Composites

An overview

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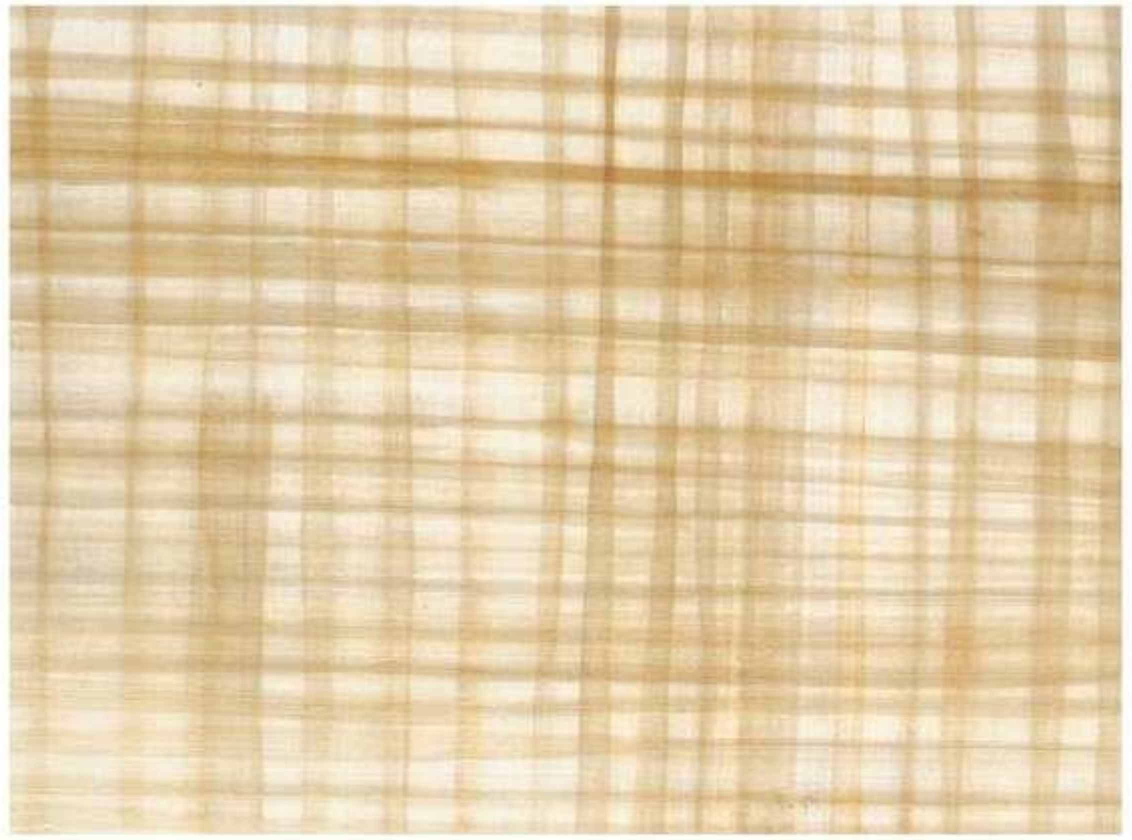
Introduction: History of Composite Materials



Egyptians 4000 BC

Laminated writing material from the papyrus plant

Introduction: History of Composite Materials

Egyptians and Mesopotamian 1300 BC

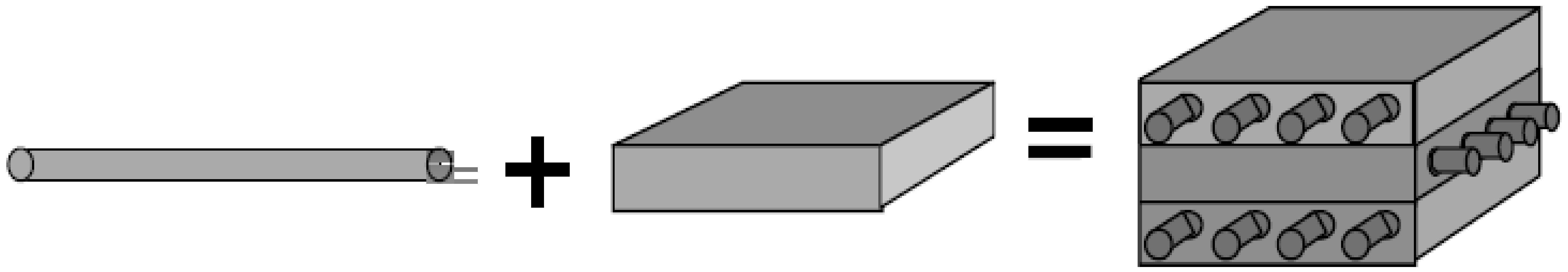
Straw bricks

Introduction: History of Composite Materials

Eskimos

House Built by moss and Ice

Composition of Composites



Composites

Fiber/Filament Reinforcement

- High strength
- High stiffness
- Low density

Matrix

- Good shear properties
- Low density

Composite

- High strength
- High stiffness
- Good shear properties
- Low density

Composites component

Composites consist of:

- **Matrix**:
  - Usually a ductile, or tough, material
  - low density
  - Strength usually = 1/10 (or less) than that of fiber
  - Serves to hold the fiber (filler) in a favorable orientation.
  - transfer stress to other phases
  - protect phases from environment
- **Fiber:**
  - Materials that are stronger and stiffer than matrix
  - low densities
  - Load bearing

Reinforcement: fibers

Glass
Carbon
Organic
Boron
Ceramic
Metallic

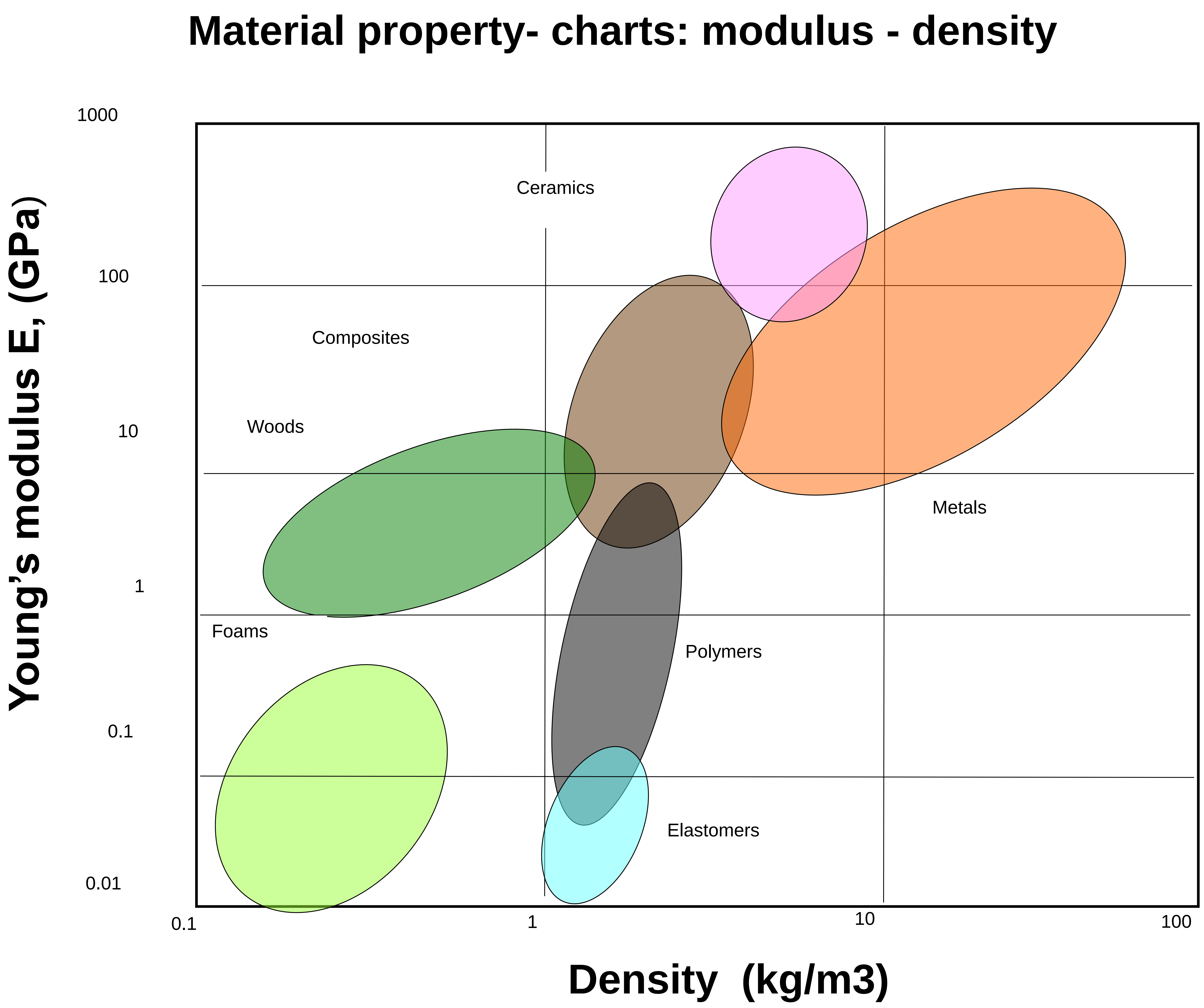




Matrix materials

Polymers
Metals
Ceramics

Composites vs other material



Composites properties:

Advantages:

- High strength to weight ratio (low density high tensile strength)!
- High creep resistance
- Impact loads or vibration Some composites can have much higher wear resistance than metals.
- Corrosion resistance
- Anisotropic – bi-directional properties can be design advantage (i.e. airplane wing)

Disadvantages (or limitations):

- Material costs
- Fabrication/ manufacturing difficulties
- Repair can be difficult
- Operating temperature can be an issue for polymeric matrix (i.e. 500 F). Less an issue for metal matrix (2,700 F).
- Properties non-isotropic makes design difficult.
- Inspection and testing typically more complex.

