Textile Engineering

KMI-TEN (Practice)

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:

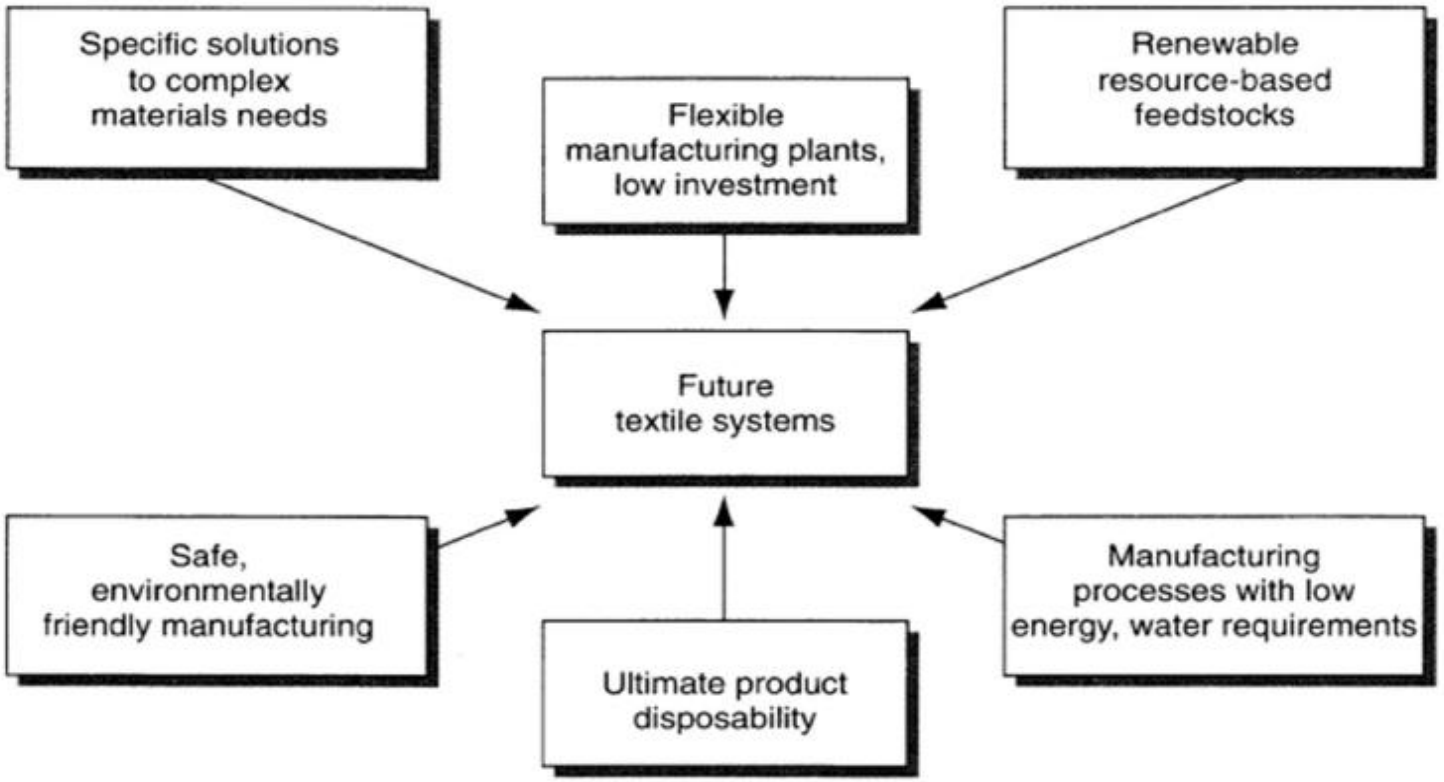
- The exercises are based on the lecture as presentation of process in technological laboratories FT TUL.
- Within the exercises the students obtain assignments on specific subject.

Credit and Exam Evaluation

Exam: Oral - 80% & Assignment - 20%

Credit: Active participation in lectures and practicals

Factors Impacting the Next Generation of Textiles



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

Novelties in Textile Machinery from Czech Republic

- **Spinning machines**

SLIVER MACHINE Short cycle spinning (drafting control).
New spinning principle NOVASPIN
ROTONA wrapped yarn formation

- **Weaving machines**

Heavy wide fabric air jet weaving (for AMOCO)
CAMEL loom (new beating mechanism). Energy spare

- **Knitting machines**

Circular warp knitting (computer controlled)

