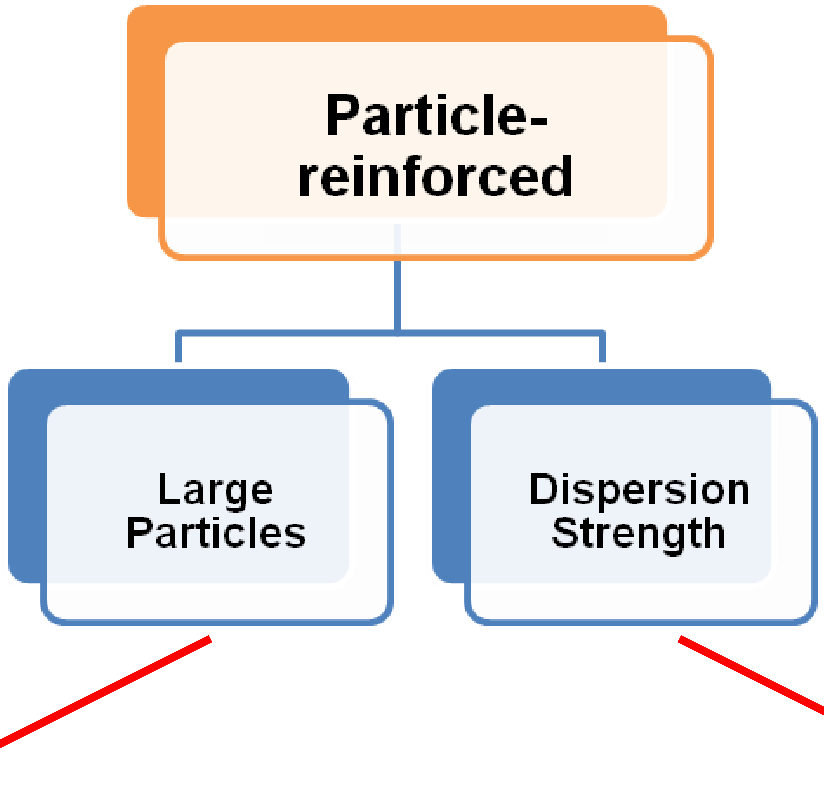
Classifications of Composites

Composites can be engineered in terms of the amount, shape, size and distribution of the reinforcing phase, as well as the interface between the matrix and reinforcing phases.



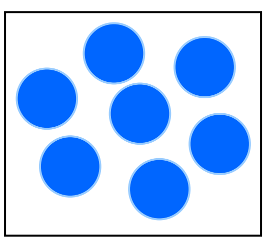
Adapted from Fig. 16.2, Callister 7e.

Classifications of Composites

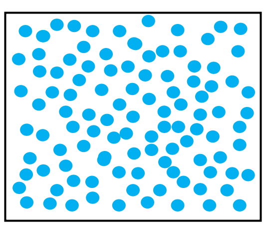


<u>Dispersion-Strengthened Composites</u>

Use of very hard, small particles to strengthen metals and metal alloys. The effect is like precipitation hardening but not so strong. Particles like oxides do not react so the strengthening action is retained at high temperatures.

