Lecture 1: Introduction to composite materials

At the end of this lecture you will have:

- ✓ An understanding of what are composite materials
- ✓ What the various types of composite materials
- ✓ Why they are used
- ✓ How they are designed

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✓ What are composites materials?

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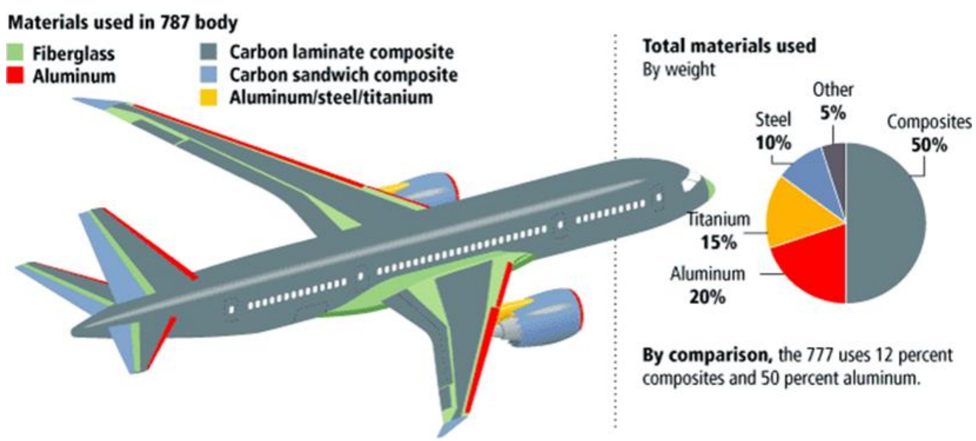
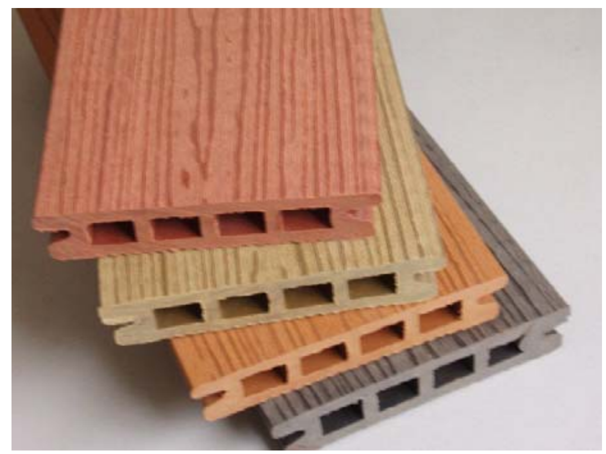
✓ What are composites materials?

Many materials are composites made up of at least two constituents





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✓ What are the various types of composites materials?

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✓ What are the various types of composites materials?

Typically made of a matrix and 1 or more reinforcements

They have different compositions, shapes and physical/chemical properties

1.1 Types of composite material 3

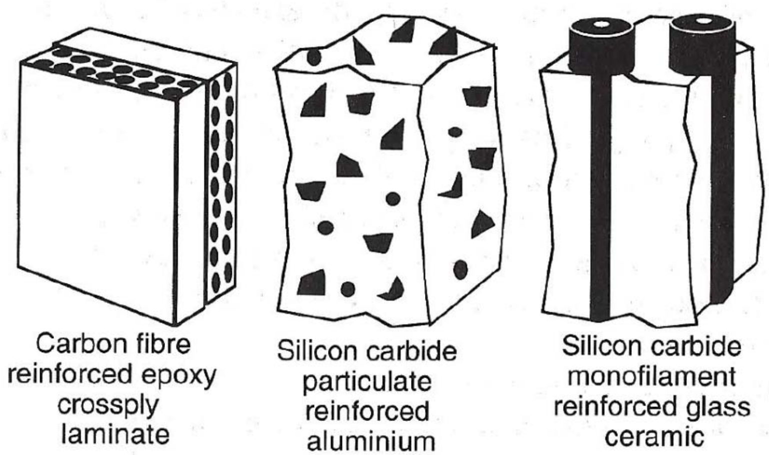

Fig. 1.1 Schematic depiction of representative polymer, metal and ceramic matrix composites.