- **Nonwoven machines**

ROTIS, Corrugated structure creation, Quasi yarns

- **Nano fibers machine**

NANOSPIDER, wide nano assembies creation

2D planar structures

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

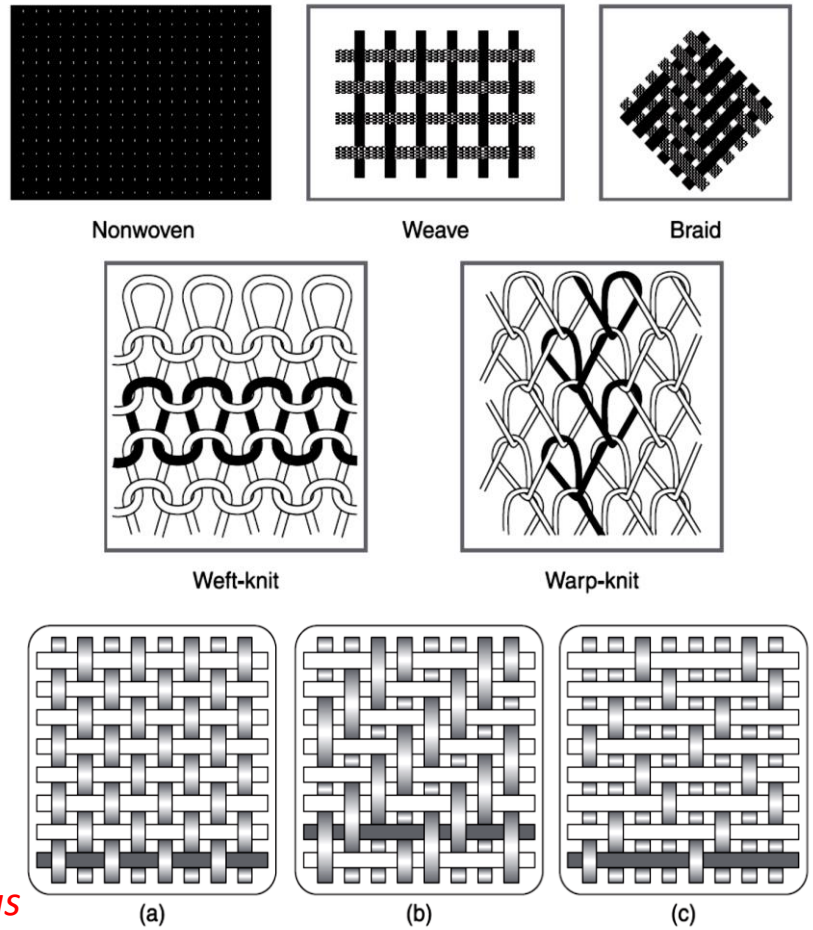
The mechanical properties for composites depend on;

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

Disadvantages;

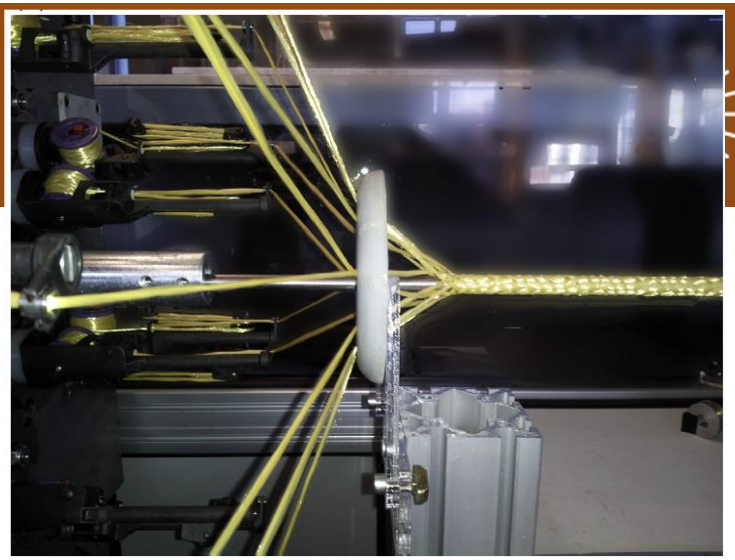
- **tendency to unravel at edges when cut,**
- **anisotropy,**
- **limited conformability,**
- **reduction on tensile efforts**
- **handling difficulty of open structures.**

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

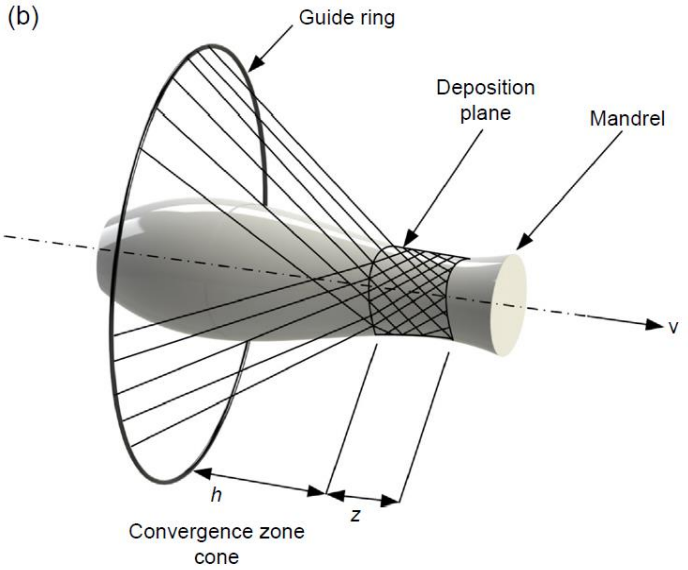


(a) Plain (b) Twill (c) Satin

CAMEL Weaving machine



- 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.



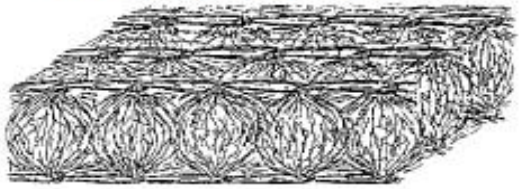
(a) Steeger maypole braider showing spools, horn gears; (b) schematic of 2-D maypole braiding with key variables and structures.