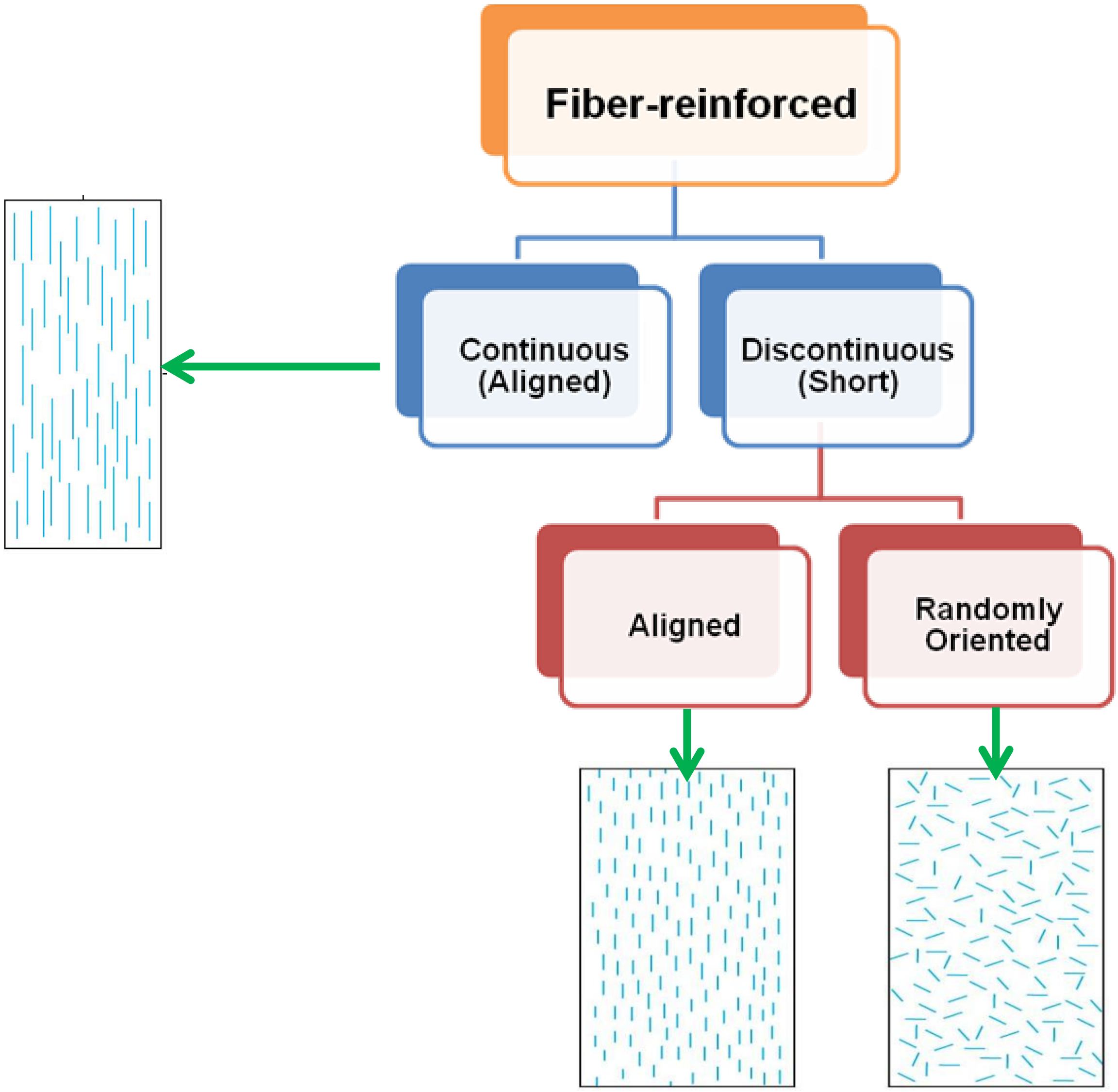


$D_{particle} > 100$ nm

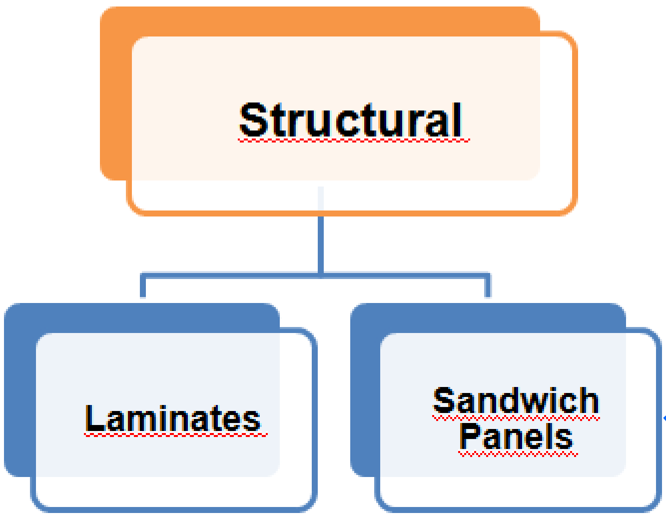


$d_{particle} < 100$ nm

Classifications of Composites



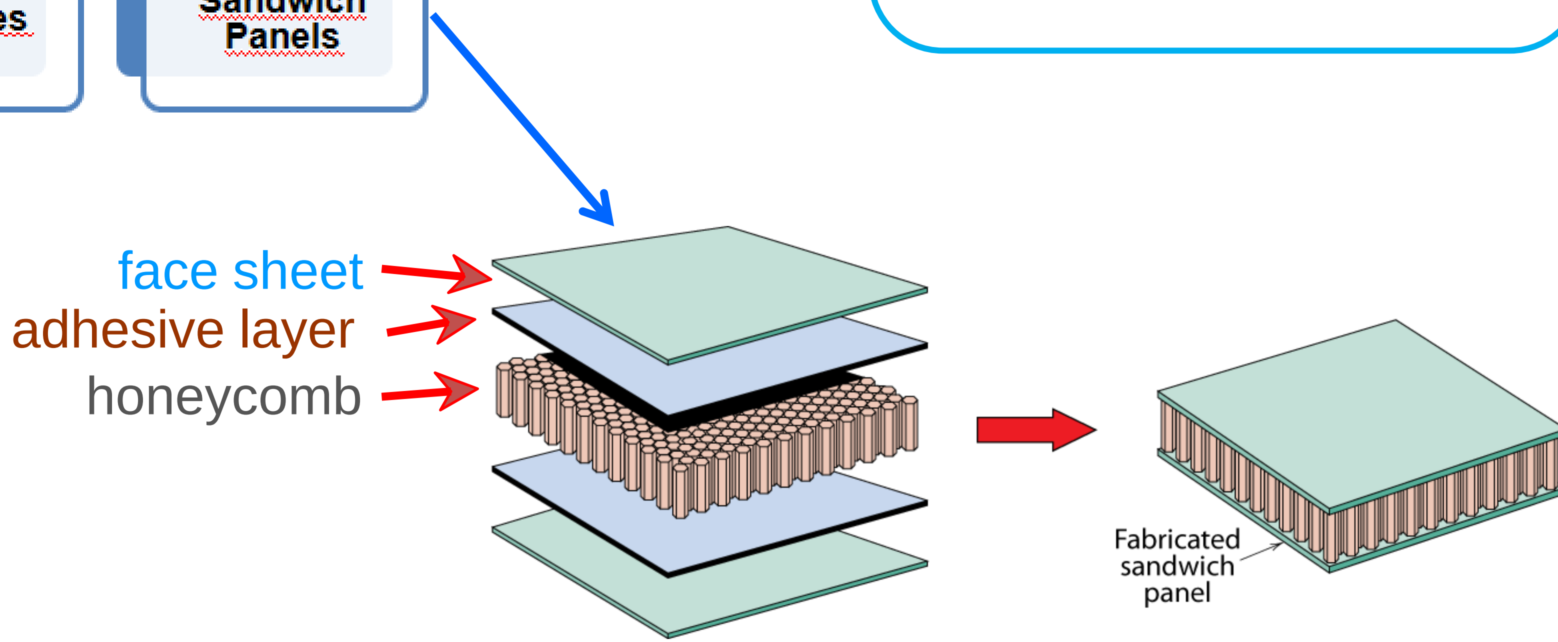
Classifications of Composites



Sandwich panels

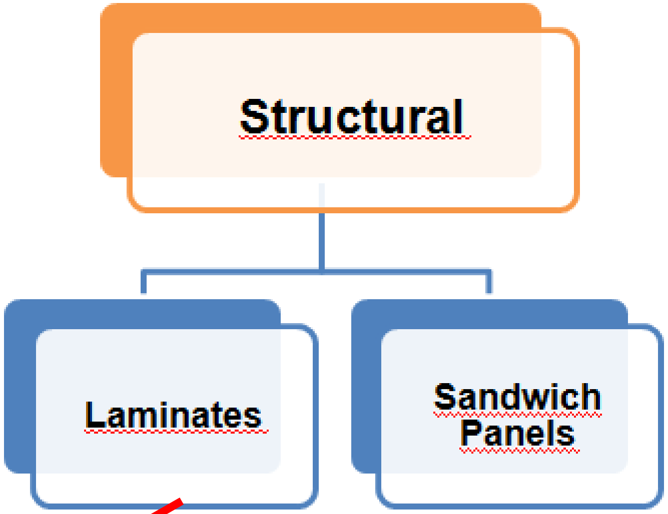