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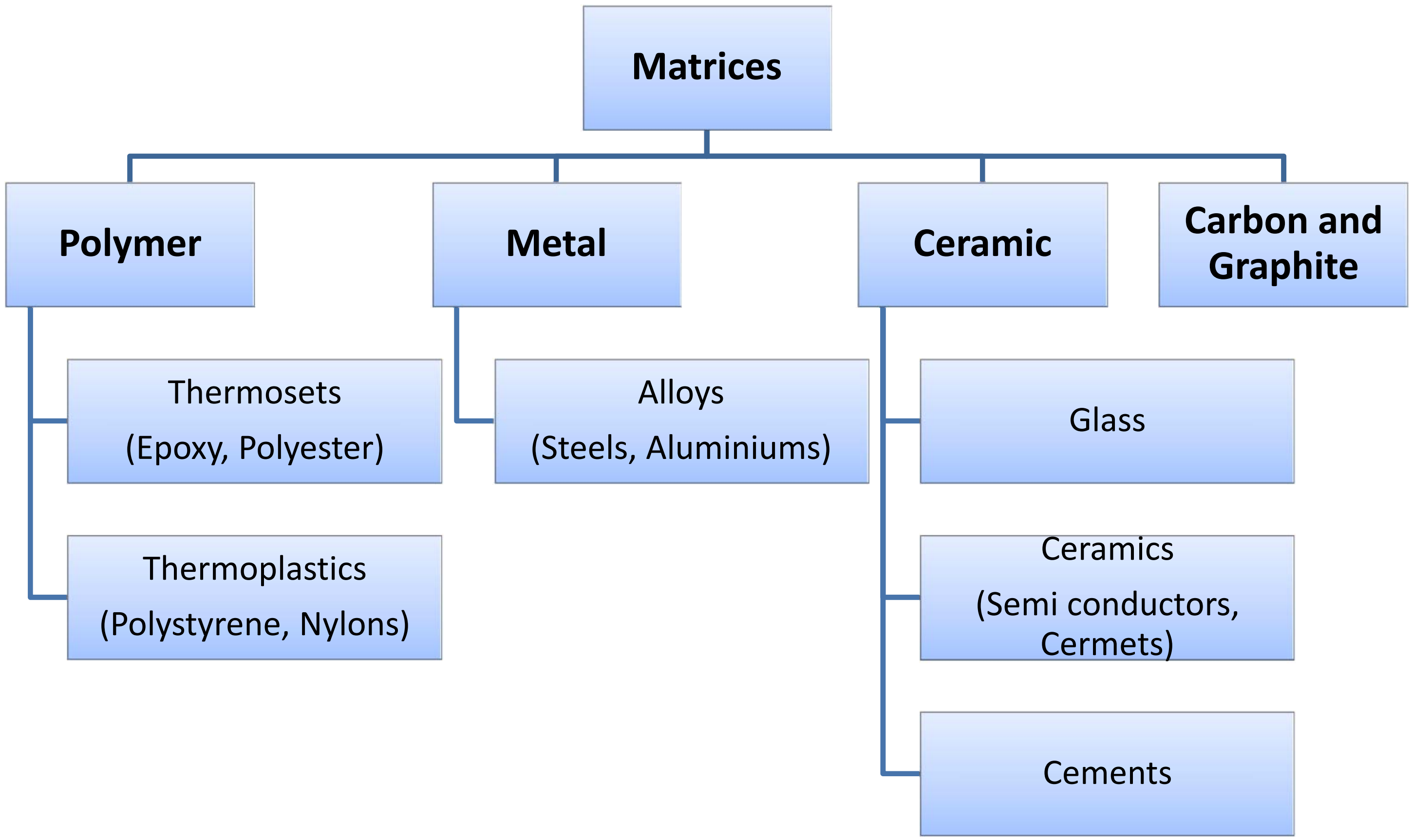
✓ What are the various types of composites materials?