Development of 3D textile products

Staple fibers

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

MULTIKNIT



KUNIT

Filament yarns

Spacer knitted fabrics
Spacer woven fabrics

Nonwovens

needle punched type
Spun-laced type
Jet-laced type

New Inflatable Systems

New 3D Inflatable Fabrics Produced by VUTS

R&D of fully automatic 3D distance fabric weaving loom (distance between outer layers 12 - 50 cm)

- INDUSTRY

- ENERGY

- RESCUE SYSTEMS

3D Woven distance fabrics

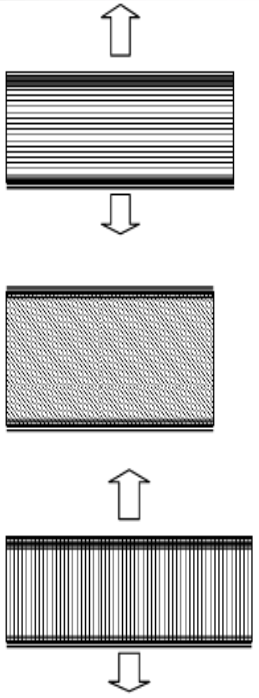
https://www.youtube.com/watch?v=a96gZl7wsvg

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.



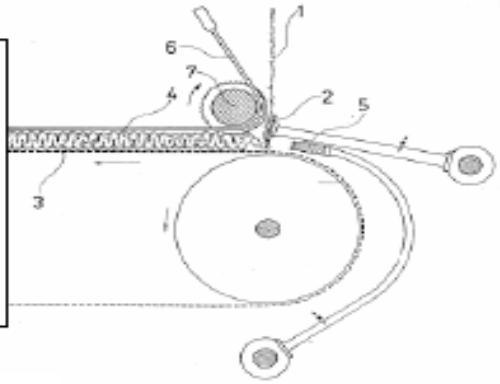