Matrix Material

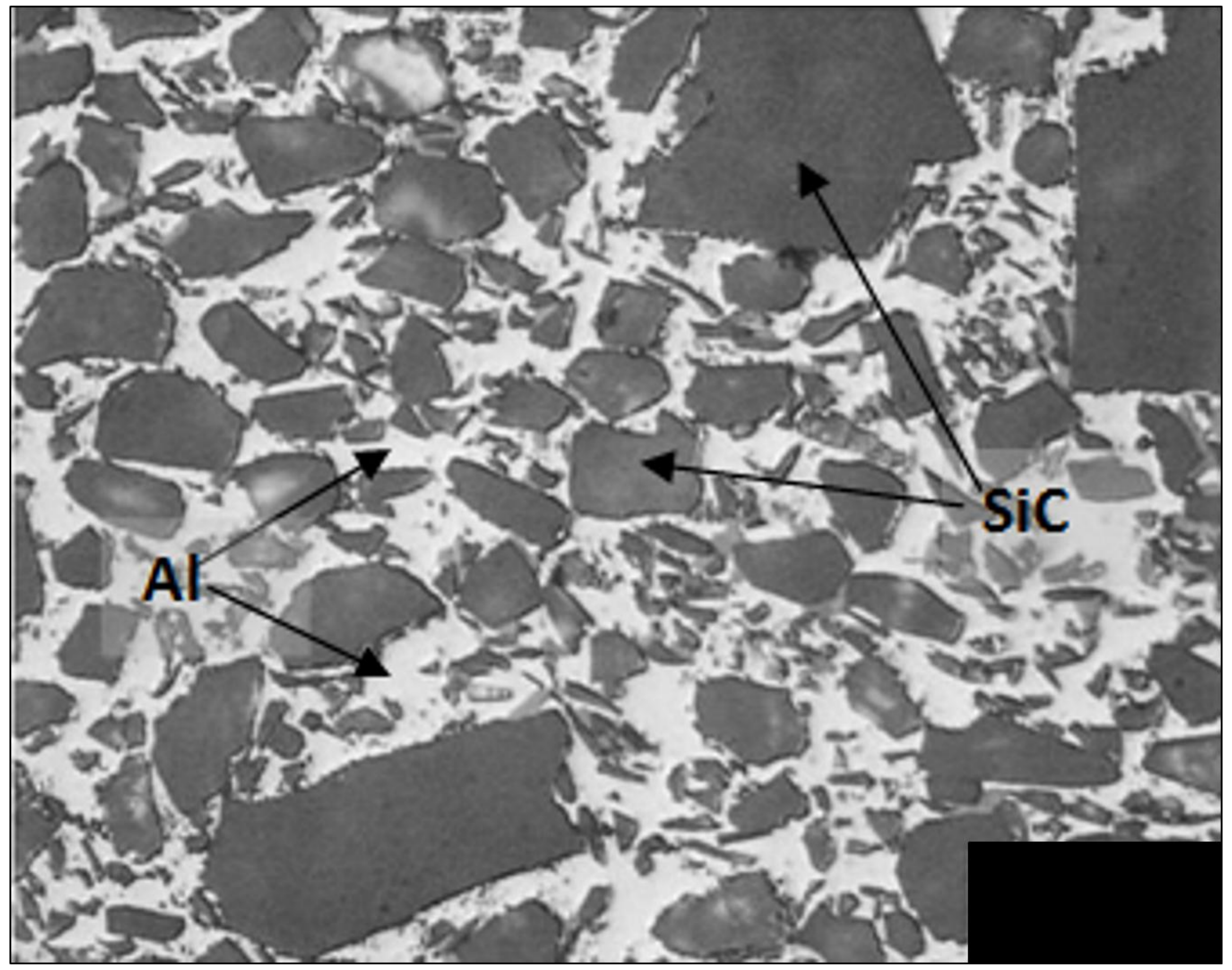
❖Metal Matrix Composites (MMC).

❖Ceramic Matrix Composites (CMC).

❖Polymer Matrix composites (PMC).

Metal matrix composites (MMC):

- The matrix is relatively soft and flexible.
- The reinforcement must have high strength and stiffness
- Since the load must be transferred from the matrix to the reinforcement, the reinforcement-matrix bond must be strong.

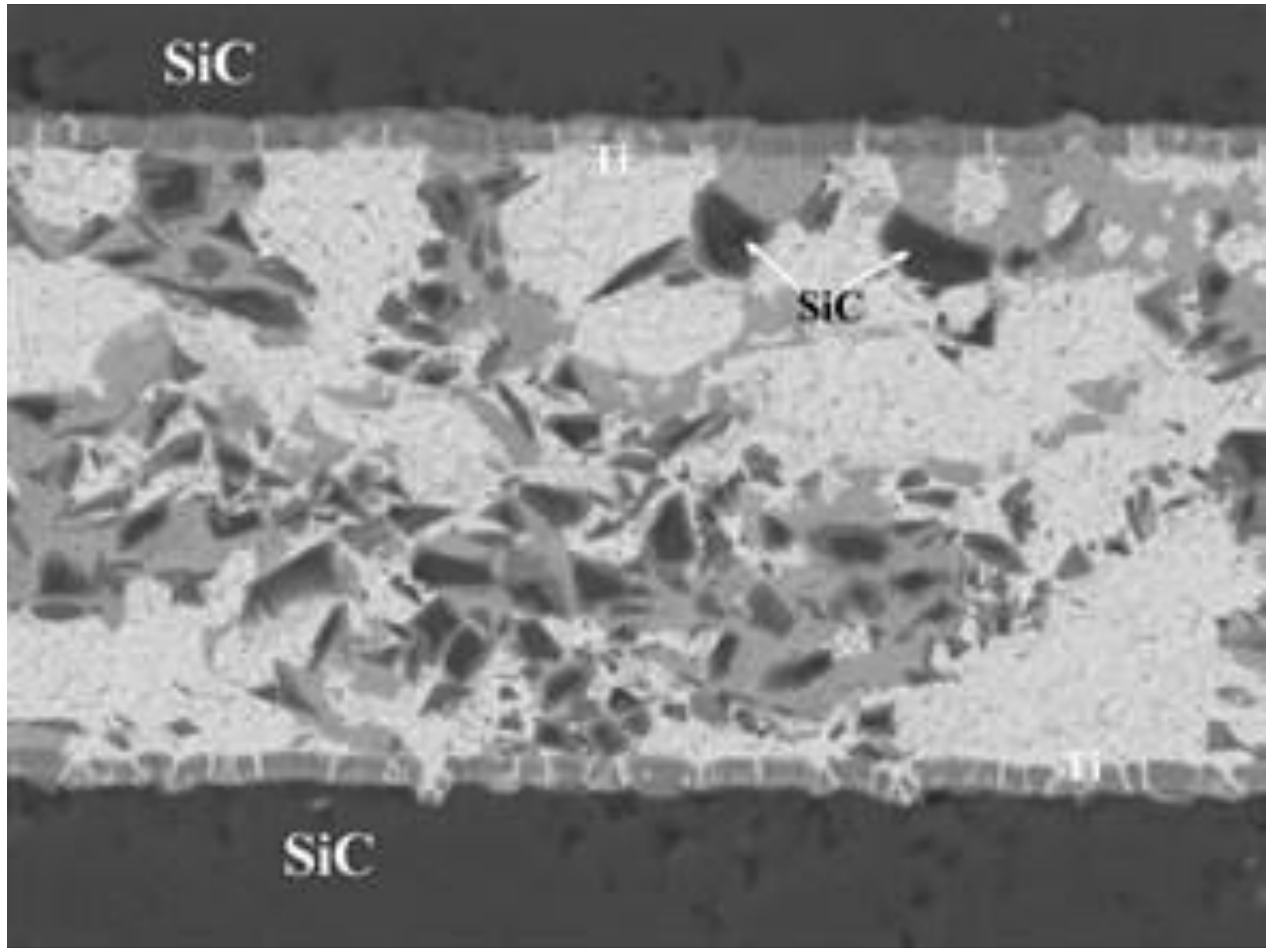


- MMCs are better at higher temperatures than PMCs
- production is much more difficult and expensive
- MMCs can have applications such as fan blades in engines, clutch and brake linings, engine cylinder liners, etc.