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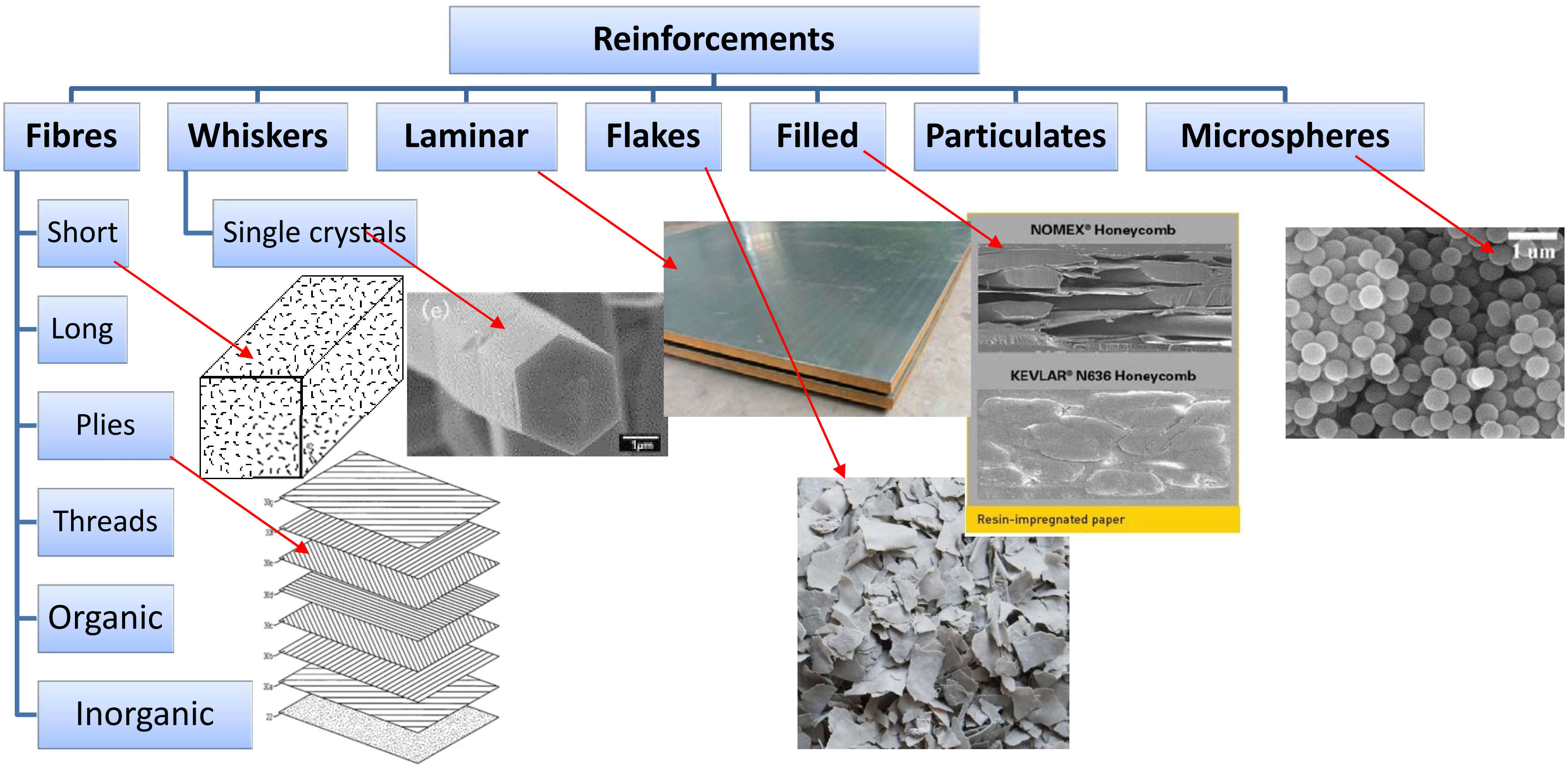
✓ What are the various types of composites materials?