-- low density, honeycomb core

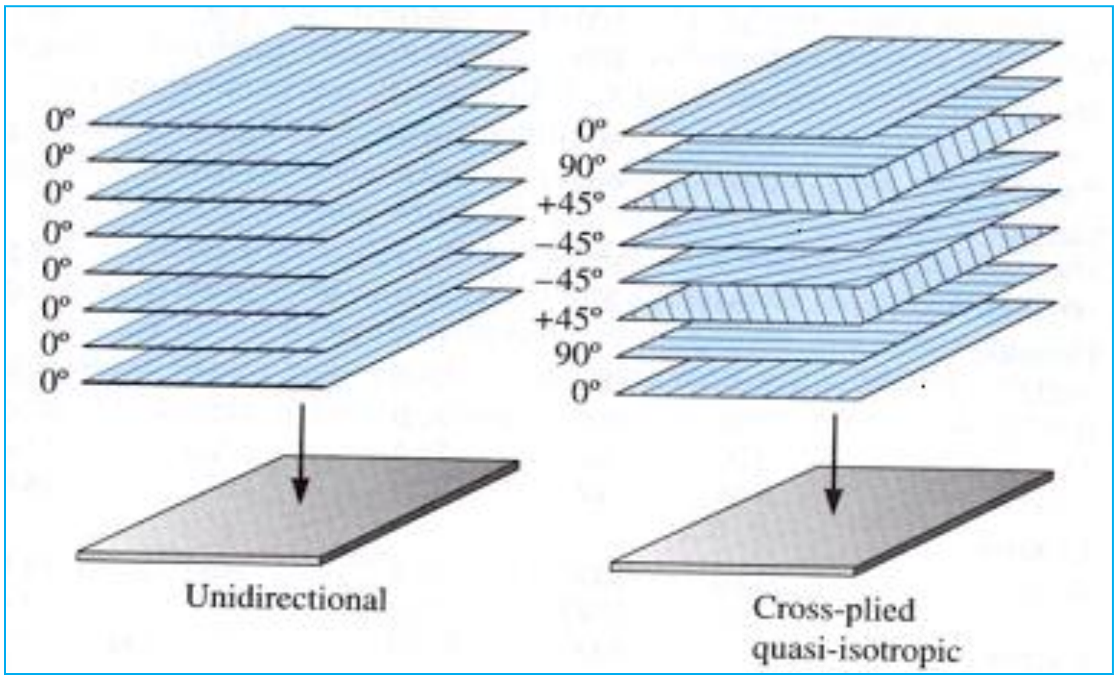
-- benefit: light weight, large bending stiffness



Classifications of Composites

Laminated composites can be thought of as sheets of continuous fiber composites laminated such that each layer has the fiber oriented in a given direction.



