Textile Engineering

KMI-TEN

Part 1: *Introduction and Textile Structures*

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Agenda – 1/8

- **19.02.2024 (14:20 – 15:55) – Lecture – Full-time**

➢ Introduction to Textiles
➢ Overview of Textile Structures and Production in the Fiber Line.
➢ Standard Textiles.
➢ Value added Products.
➢ Application of structures and technologies for technical and medical textiles.

- **20.02.2024 & 22.02.2024 – Practical – Full-time**

➢ Textile Structures and their applications. Assignment.

Course content

Lectures:

1. Introduction to Textiles - Overview of Textile Structures and Production in the Fiber Line - Standard Textiles - Value added Products.
2. Development and current trends in yarn production technology (classic and unconventional spinning systems - Airjet, Vortex, DREF). Effect of technology on yarn properties.
3. Production of 2D and 3D woven structures using gripper projectile, Air and water jet weaving machines. Fabric structure and quality control of fabrics.
4. Modern knitting techniques in weft and warp knitting technology (distance knitting fabrication technology and their comparison in warp and weft knitting technology). New Trends of Knitted Textiles and Structures. Innovations in the field of technical knitted products.
5. Technical applications of nonwovens (hygienic and medical textiles, textiles for the automotive industry). Nanofibrous materials (applications, production technology).
6. Coloring theory. Color Stability - Principles and Methods of Evaluation. Fiber properties after pre-treatment. Dyeing of cellulose, animal and synthetic fibers. Interactions between fibers and dyes.
7. Textile finishing (easy-care, low flammability, water-repellent) - refining, testing methods. Special treatment methods using UV, laser, plasma.
8. Technology of garment production using automation (technical preparation of clothing production, editing, CAD/CAM, cutting, sewing machines, automation).
9. Application of modern methods of construction and evaluation of clothing products (comfort, KES system, editing, modeling using computer technology)
10. Application of structures and technologies for technical and medical textiles.

Laboratory workshops:

- The exercises are based on the lecture as presentation of process in technological laboratories FT TUL.
- Within the exercises the students obtain assignments on specific subject.

Credit and Exam Evaluation

Exam: Oral - 80% & Assignment - 20%

Credit: Active participation in lectures and practicals

Design of textile structures

- Textile structures have unique properties and are widely used as **composites and technical materials for building construction, agriculture, geotechnology, automotive, medical..etc.** There are new interdisciplinary specialization like wearable electronics and wearable computing.
- Textile production is based on the empirical experiences, practical knowledge (trial and error method)
- New objective technique are necessary for using of new materials, technologies, application field

- **Prediction of virtual textile properties**
- **Technology optimization based on product properties**
- **Selection of optimal raw material**
- **Prediction of textile quality – clothing comfort (hand, appearance)**

- *In developed countries annual consumption of textiles is around* ***25-30 kg per person.***
- *Annual turnover is approximately* ***1620 trillion USD.***

Impulses to Innovations

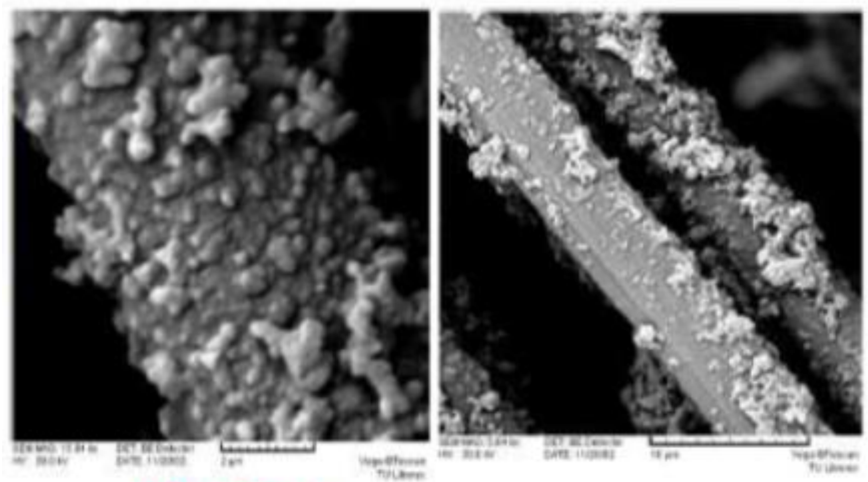
Development of new materials and technological principles.

Simulation of the nature (biomimetics).

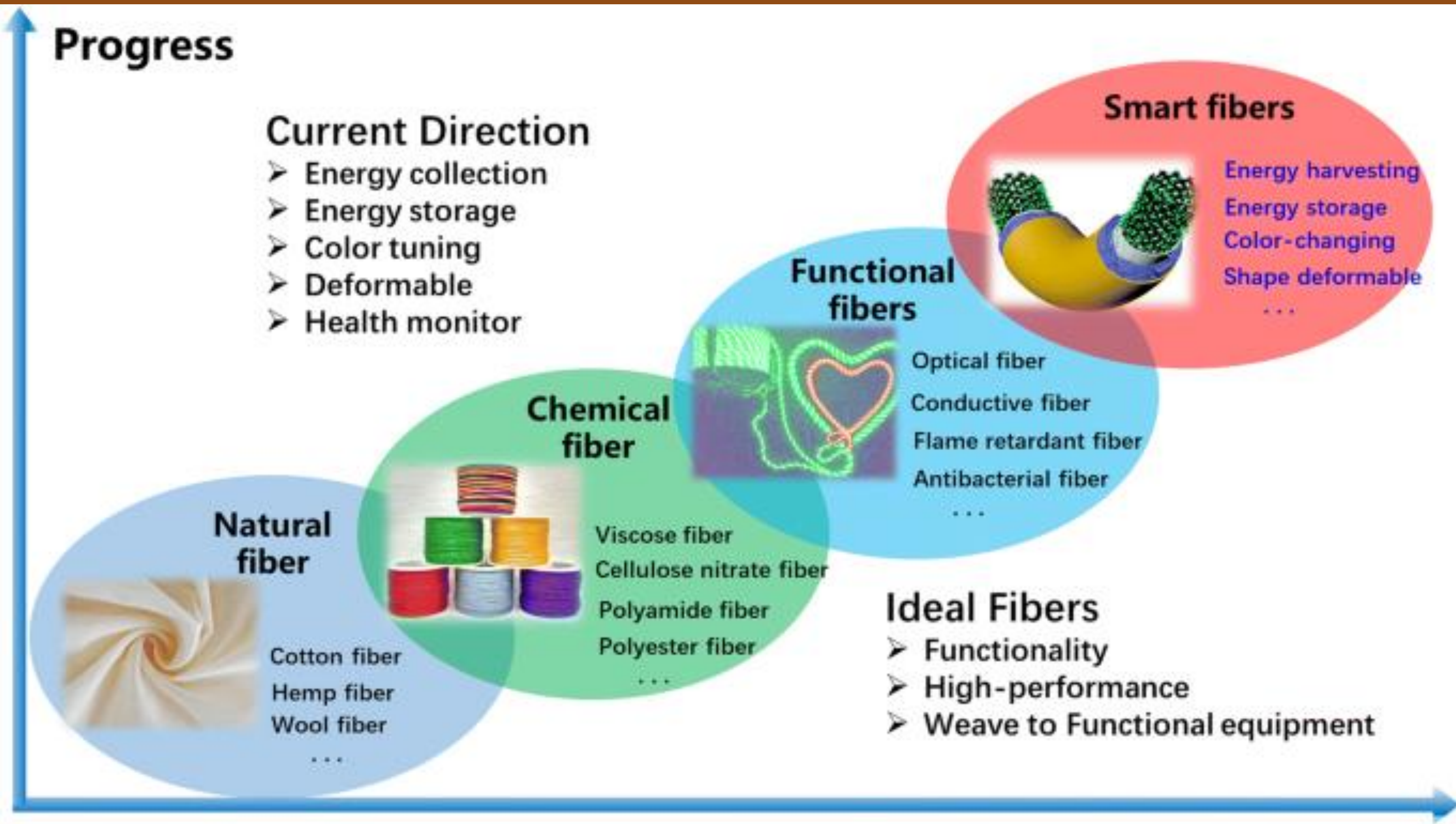
Progress in new technologies of fabric creation.

Transfer of materials and technologies from another branches.

The common doubt is that development is based on the new materials, new patents and new technologies, which is very expensive and time consuming



Surface Electro-polymerization


Progress
Current Direction
➢ Energy collection
➢ Energy storage
➢ Color tuning
➢ Deformable
➢ Health monitor
Smart fibers
Energy harvesting
Energy storage
Color-changing
Shape deformable
...
Functional fibers
Optical fiber
Conductive fiber
Flame retardant fiber
Antibacterial fiber
...
Chemical fiber
Viscose fiber
Cellulose nitrate fiber
Polyamide fiber
Polyester fiber
...
Natural fiber
Cotton fiber
Hemp fiber
Wool fiber
...
Ideal Fibers
➢ Functionality
➢ High-performance
➢ Weave to Functional equipment

Basic Features of Clothing Textiles

- Drapability (*adaptation to body changes-formability*)
- Low initial stiffness (*good initial deformability*)
- High porosity (*wide pores ditribution from nano to micro*)
- Partially random structure
- Surface roughness (*huge surface area – 10^2-10^4 m^2/g*)
- Planar unevenness (*periodic*, *random*)
- Hand
- Washability
- Abrasion resistance
- Slow aging during use (*influence of moisture, heat, UV, temperature, friction*)

Negative changes to these features can cause:

- Non acceptance of clothing
- Limitation of long term use
- Loss of comfort
- Unpleasant aesthetics
- Skin irritation/ sores

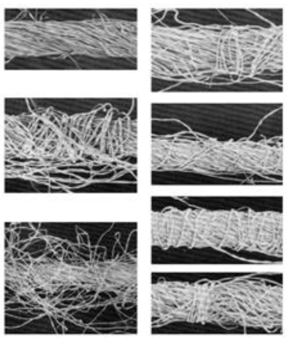
Majority of these features are influenced by using of special coatings, membranes, high performance fibers, resins etc. necessary for achievement of protections and smartness.

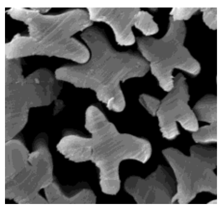
Hierarchy of textile structures

Fiber → Yarn → Fabric

Fiber structure ⇒ properties

Spinning Technology





Yarn structure ⇒ properties

Monofilament, Multifilament

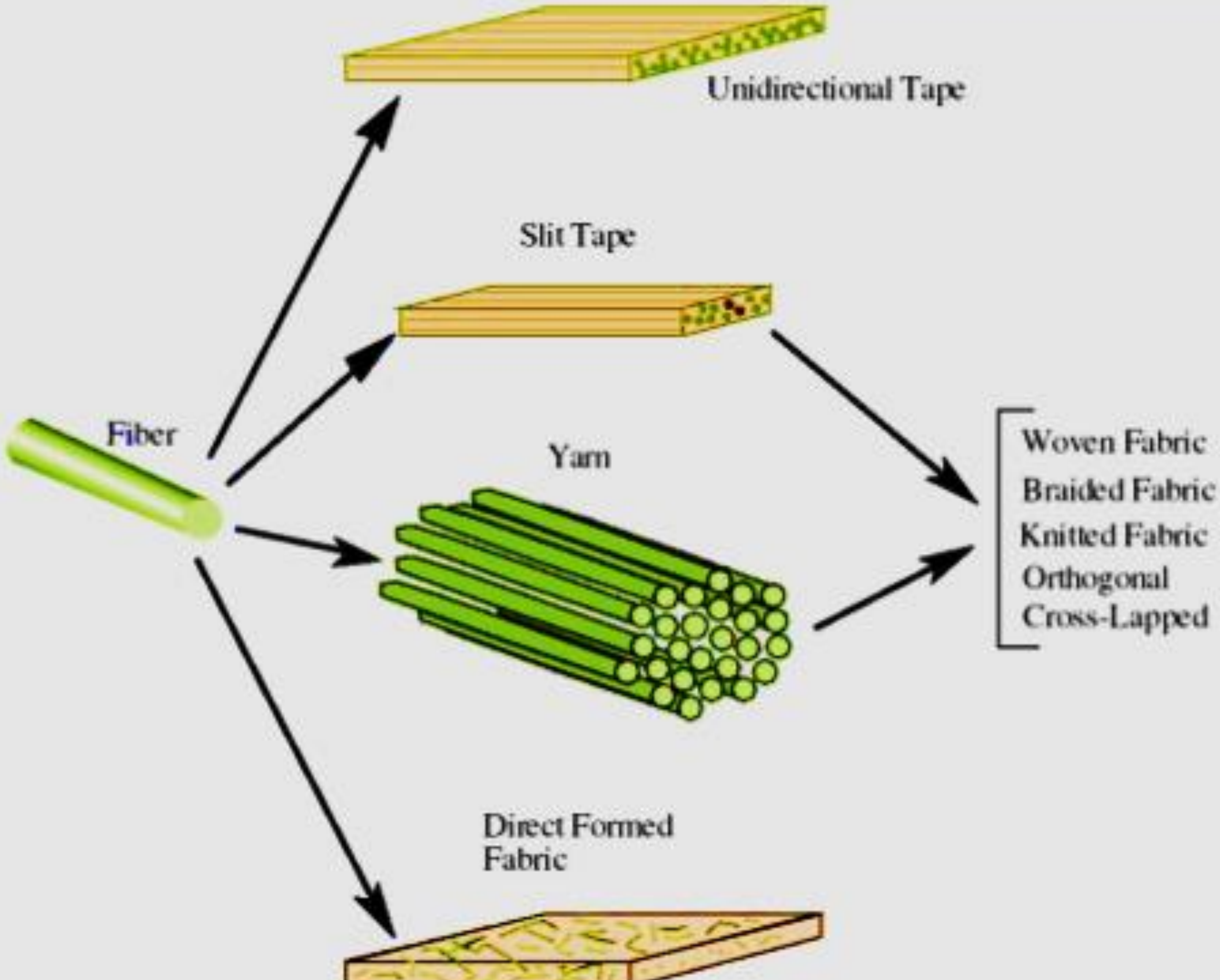
Weaving, Knitting, Nonwovens

Fabric structure ⇒ properties

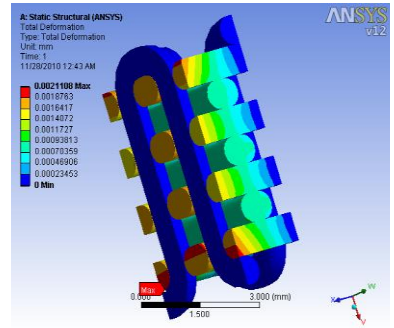
Textile Finishing, creation of product

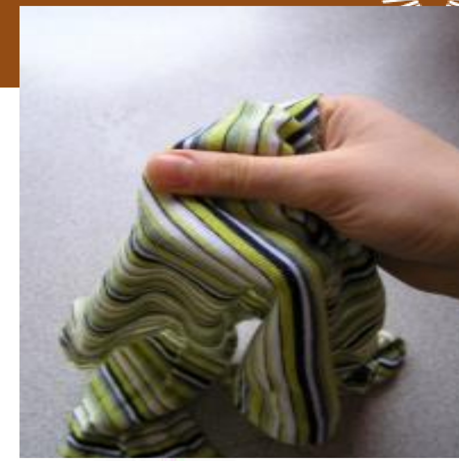
Product properties

Hierarchy of Textile Materials



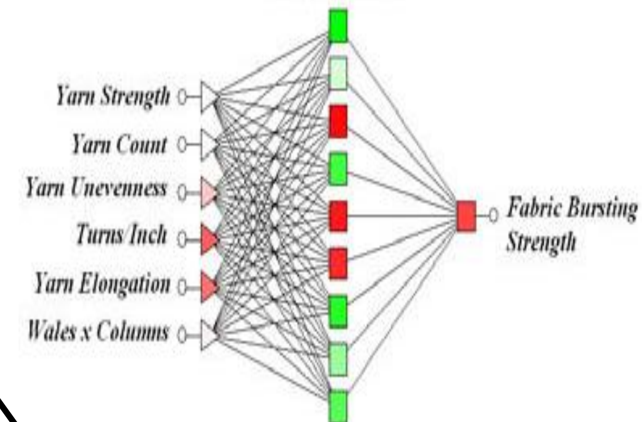
Models and textile





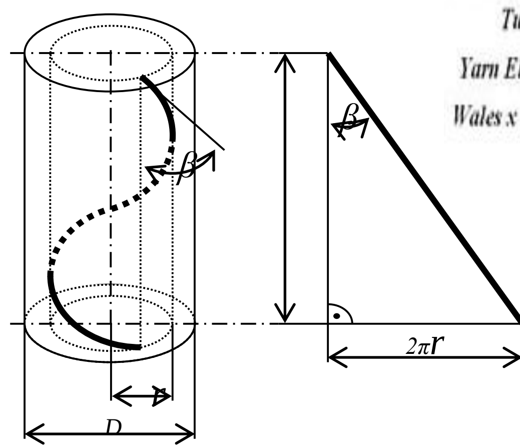
Objective aspect – rules connected with product formation (known and unknown rules of natural and technical sciences)