The arrangement of the reinforcement (distribution, size, shape, and orientation matters)

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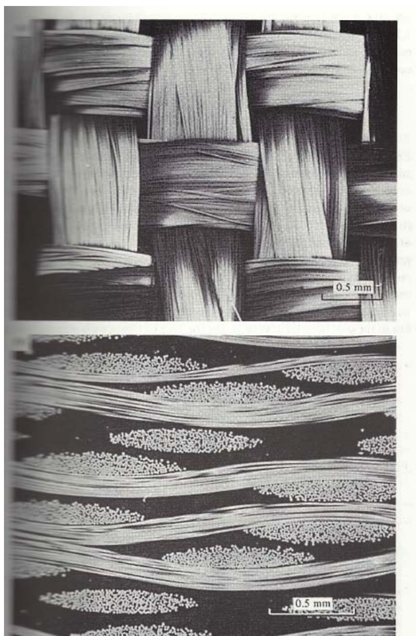
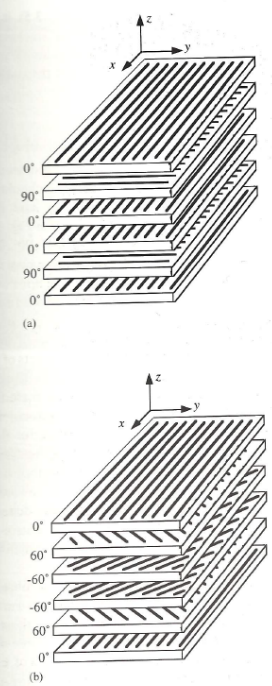
✓ What are the various types of composites materials?

The type, distribution, size, shape, orientation, and arrangement of the reinforcement will determine the properties of the composites material and its anisotropy



(a) SEM micrograph of a woven roving before infiltration with resin. ...rograph of a polished section through a woven roving laminate parallel to one set of fibres.

3.2 Long fibres 45



Arrangement of plies in (a) a crossply laminate and (b) an angle-ply laminate sandwiched between 0° plies.

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✓ What are the various types of composites materials?

Classification of composites:

- Matrices:
  - Organic Matrix Composites (OMCs)
    - Polymer Matrix Composites (PMCs)
    - carbon-carbon composites
  - Metal Matrix Composites (MMCs)
  - Ceramic Matrix Composites (CMCs)
- Reinforcements:
  - Fibres reinforced composites
  - Laminar composites
  - Particulate composites

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✓ Why are composites materials used?

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✓ Why are composites materials used?

Advantages

- Lower density (20 to 40%)
- Higher directional mechanical properties (specific tensile strength (ratio of material strength to density) 4 times greater than that of steel and aluminium.
- Higher Fatigue endurance .
- Higher toughness than ceramics and glasses.
- Versatility and tailoring by design.
- Easy to machine.
- Can combine other properties (damping, corrosion).
- Cost.

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✓ Why are composites materials used?

Disadvantages

- Not often environmentally friendly.
- Low recyclability.
- Cost can fluctuate.
- Can be damaged.
- Anisotropic properties.
- Matrix degrades.
- Low reusability.

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✓ Why are composites materials used?