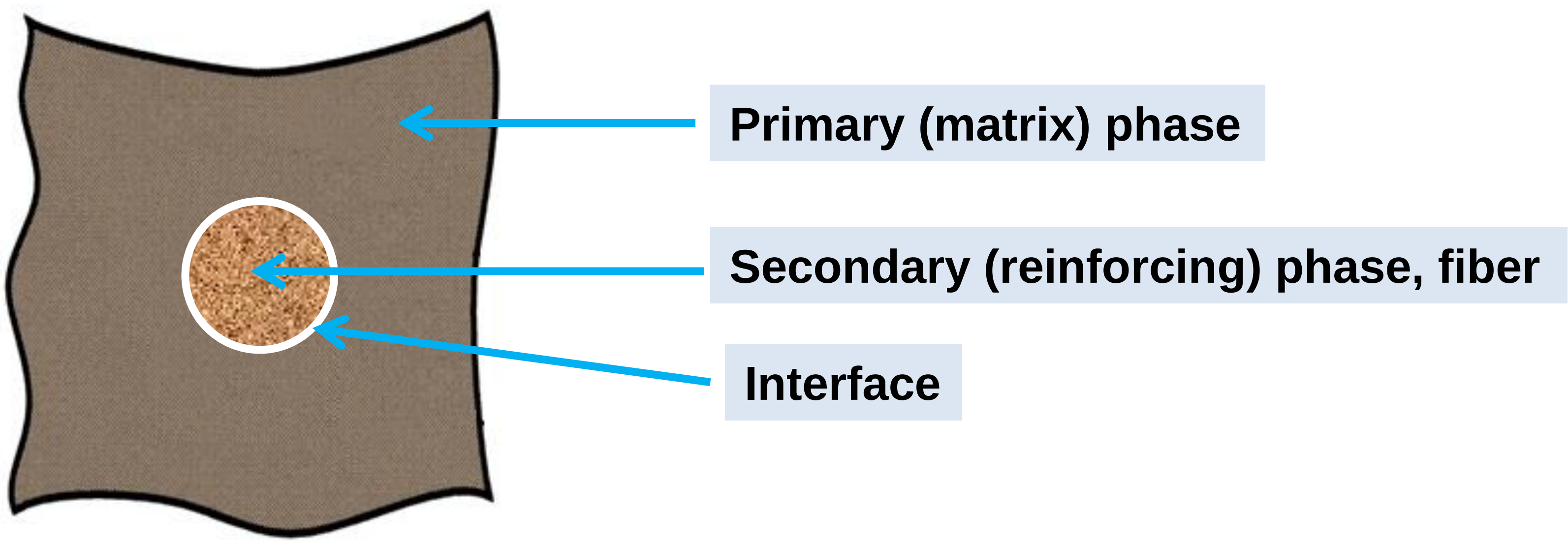


Interface

<u>INTERFACE:</u> Zone across which matrix and reinforcing phases interact (chemical, physical, mechanical)

- To transfer the stress from matrix to reinforcement
- Sometimes surface treatment is carried out to achieve the required bonding to the matrix

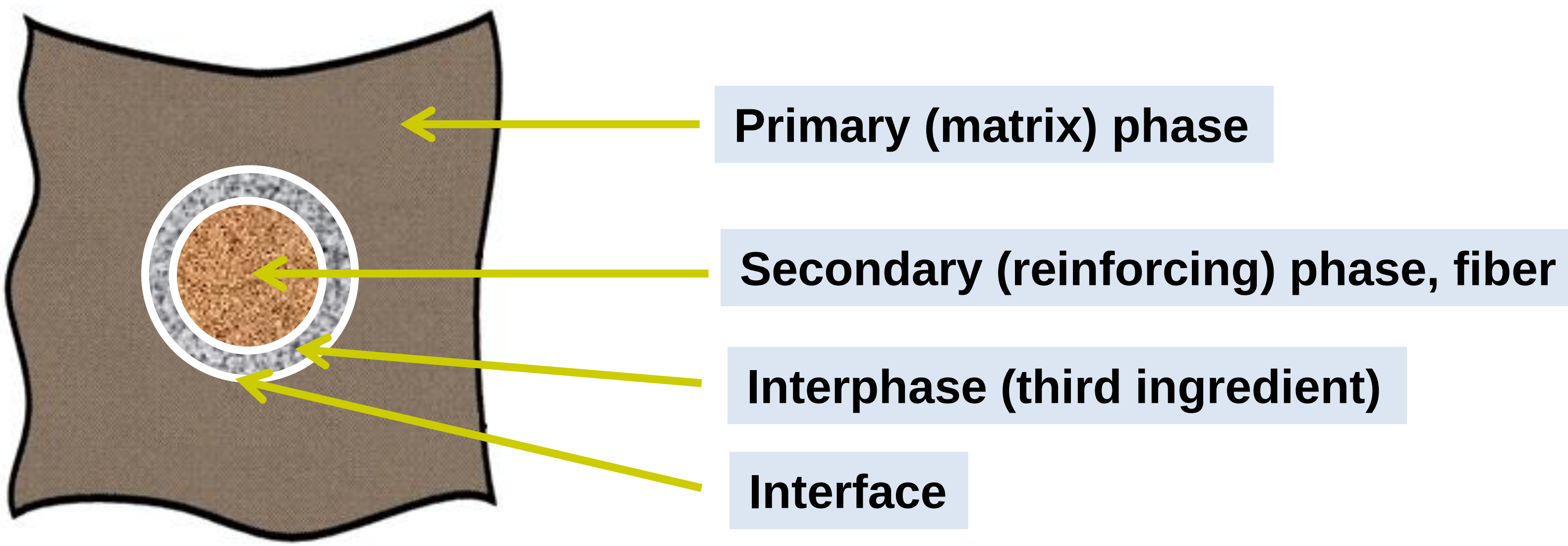
There is always an interface between constituent phases in a composite material. For the composite to operate effectively, the phases must bond where they join at the interface.