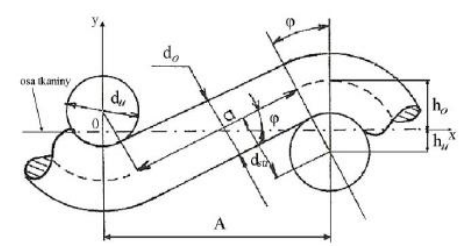
Subjective aspect – rules connected with human sensations (appearance, hand)



Models:

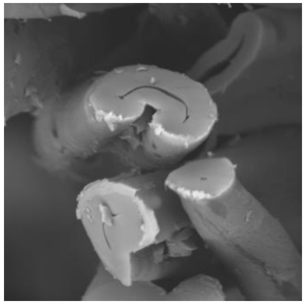
- Physical
- Mechanistic
- Simulation based
- Stochastic: empirical – statistical

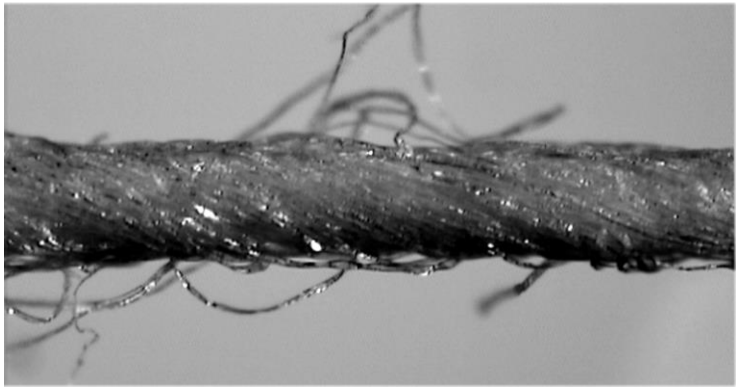


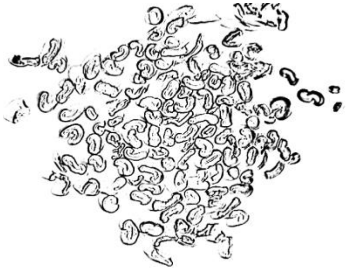


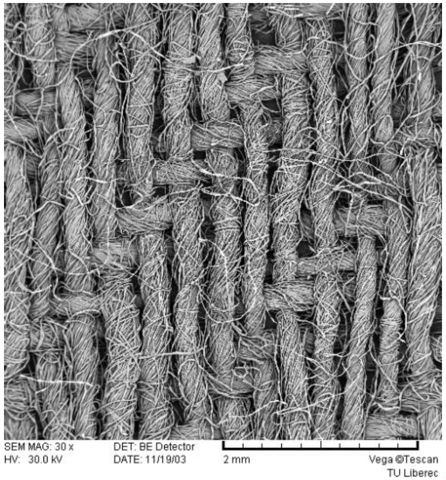
Major challenges

- Standard construction materials (metals, plastics, wood, etc.) have defined dimensions – diameter, length.
- Textile materials are very uneven – it is necessary to use statistical description.
- Some geometrical characteristics of textile materials are not precisely specified – yarn diameter.

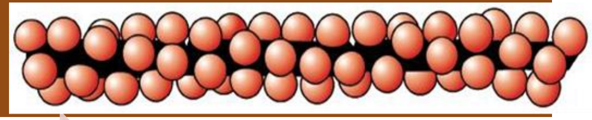






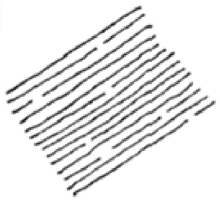


Polymers structural peculiarities

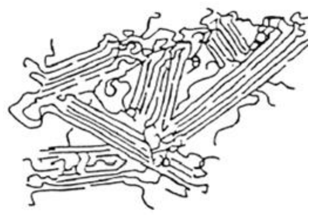


Polymers have some typical features

- **High viscosity** increasing with decreasing temperature. Only regular linear structures without side groups are able to crystallize. Some polymers are in amorphous state after solidification.
- Polymer structure are with **amorphous regions, crystallites and semicrystallinity.**
- Possibility to prepare polymeric mono crystals (from solution).
- Majority of fibers are with semi-crystalline polymers having crystallinity degree X

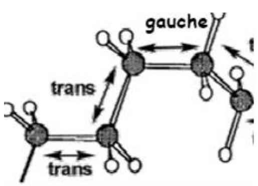


Crystalline

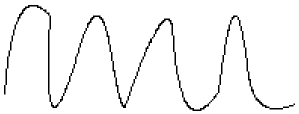


Semi crystalline

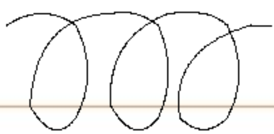
Amorphous



TTT



TGT



GGG

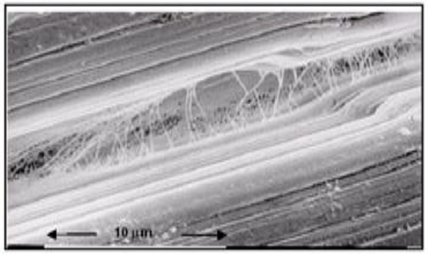
Planar zig zag (trans or trans with gauche defects), stacked (gauche or TGT) and spatial helix (gauche GGG)

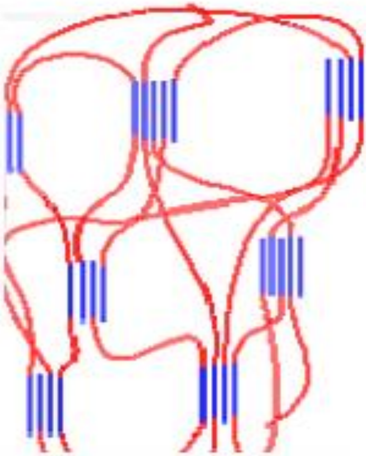
Fibrous structure is typical both for natural and synthetic fibers.

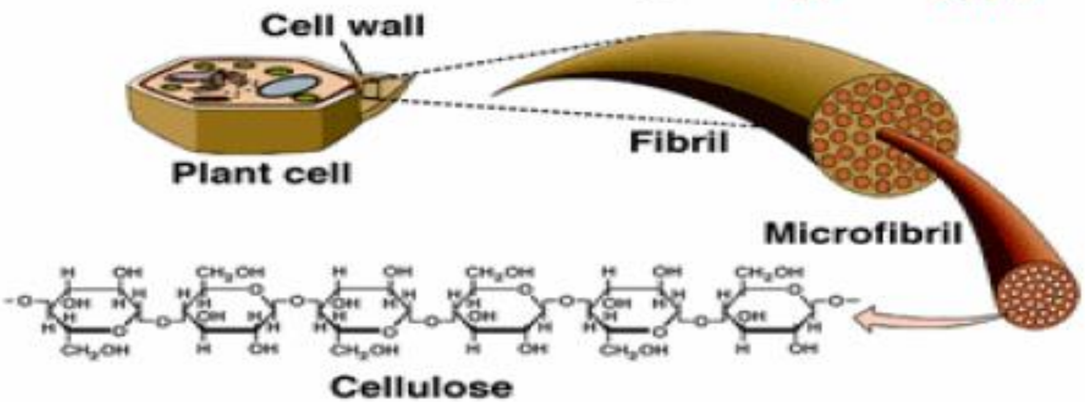
Fibrous structure

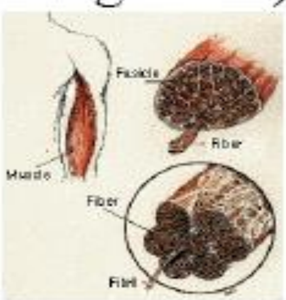
- **<u>This structure</u>** is originated due to irreversible orientation of macromolecular chains along fiber axis and partial crystallization (i.e. 3D arrangement).

On the individual structural levels have basic elements elongated spindle like form.

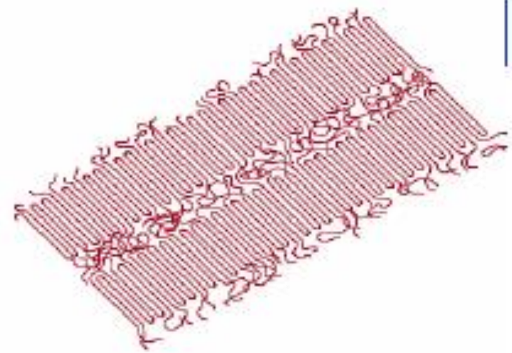




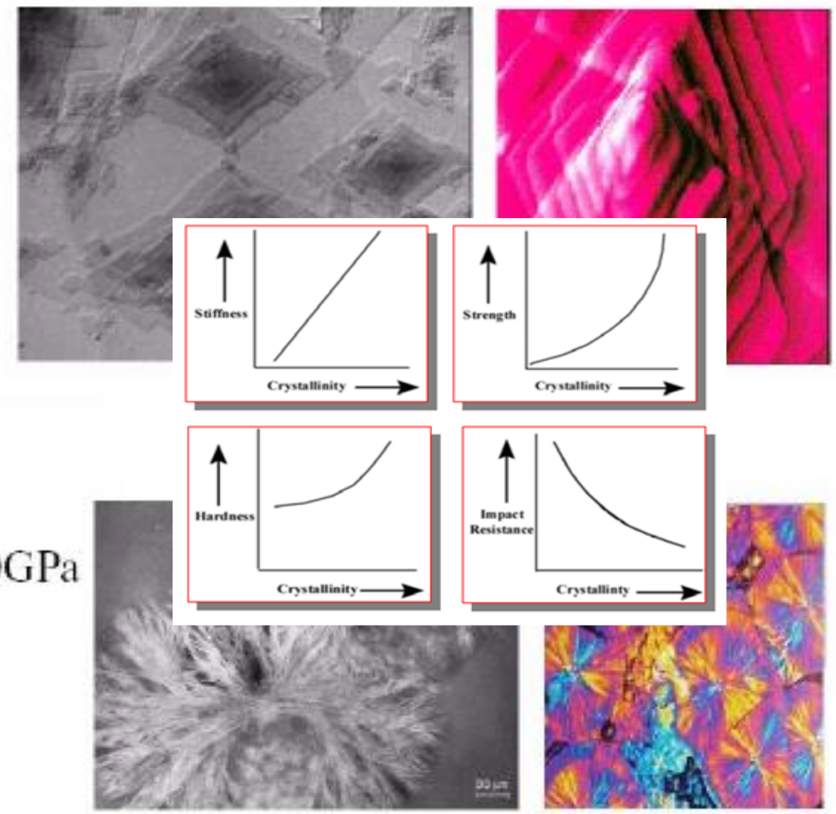




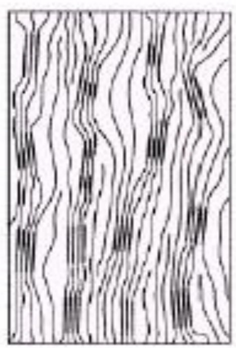
Super molecular structure



- Dependent on the chains orientation mainly
- Deformation strengthening



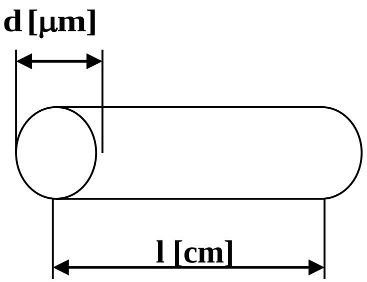
E~1GPa



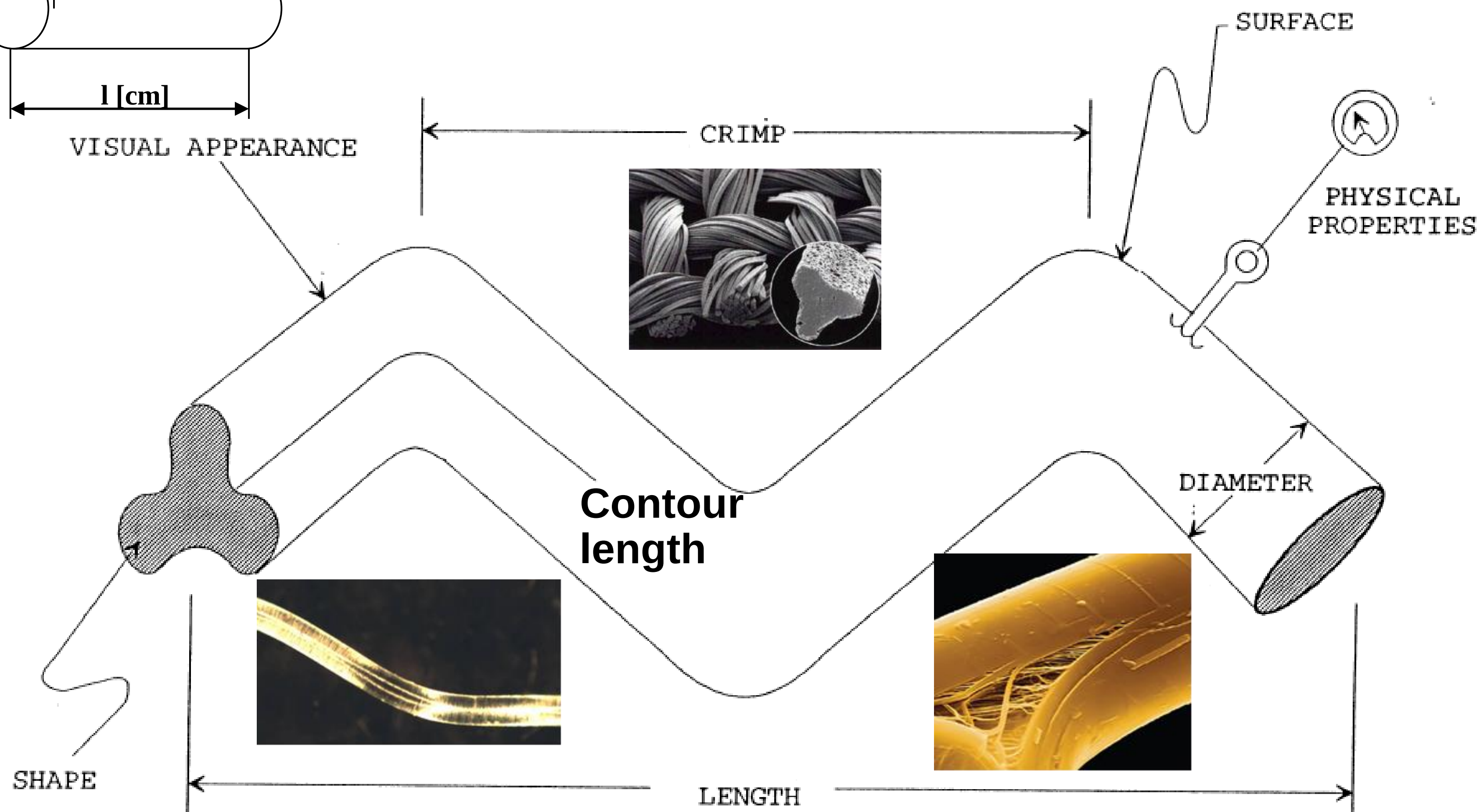
E~100GPa

The fiber menu

$l/d > 10^3$



Distance between polymeric chain ends in melt is about **15 nm**.
Length of fully extended polymeric chain is about **1 500 nm**



Drawing limits

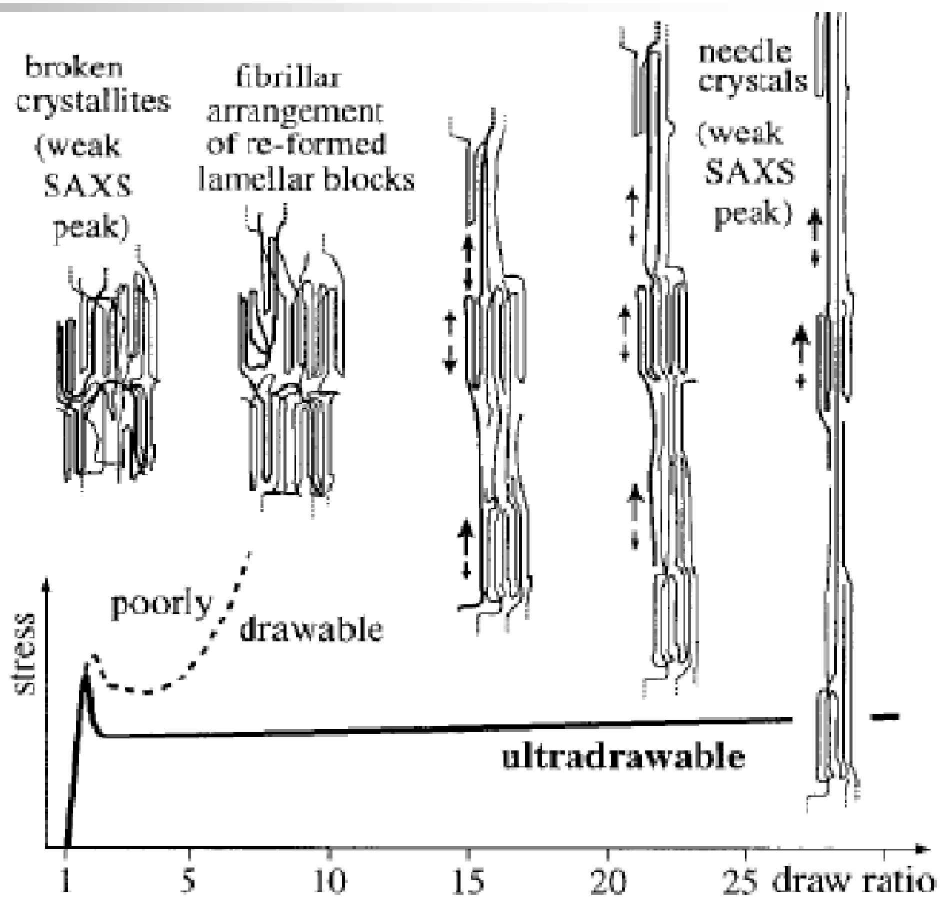
Super drawing

λ>30: PP,PE, POE,POM,PTFE

Ultra drawing

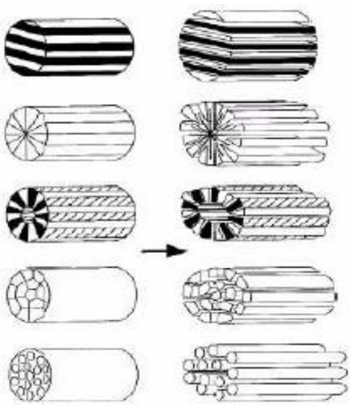
- Heating of amorphous, low oriented linear polymers above T_g
- Drawing to very small diameters with gradual increasing of orientation. Level of stressing is very low.
- Crystallinity, entanglements or orientation are constrains of this drawing.
- This process can be stopped and transform to the normal drawing under T_g