- Metal matrix: Al, Ti, Mg, Fe, Cu, Ni
- Example: Al-SiC (silicon carbide)
- Example: Al-Al2O3 (aluminum oxide)
- High strength, high stiffness, abrasion resistance, dimensional stability, high temperature and toughness.

Ceramic matrix composites (CMC):

- The matrix is relatively hard and brittle
- Silicon carbide-silicon carbide (SiC-SiC)
- high temperature materials for use in applications such as gas turbines
- SiC-SiC high has thermal, mechanical, and chemical stability
- high strength to weight ratio



Polymer matrix composites (PMC):

- The matrix is relatively soft and flexible
- The reinforcement must have high strength and stiffness
- Since the load must be transferred from matrix to reinforcement, the reinforcement-matrix bond must be strong
- There are two basic categories of polymer matrices:

-Thermoplastics

-Thermoset plastics

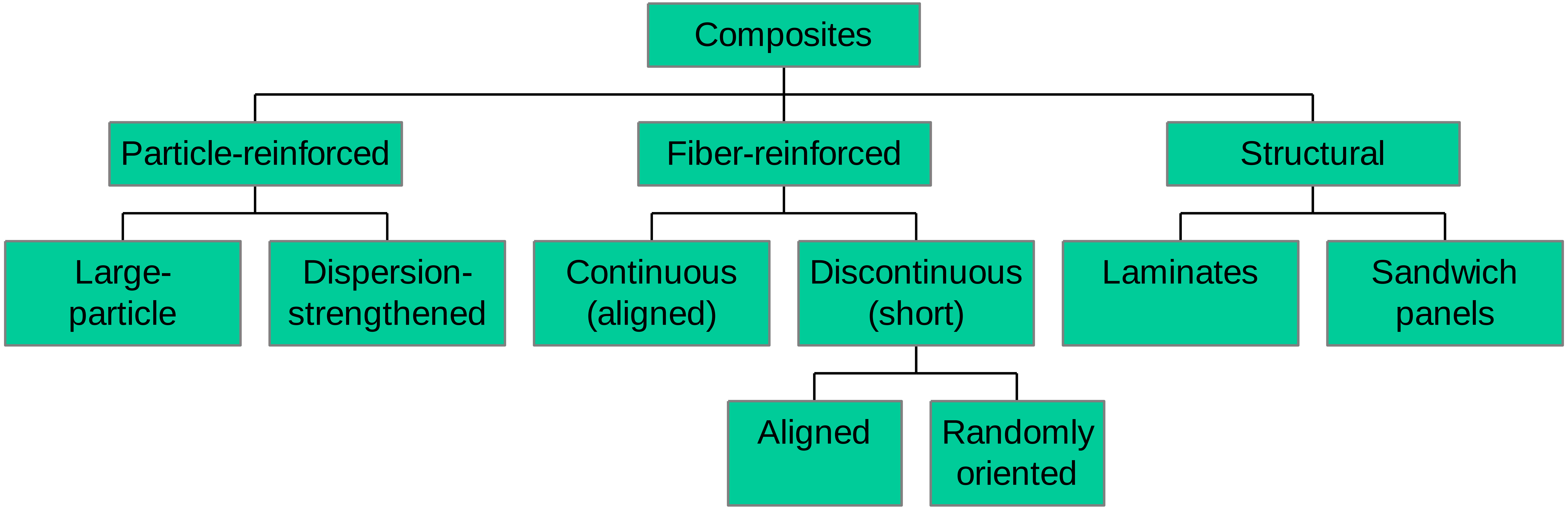
- Roughly 95% of the composite market uses thermosetting plastics
- Thermoplastics: PE, Nylon, PS, PP, PC, PVC
- Thermosets: Epoxy, polyester, phenolics
- Have high strength and stiffness to weight ratio

Epoxy

polyester

phenolics

Reinforcement form



Particle Reinforced Composites:

- ❖ increase the modulus of the matrix
- ❖ decrease the permeability of the matrix
- ❖ decrease the ductility of the matrix
- ❖ produce inexpensive composites
- ❖ Particle reinforced composites support higher tensile, compressive and shear stresses

Examples:

- ❖ automobile tire which has carbon black particles in a matrix of elastomeric polymer.
- ❖ concrete where the aggregtes (sand and gravel) are the particles and cement is the matrix.

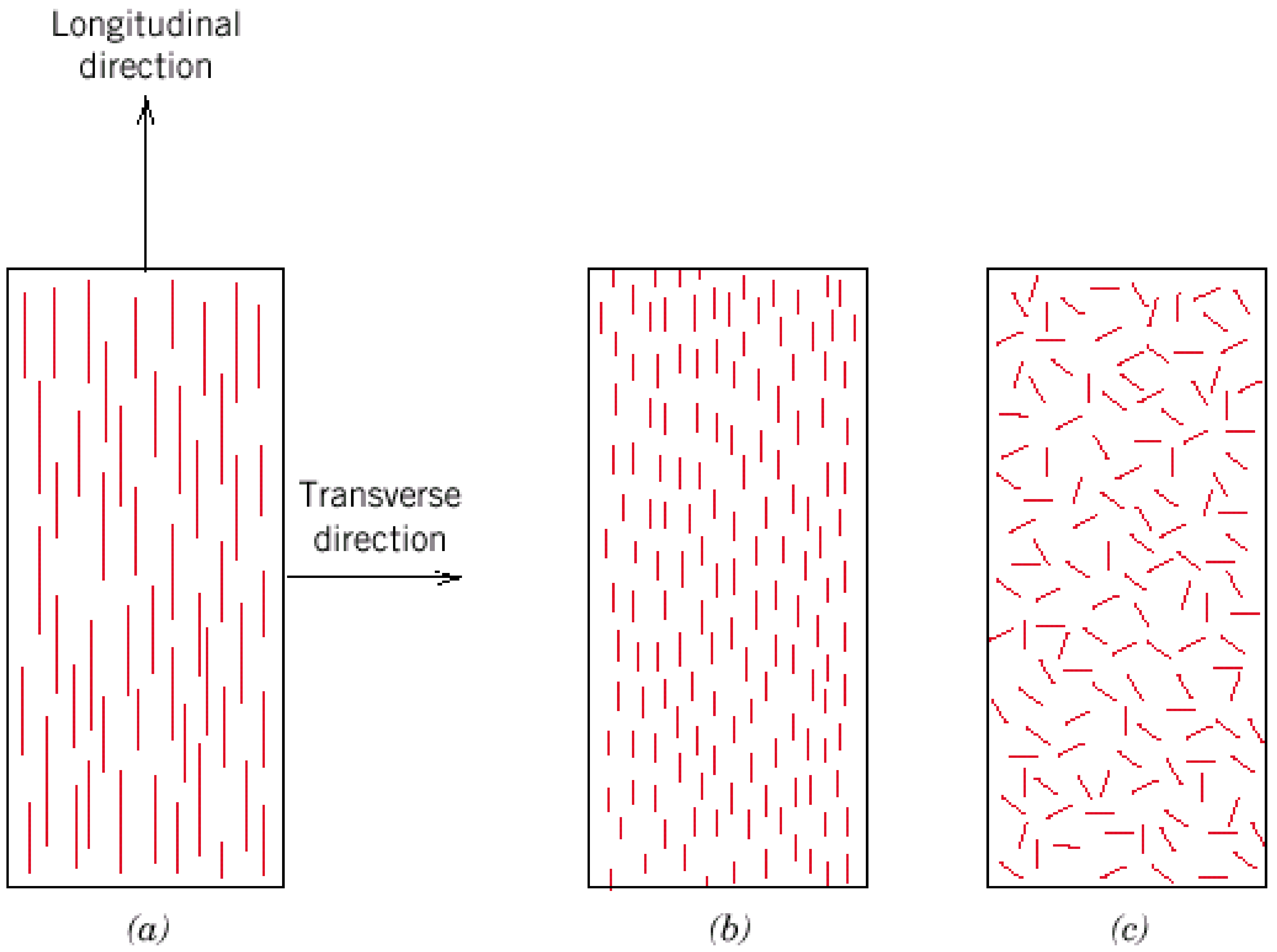
Fiber-reinforced Composites:

- ❖ Fibers increase the modulus of the matrix material
- ❖ Fibers increase the strength of the matrix material
- ❖ Fibers increase the thoughness of the matrix material

Examples:

- ❖ sports equipment, carbon fibers in a thermoset polymer matrix.
- ❖ cars and some automobiles, composites made of glass fibers in a thermoset matrix.
- ❖ Aerospace vehicles such as Airplane, Missile, shuttle ,composites made of carbon fibers in a thermoset matrix
- ❖ Boats, ships

