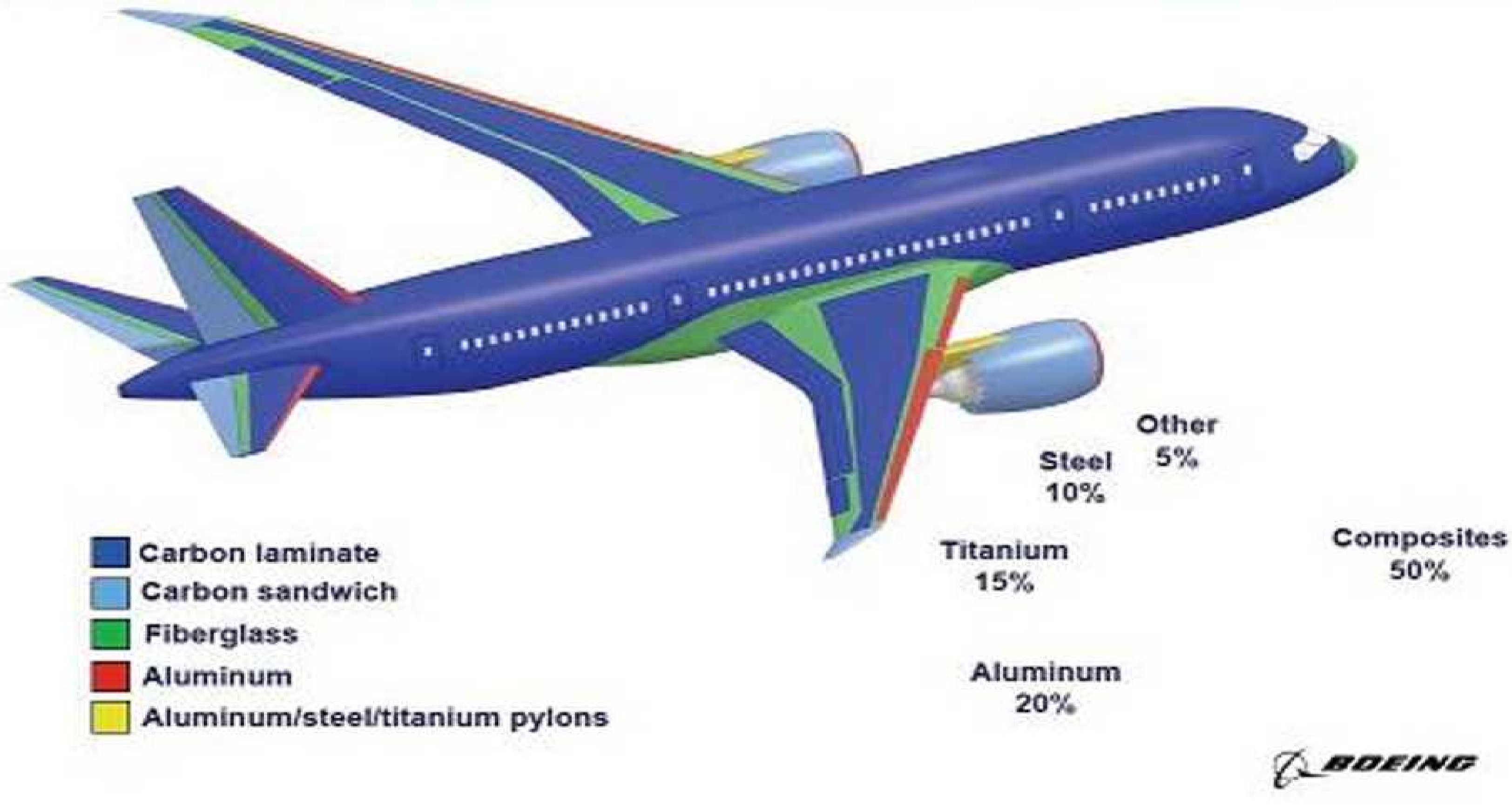
Definition and classification of composites



Zdroj:
http://en.wikipedia.org/wiki/Boeing_787

Contents of lecture

- 1. The role of composite between technical materials
- 2. Basic requirements and properties of engineering materials
  - homogeneity
  - isotropy
- 3. Definition of composites and nanocomposites
- 4. Historical examples
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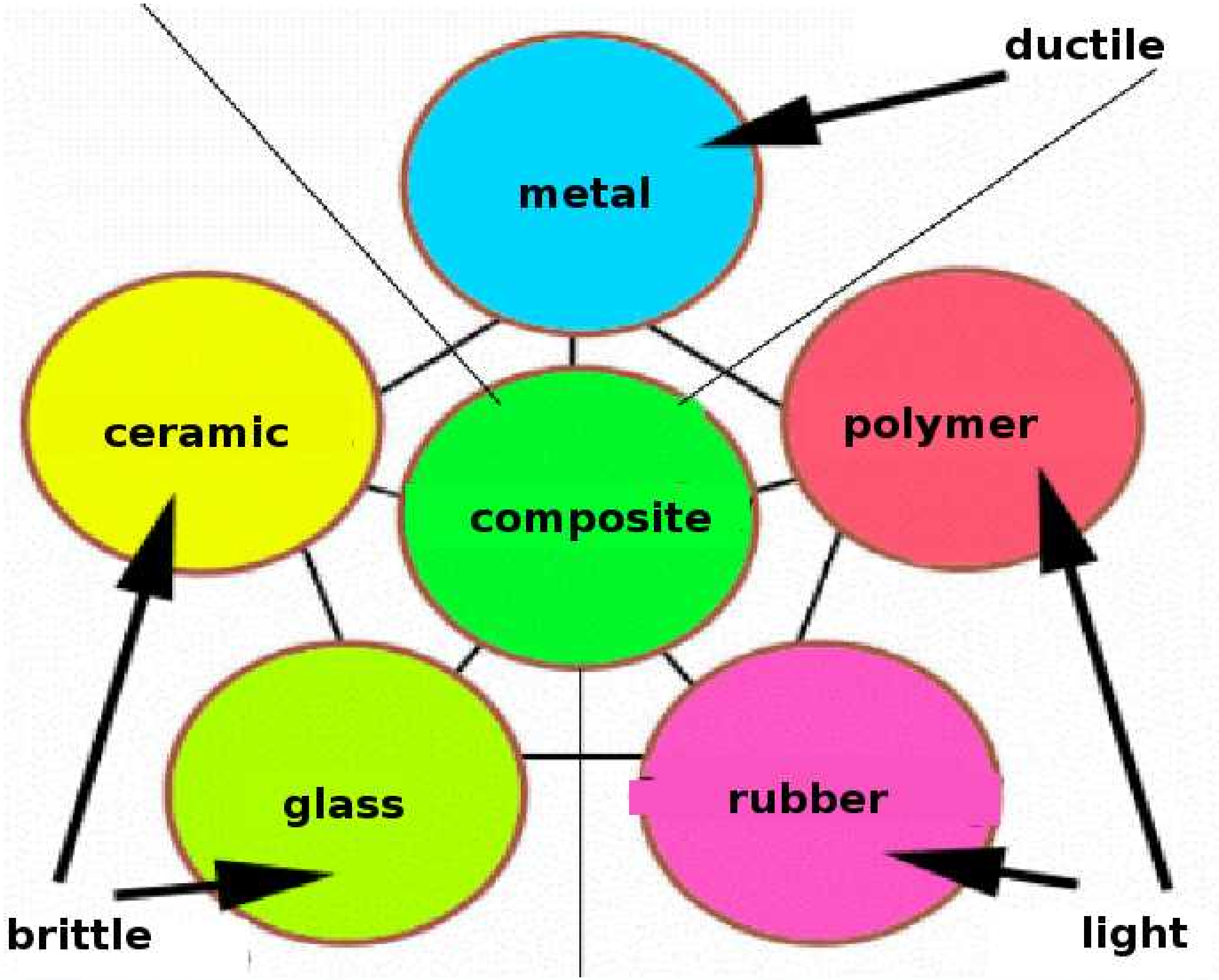
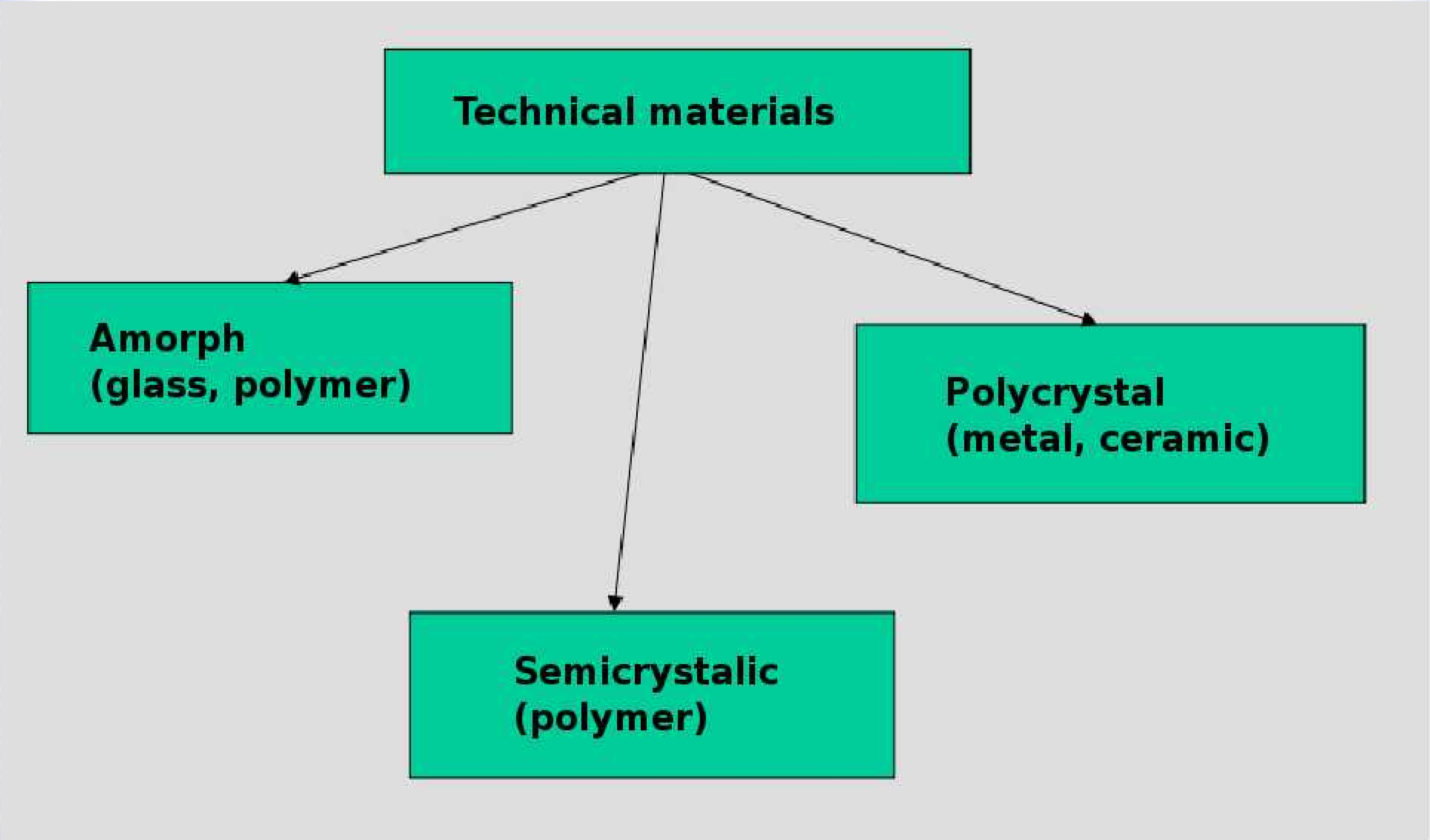
- 6. Anizotropy of composites