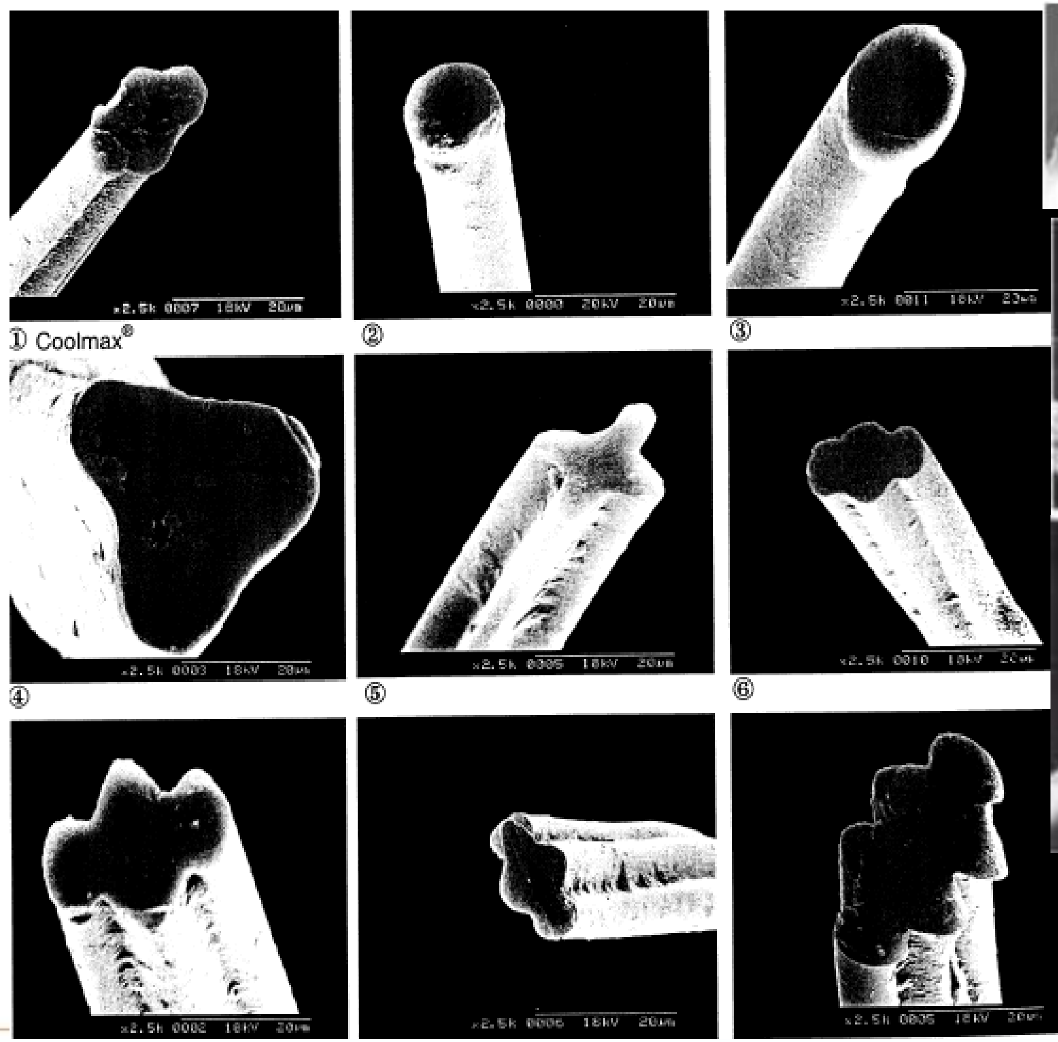
Pace: US Patent 2 578 899 1949

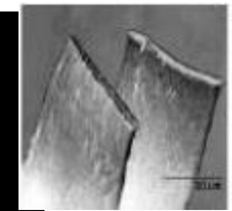


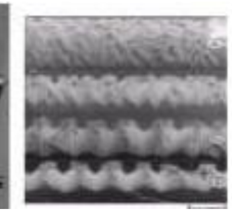
Stretch the random coil to fully extended state needs draw ratio about 100-1000

Engineered fiber shapes



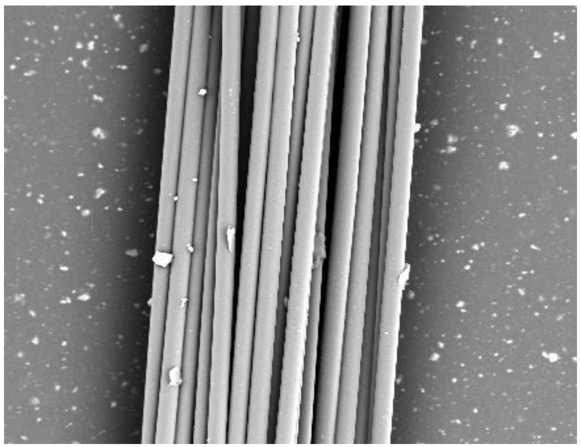


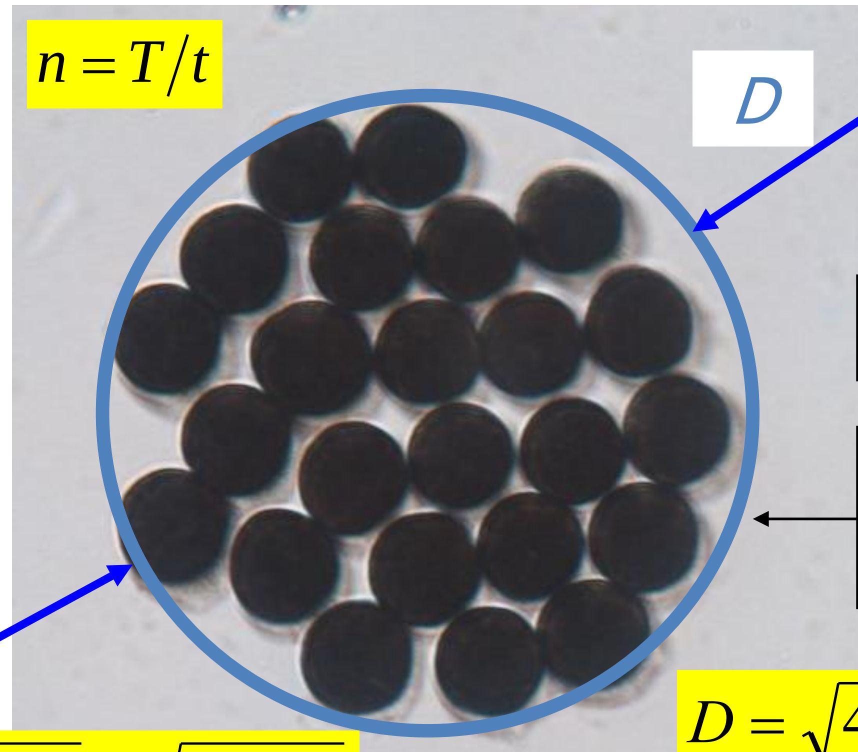




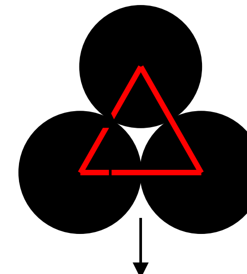
Multifilaments

T – bundle fineness, *M* – bundle mass, *L* – bundle length, *V* – fiber volume in bundle, *S* – cross section areas of fibers in bundle, S_C – total bundle cross section area, ρ – fiber density, D_S – minimum possible bundle diamater, μ – bundle packing density, *n* – number of filaments in bundle, *t* – filaments fineness





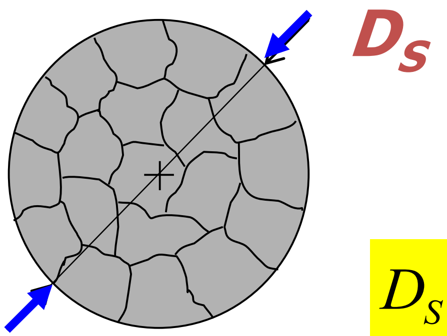
$n = T/t$



μ=0,907

Approx. μ=0,7

$D = \sqrt{4T/\pi\mu\rho}$



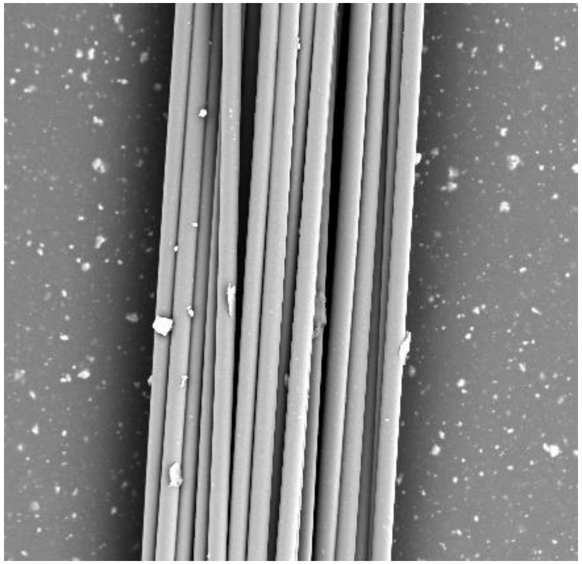
$D_S = \sqrt{4S/\pi} = \sqrt{4T/\pi\rho}$

$T = M / L = \rho V / L = S\rho = \pi D_S{}^2 \rho / 4$

$\mu = V/V_c \approx S/Sc = D_S^2 / D^2$

BUNDLE PACKING DENSITY

PET flat bundle

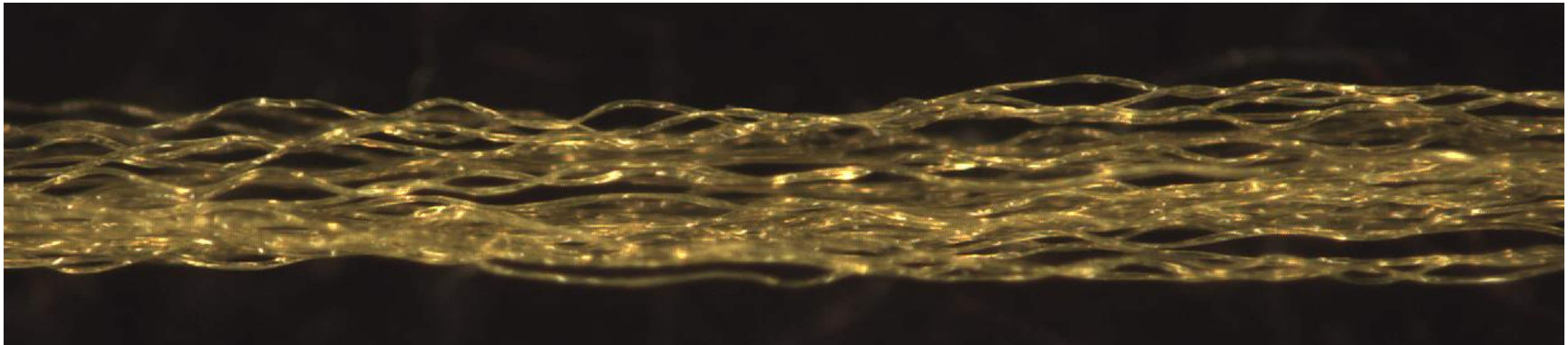


$$\mu = \frac{\rho_b}{\rho_f} = \frac{\text{Bundle density}}{\text{Fiber density}}$$

PET 1360*0,7=952 kg/m³

PP 940*0,7=658 kg/m³

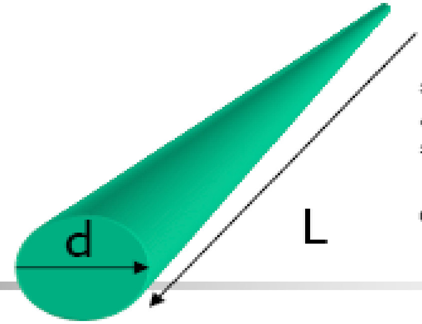
PET air textured bundle

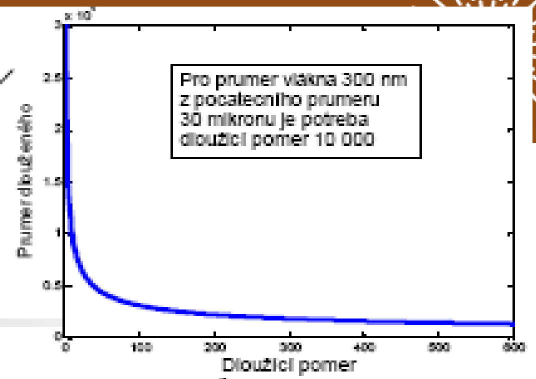


Less packing μ – density less than 952kg/m³

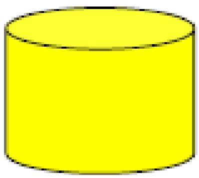
Micro/nano fibers

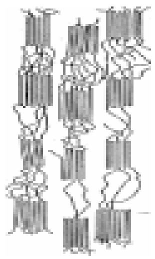
L/d > 100





- **Microfibers** (under 1 dtex)





Strongly oriented fibrous structure

P(1000 nm) = 0.094%

d around 1 μm

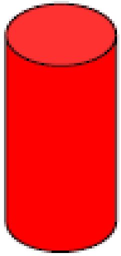
Constant volume:

$$\left(\frac{D}{d}\right)^2 = \lambda \ , \ d = \frac{D}{\sqrt{\lambda}}$$

D undrawn fiber

λ draw ratio

- **Nano fibers** (excluding CNT)



Slightly oriented irregular net

no dyed

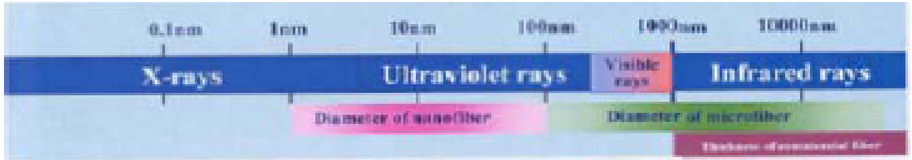
P(10 nm) = 9.42%

1 nm < d < 100 nm (400 nm)

Chains portion on surface

$$P\,[\%] = \frac{100\pi\, d_r}{d}$$

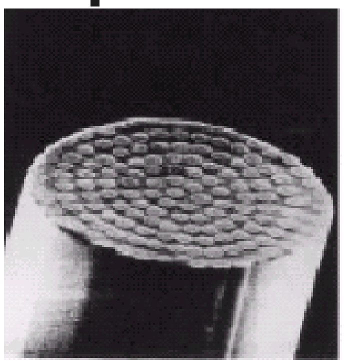
d_r chain diameter 0.3 nm

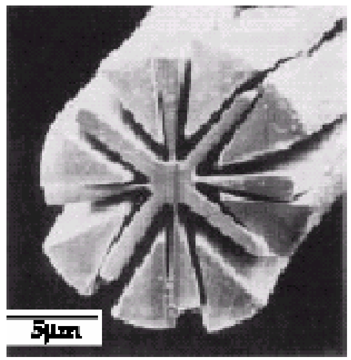


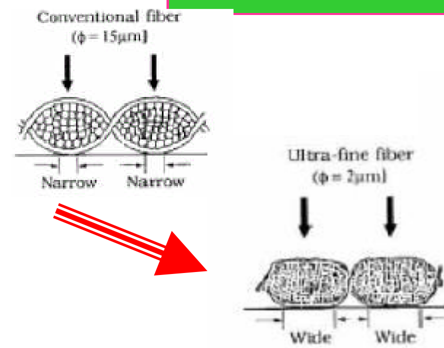
Micro fibers

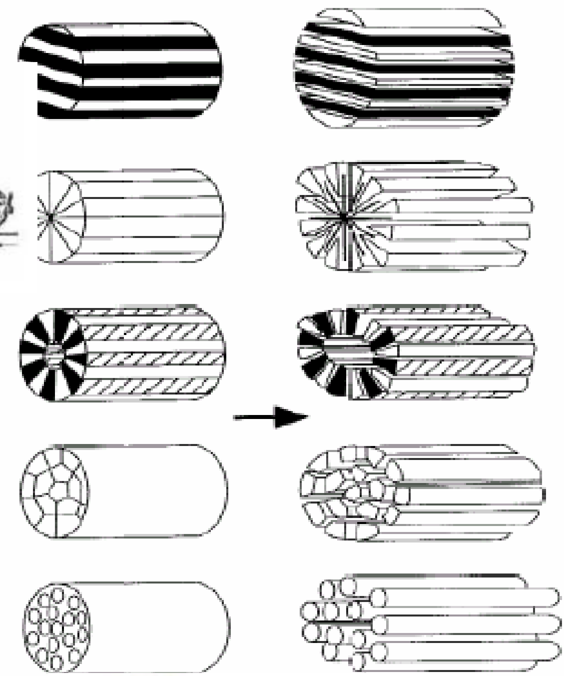
$$c_2 = c_1 * \sqrt{\frac{Tex_1}{Tex_2}}$$

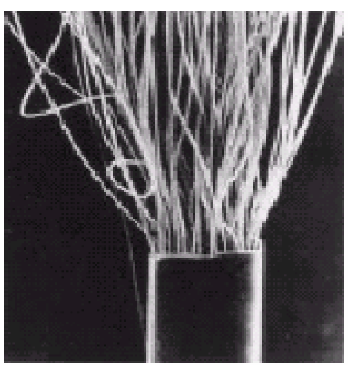
Replacing standard PES 3,5 dtex by fineness 0,55 dtex requires to multiply the concentration of dye by 2,52.