Stratification = layering

3D Nonwovens creation

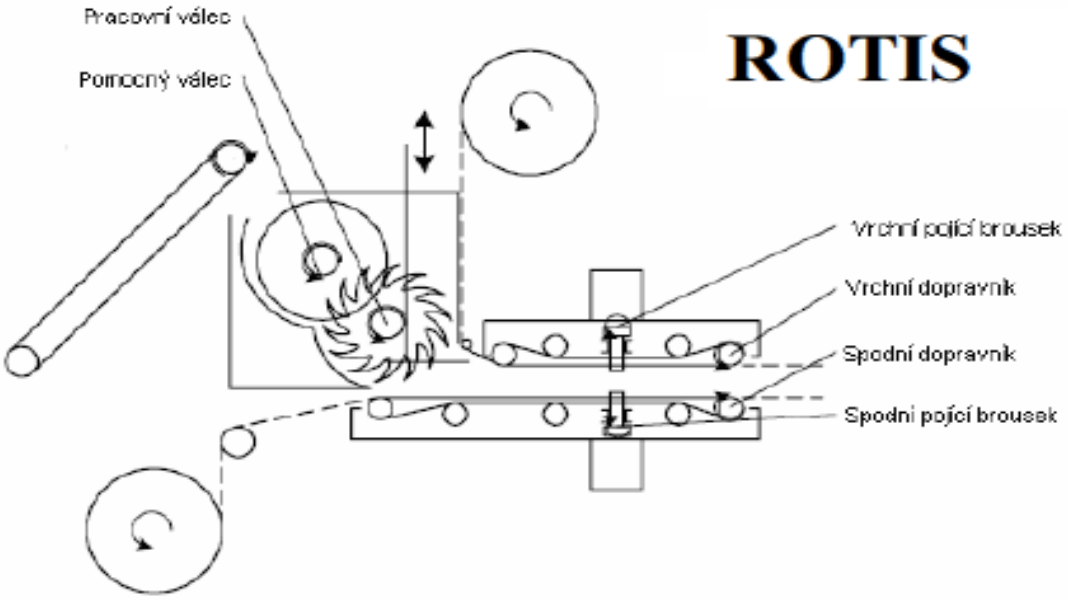
STRUTO

Product

Hot air chamber

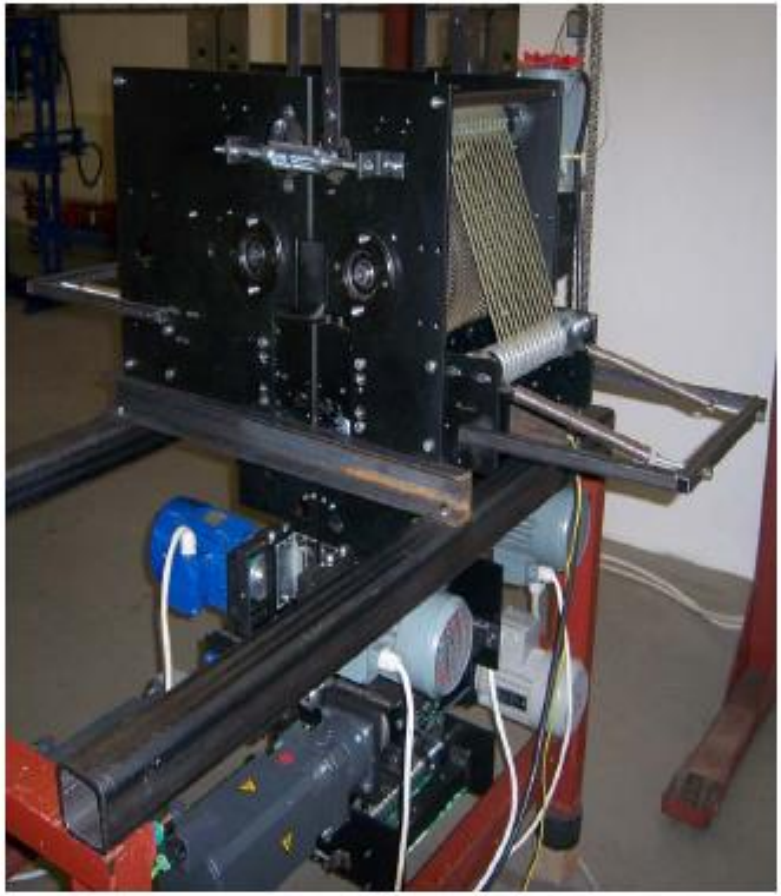


ROTIS

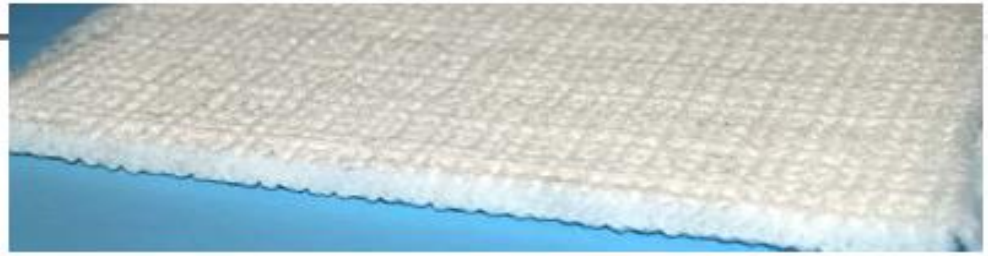


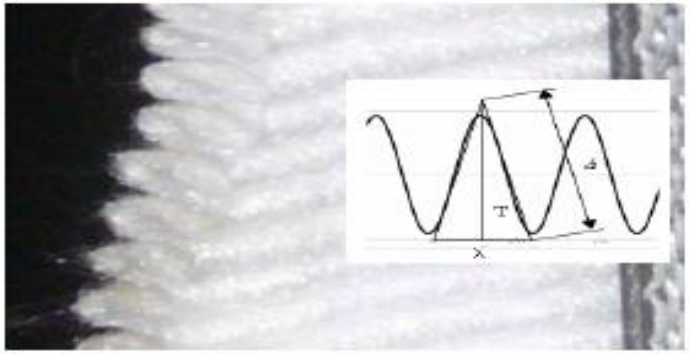
Product

Laboratory unit



Structure control



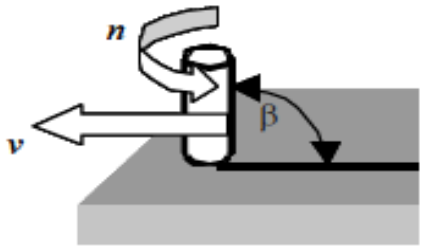


T = thickness, k = compression, P = gear intersection

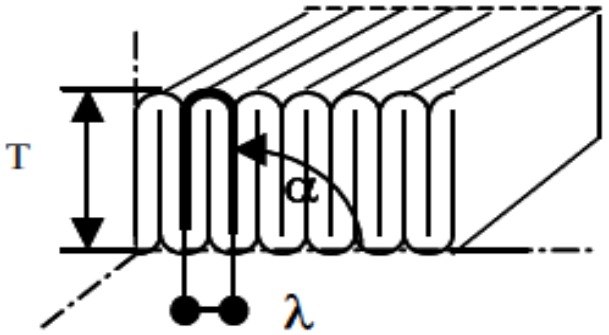
$$T = \sqrt{\frac{P^2 k^2 + \left(\frac{a}{2}\right)^2 k^2 - \left(\frac{a}{2}\right)^2 - P^2}{k^2}}$$

$$P = \sqrt{\frac{-\left(\frac{a}{2}\right)^2 k^2 + \left(\frac{a}{2}\right)^2 + T^2 k^2}{k^2 - 1}}$$