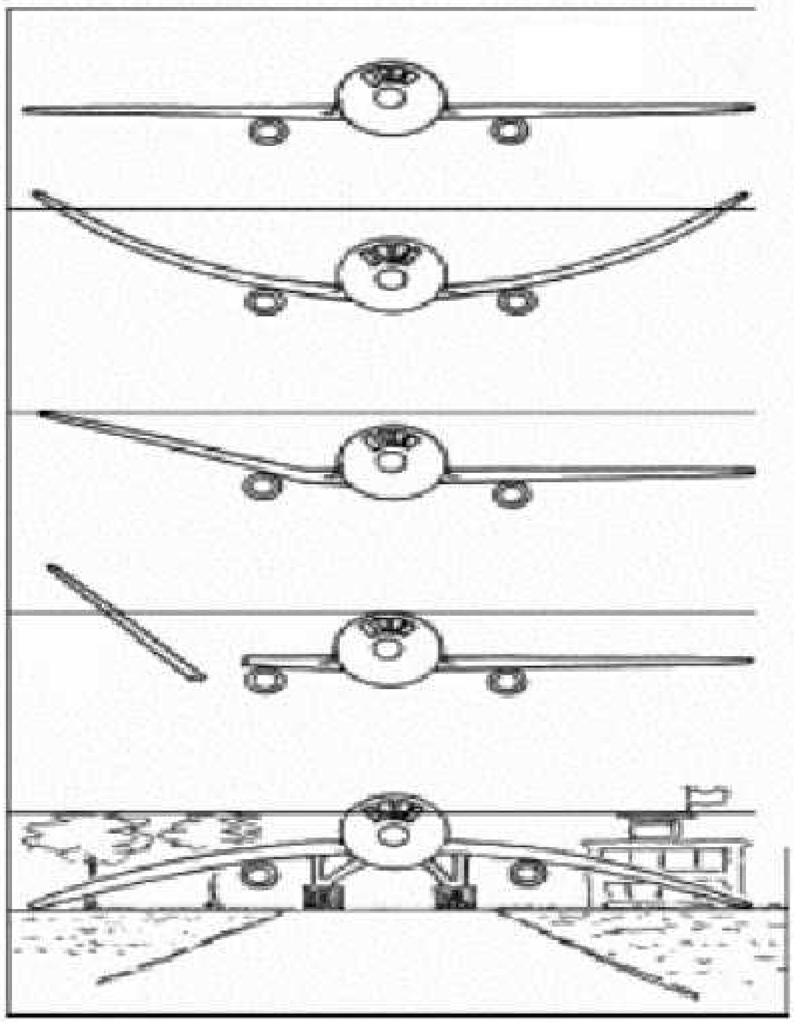
Technical materials



Structure classification



What must meet the technical material ?



- All OK
- small stifness (E)
- low strength (Rm)
- low thoughthness (KIc)
- much weigh (G)

What is technical material

- Continous solid – constant size and shap

  – continuum

- In all places the same properties
  - homogenity

- In all directions the same properties

- – isotropy

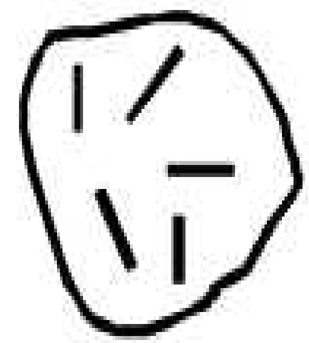
- Main technical disciplines premise homogeneous isotropic continuum
  – mechanics, elasticity, strength

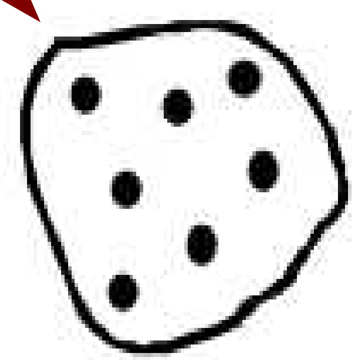
Material as continuum

- Technical material need constant size and shape, may not be easily divisible into parts
- Basis must be at least one solid phase.
- There are two options by composite material :
  - one solid phase – matrix,
    inside more discontinuous phase
    - dispersion
  - at least two solid phases mutually penetrating