Micro fiber (below 1 μm):

Special hand

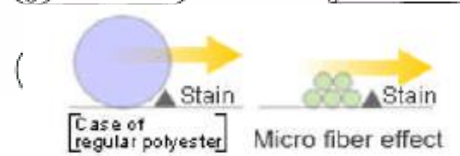
Denser fabric

Higher sorption capacity

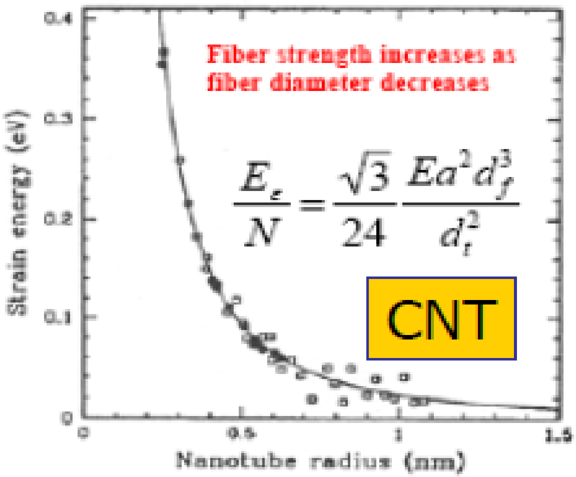
Capillary transport

Pale shade

Higher rate of dyeing



Nano fibers advantages



- Extremely high relative surface area
- Quantum effects (tunneling)
- Higher surface energy and reactivity
- Higher electric and thermal conductivity
- Weaker cohesion
- Higher bio activity
- Translucency

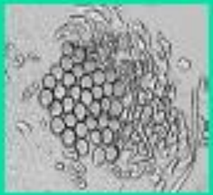
$$F = \sigma * S = \sigma * T / \rho$$

σ = 1 GPa
$F(r=10^2 nm)$=0.0314mN
$F(r=10^3 nm)$= 3.14 mN

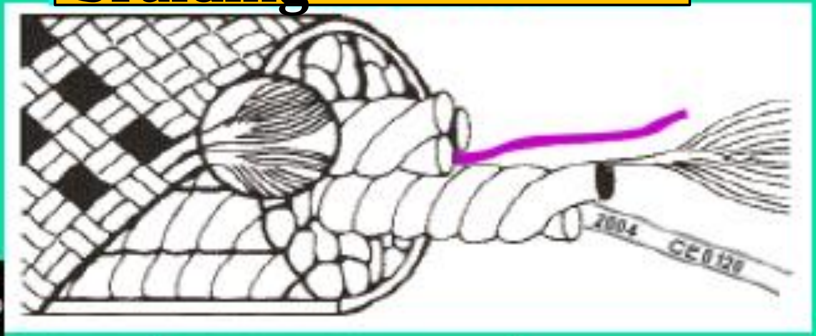
Nano fibers spun electrostatically have usually worse mechanical properties in comparison with classical fibers. For random arranged assembly of nano fibers is tensile strengrh about 40 MPa

Combined yarns

Core wrapped

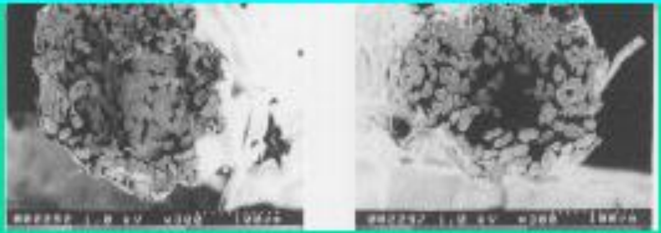


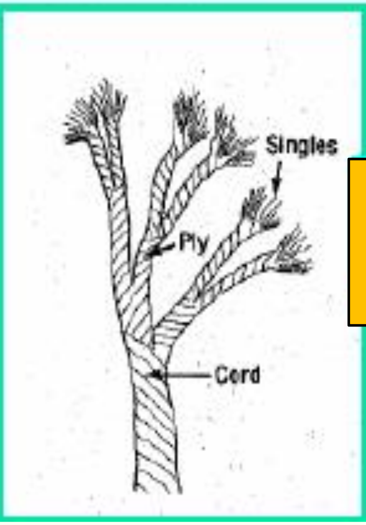
Ropes- wrapping, braiding



Ply yarn

Holow yarn (PVA **dissolved in hot water)**





Multiple ply yarn

FACU

Technical Textiles Developments

Fiber chemistry

- Fibers with an outstanding profile of properties (Teflon, Basofil, Kynol, modified PAN fibers, Spandex, conductive fibers etc.,)
- Fibers with high breaking strengths (Dynema, Kevlar)
- High modulus fibers (C-fibers, ceramic)
- Fibers with an outstanding thermal stability (PBI, P84)

Textile chemistry

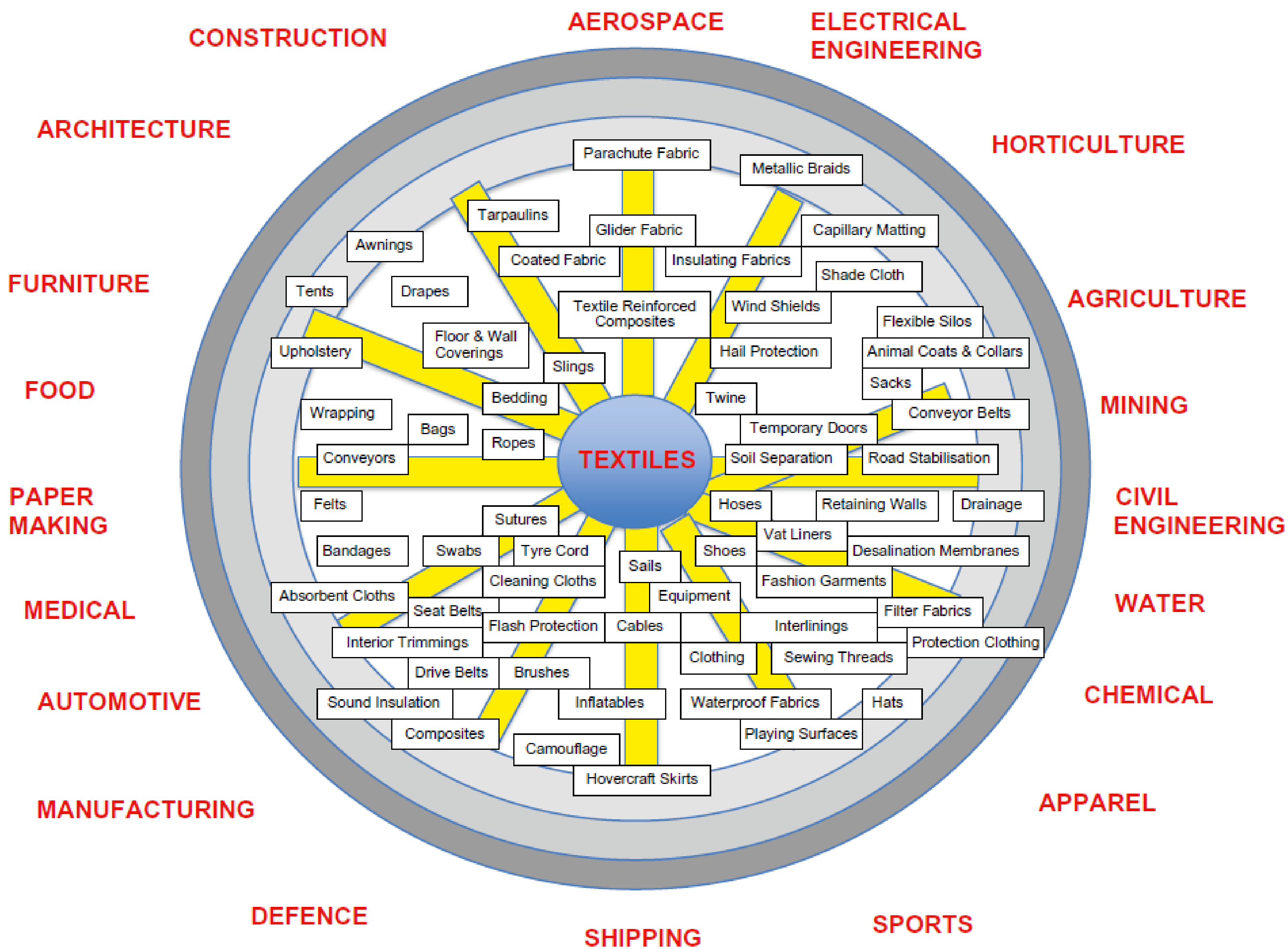
- Special TTP and special procedures of textile treatments (capsulation)
- Application of plasma, laser, ultrasound, radiation

"Active" materials

- Shape-memory materials (SMA), piezomaterials, piezopolymers, electro active polymers, phase change materials (PCM)
- Nanotechnology (analysis of manufacturing process and structures of materials on their molecular level)

Classification of Technical Textiles

Medical textiles	• hygiene and medical (Healthcare Textiles)
Agro Tech	• agriculture, aquaculture, horticulture and forestry
Build Tech	• building and construction
Cloth Tech	• technical components of footwear and clothing
Geo Tech	• geotextiles and civil engineering
HomeTech	• technical components of furniture, household textiles
Indu Tech	• filtration, conveying, cleaning and other industrial uses
MobilTech	• automobiles, shipping, railways and aerospace
Oeko Tech	• environmental protection
Pack Tech	• packaging components
Pro Tech	• personal and property protection
Sport Tech	• sport and leisure



Diversity of technical textiles

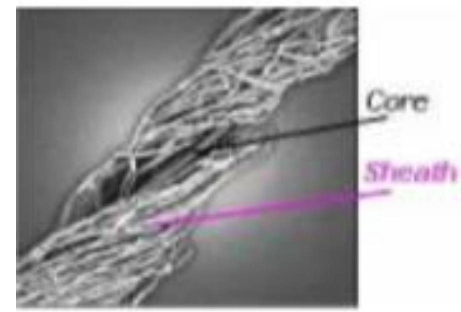
Classification of textile structures

1D textile

- Spinning of staple yarns; Ring-yarns, Break-spinning yarns, DREF system, Splicing

Planar or conventional structures (2D)

- - Weaving; all types of weaving machines
- - Knitting ; Course and wales
- - Netting
- - Nonwovens; fibers-web, polymer-web



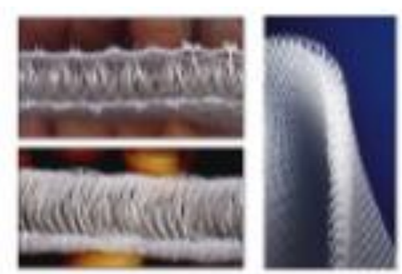
Three-dimensional structures (3D)

- - Weaving, Knitting, Nonwoven technology, Specialties; winding, splicing, braiding (ropes, sealing)

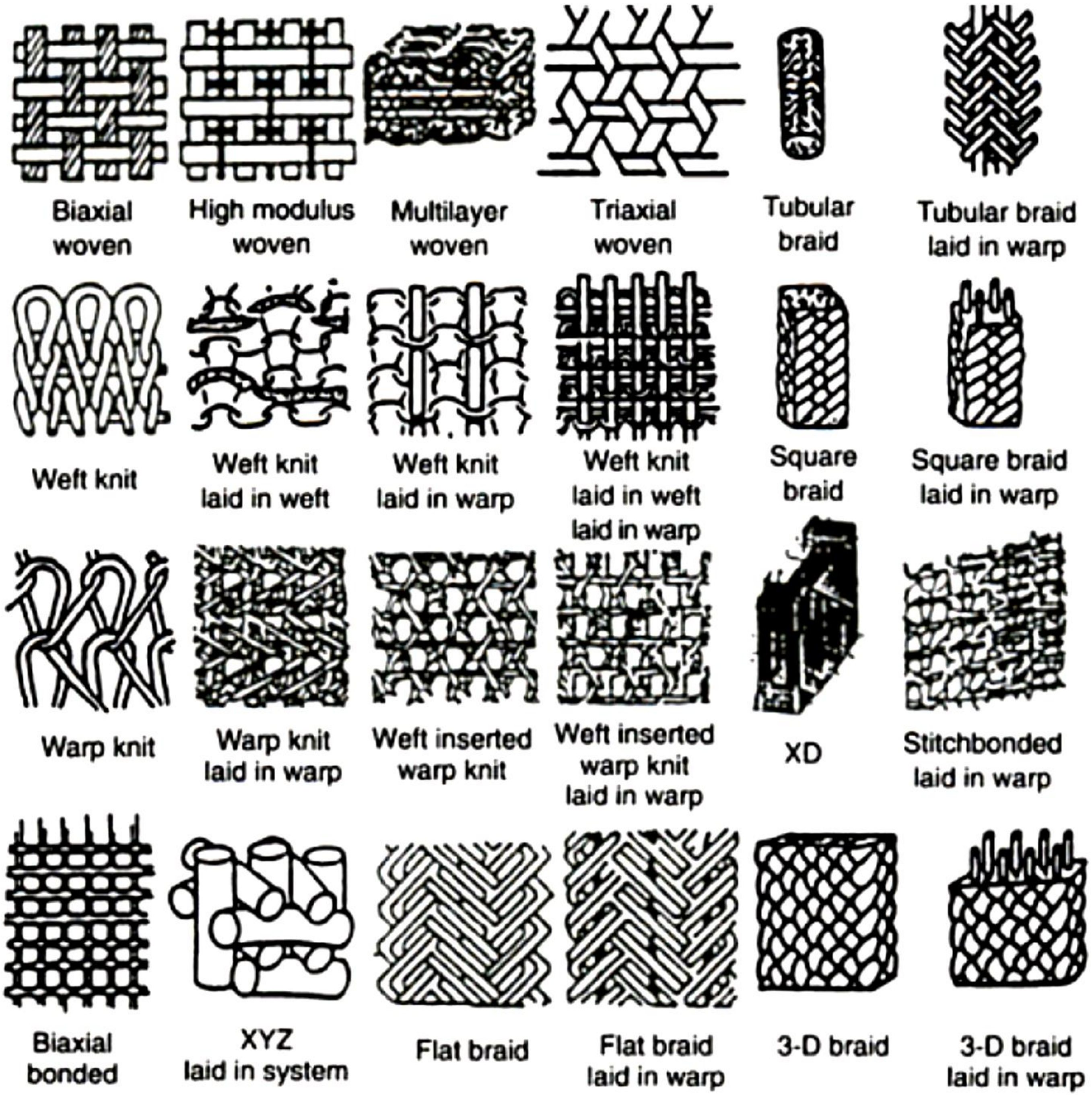
Directionally oriented structures (DOS)

Hybrid structures

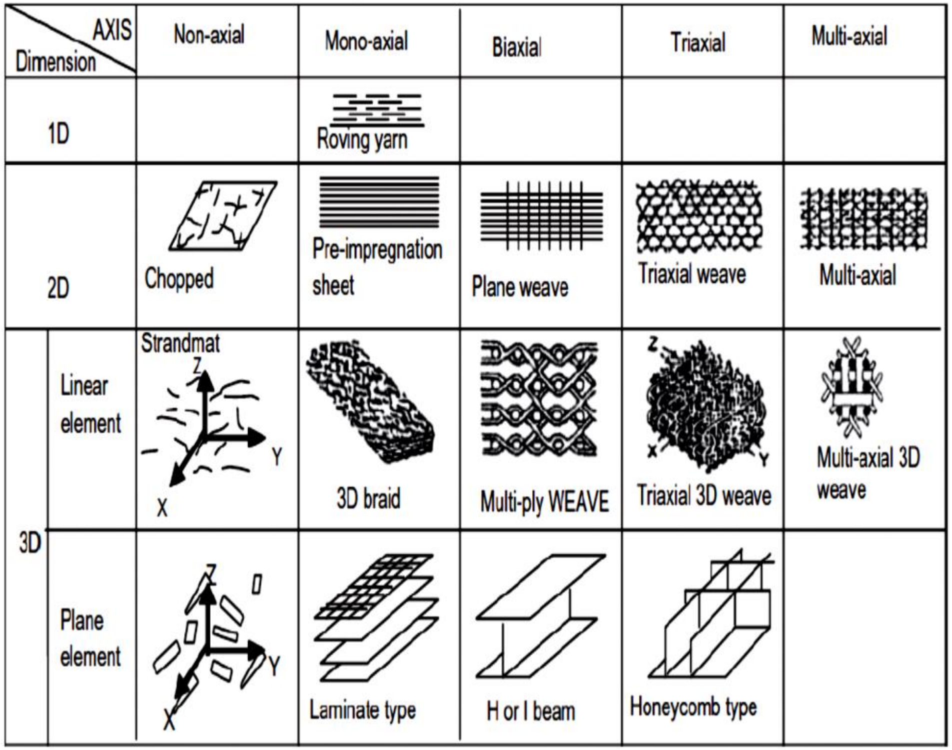
- Hybrid structures are mainly produced by sewing and warp-knitting technologies.