Fiber Orientations

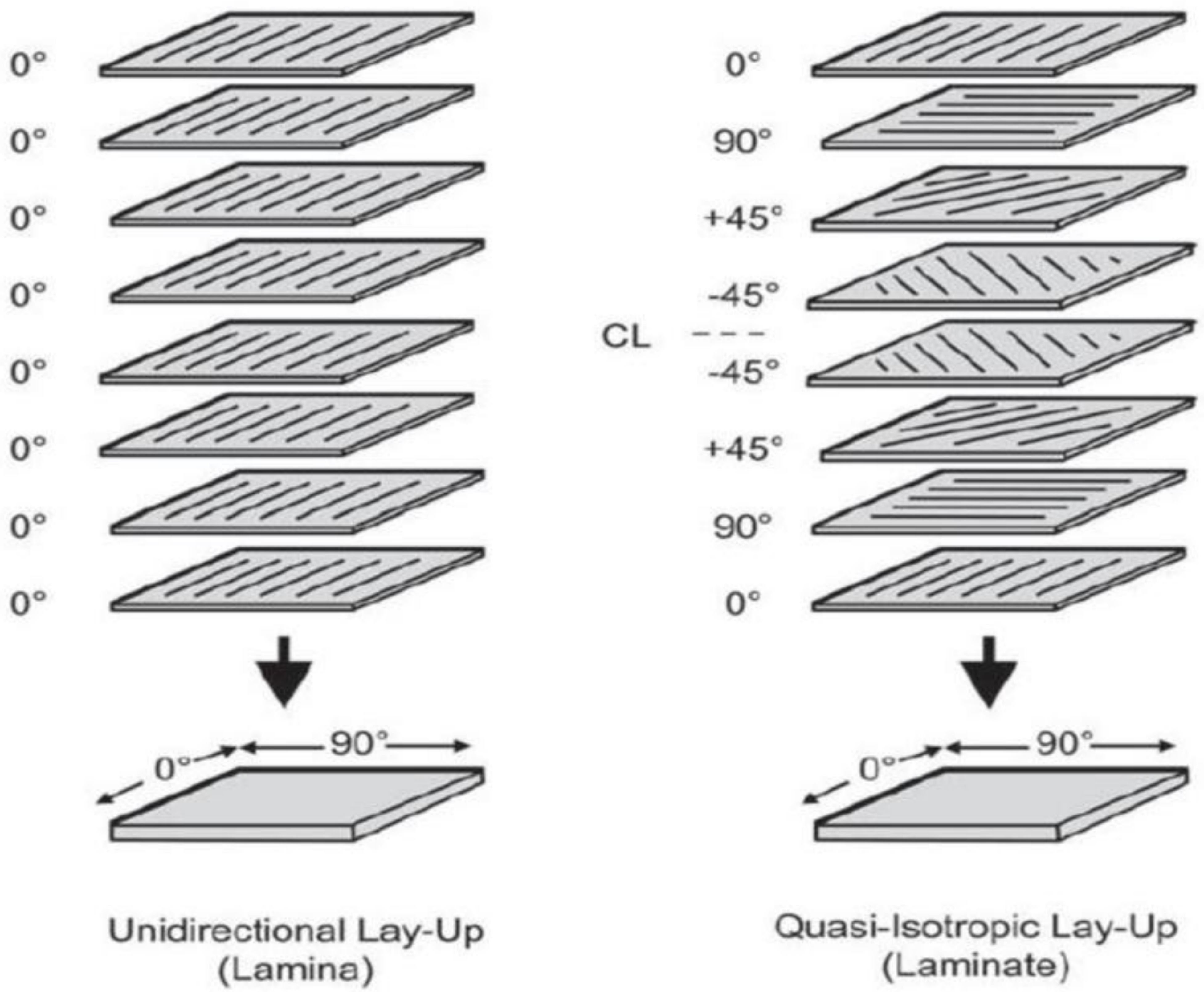


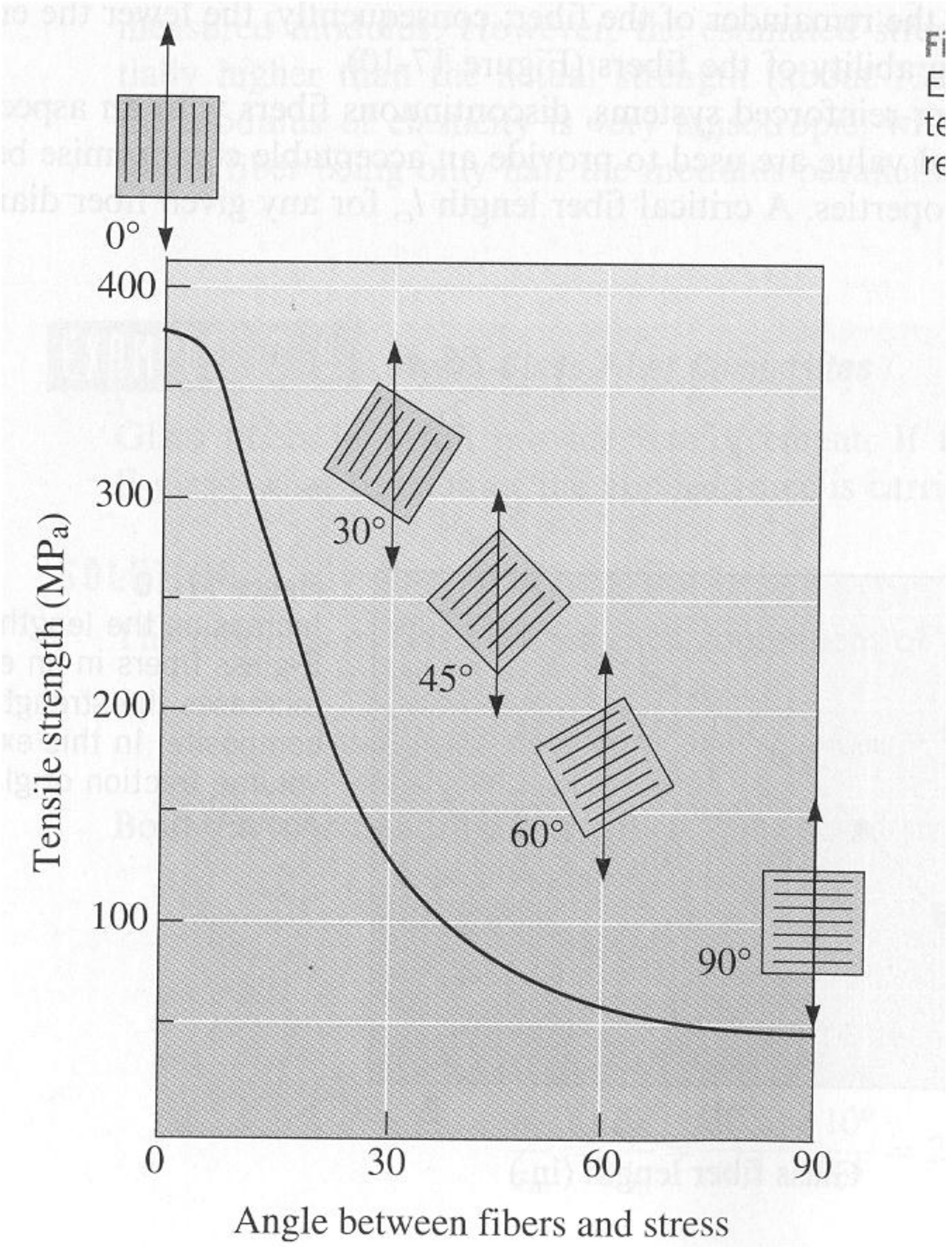
aligned continuous

aligned **random**
discontinuous

Fiber Orientations

❖ **Maximum strength is obtained when long fibers are oriented parallel to the applied load**