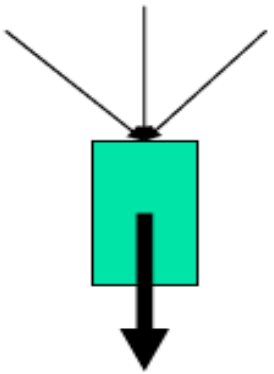
Surface Fixation



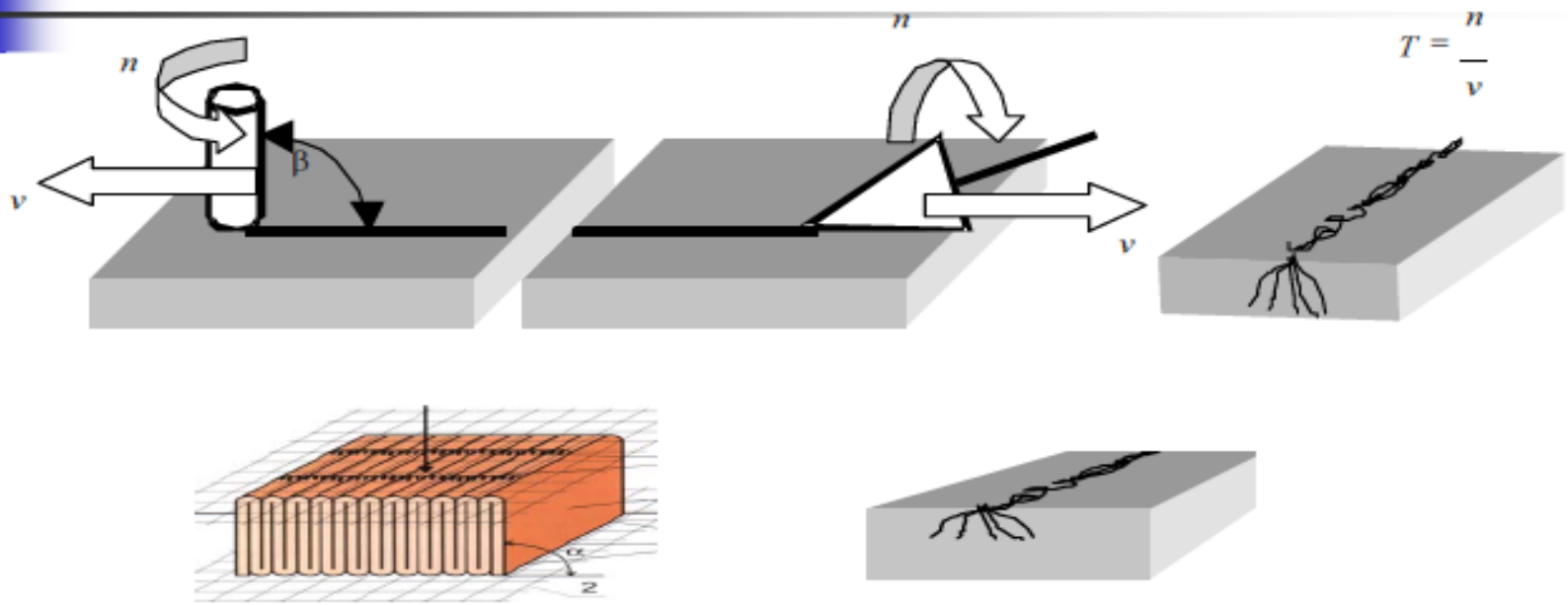
Fixation by quasi yarns requires dense corrugated surface ($\lambda = 2t$), with minimaldifference in fold thickness T



Stratification mechanism enables multiple layers stacking.
Layers are not mutually connected.