Interesting mix of properties in which density is always a plus

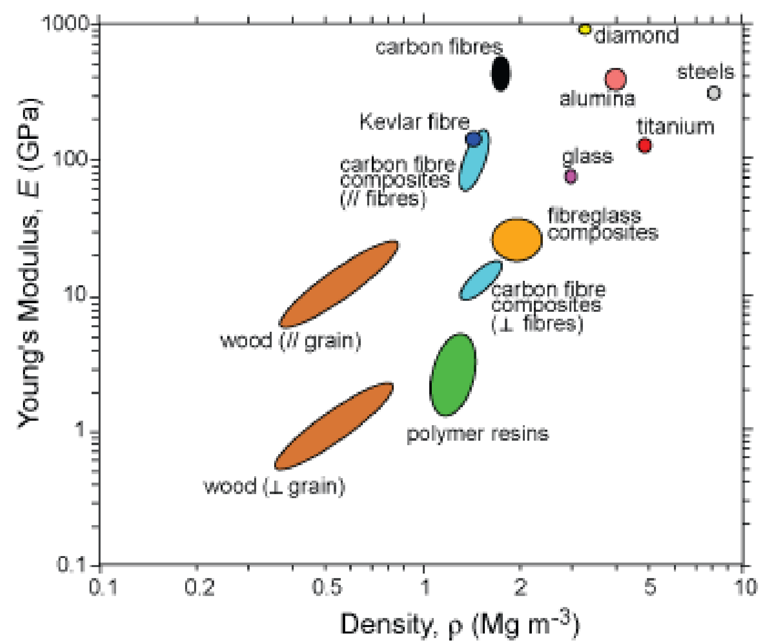

Fig.1.1 Data for some engineering materials, in the form of a map of Young's modulus against density

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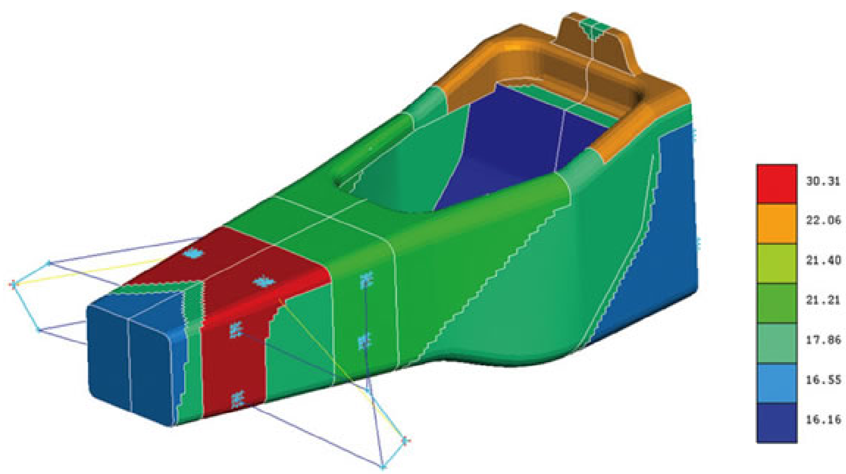
✓ Why are composites materials used?

High versatility of shape and properties by design



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✓ How are composites materials designed?

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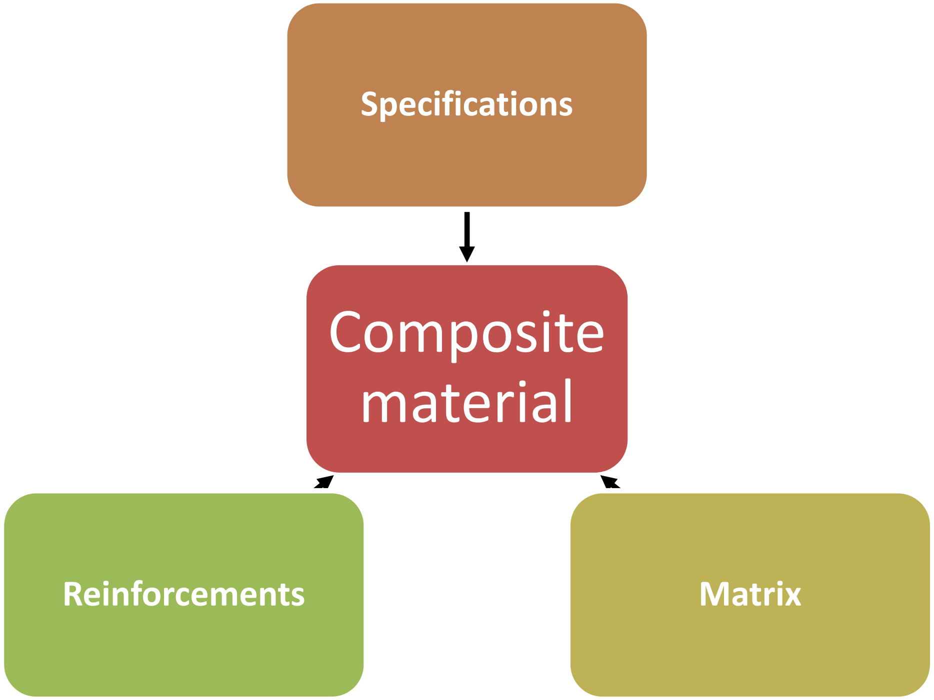
By comparing, and trying to combine the properties of the various engineered materials to meet the specifications of the usage planned for the composite.