Textile Structures



Classification



Dimension \ AXIS		Non-axial	Mono-axial	Biaxial	Triaxial	Multi-axial
1D			Roving yarn			
2D		Chopped	Pre-impregnation sheet	Plane weave	Triaxial weave	Multi-axial
3D	Linear element	Strandmat	3D braid	Multi-ply WEAVE	Triaxial 3D weave	Multi-axial 3D weave
	Plane element		Laminate type	H or I beam	Honeycomb type	

Dimensions \ Orientation		randomly	mono axial	bi axial	tri axial	multi axial
1D		fibre	tow, yarn			
2D		non woven	uni directional	Fabric: Woven, knitting, bi axial braiding	tri axial braiding: flat, over braid	NCF stitch bonded, NCF woven
2D+		thick non woven		woven interlock	multi axial multi-layer interlock	
3D	surface	shaped non woven		tetrahedron ply stamping	over-braiding, preforming, stamping of braid or/and multi axial	
	volume			assemblies by tufting, stitching, nailing/pinning	cross of shaped	BWS, cross of stiffeners (integral 3D)

2D planar structures

Most common woven structures; **plain weave, twill weave and satin weave.**

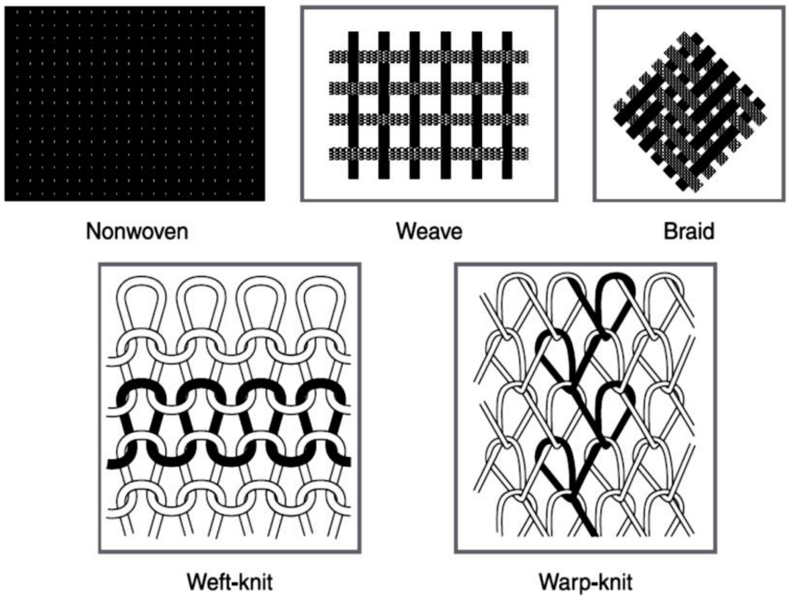
The mechanical properties for composites depend on;

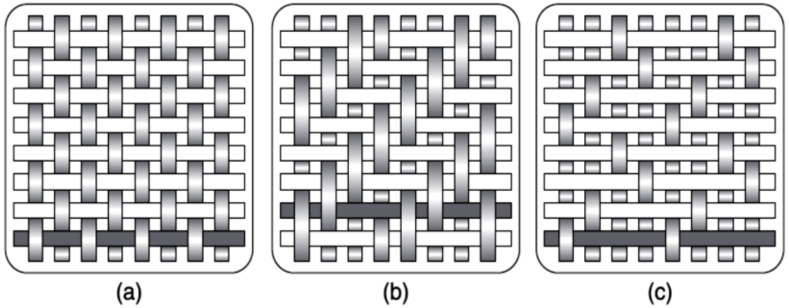
- **raw materials**
- **warp and weft linear mass**
- **yarn density**
- **Weave structure**

Disadvantages;

- **tendency to unravel at edges when cut,**
- **anisotropy,**
- **limited conformability,**
- **reduction on tensile efforts**
- **handling difficulty of open structures.**

Drawbacks can be overcome by using special fibrou structures, for example triaxial woven.

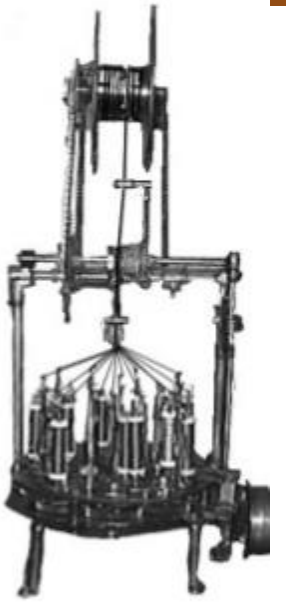


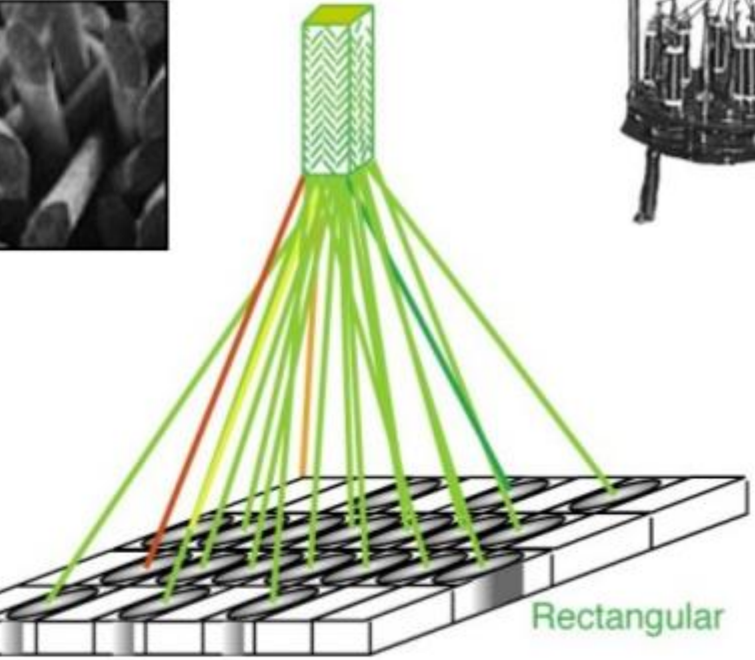


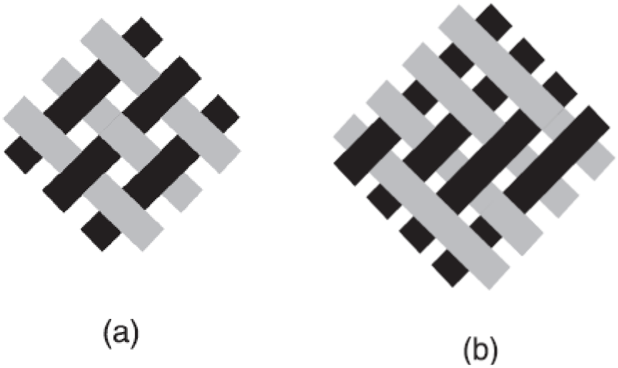
(a) Plain (b) Twill (c) Satin

Braided structures

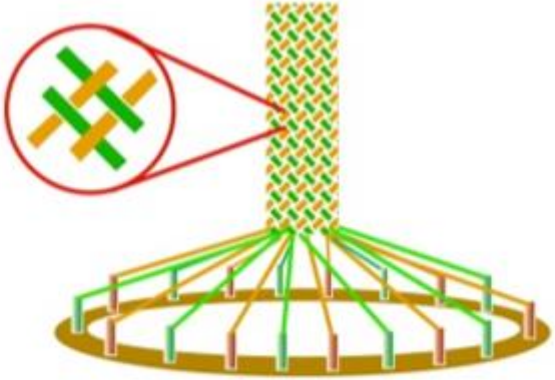
- Braids are formed by a "Maypole" pattern of yarn carrier motions.
- There are three main types of braided structures; ***diamond, regular and hercules***



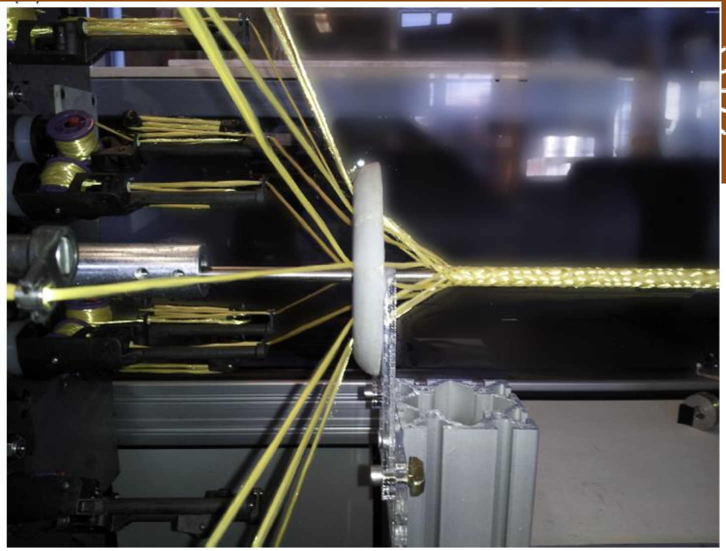


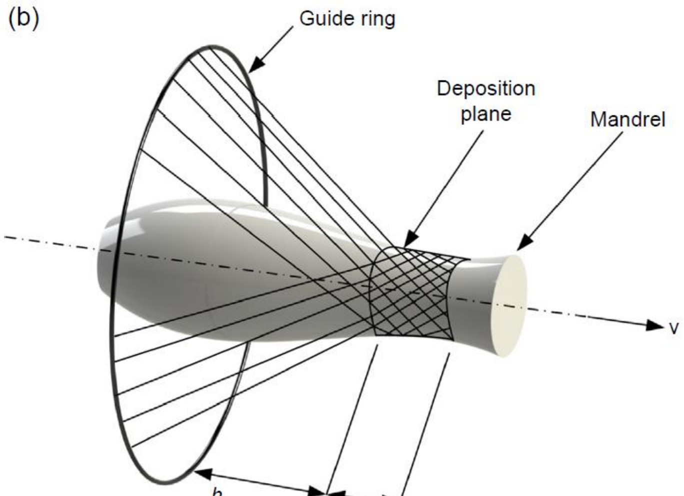


(a) Diamond (1x1)
(b) Regular (2x2)
(c) Hercules (3x3)



- Braid is a flexible product, manufactured in various shapes, using a mandrel which can shape the braid in several ways during the manufacturing stage.
- Their limitations are related to the equipment, presenting restricted width, diameter, thickness and shape selection.
- Braided structures present weak axial stability and compression in yarn direction, and have multidirectional conformability.
- 3D braids major limitations are productivity and fabric length.





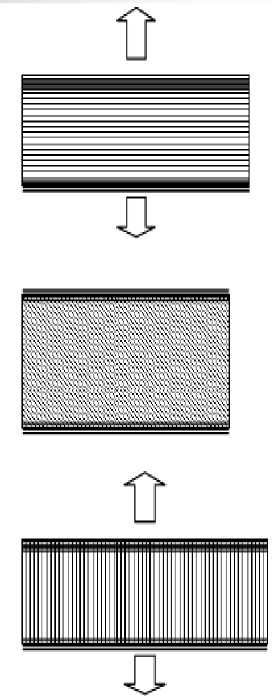
(a) Steeger maypole braider showing spools, horn gears; (b) schematic of 2-D maypole braiding with key variables and structures.

Nonwovens

- Nonwovens used in advanced composites are fibre mats, nonwovens stitch-bonded, adhesively bonded, and the xyz nonwovens (3D)
- Nonwovens production is divided into web formation and bonding (mechanically, thermally or chemically).
- The web formation are: hydrodynamic, aerodynamic, mechanical and spunlaid web formation.
- Primary alternatives - geotextiles, materials for building, thermal and sound insulating materials, hygienic and health care textiles, and the automotive industries.

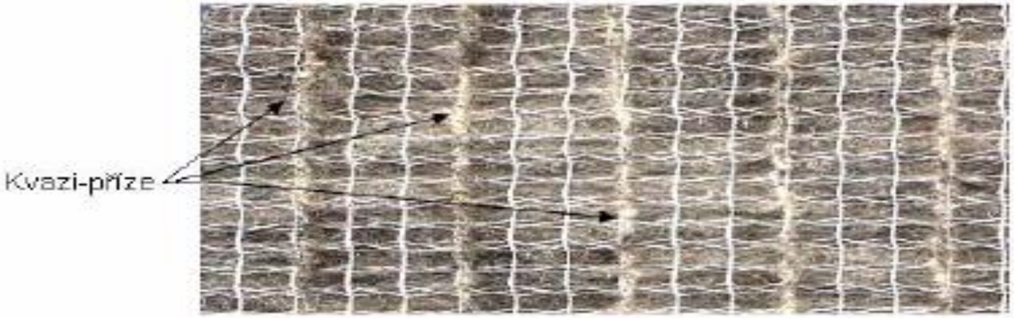
STRUCTURE FORMATION OF THICK NONWOVENS

- Horizontal stratification;
- Slanting stratification;
- Vertical stratification.

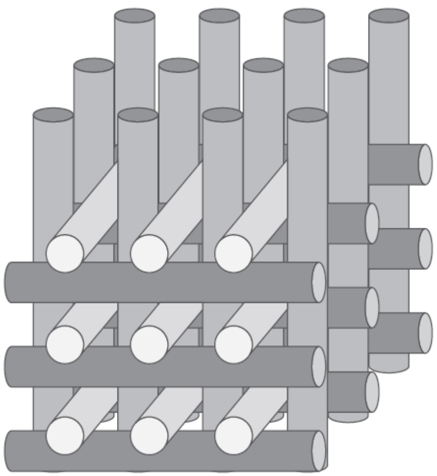


Stratification = layering

Characteristic appearance

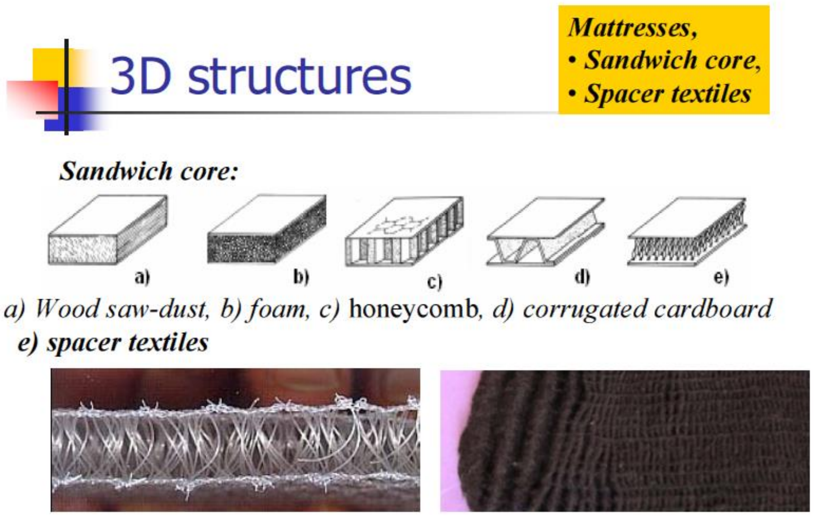


3D fibrous structure



- When compared to 2D fibrous structures, 3D structures provide high mechanical properties in x, y and z directions.