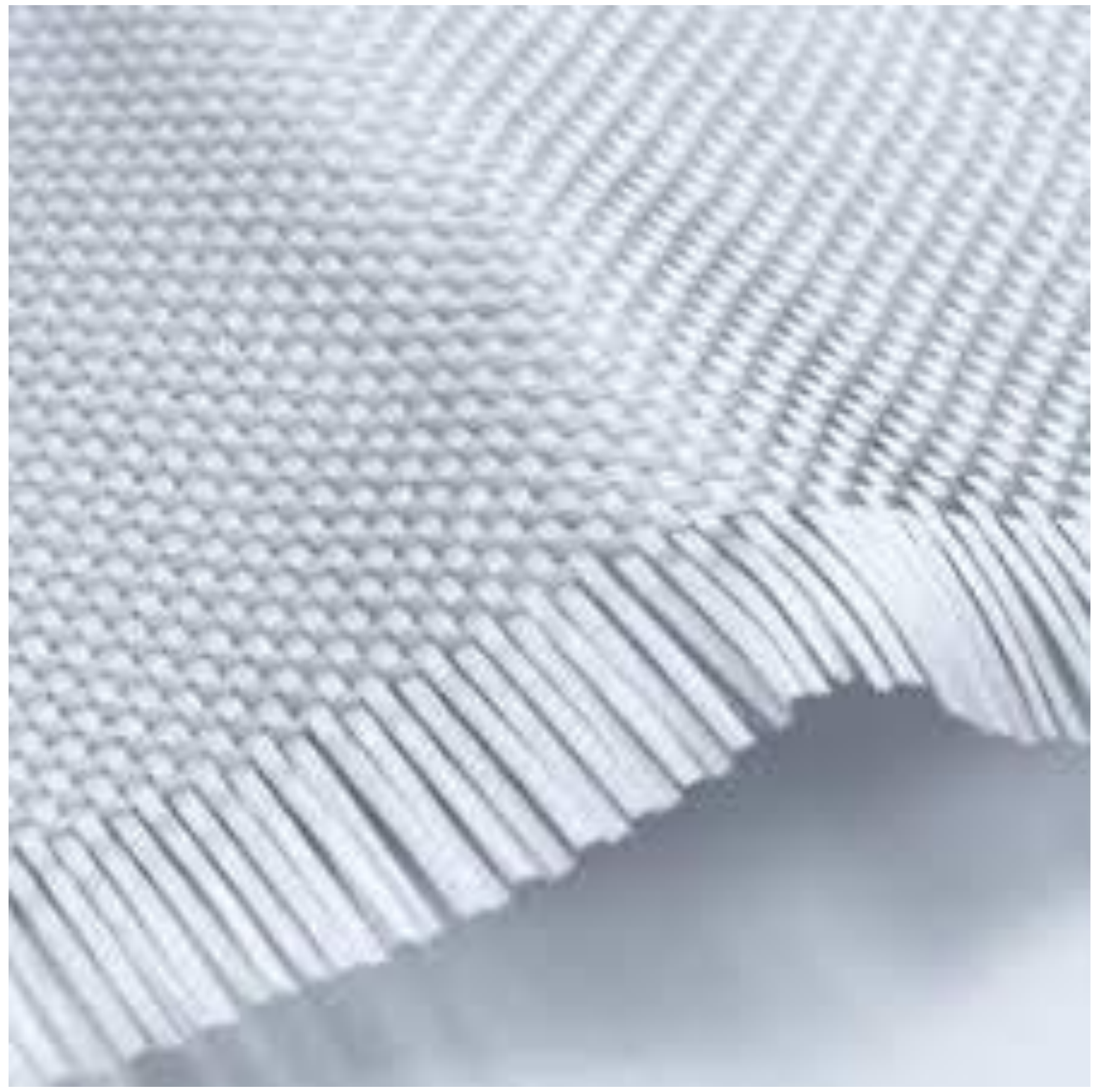




GLASS FIBERS

- Due to the relatively inexpensive cost glass fibers are the most commonly used reinforcement
- There are a variety of types of glass, they are all compounds of silica with a variety of metallic oxides
- The most commonly used glass is E-glass, this is the most popular because of it's cost

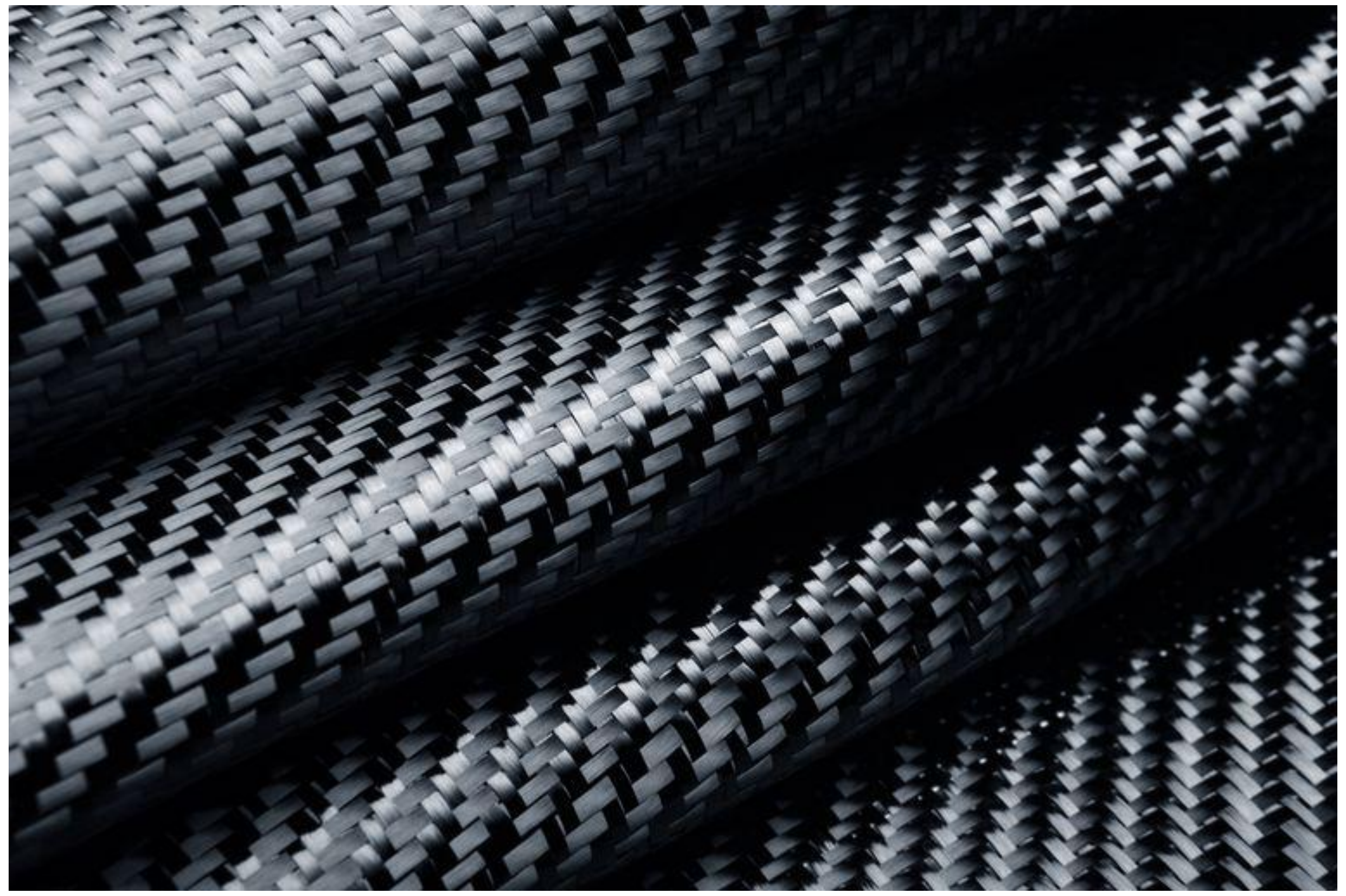
Designation:	Property or Characteristic:
E, electrical	low electrical conductivity
S, strength	high strength
C, chemical	high chemical durability
M, modulus	high stiffness
D, dielectric	low dielectric constant



Carbon FIBERS

- **Carbon fiber composites are five times stronger than 1020 steel yet five times lighter. In comparison to 6061 aluminum, carbon fiber composites are seven times stronger and two times stiffer yet still 1.5 times lighter”**

- **Initially used exclusively by the aerospace industry they are becoming more and more common in fields such as automotive, civil infrastructure, and paper production**
- **Thermal stability**
- **X-ray non permeability**