Interfaces between phases in a composite material:
Direct bonding between primary and secondary phases

Interphase

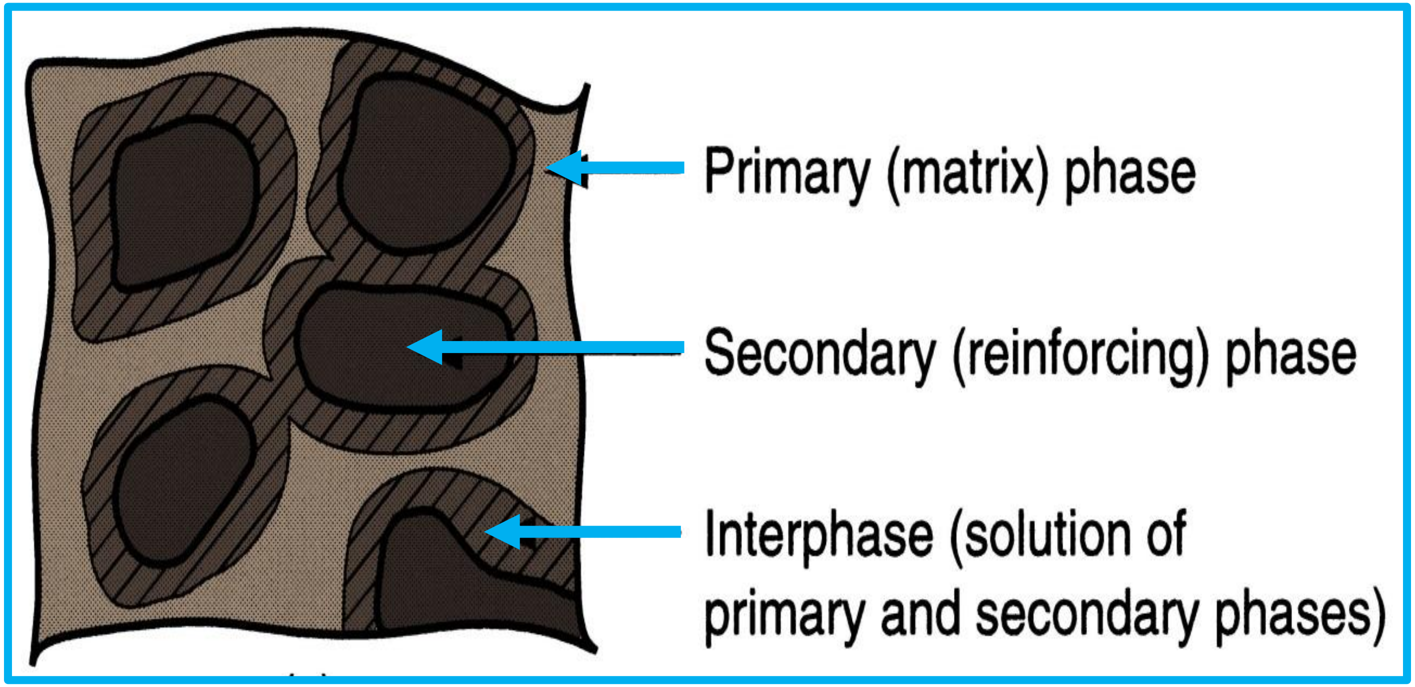
In some cases, a third ingredient must be added to achieve bonding of primary and secondary phases. Called an interphase, this third ingredient can be thought of as an adhesive.