Basic cases

- fiber composite
- particle composite
- plate composite





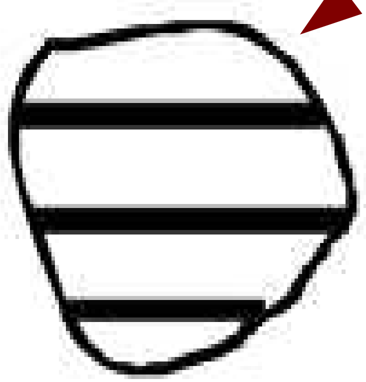
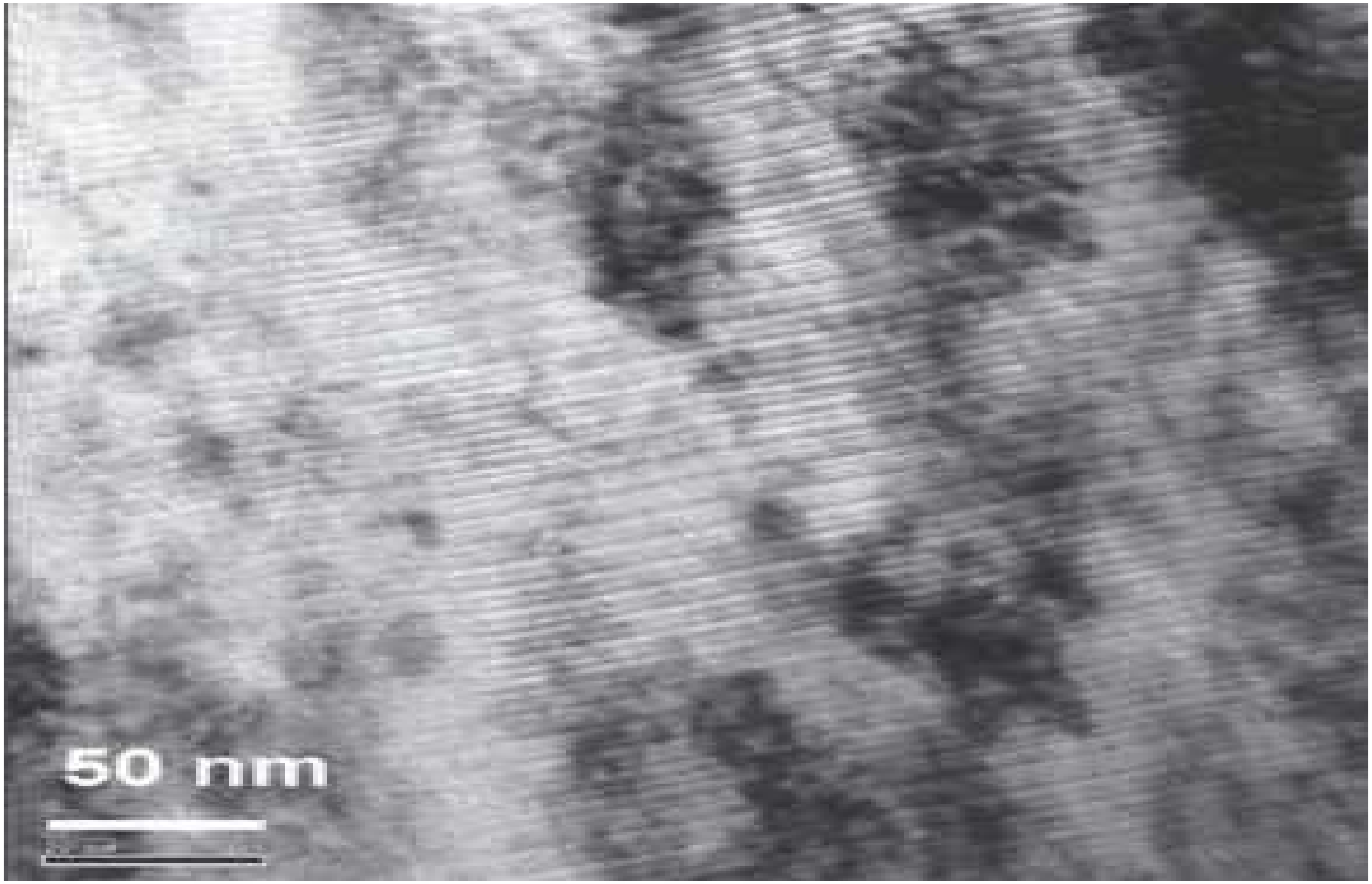


Plate nanocomposite



Homogenity of material

- Virtually never completely fulfilled - depends on the scale and distinctiveness
- Material must be homogenous in comparison with the dimensions of the components

Microstructure of common steel

Size of inhomogeneities

- We must not fall into the field of chemistry or atomic physics
- Inhomogeneites of material must be sufficiently large compared to the dimensions of the atoms and atomic bond length
  – then it is a composite or nanocomposite.

Distribution of inhomogeneities

- To be regarded as a homogeneous material must be discontinuous parts distributed approximately equally in the material and their number must be large (theoretically infinite).
- Systems in which is a small number of discontinuities are known as composite systems.
  Example – multilayer.
- Number of conclusions for composites applies to composite systems.

Isotropy of materials

- Materials of isotropic nature - glass
- In metals and ceramics are anisotropic crystallites but random distribution of a large number of crystallites
  - whole is isotropic
- Isotropy may disrupt weak external influences
  – cold forming, rolling
- Overall, the common materials may be considered as isotropic

Anisotropy of composites

- Most typical composites is arranged so that it is anisotropic.
- Composites anisotropy is very large - up to several orders of magnitude greater than other materials.
- Sometimes it is possible anisotropy of use: bows, skis.
- If we need an isotropic material, we need artificial settlement anisotropy - laminates: actually composite system composed of several anisotropic composites.

Problems with homogeneity of composites

- There are composed of several clearly distinct stages - inhomogeneous, but as a whole are regarded as homogeneous – we count with the composite as a whole.
- Therefore, it is necessary to establish values for the composite as a whole – actually fictive values

Fictive density

- Density of aluminium foam 0,18 g/cm3
- Massive aluminium - density 2,7 g/cm3
- That is a composite with 7 % of aluminium matrix and 93 % of dispersion – pores.
- Ducks in water

Alporas

Deformation of composite

for each component of the composite with elastic deformation we can apply Hooke's Law :

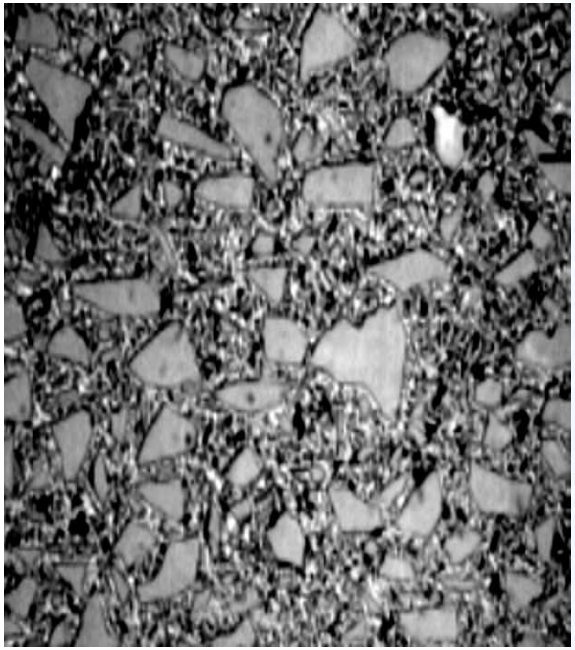
$$R = S * E,$$

R … stress, S … deformation, E … Young's modulus.

But if matrix and dispersion do not have the same Young's modulus, they can not be the same tension and strain.

Fictive stress

- To work with the composite stress is defined therein as the ratio of power and cross section.
- Particles SiC – E = 415 GPa, matrix ... Al – E = 68 GPa
- For the same deformation stress of particles must be equal to six times stress of matrix (E ratio)
- Composite stress is between them – is only fictive.