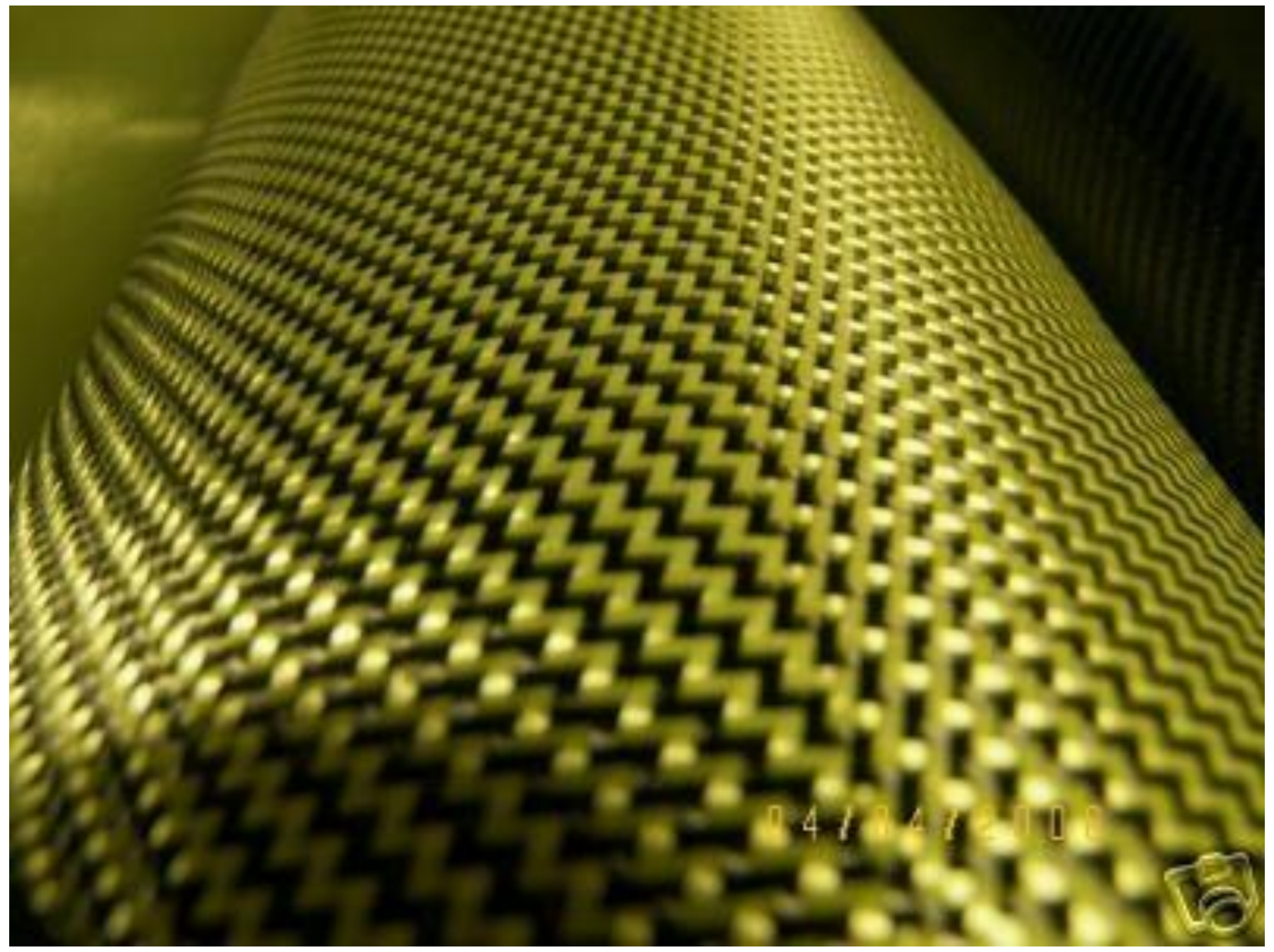


Kevlar FIBERS

- They are commonly used when a degree of impact resistance is required

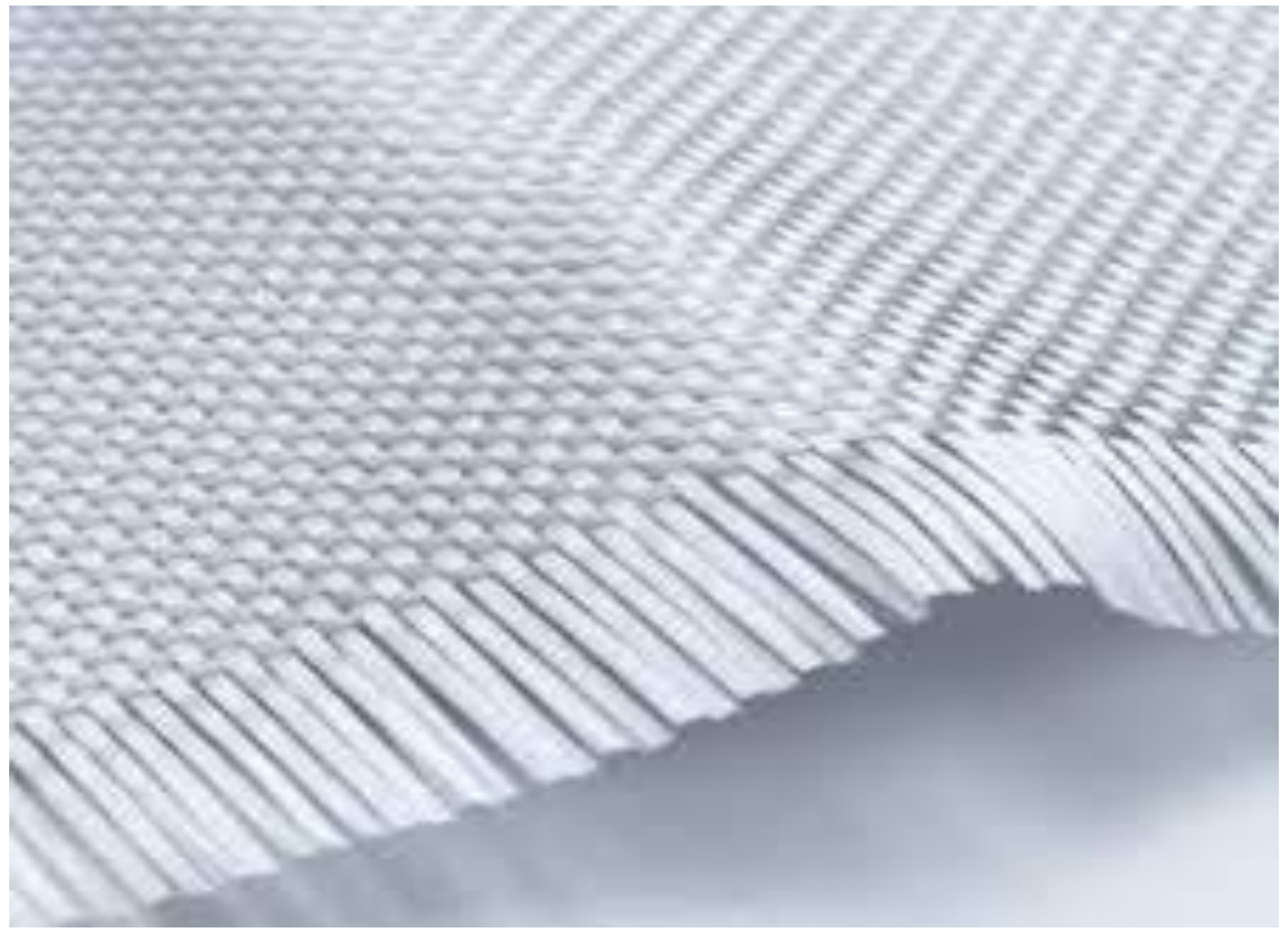