Interfaces between phases in a composite material: Direct bonding between primary and secondary phases

Interphase

Interphase consisting of a solution of primary and secondary phases



Interfaces and interphases between phases in a composite material:
Formation of an interphase by solution of the primary and secondary phases at their boundary

Characteristics of Composites

Depends on:

- properties of the matrix material.
- properties of reinforcement material.
- ratio of matrix to reinforcement.
- matrix-reinforcement bonding/adhesion.
- mode of fabrication.

Applications of Composites

- Straw in clay construction by Egyptians
- Aerospace industry
- Transportation
- Mechanical Industry
- Sporting goods
- Automotive
- Construction
- …

Applications of Composites

- Composite materials offer a diverse range of properties suited to an equally wide range of applications, offering the design engineer a plethora of opportunities for many different end uses.
- Applications vary significantly in size, complexity, loading, operating temperature, surface quality, suitable production volumes, and added value.
- The expanding choice of raw materials, in terms of reinforcement type (concentration and fiber architecture) together with matrix material (subsets of both thermoplastic and thermoset polymers), followed by many subsequent final conversion processes gives impressive flexibility.
- These variables often interact to create for the uninitiated an often confusing material and process system.

Applications of Composites

- **A leading role** in the development of both composite materials and processing technology has been taken by the **aerospace industry**.

- The high specific stiffness and strength of the reinforcement offered the potential for reduced fuel consumption and increased range with passenger aircraft and increased performance (range, turn rates, stealth) for military aircraft.

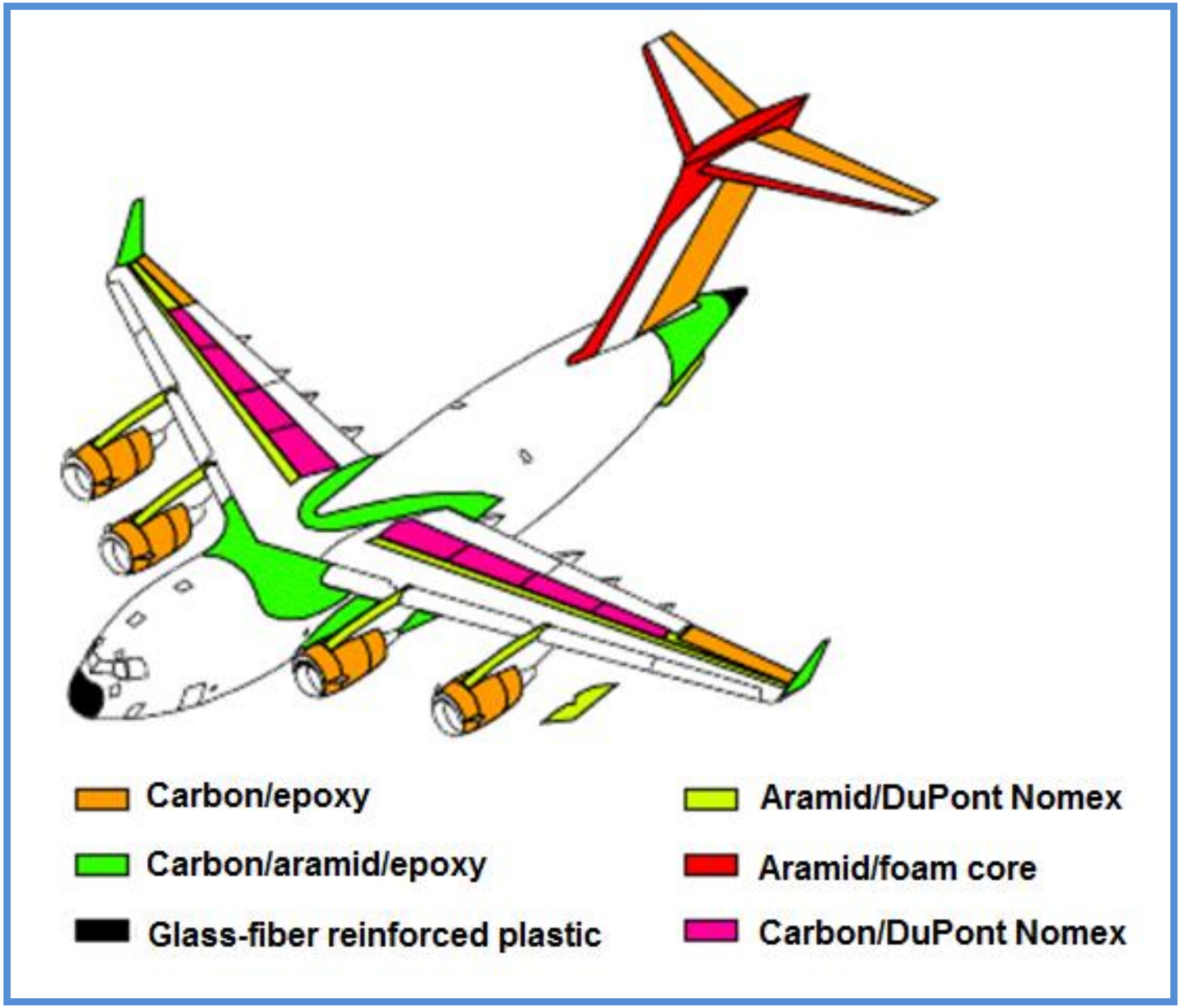
- The ability to tailor thermal expansion together with the low material density also made materials attractive for space applications. A substantial research effort was therefore made by the aerospace industrial, governmental, and academic communities to develop this material class.