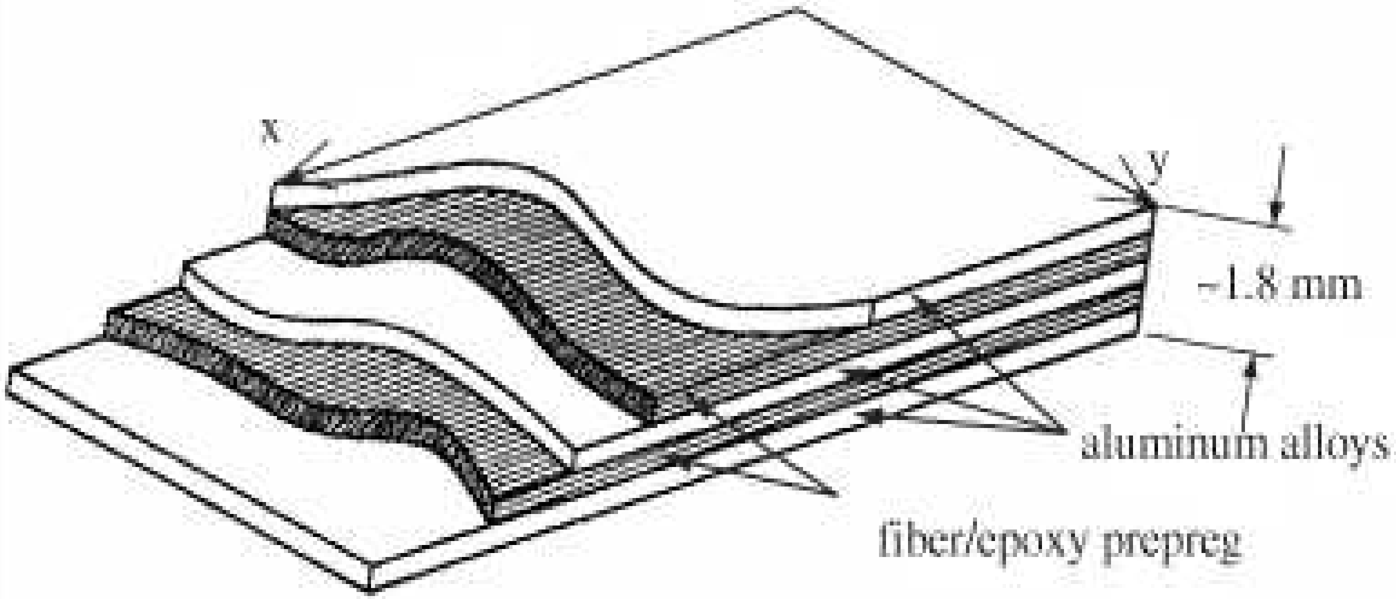


Composite matrix Al with particles SiC

Fundamental role of models

- Physical properties of the individual components of the composite - are real - micromechanics
- Physical properties of the composite as a whole - are fictive, but necessary for the use of composites - macromechanic
- Determination of macromechanics from micromechanics - necessary models.
- Often multiple solutions - laminates GLARE composite systems.

GLARE



Composite system developed for the Airbus

Definition of composite - problems

- Eldest : any multiphase material
  - wood, cast iron, concrete.
- Newer - phase retain their properties, but the system will apply their strengths and weaknesses override.
- Phase uniformly distributed in the volume - not always
- EU experts: phase must occur separately and composite created their combinations - it excludes eg. guided solidification.
- Sometimes it requires only an artificial system, sometimes divided into artificial and natural composites.

Modern definition (USA)

- Definition MIL – NASA (USA) :
  A combination of two or more materials differing in macroscale shape or composition. The components retain their identity (no dissolution or reaction), but in external environement they are interacting in cooperation (synergy). Each component can be physically identified and between it and other components of the interface.

Modern definition (EU)

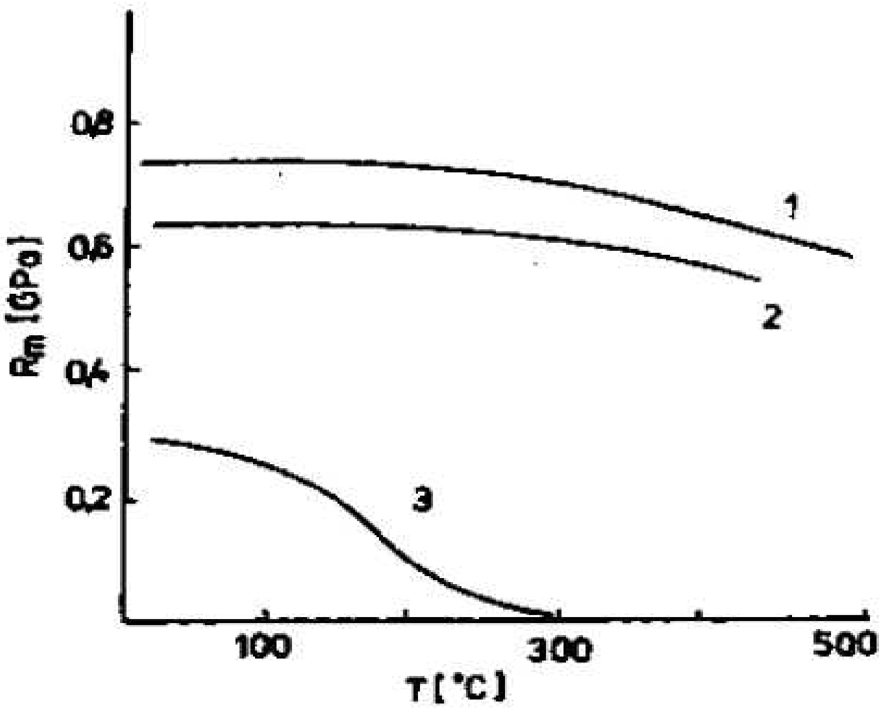
- Definition G. F. Milton, Cambridge, UK :
- Materials with inhomogenities much larger than atomic dimensions (which allows you to use them for the equations of classical physics - for nanocomposites not always), but they are naturally on a macroscopic scale (statistically) homogeneous.

Used a simplified definition

- For our purposes it is sufficient
- Solid substance composed of two or more phases, natural or artificial.
- The whole composite achieve properties, which can not be achieved by the summation of properties that have components - **synergic effect**.

Example of synergic effect

- Graphite - has great strength, but oxidized
- Aluminium – no oxidation, but strength decreases rapidly with temperature
- Composite - up to 500 ° C resistant to oxidation



3 – aluminium alloy AlMgSi
1, 2 – the same alloy with various C fibres

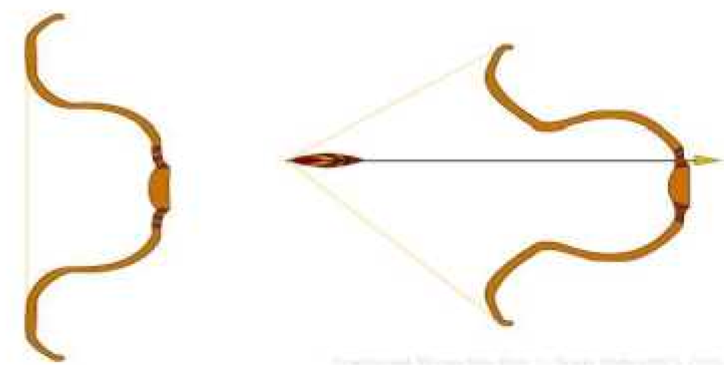
Definition of nanocomposite

- For our purposes - is not definitive
- Must be a composite in which the dispersion characteristic dimension is below 100 nm (typically tens of nm).
- Characteristic dimension :
  - for fiber and one-dimensional particle equivalent transversal diameter
  - for two-dimensional particle equivalent thickness
  - for three-dimensional particle equivalent diameter of particles
  - for composite plate thickness thinner slabs.