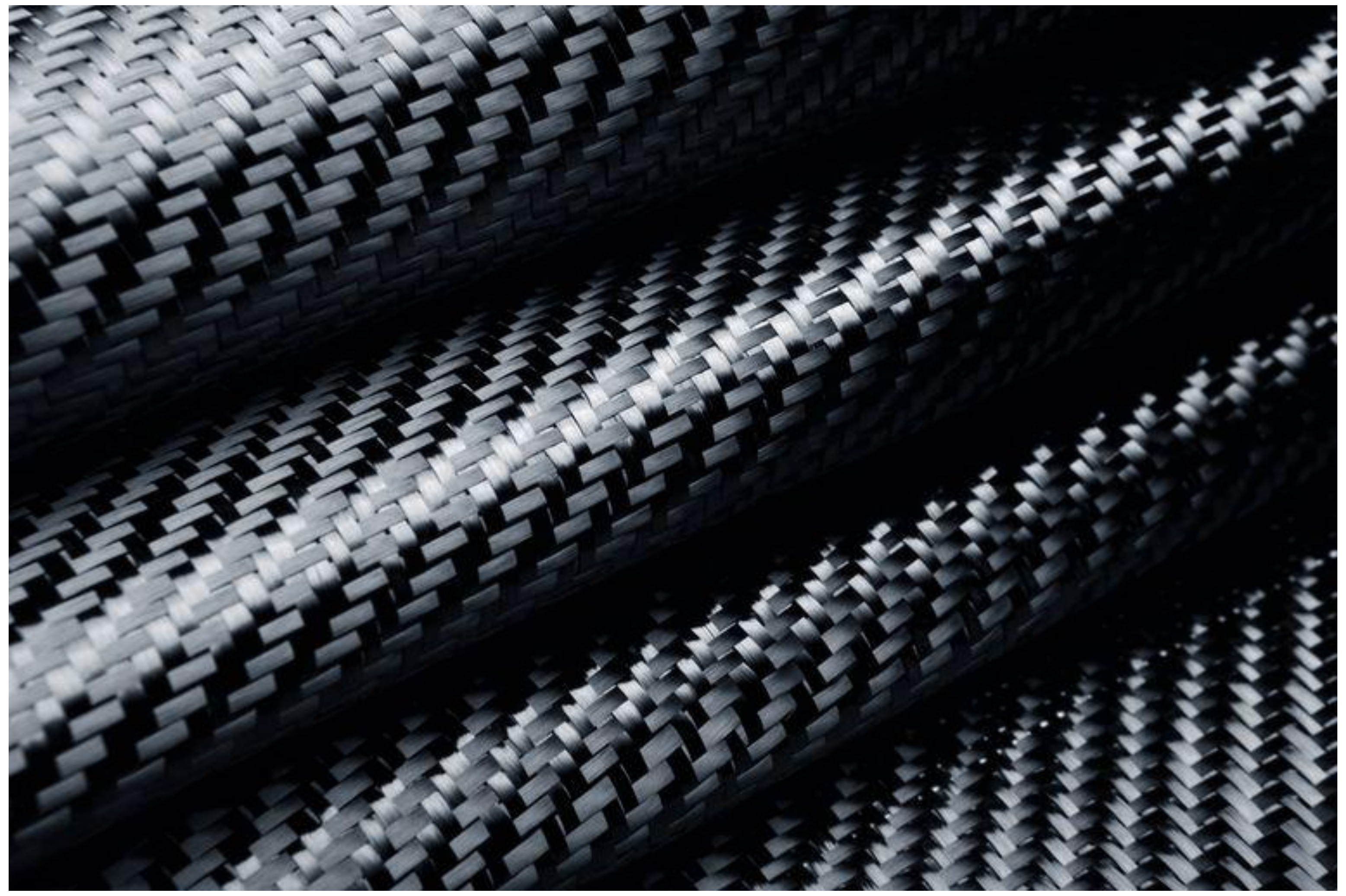
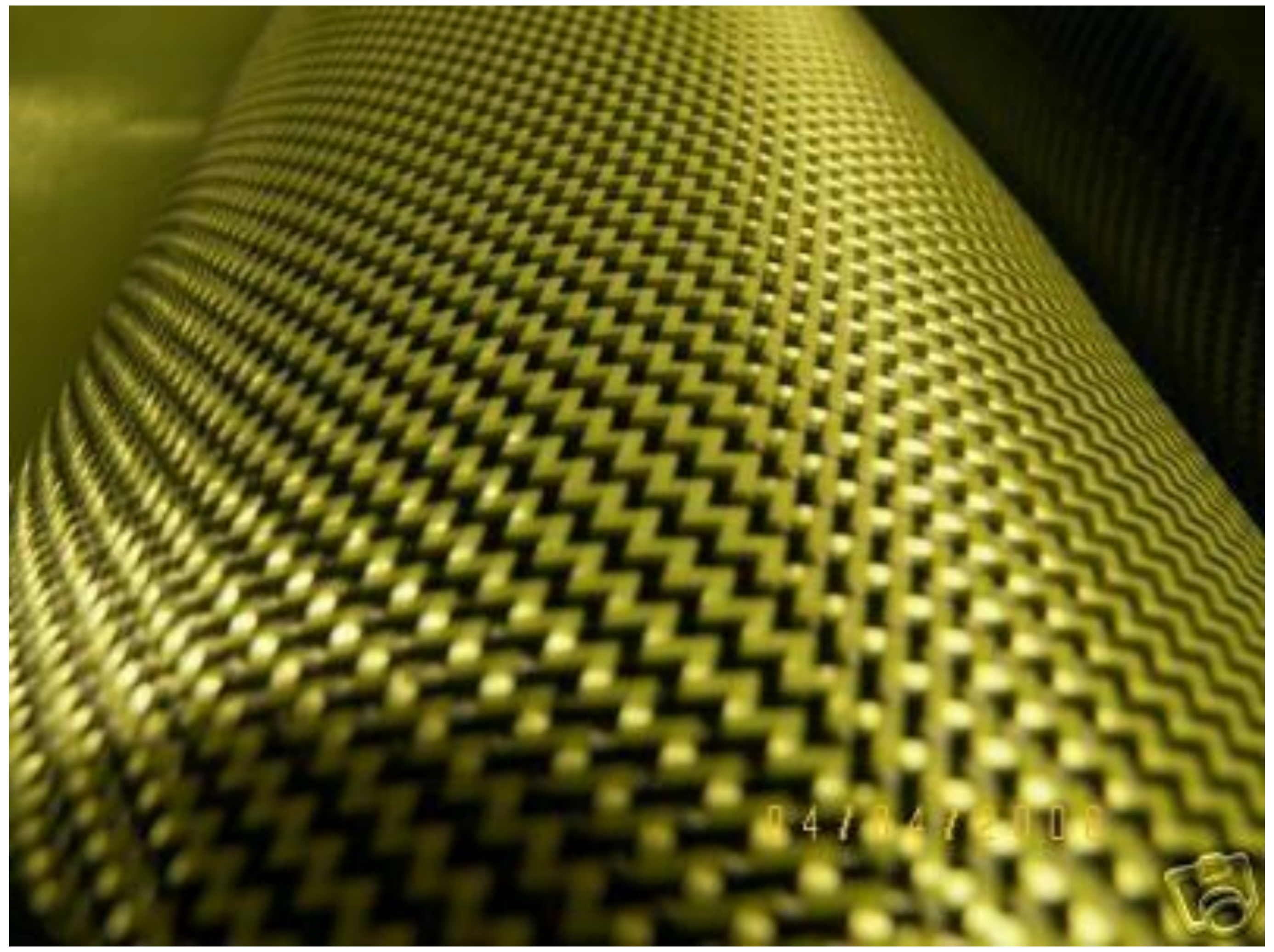
- They have the highest level of specific strength of all the common fibers