- Classification of these structures has to consider;
  - **macrogeometry (form and dimension);**
  - **the structure formation method (construction)**
  - **microgeometry of the resultant structure (that it includes the reinforcement directions);**
  - **the linearity of the reinforcement in each direction;**
  - **the continuity of the reinforcement;**
  - **the density of the fibres;**
  - **the size of the fibre beam in each direction**
  - **geometric characteristic of the fibre beams that is, linear or curvilinear,**
  - **The degree of bending, etc.**



Development of 3D textile products

Staple fibers

Knit (interlacing)
Multiknit (interlacing)
Struto (heat fixing)
Rotis (quasi-yarns)

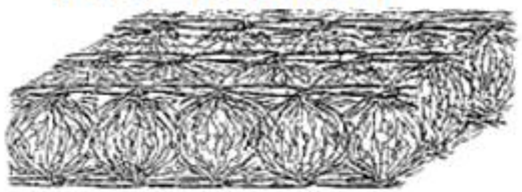
Filament yarns

Spacer knitted fabrics
Spacer woven fabrics

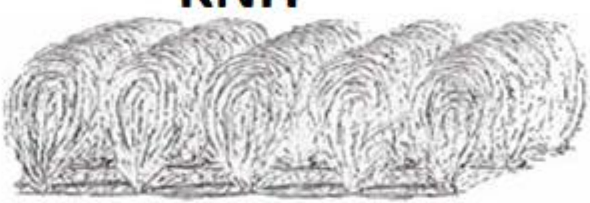
Nonwovens

needle punched type
Spun-laced type
Jet-laced type

MULTIKNIT



KNIT



Combined structures I

Input: one 2D web or sheet,
Output: one layer 3D textile

one layer 3D textile

Input: more 2D webs or sheets,
Output: multiple layer 3D textile

Two layer textiles

Directionally-oriented structures (DOS)

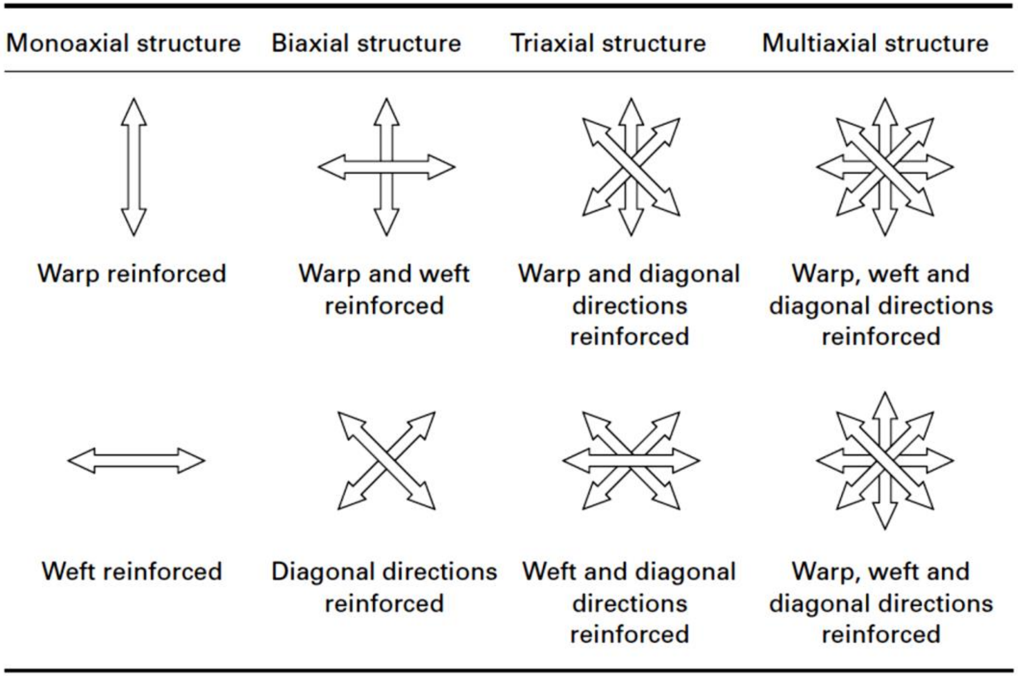
DOS are 2D in nature, due to the in-plane reinforcement provided by the in-laid yarns they are called as directionally oriented structures (DOS).

Warp-knitting technology is suitable to produce DOS allowing the introduction of reinforcing yarns in four different directions.

Warp-knitted multiaxial fabrics are being used in polymeric matrix reinforcements.

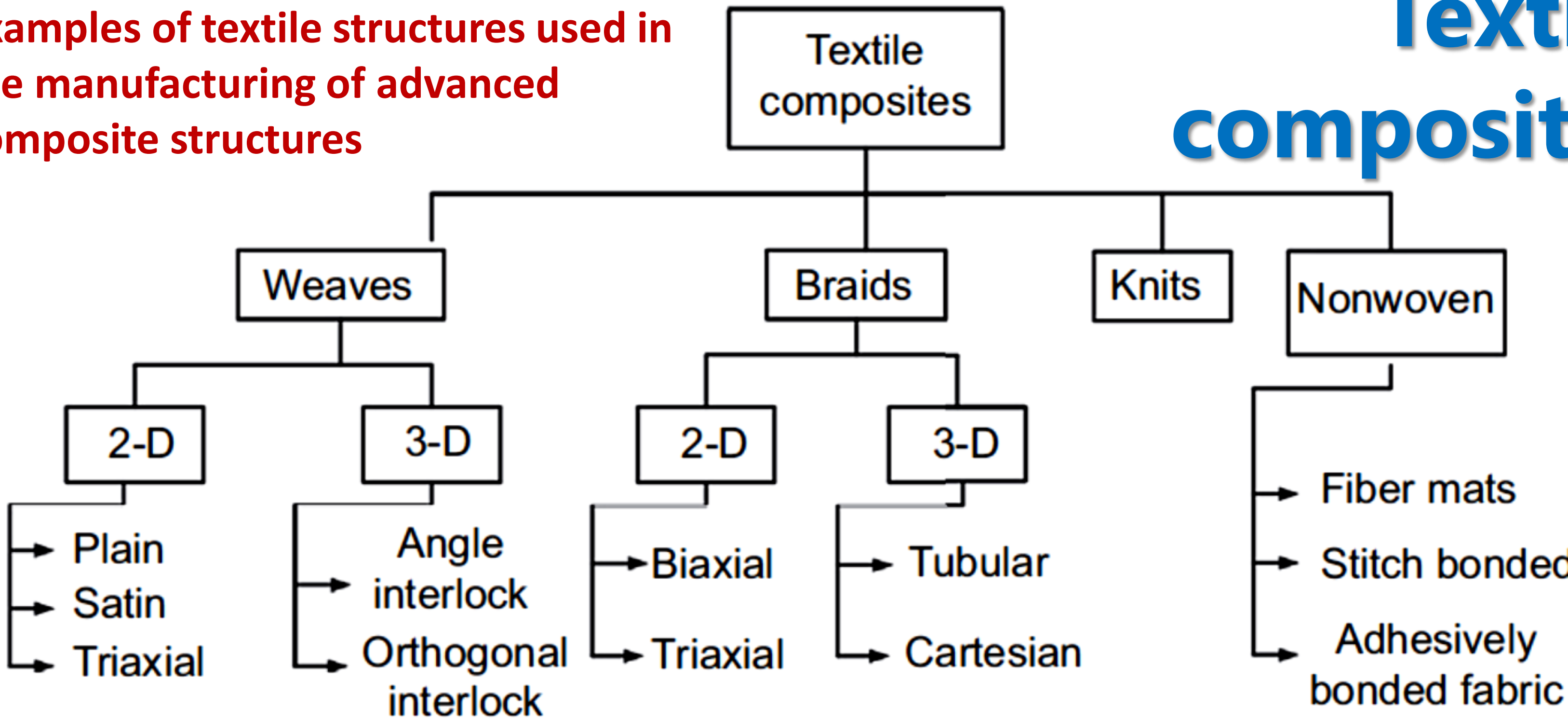
Biaxial structures are used in textile membranes for architecture purposes and in building construction in order to prevent small cracks.

Classification of DOS



Textile composites

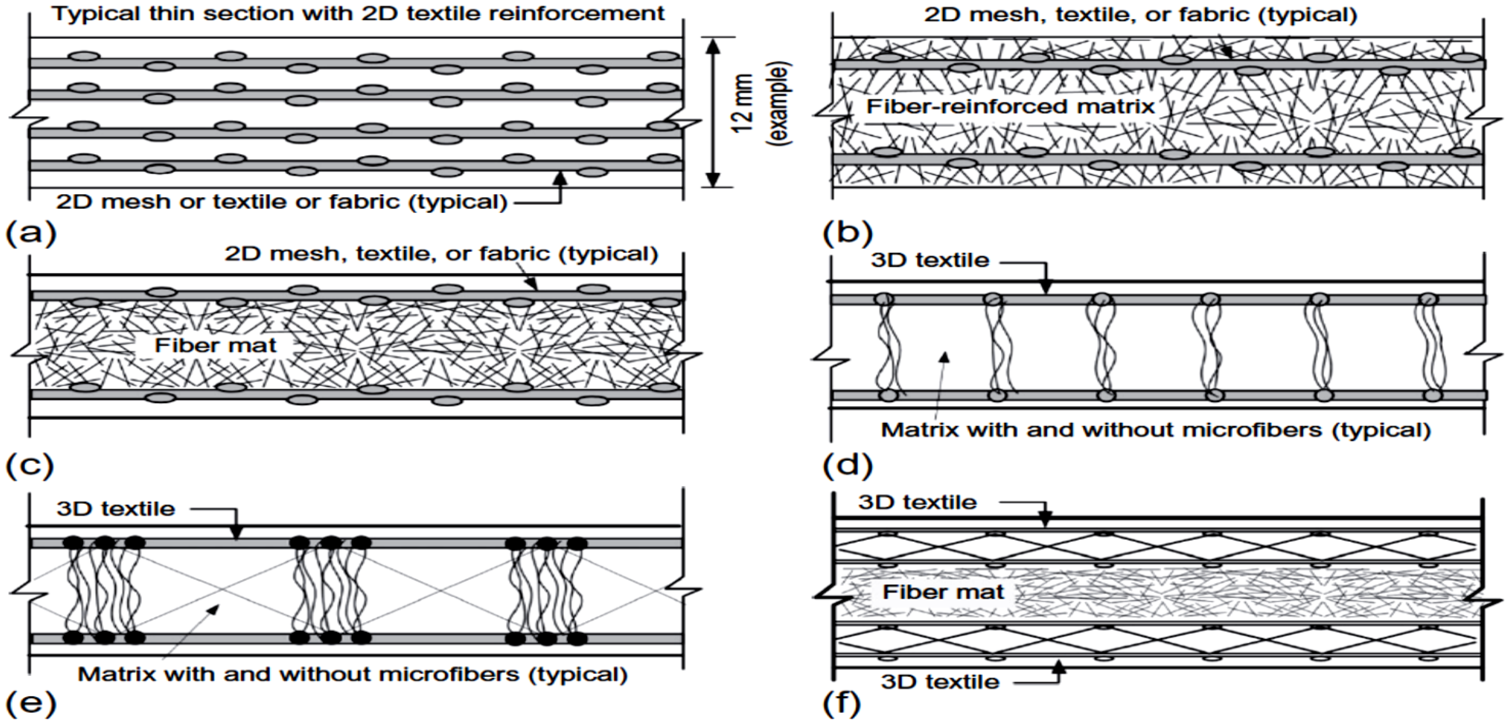
Examples of textile structures used in the manufacturing of advanced composite structures



Advantage of reinforcement by fibers

- Increases stiffness (modulus)
- Decreases deformability due to thermal expansion (suppressing thermal expansion)
- Increase strength
- Decrease weight of products

Textile reinforced composites



(a) Several layers of 2D textile (minimum of two layers, one near each face)

(b) most efficient for bending (two extreme layers of 2D textile with fiber reinforced matrix)

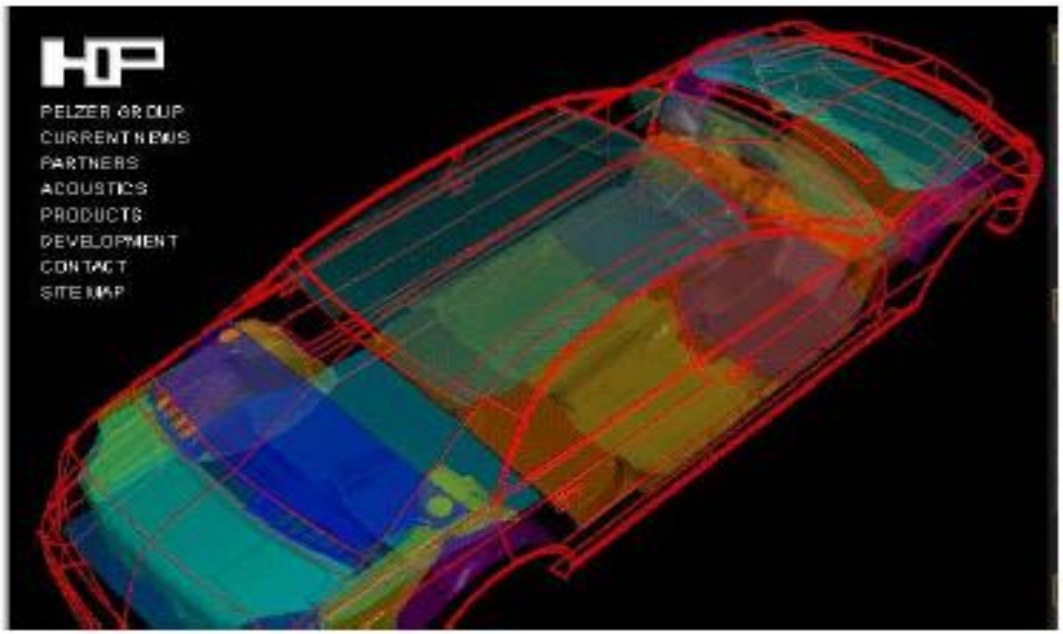
(c) two layers of 2D textile sandwiching a fiber mat

(d) One layer of 3D textile covering entire depth

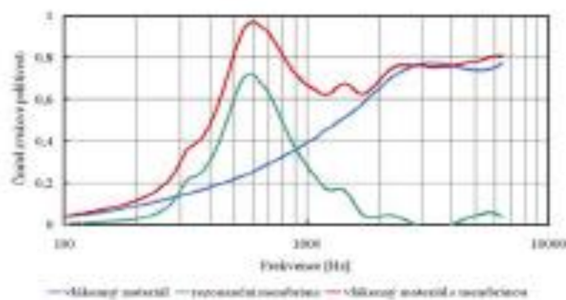
(e) One layer of 3D textile covering entire depth

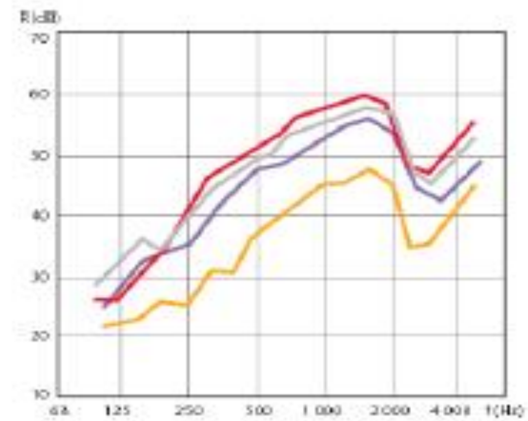
(f) two layers of 3D textile sandwiching a fiber mat

Textiles in Cars



Sound absorption





Sound transmission loss

Textile products in cars:

Comfort (upholstery, trimming), insulation (sound absorption, heat, vibration damping), passengers safety (airbags, seat belts, safety nets).

Textile Based Composites in Cars

Composite components (textiles, glass fibres, PU foam, adhesive).