Applications of Composites

- ***The main driving forces for the aerospace industry are therefore primary weight reduction by using a material with higher specific mechanical properties (mechanical property/density), facilitating secondary weight savings, leading to considerable additional weight reduction.***

- The strong demand for weight saving in aerospace applications, as well as the lower sensitivity of this industry to production rates and material costs, has led to the development of finely-tuned high-performance processing techniques and materials.

Applications of Composites



Applications of Composites

Boeing 757-200

Aft flaps
Outboard (graphite)
Inboard (graphite/fiberglass)

Flap support fairings
Fwd segment (graphite/Kevlar + non-woven Kevlar mat Aft segment (graphite/fiberglass)

Rudder (graphite)

Tip fairings (fiberglass)

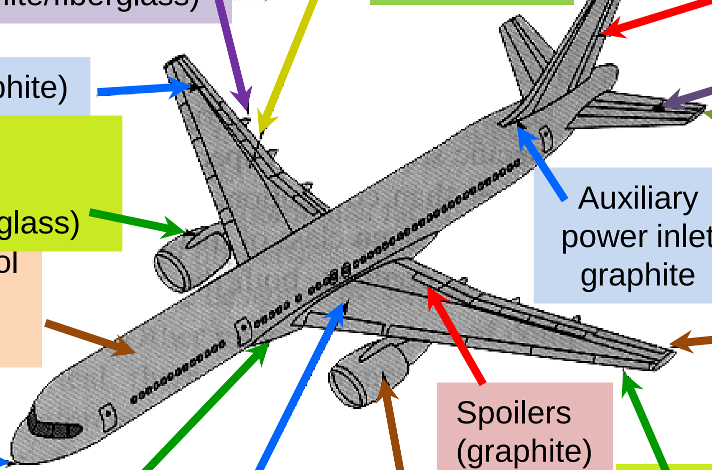
Fixed trailing edge panels graphite /Kevlar + non-woven Kevlar mat)

Elevators (graphite)

Ailerons (graphite)

Engine strut fairings (Kevlar/fiberglass)

Environmental control system ducts (Kevlar)



Auxiliary power inlet graphite

Fixed trailing edge panels upper (graphite /fiberglass), lower (graphite /Kevlar + non-woven Kevlar mat)

Fixed trailing edge panels Graphite/Kevlar + non-woven Kevlar mat

Nose landing gear doors (graphite)

Spoilers (graphite)

Cowl components (graphite)

Wing leading edge lower panel Kevlar/fiberglass

Wing to body fairings (graphite/Kevlar/Fiberglass and Graphite/Kevlar + non-woven Kevlar mat

Body main landing gear doors (graphite)
Trunnion fairings and wing landing gear doors (graphite/Kevlar)
Brakes(structural carbon)

From http://matse101.mse.uiuc.edu/

Applications of Composites

- The transportation industry represents a potentially large application area for fiber reinforced composites and is driven by a complex set of interacting driving forces.
- If the needs of the aerospace industry have led to the development of advanced composites, then the needs of the automotive industry have dominated the development of engineering composites, with increased shape complexity and a strong emphasis on decreasing system cost.
- Decreasing cost must be considered while maximizing quality, functionality, and return on manufacturing investment together with meeting legislative requirements for safety, emissions, and recycling.
- In the automotive industry, weight increases from improved safety, refinement, and functionality interact with the vehicle mass reductions necessary to improve fuel economy and reduce emissions.

Applications of Composites

- The mechanical industry is currently undertaking large efforts to apply advanced composite materials to specific applications.
- Here, the volumes and application demands can generally be considered as lying between those of the aerospace and automotive industries.
- While production volumes and part needs have not in many cases been sufficient to justify an independent composites strategy, knowledge in design, analysis, and manufacture from the aerospace and automotive industries has been successfully applied to this market sector.

Applications of Composites

- The mechanical industry, which may be exemplified by advanced machine elements in high-speed reciprocating or rotational applications, has its main reason for weight reduction in improvement of operation rates and efficiency, as well as in convenience and handling.
- Machine elements in high-speed textile and packing machines, pumps, energy conversion equipment, and lightweight hand-machines are some examples of applications in which advanced composite materials are presently being used or evaluated.
- These are typically small and are manufactured in series of some dozens to several thousand pieces. Here, the advantages of composites in terms of a longterm high stress fatigue resistance, tribological properties, and corrosion resistance in aggressive environments can be exploited.

Applications of Composites

- As an example, a wheel in a band-weaving machine is briefly taken. This is driven between a transition of 0±3608 at a frequency of 10 Hz, where a reduction in component mass will reduce the axial torsional moment to meet this acceleration profile.
- Where the high specific properties of composites enable the machine to work faster by reducing the bottleneck in the whole machine, relatively expensive materials can improve the efficiency of the machine with the critical component only forming a small fraction of the total machine cost.