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Properties of some matrices

Table 2.5 *Selected properties for different types of matrix*

Matrix	Density ρ (Mg m^{-3})	Young's modulus E (GPa)	Poisson's ratio ν	Tensile strength σ_* (GPa)	Failure strain ϵ_* (%)	Thermal expansivity α (10^{-6} K^{-1})	Thermal conductivity K (W m^{-1} K^{-1})
Thermosets							
epoxy resins	1.1–1.4	3–6	0.38–0.40	0.035–0.1	1–6	60	0.1
polyesters	1.2–1.5	2.0–4.5	0.37–0.39	0.04–0.09	2	100–200	0.2
Thermoplastics							
Nylon 6.6	1.14	1.4–2.8	0.3	0.06–0.07	40–80	90	0.2
polypropylene	0.90	1.0–1.4	0.3	0.02–0.04	300	110	0.2
PEEK	1.26–1.32	3.6	0.3	0.17	50	47	0.2
Metals							
Al	2.70	70	0.33	0.2–0.6	6–20	24	130–230
Mg	1.80	45	0.35	0.1–0.3	3–10	27	100
Ti	4.5	110	0.36	0.3–1.0	4–12	9	6–22
Ceramics							
borosilicate glass	2.3	64	0.21	0.10	0.2	3	12
SiC	3.4	400	0.20	0.4	0.1	4	50
Al_2O_3	3.8	380	0.25	0.5	0.1	8	30

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✓ How are composites materials designed?

Table 2.2 *Fibre properties*

Fibre	Density ρ (Mg m^{-3})	Young's modulus E (GPa)	Poisson's ratio ν	Tensile strength σ_* (GPa)	Failure strain ϵ_* (%)	Thermal expansivity α (10^{-6} K^{-1})	Thermal conductivity K (W m^{-1} K^{-1})
SiC monofilament	3.0	400	0.20	2.4	0.6	4.0	10
Boron monofilament	2.6	400	0.20	4.0	1.0	5.0	38
HM[a] carbon	1.95	axial 380 radial 12	0.20	2.4	0.6	axial −0.7 radial 10	axial 105
HS[b] carbon	1.75	axial 230 radial 20	0.20	3.4	1.1	axial −0.4 radial 10	axial 24
E-glass	2.56	76	0.22	2.0	2.6	4.9	13
Nicalon™	2.6	190	0.20	2.0	1.0	6.5	10
Kevlar™ 49	1.45	axial 130 radial 10	0.35	3.0	2.3	axial −6 radial 54	axial 0.04
FP™ fibre	3.9	380	0.26	2.0	0.5	8.5	8
Saffil™	3.4	300	0.26	2.0	0.7	7.0	5
SiC whisker	3.2	450	0.17	5.5	1.2	4.0	100
Cellulose (flax)	1.0	80	0.3	2.0	3.0	—	—

[a] High modulus
[b] High strength