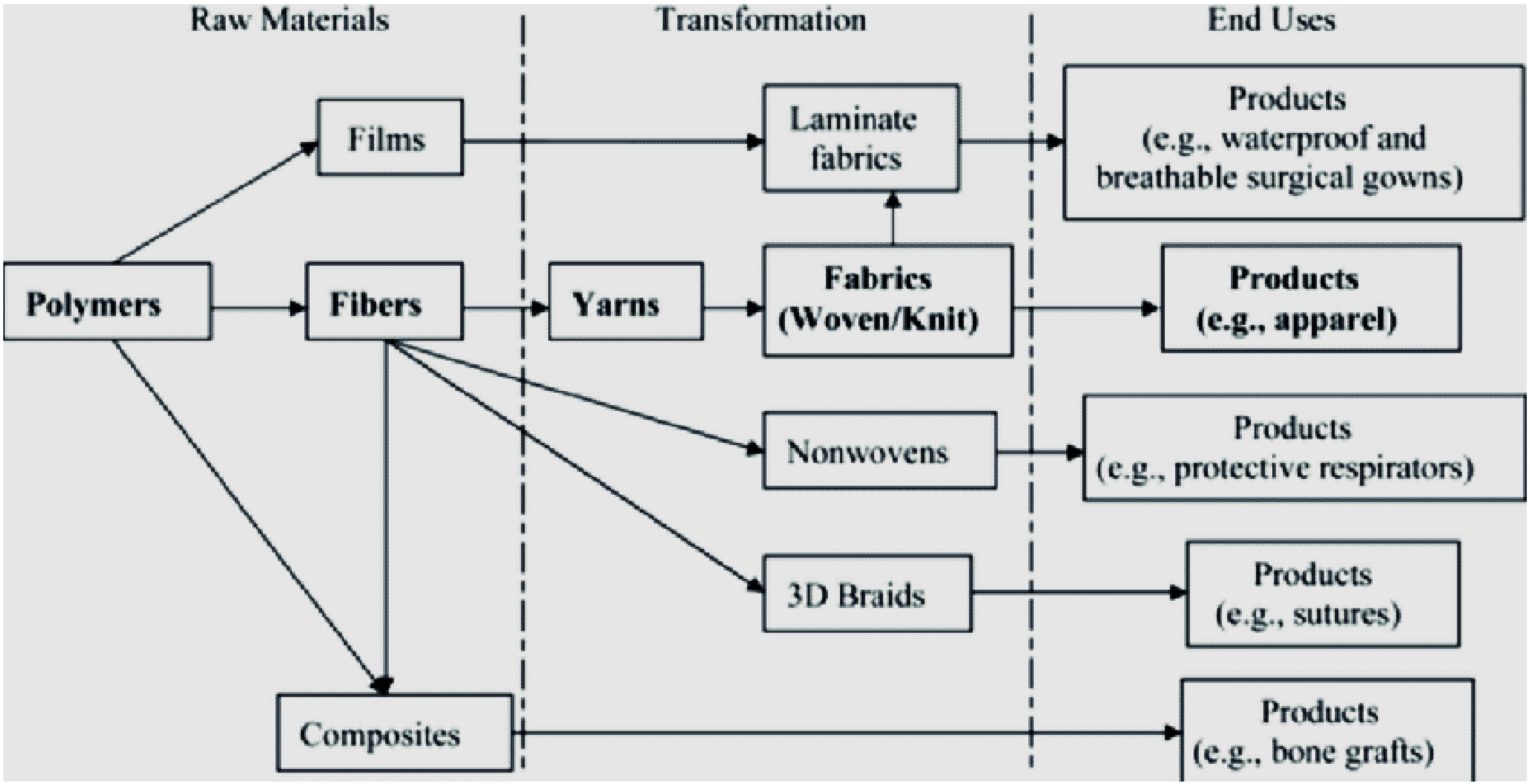
Cabin ceiling – pressed pieces

Classification of various medical textiles

Medical textile

- **Implantable materials (heal and repair)** →
  - Suture
    - Natural
    - Synthetic
    - Absorbable
    - Nonabsorbable
  - Vascular grafts
    - Woven
    - Weft knitted
    - Warp knitted
    - Membrane
    - Polyurethane polymer
  - Grafts
  - Reabsorbable polymer
- **Nonimplantable materials (external applications)** →
  - Absorbent
    - Hydrogel, alginate, collagen
    - Odor absorbent
  - Semipermeable
    - Film
    - Form
    - Hydrocolloid
    - Polyurethane foam
  - Secondary dressing
    - Nonadherent,
    - Low-adherent,
    - Adherent
  - Vapor permeable
  - Pressure garments
    - Elastic and nonelastic compression bandage
- **Healthcare/hygiene** →
  - Disposable—eg, wipes, panty shields
  - Clothing—eg, mask, uniform
  - Infection control
  - Antimicrobial/antistatics
  - Dental products
- **Extracorporeal devices (purification, filtration, and circulation of blood)** →
  - Artificial and bioartificial kidney, liver, and pancreas
- **Intelligent medical and healthcare textiles** →
  - Chromic materials—photochromistic, thermochromistic, electrochromistic, halochromistic
  - Phase changing materials—thermoregulating, shape memory polymers
  - Intelligent textile systems—active smart, passive smart, or adaptive function

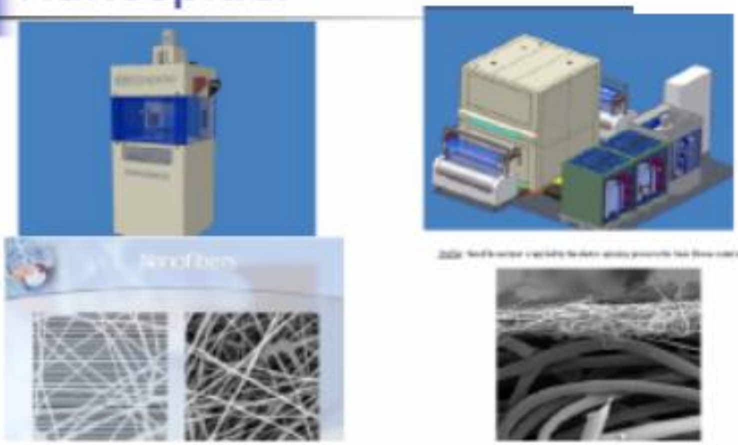
Application of Medical textile



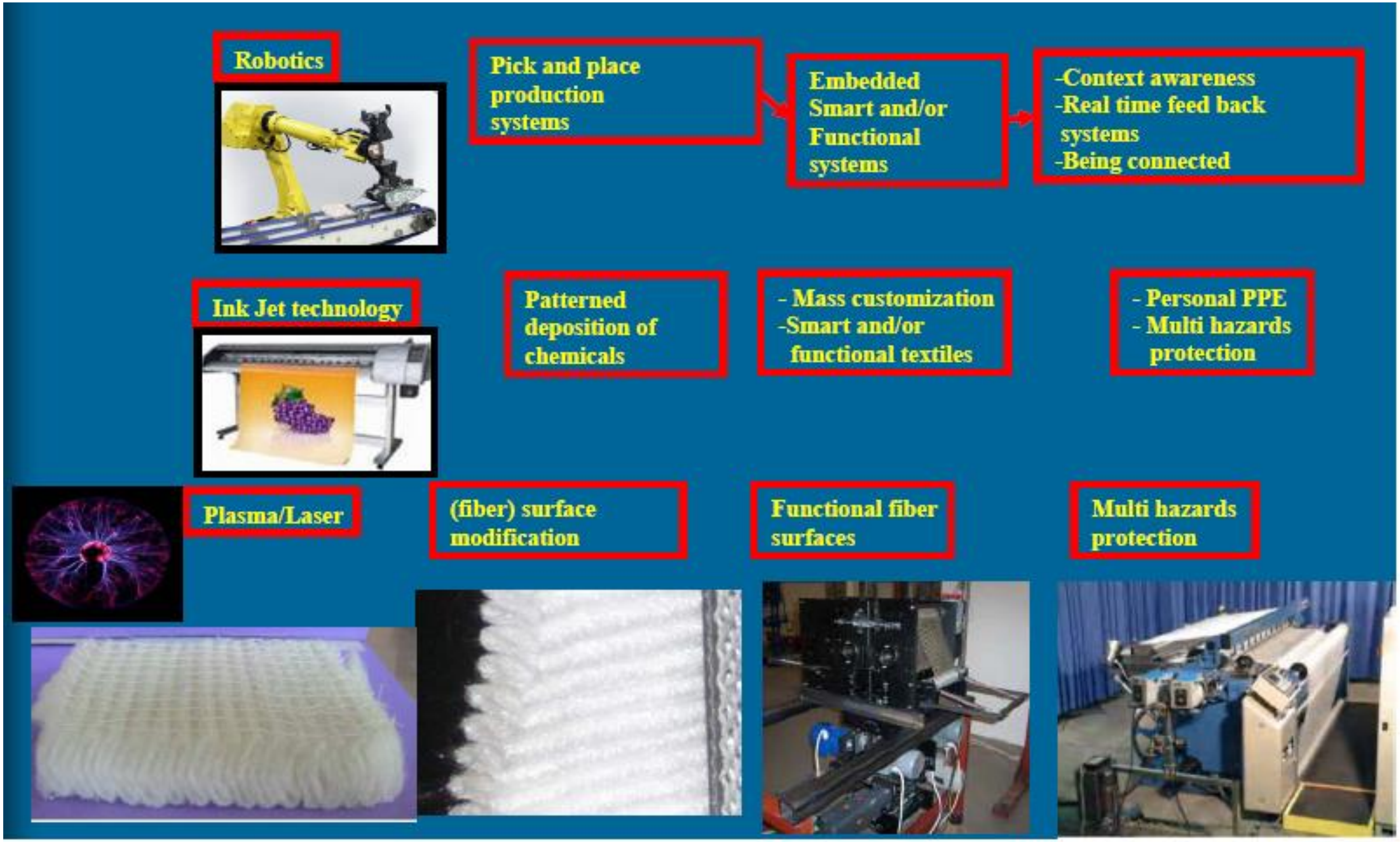
TECHNICAL TEXTILES PRODUCTION LINES

- Impregnating lines (active agents penetrates into product);
- Coating lines (agent remains up of products surface);
- Stretching and equalizing lines;
- Shrinking lines;
- Splitting lines;
- Lines for special technology; (Lines for abrasive textiles production, for heat and acoustic insulations etc).

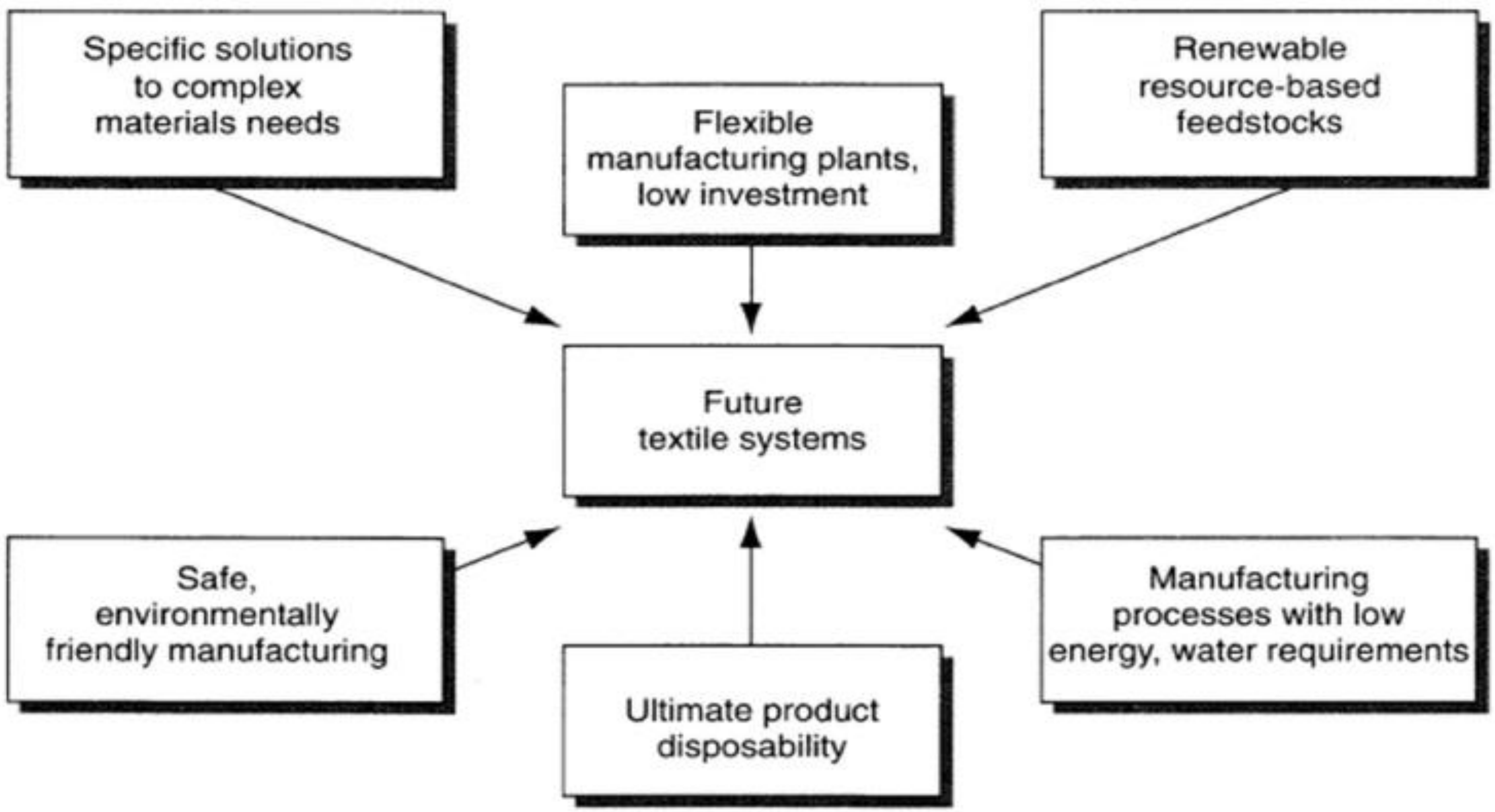
Nanospider



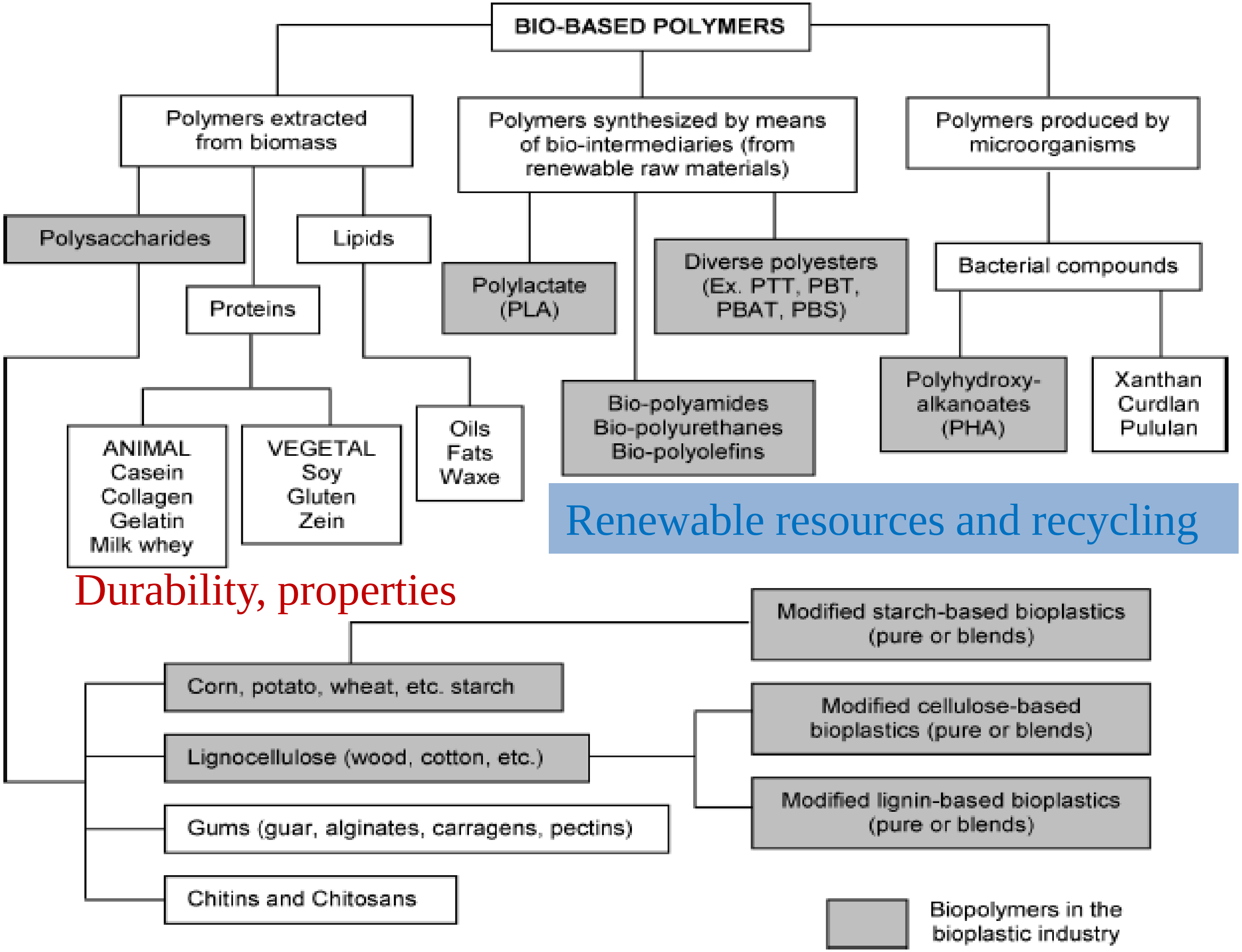
Advanced Production Technology



Factors Impacting the Next Generation of Textiles



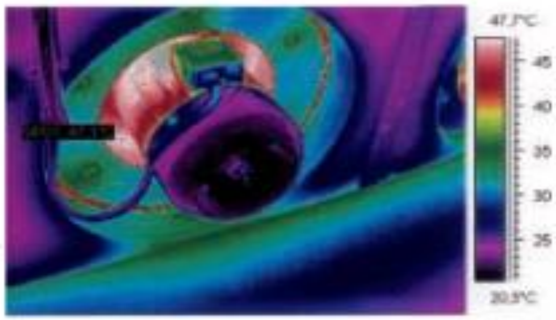
Sustainable polymers



Renewable resources and recycling

Durability, properties

Reduction of Energy Consumption



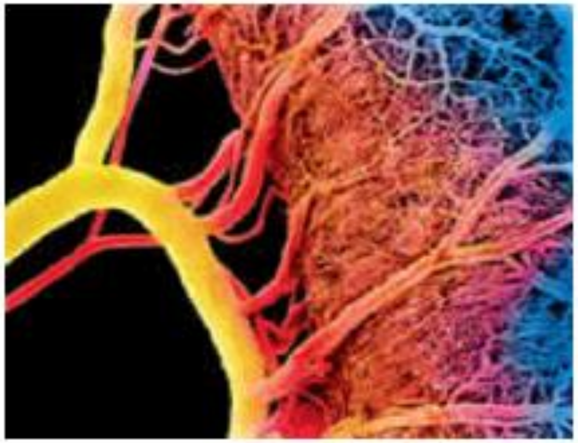
- Energy is expensive
- Energy consumption leads to ware-house effect
- Energy sources are limited