Historical example of composite

The dried clay with straw fibers - References in the Bible - findings in Israel 800 years BC - 7 MPa strength

Mongolian laminated bow - wood, sinew and horn
- Tatar raids (range 300 m)



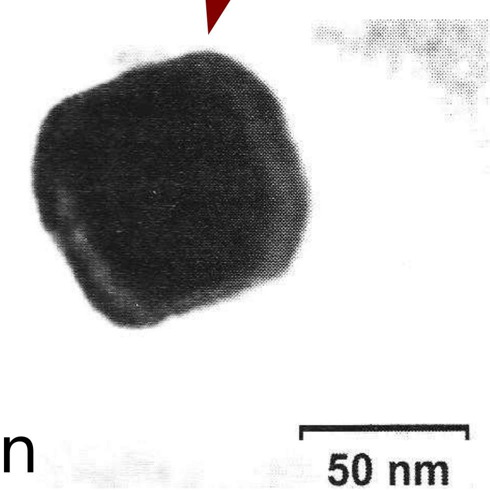
Damascus steel
- alternating slices of high carbon and low carbon steel

Nanocomposite – Lycurgus cups

Cups of period Roman Empire
Ordinary glass with
a small amount of
nanoparticles electron
(an alloy of 30% Au, 70% Ag)

View in external (reflected) light

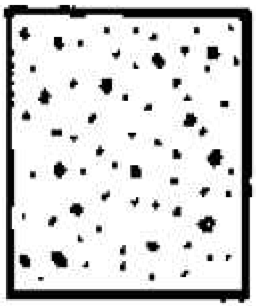
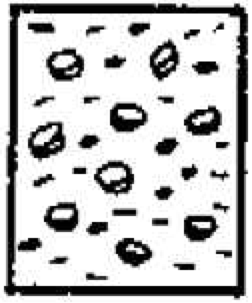
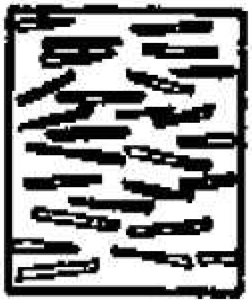
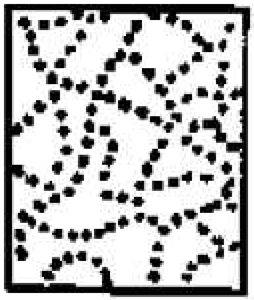
The light source is within



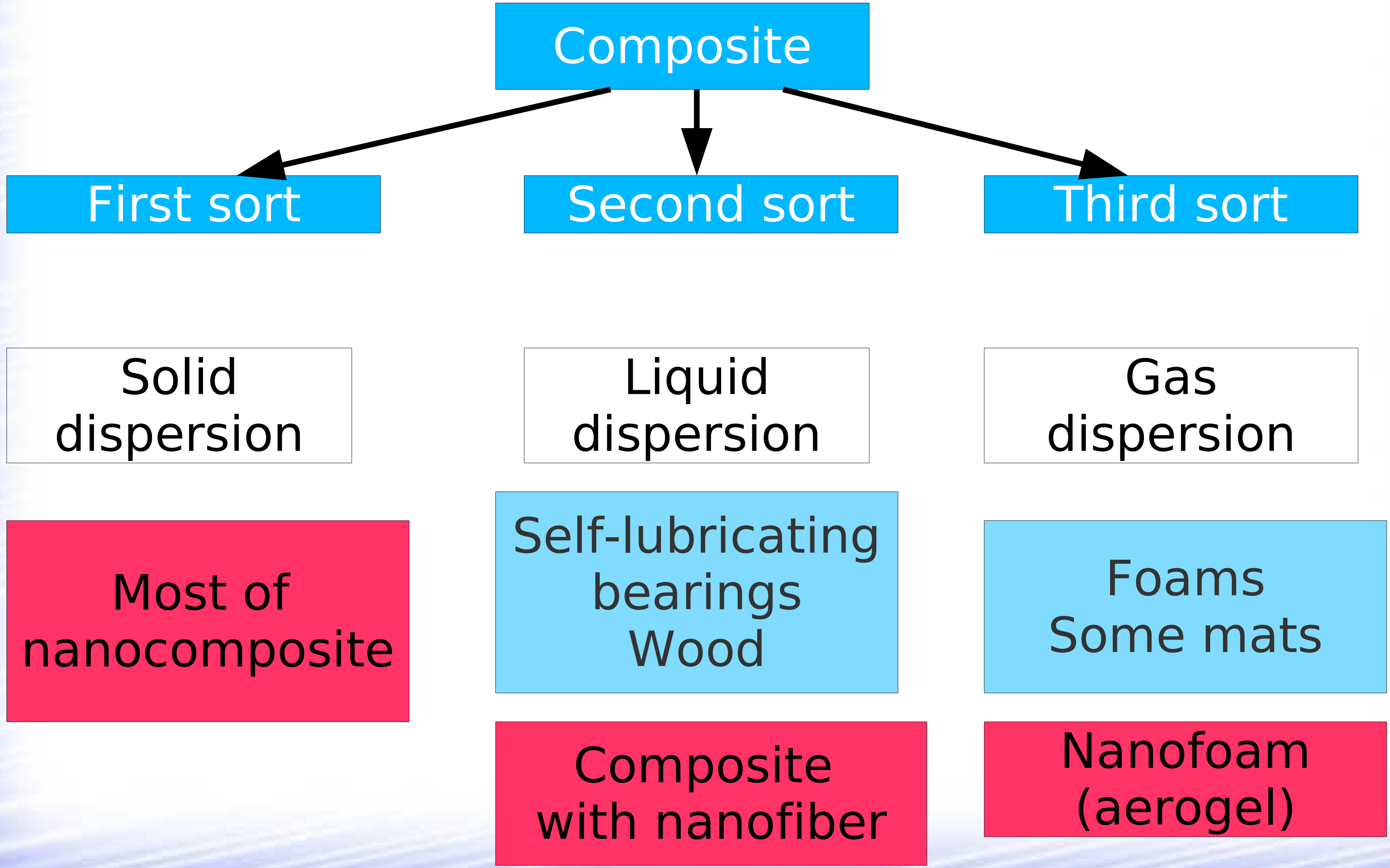
The method of manufacture is not known
From the fourth century AD
- British Museum, London

Phase in composite

- At least one continuous solid phase that holds the composite together - **matrix**
- The next phase (one or more), a discrete, evenly distributed as possible - **dispersion**

a)  b)  c)  d) 

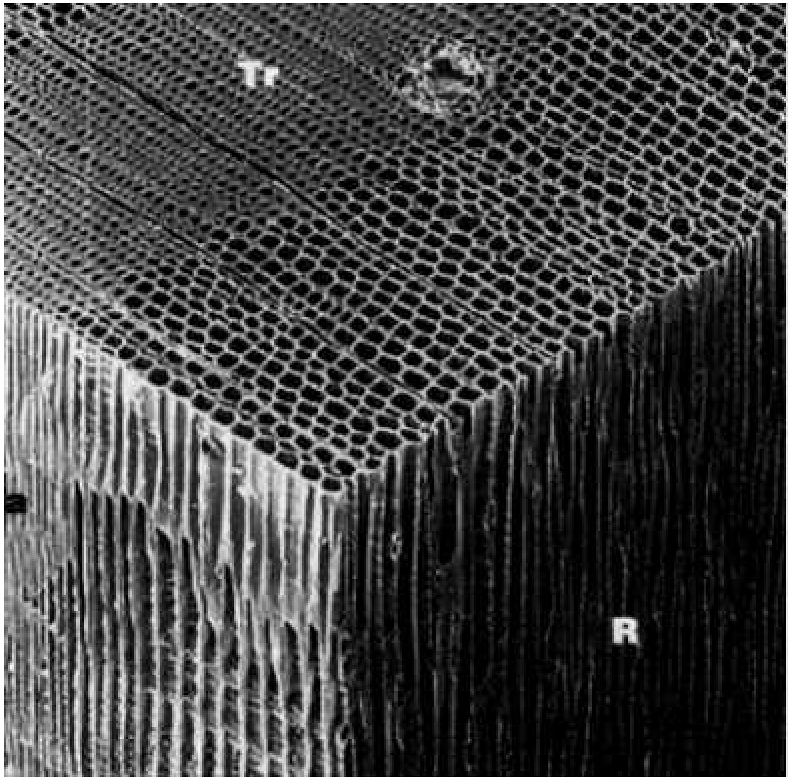
Sorts according to the type of dispersion