- The most common type of aramid is Kevlar



Comparison of FIBERS

Property	Glass	Carbon	Kevlar
Strength	Worst	In - between	Best
Stiffness	Worst	Best	In – between
Cost	Best	Worst	In – between
Weight	Worst	Best	In-between

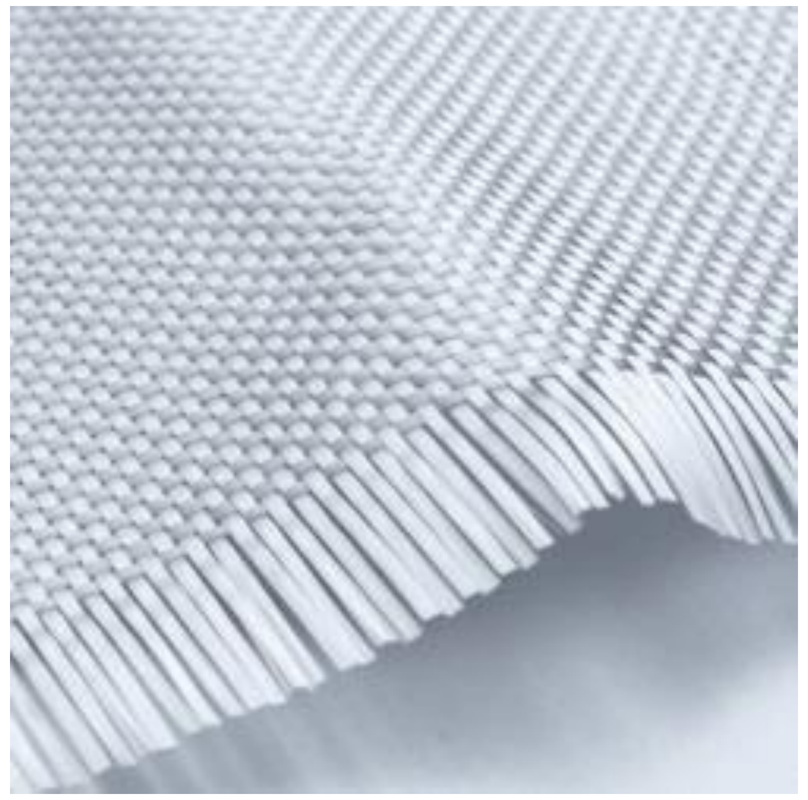




Different forms of fibers

Roving

Yarns

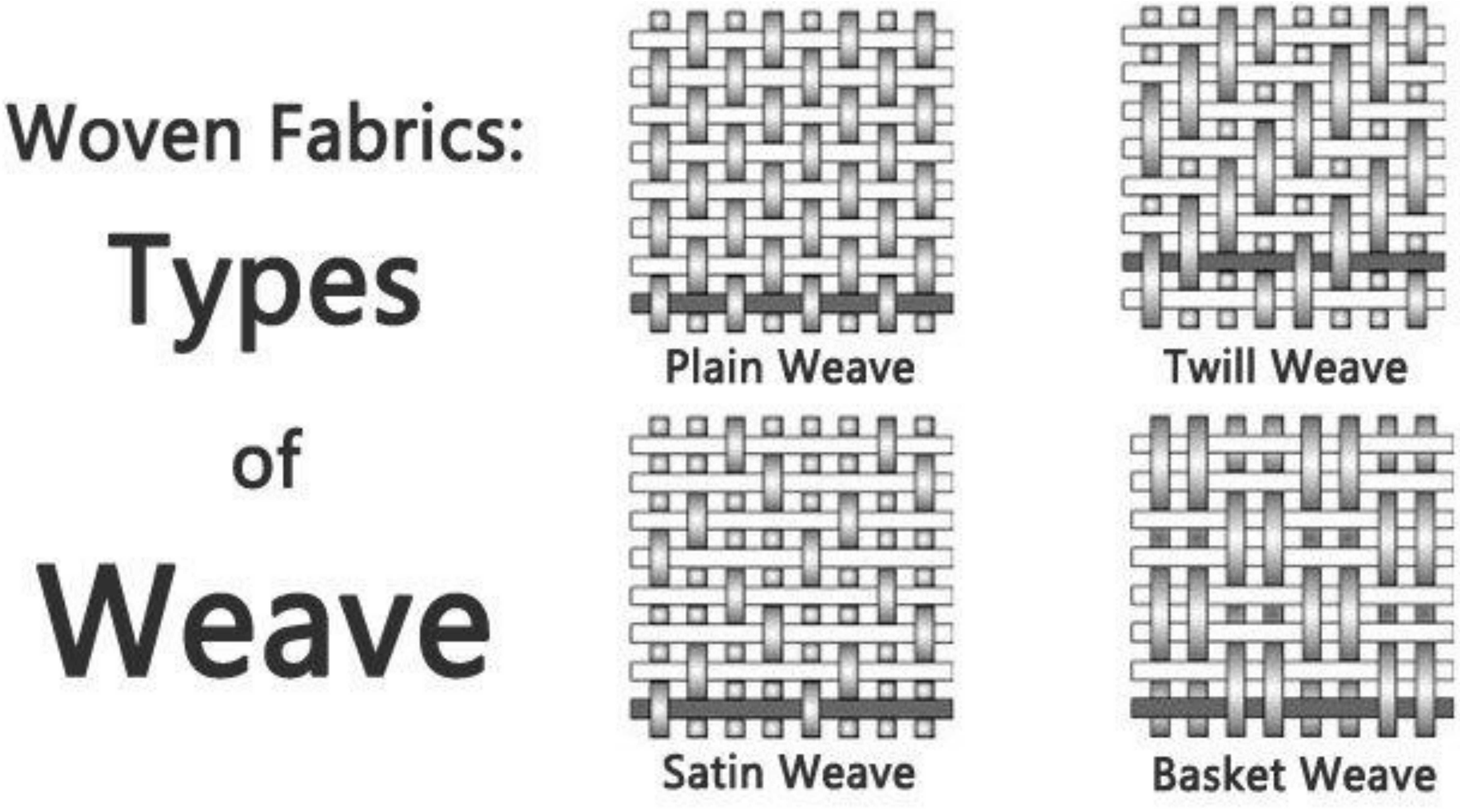
Mats



Fabrics

Chopped Strands

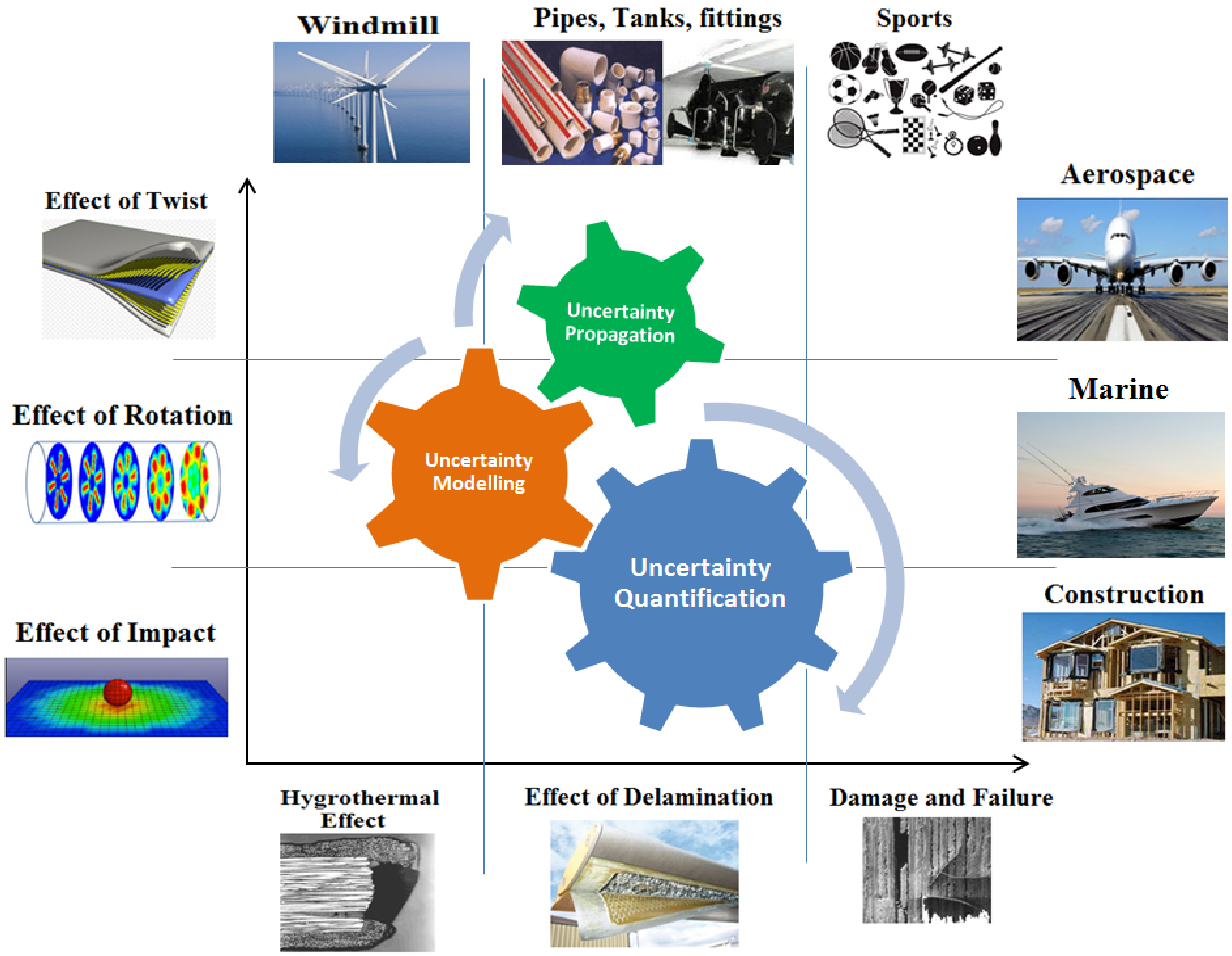
Types of Weave



Types of Weave

3D woven Fabrics

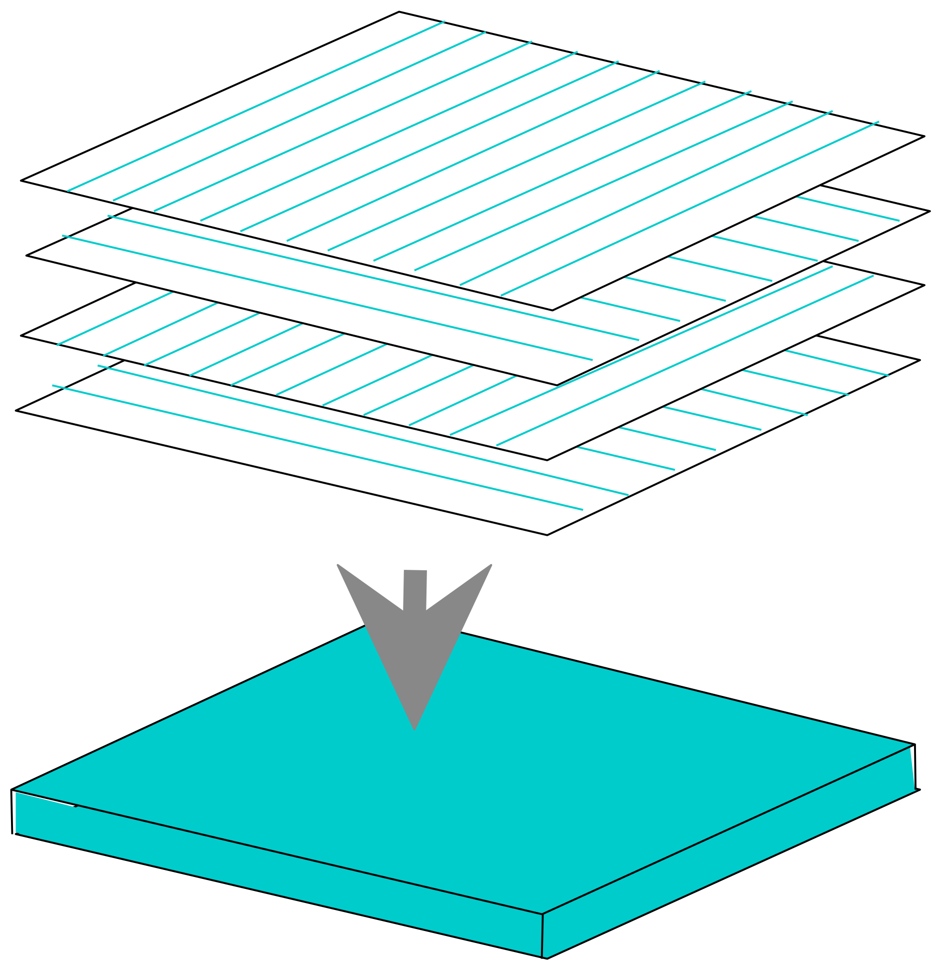
Design Challenges



Structual Composites:

- **Laminar:**
  composed of two-dimensional sheets or panels

  Stacked and bonded fiber-reinforced sheets
  - stacking sequence: e.g., 0º/90º or 0°/45/90º
  - benefit: balanced, in-plane stiffness



- **Sandwich Panels:**
  Consist of two strong outer sheets
  and Core may be a honeycomb structure

- Sandwich panels
  - -- low density, honeycomb core
  - -- benefit: light weight, large bending stiffness