Basic solutions

Sustainable solutions

Low energy equipments

- New machinery with reduced weight (composites), reaction volumes and computer control – **digital finishing**, Infrared, microwaves heating, **insulation**, alternative solvents, **nano finishing**



Low energy processes

- Bio processes (enzymatic treatment)
- Catalytic processes
- (Atmospheric) Plasma technology
- Wet to wet processes
- Dry processes
- Optimized processes

Potential of energy conservation

Industry	Saving Potential %
Iron and Steel	10
Fertilizer	15
Textile	25
Cement	15
Paper	25
Aluminum	10
Sugar	20
Petrochemicals	15
Refineries	10

Reference slides

Fiber

Density

Fineness

Diameter

UHM

UI index irregularity

L50 mean length

Bundle strength Pressley

Bundle strength HVI

Fiber strength

Break elongation

Initial tensile modulus

Friction coefficient

Moisture regain

Yarn

One- two component yarn

single ply

Fineness

Twist

Packing density/Porosity

Diameter

Fiber number in cross section

Hairiness Uster and TUL

CV Uster

Strength

Break elongation

Initial tensile modulus

Spinning technology

Ring, compact, Novaspin, rotor

Fabric

weave

Sett (warp /weft)

Shortening (warp / weft)

Interlacing angle (warp /weft)

Yarn length in weave repeat (warp /weft)

Areal mass/ Thickness

Areal cover(warp/weft)

Air permeability

Roughness (warp /weft)

Drape coefficient

Creasing resistance (warp /weft)

Strength (warp/weft)

Break elongation (warp / weft)

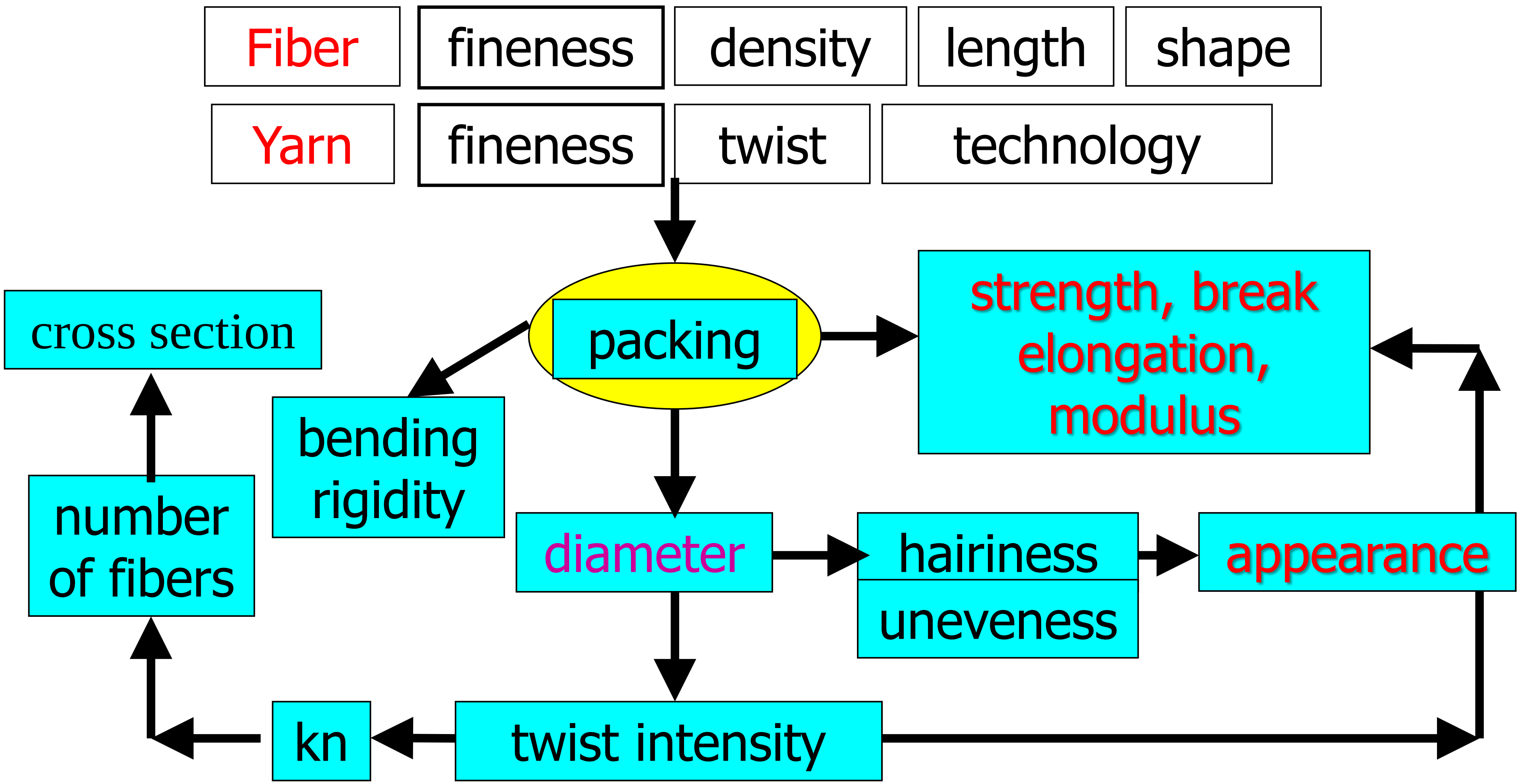
Initial tensile modulus (warp /weft)

Bending stiffness modulus (wa /we)

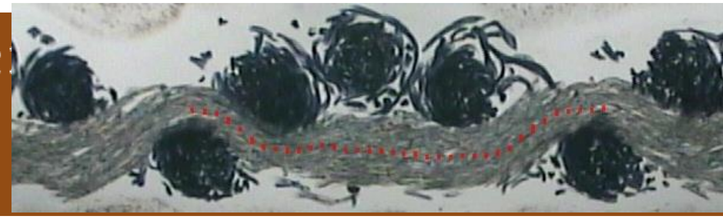
Shear stiffness modulus

Thermal comfort

Fiber to yarn transformation



Woven Fabric



Warp
Weft
Yarn

Fineness | Diameter | Widening/thickness =flattening

CV Uster | Strength Def. at break Bending rigidity

Fabric

Warp sett, weft sett | Weave

Binding Point Geometry

Shortening, interlacing angle, yarn length in weave repeat, waviness

Fabric Visualization

Hairiness

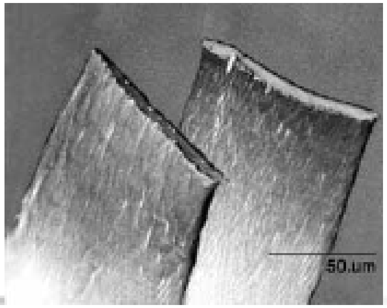
Roughness
Hand

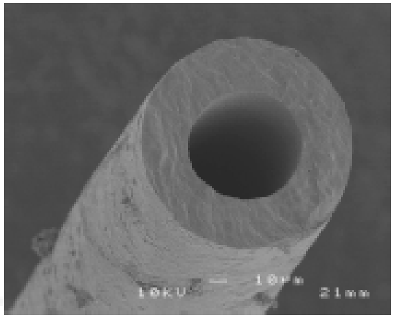
Areal mass, Thickness, Cover factor, Porosity

Air permeability, Thermal comfort

Strength, Def. at break
Bending rigidity

Fiber properties





Geometrical properties: length, fineness a cross section shape, surface roughness…

Mechanical properties: strength at break (tenacity), strain at break, initial modulus, stiffness, toughness, bending rigidity, fatigue..

Thermal and thermomechanical properties: melting point, softening point, glass transition temperature, thermal conductivity, loss tangent, storage modulus, loss modulus…

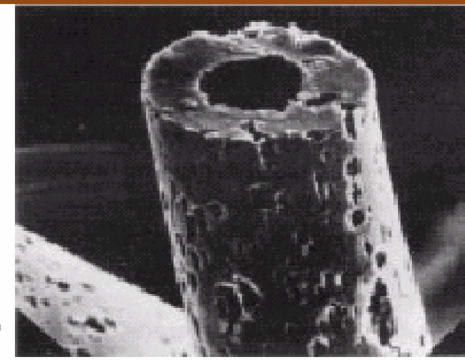
Electrical properties: static charge, surface resistivity, volume resistivity, dielectric constant…

Sorption characteristics: moisture regain, longitudinal swelling, axial swelling volume swelling, heat of sorption…

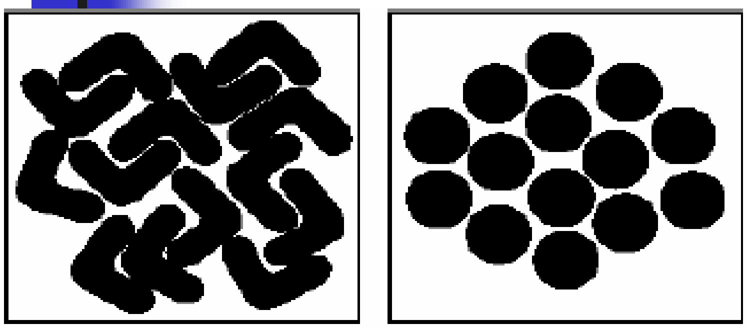
Abrasion and wear

Chemical resistance weather resistance, flame resistance…

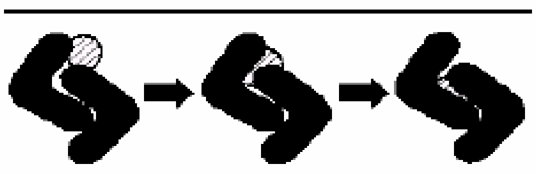
Wicking improvement



"Wellkey"



"Cisbet" Ordinary nylon



"Killat N"
(Kanebo, Ltd.)

Wicking into cylindrical capillary of radius r_k .Equilibrium height H_{Max}

$$H_{MAX} = \frac{\gamma_{LG} \cos(\Theta)}{\rho\, g\, r_K}$$

γ_{LG} surface tension liquid /air [$N.m^{-1}$]

Θ contact angle [-]

ρ liquid density [$kg.m^{-3}$]

Wicking into infinite bundle of parallel fibers of radius r and packing density μ

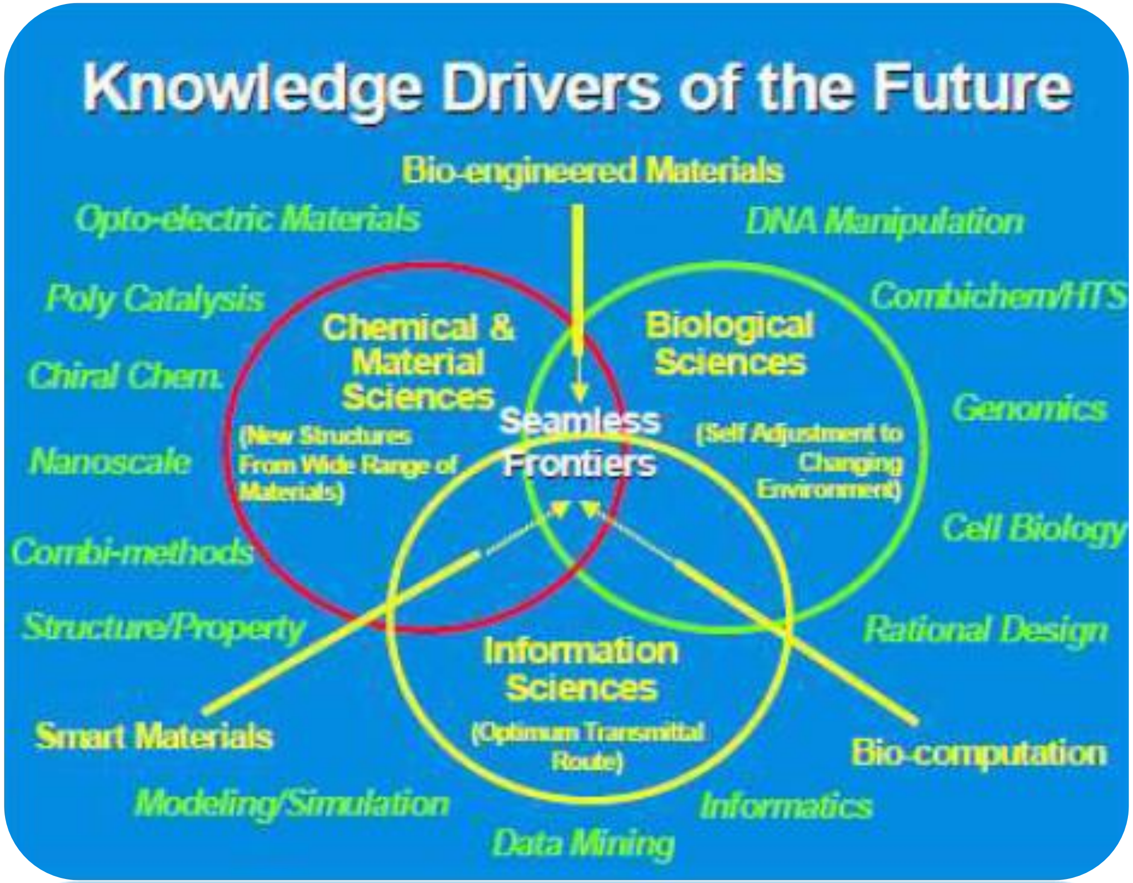
$$H_{max} = \frac{\gamma_{LG} \cos(\Theta) \mu}{r\, g\, \rho\, (1-\mu)}$$

Functional Textiles

Clothing: Multiple Functions
Functional Clothing: Specifically engineered to deliver the performance or functionality over and above its normal functions.

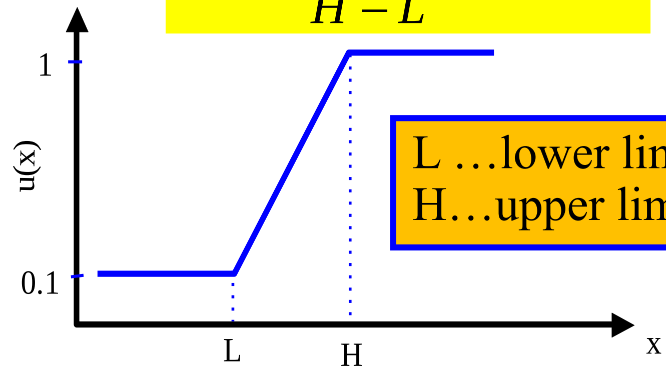
Advanced technologies are not distinguishable from Magic.
- Sir. A.C. Clark

Protective:	protection against extreme environmental factors and weather, hazardous matters, different energy field
Medical:	healing support, medical cloth, implantable/non-implantable materials, monitoring vital sights
Sport:	performance enhancing, fatigue reduction
Vanity:	body shaping, appearance
Cross functional:	comfort, life support, communication, performance



Utility value concept

$$u(x) = \frac{0.9}{H-L}(x-H)+1$$



L …lower limit
H…upper limit

Let we have *m* fabrics properties $R_1,\dots,R_m$ (utility properties). Based on the direct or indirect measurements it is possible to obtain some <u>quality characteristics</u> $x_1,\dots,x_m$ (mean value, variance, quantiles etc.). These characteristics represent utility properties. Functional transformation of quality characteristics (based often on the psycho physical laws) leads to partial utility functions (PUF)

$$u_i = f(x_i, L, H)$$

L is value of characteristic for just non acceptable fabric ($u_i \sim 0.1$) and *H* is value of characteristic for just fully acceptable fabric ($u_i = 1$). Utility value *U* (quality index) is weighted average of u_i with weights b_i

$$U = \bar{u}_R = ave(u_i, \beta_i)$$

Knight, Baber: The Journal of the Human Factors and Ergonomics Society, February 2005

WEARABLE ELECTRONIC AND COMFORT

Title	Description
Emotion	I am worried about how I look when I wear this device. I feel tense or on edge because I am wearing the device.
Attachment	I can feel the device on my body. I can feel the device moving.
Harm	The device is causing me some harm. The device is painful to wear.
Perceived change	Wearing the device makes me feel physically different. I feel strange wearing the device.
Movement	The device affects the way I move. The device inhibits or restricts my movement.
Anxiety	I do not feel secure wearing the device.

Group	Description
1	Emotions, concerns about appearance and relaxation
2	Physical feel of the device on the body, attachment
3	Physical effect, damage to the body
4	Feeling physically different, upset
5	The device physically affects movement
6	Worry about the device, safety, and reliability

References

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