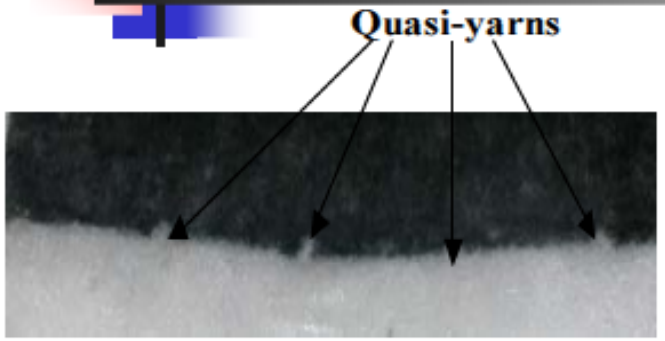


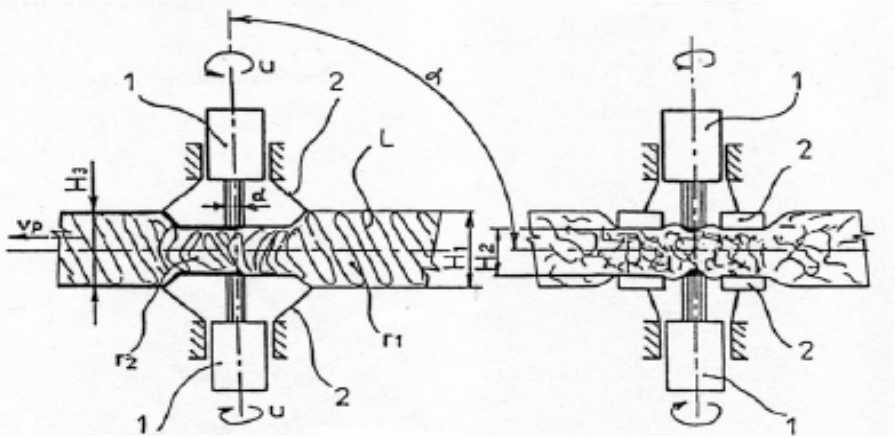
Principle of quasi-yarn formation



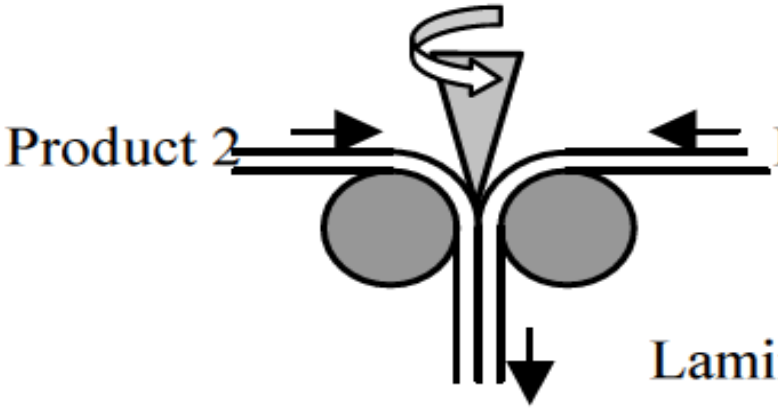
- Quasi-yarn is formed by twisting of fibre ends, which are protruding from the surface of textile material;
- Twisting body moves on the surface of a textile fabric.

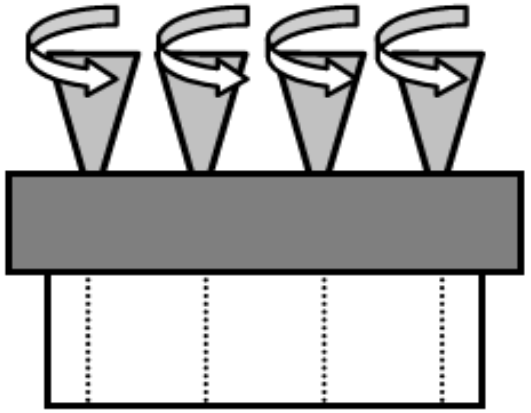
Mechanical lamination





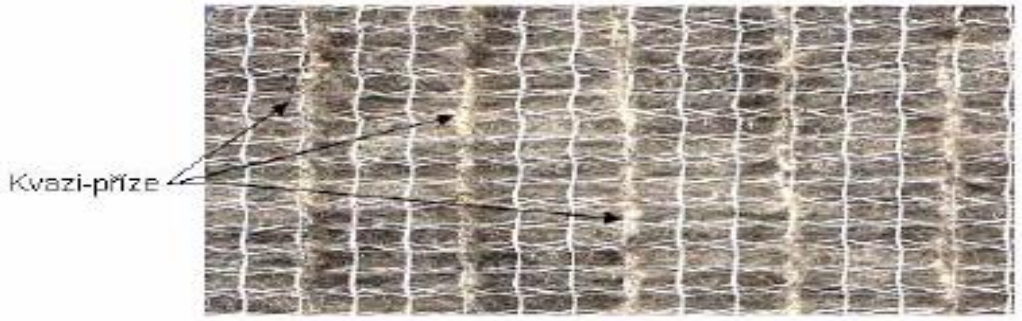
Rotating elements





„Surface "lamination makes possible to produce thickness to 200 mm.

Characteristic appearance



Advanced Production Technology

Robotics

Pick and place production systems → Embedded Smart and/or Functional systems → -Context awareness -Real time feed back systems -Being connected

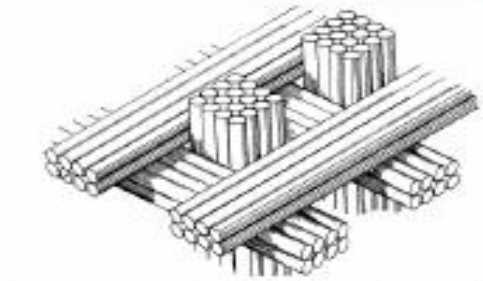
Ink Jet technology

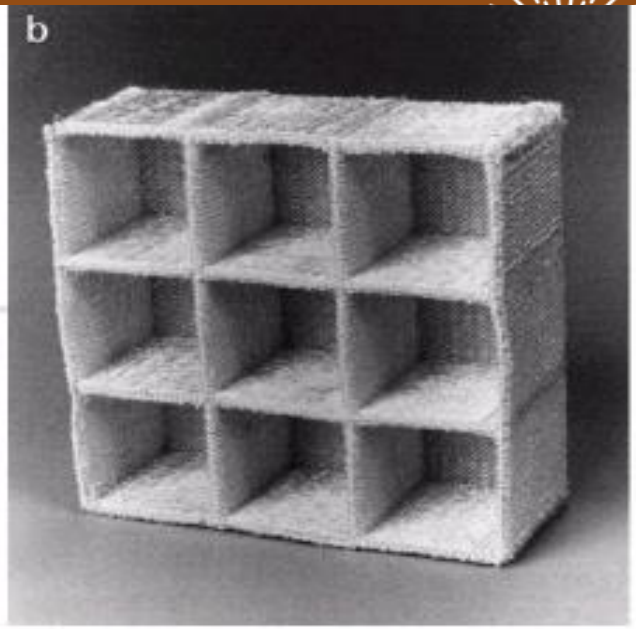
Patterned deposition of chemicals → - Mass customization -Smart and/or functional textiles → - Personal PPE - Multi hazards protection