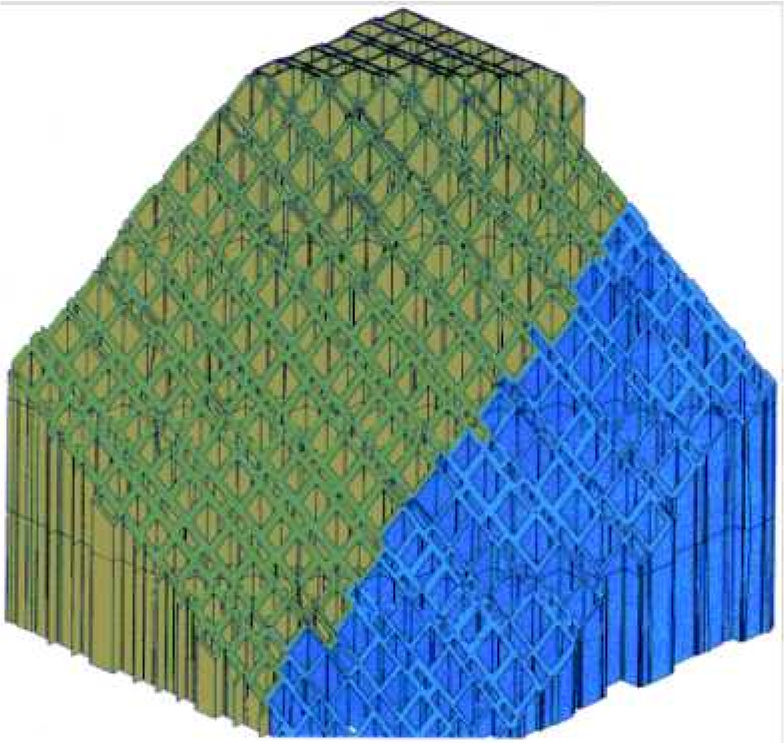
Third sort – metal foams

Wood – natural composite

Micrograph strukture of wood



Artifical model Structure of wood



First sort of composite

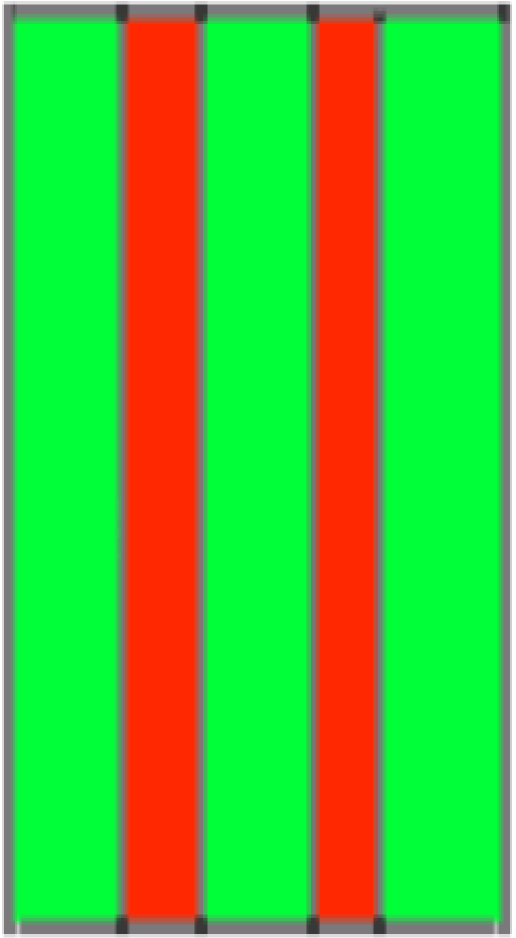
- The most important in technology
- Classification by matrix :
  PMC – polymer matrix composite
  MMC – metal matrix composite
  CMC – ceramic matrix composite
- Today, the most common PMC
- Glas matrix we classify as CMC.

Classification by shape of dispersion

- Fiber – negligible flexural stiffness
  - continual – full length of composite
  - long – fully utilized their strength
  - short – only partially utilized their strength
- Particle
  - izometric – ball, cube
  - two-dimensional – platelets (transverse dimensions not over the entire width)
  - one-dimensional – needle, stick
- Plates – special case
  disappears difference between matrix and dispersion

Plate composite

- No difference between red and green phases
- No phase is completely continuous
- Shape maintain both phases simultaneously
- For models any choice , what is dispersion and what is matrix - matrix usually that what is more



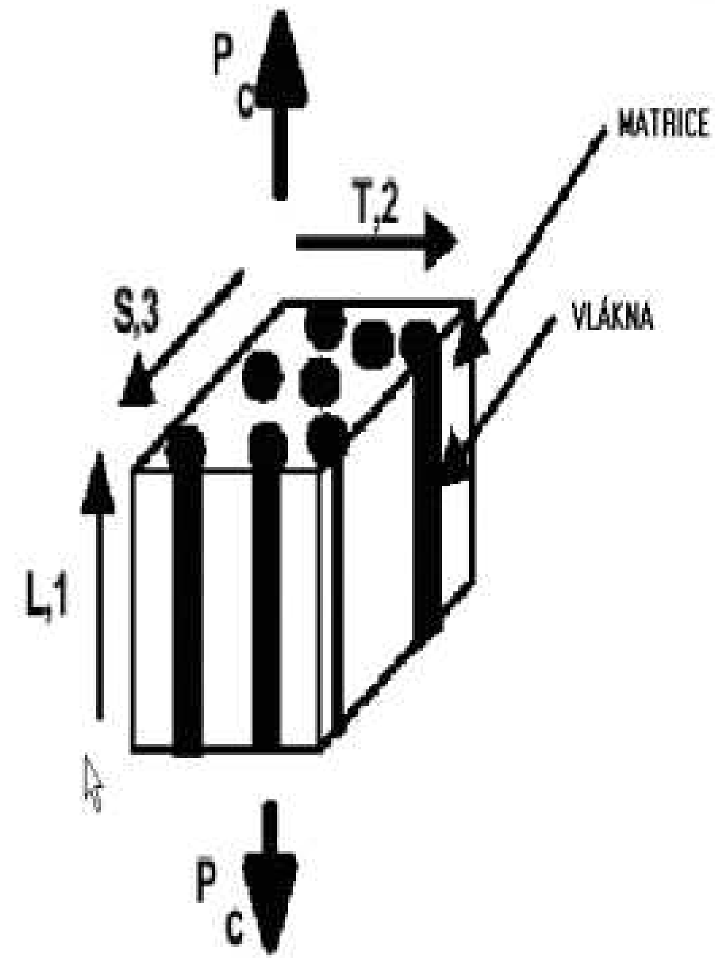
Fiber and one-dimensional particle

- Continuous fibers are clearly defined
- Sometimes doubts arise, what is short fiber and what uniaxial particle (needle, stick)
- Decisive is the flexural rigidity – by the fibers is always negligible stiffness against strength - pressure. For uniaxial particles is not negligible (on the one-dimensional particle can not be done node)