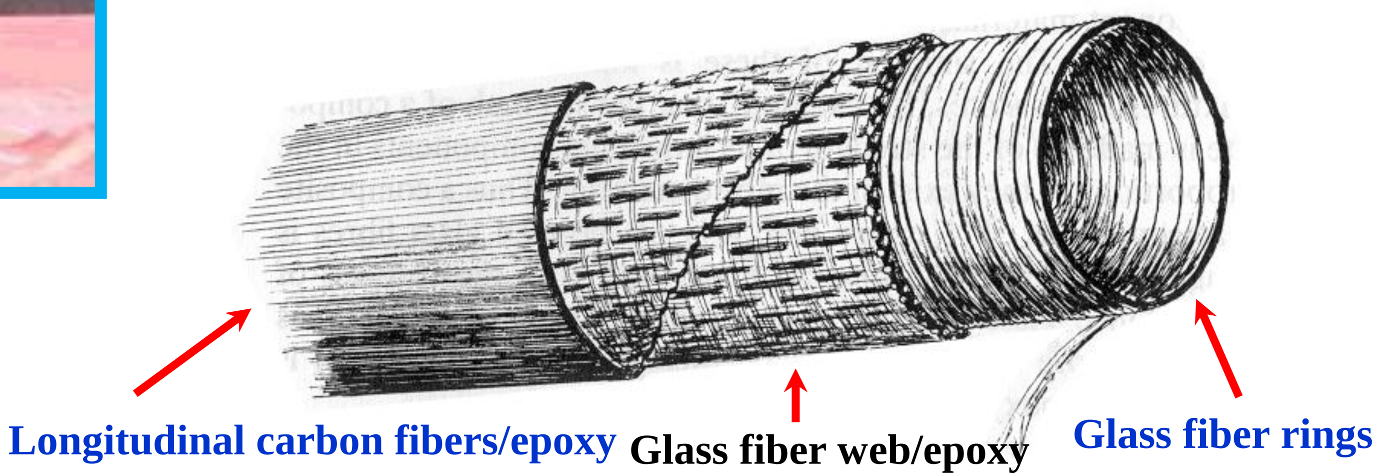
Applications of Composites

- Branches such as the leisure, building, and marine industries are also significant users of composites, in a diverse range of materials, processes, and applications with a wide range of driving forces.

- The leisure industry, and particularly the sports industry, has many applications where the introduction of polymer composites has had considerable impact on the product performance. As this industry undergoes frequent product replacement, several generations of composite applications have been in use and a suitable range processing techniques have been developed and refined. This includes applications such as ball game rackets and clubs, bicycle frames, fishing rods, and water sports boards, which are well known and in widespread use. Both specialized low-volume and highly automated mass production techniques are used with a variety of materials, generally in continuous fiber form. Here driving forces are again complex, being driven both by performance and user image with a strong marketing influence.

Applications of Composites

Vaulting poles are made using a carbon fibre composite to provide increased strength, flexibility and elasticity. Composite materials are used extensively in the world of sport.



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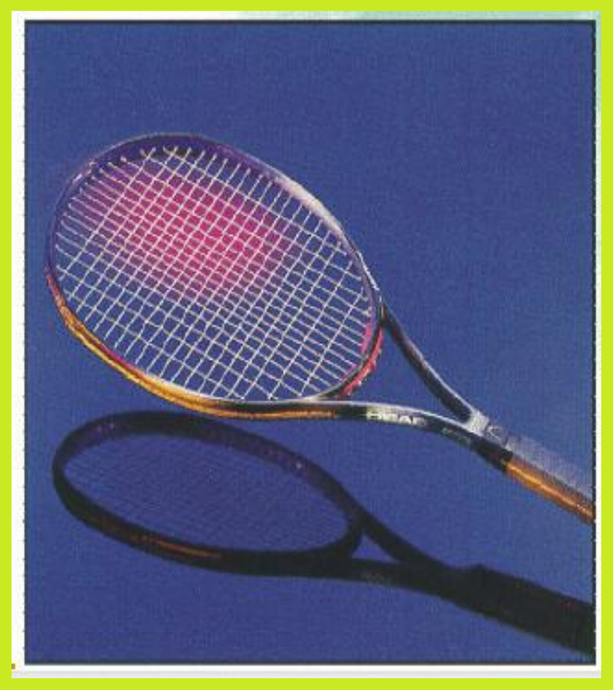
Applications of Composites

Composite Bicycle

Laminated Fiberglass Bow



Tennis rackets are made from a composite of polyamide fibre in epoxy resin

Applications of Composites

Bicycle forks

Braided and unidirectional S-2 glass and carbon fibers are used to produce forks with different stiffness.

- High Strength
- Weight Reduction
- Design Flexibility
- Cost Performance

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Graphite Snowboard

Thanks for your kind attention

THE END

Any Questions