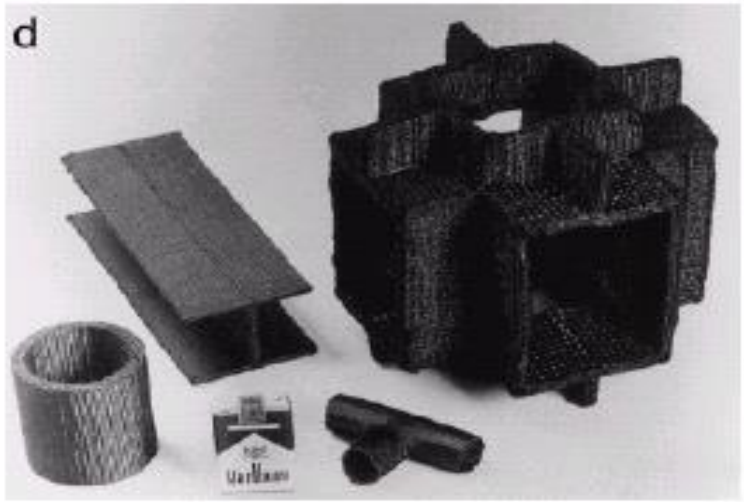
Plasma/Laser → (fiber) surface modification → Functional fiber surfaces → Multi hazards protection

Special textile products

3D knitting







Braiding

Nonwovens

3D Weaving

Composite preparation @ Cxi TUL

https://www.youtube.com/watch?v=lBRGrESGkgI

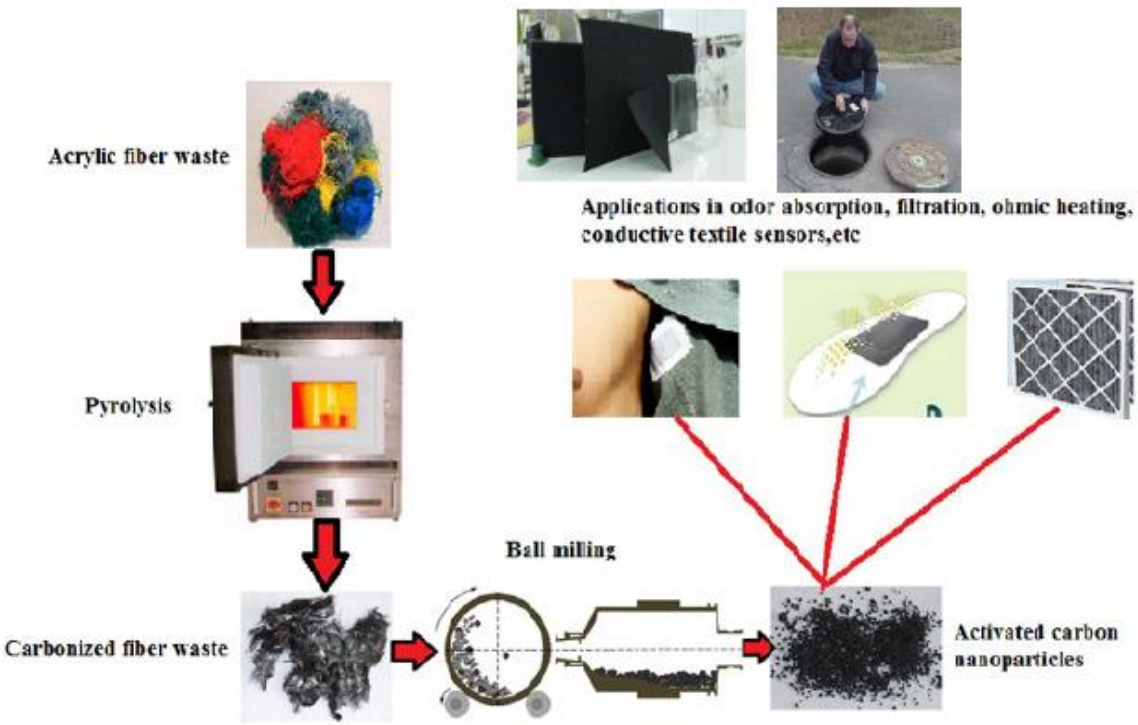
3D Fiber Preforming

https://www.youtube.com/watch?v=IRuIR3uhkX8

Transformation of acrylic fibrous wastes to the high value added products

•Carbonization of textile wastes (i.e. acrylic and their blends) by pyrolysis under microwave, hydrothermal or cyclic oxidation conditions

•Preparation of conductive carbon nanoparticles from pyrolysed textile wastes using high energy ball milling and their subsequent applications as sensors in polymers, textiles, composites, health care industries, etc.



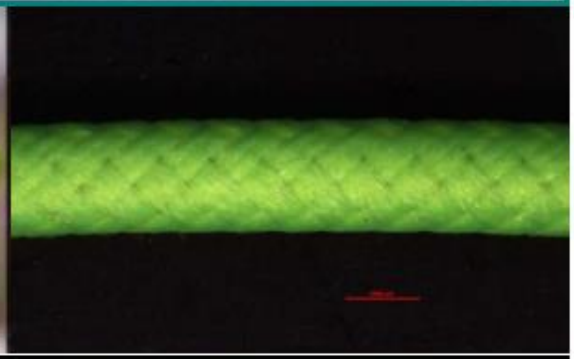
•Preparation of activated carbon from pyrolysed textile wastes by exposure of steam or gases and their subsequent applications in filtration of gases and liquids.