One-dimensional arrangement

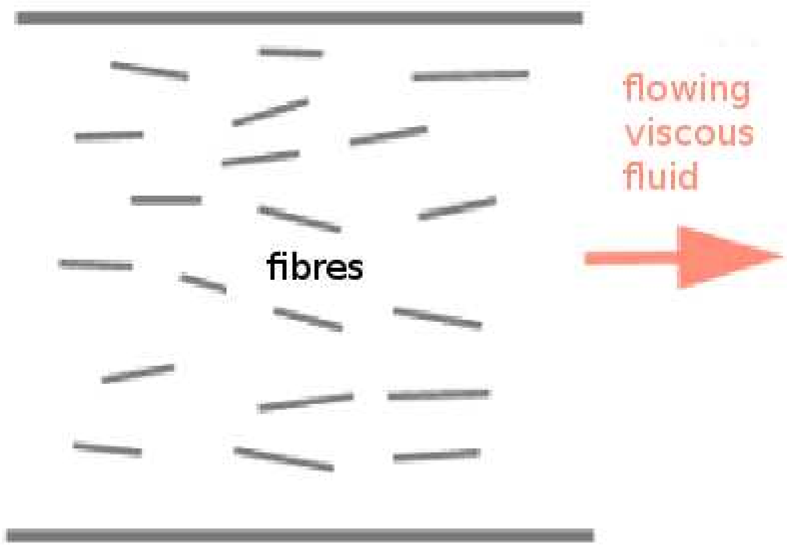
- Fibers (or needels, sticks) with axis in one direction
- Marking **1D** - one-dimensional arrangement
- Direction of fibers – direction of length of composite - designation L or x1
- Direction normal to fibers – with of composite - designation T or x2
- Third direction

  – thickness of composite - designation S or x3



Manage of 1D arrangement

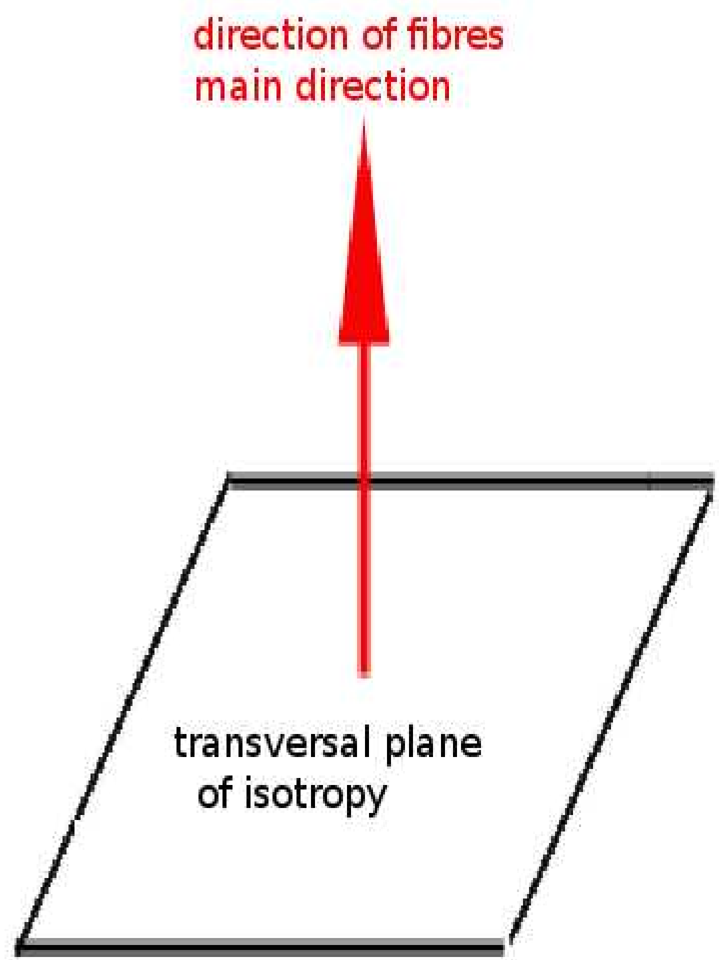
- Principle : rotation axes of fibers in flowing viscous liquid
- The fibers are not collapse - good wettability



Continuous or sufficiently long fibers
is possible to fix at the end.
Often is also used fabrics - disadvantages:
the fibers are not fully stretched, in the longitudinal direction is only about 50% of the fibers.
From the shorter fibers thread - multifil

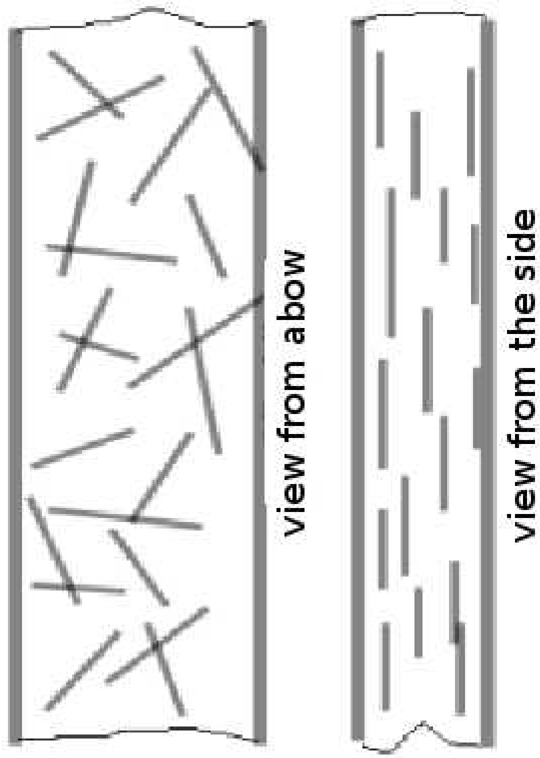
Symmetry of 1D arrangement

- In the longitudinal direction the fibers causes most
  - **main direction**
- If the matrix is isotropic, the behavior of the composite in all directions perpendicular to the fibers is the same
  - **transverse plane of isotropy**
- Composite is **transversal isotropic**



Fibers in one plane

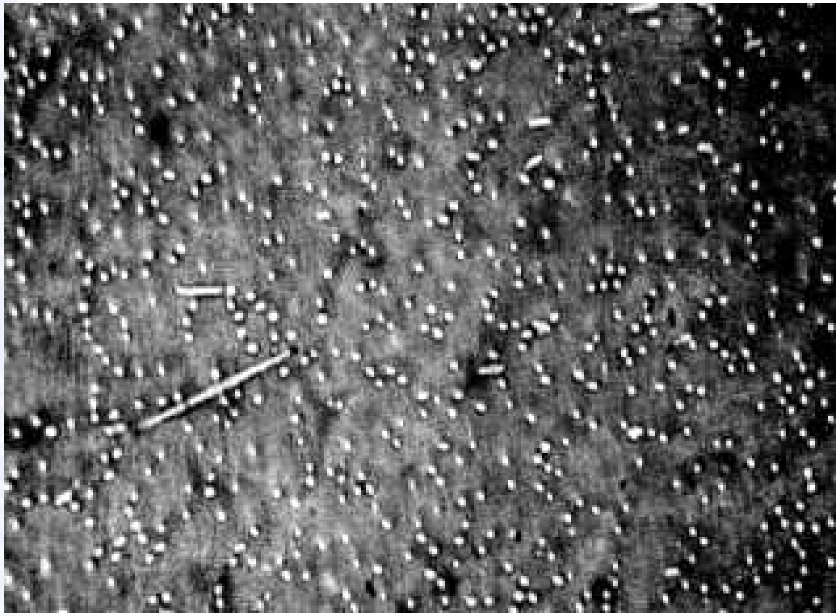
- Random scattering needles on a horizontal plane
- Axis of fibers are paralel with that plane – main plane.
- Two-domensional (2D) arrangement of fibres or needles.

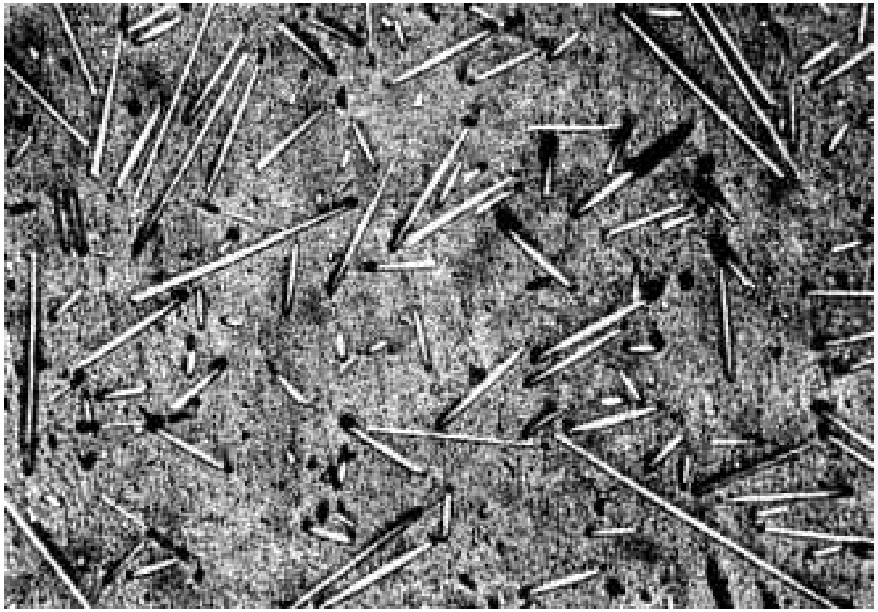


Anisotropy of 2D fibres

- Due to the random arrangement of fibers in the major axis plane is that plane of isotropy.
- All fibers are perpendicular to the normal of that plane - in this direction are significantly different properties - the main direction.
- Again, it is therefore a **transversal isotropic** composite - main direction is the normal to the main plane.
- Usually the opposite of the main axes - the best direction for 1D structure, worst direction for 2D structure.

Example 1D and 2D structure

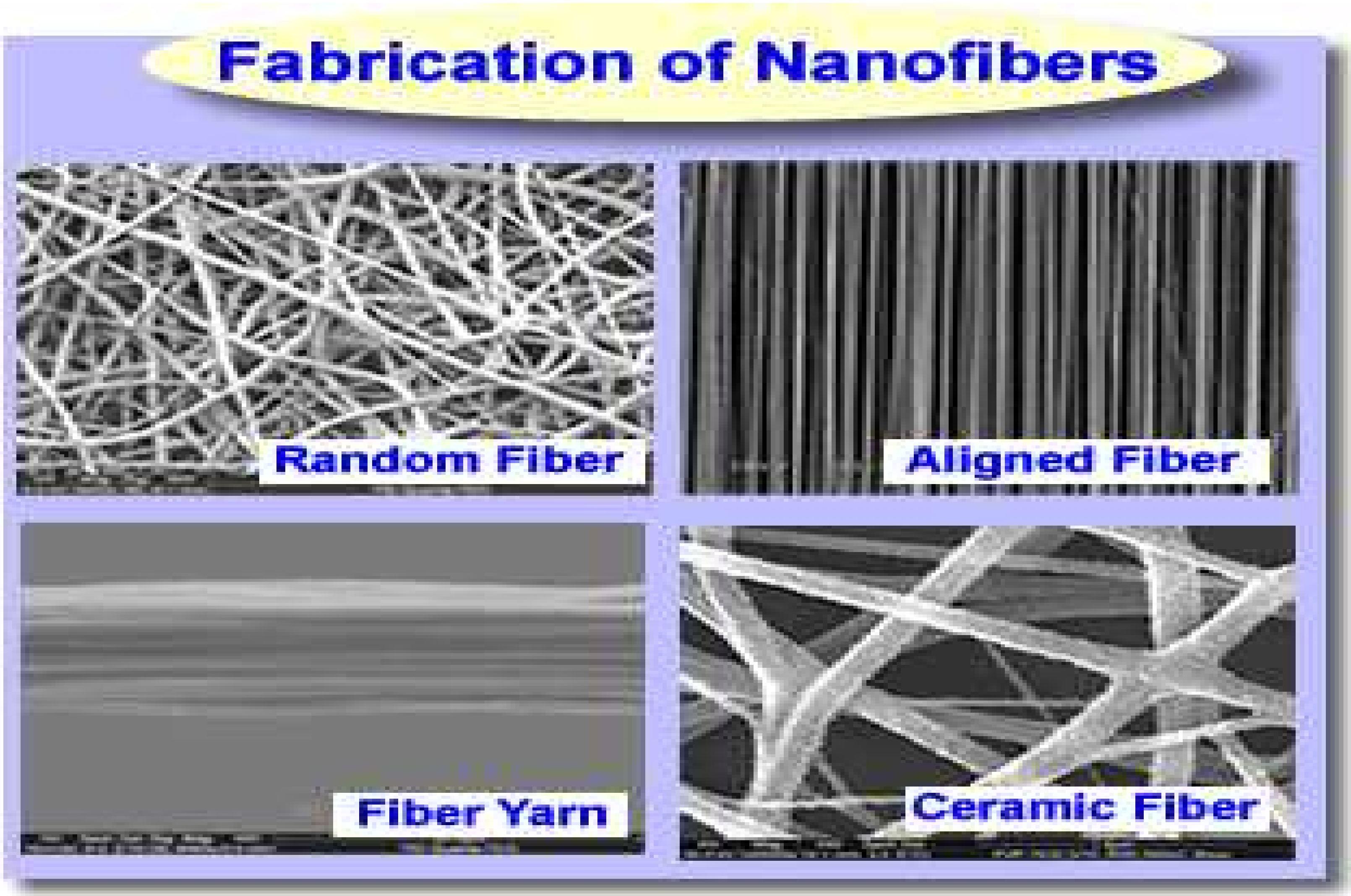




Micrograph of 1D Plane of isotropy

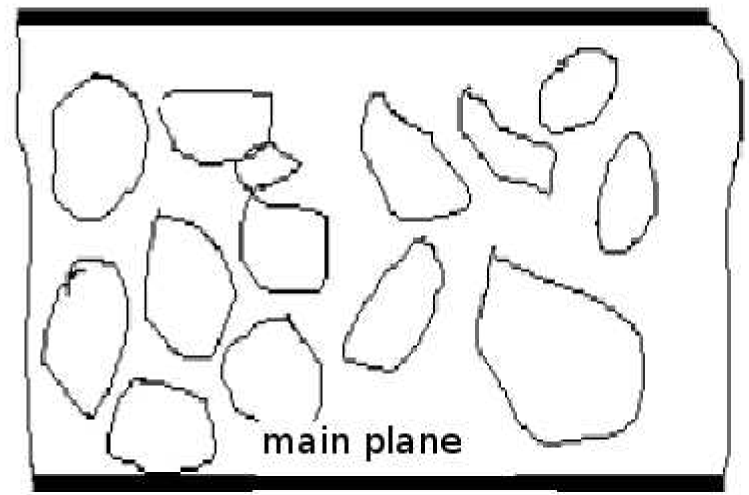
Micrograph of 2D Plane of isotropy

Arrangement of nanofibres

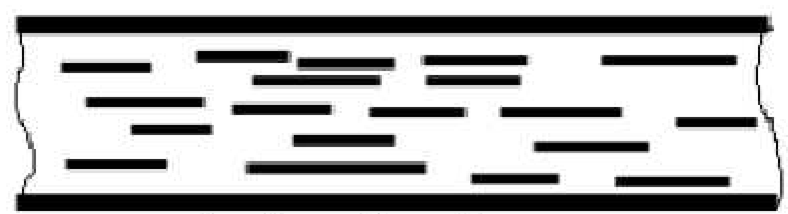


Platelets in one plane

- Platelets scattered on the horizontal plane - the main plane
- The normal to the main plane is the main direction
- For platelets the simplest organized orientation
- Again transversal isotropic composite



view from abow



view from the side

Basic symmetry of composite

- All previous cases are
  \- **transversal isotropic composite.**
- Composite can be rotated by any angle around the main axis, without changing its properties
- We're talking about one axis of rotational symmetry.
- It is a symmetry as an rotational ellipsoid
- The same symmetry must have all the properties of the composite.
- Not to be confused with orthotropy!

Orderless (isotropic) composite

- The composites with isometric particles are equivalent in all directions.
- Also in the composite with plates or needles with randomly arranged axes
- There is rather difficult to achieve a uniform distribution of fibers so that their axes directed randomly in all directions
  - 3D structure of fibers
  (fiber may form a ball).