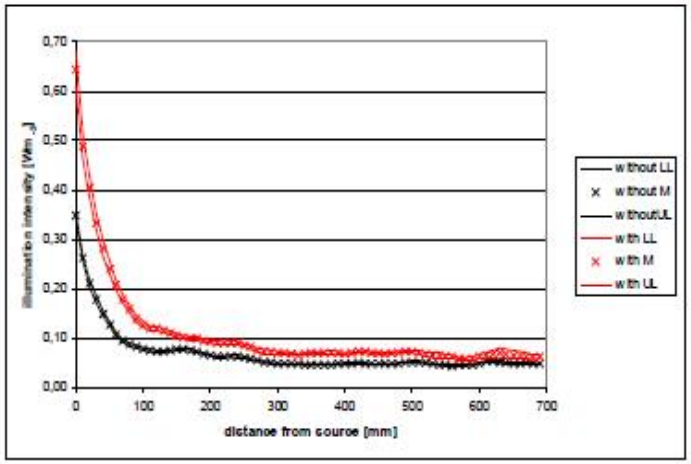
Composite structures with POF

Textile structures containing embedded side emitting POF

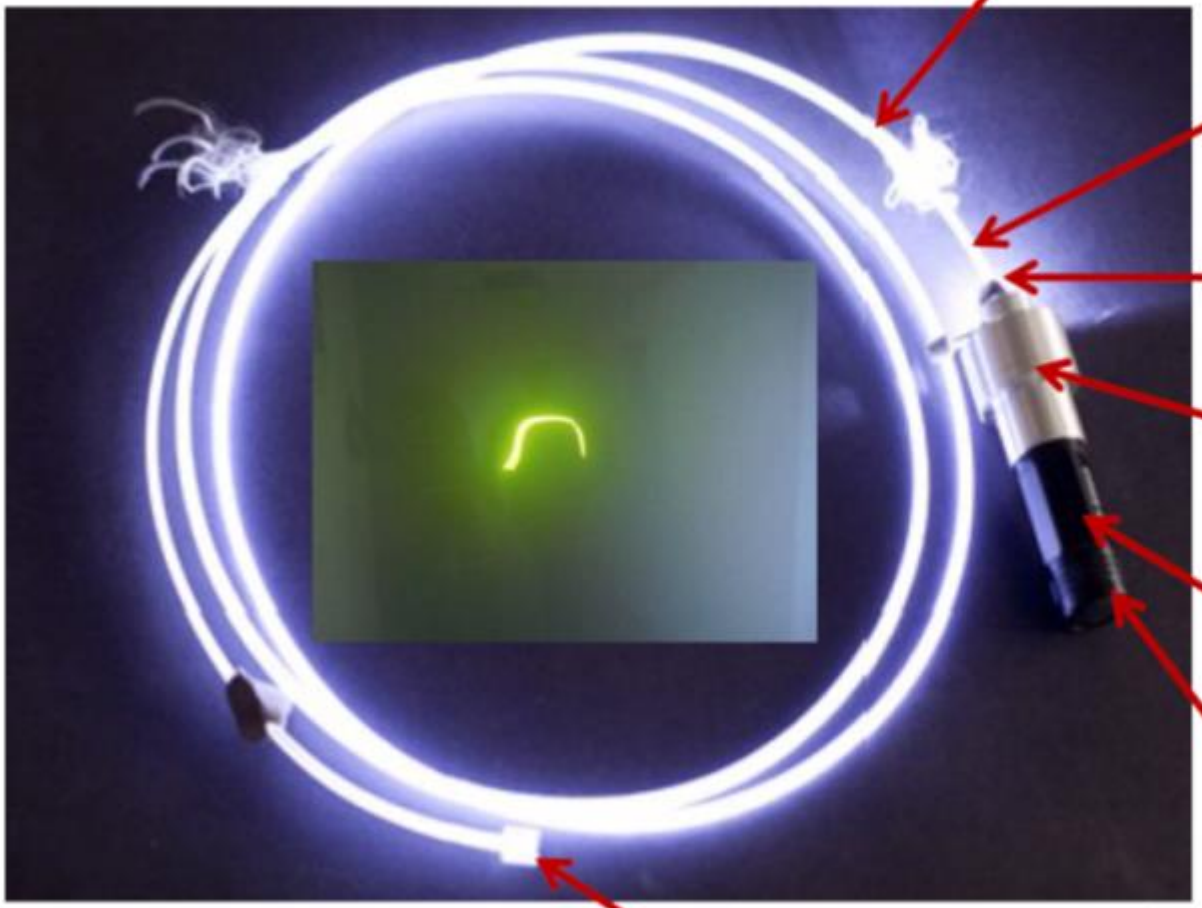
Benefits:

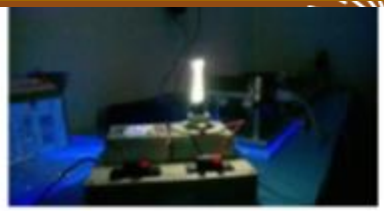
1. Enhancing illumination intensity
2. Protection against weather
3. Protection against UV radiation
4. Enabling washing
5. Color effects
6. Suppressing abrasion
7. Increase repeated bending resistance
8. Simplify attachment to textiles





System Components





Textile cover

Side emitting polymeric optical fiber

Light source - LED

Control circuit

Power source battery

Cooling option

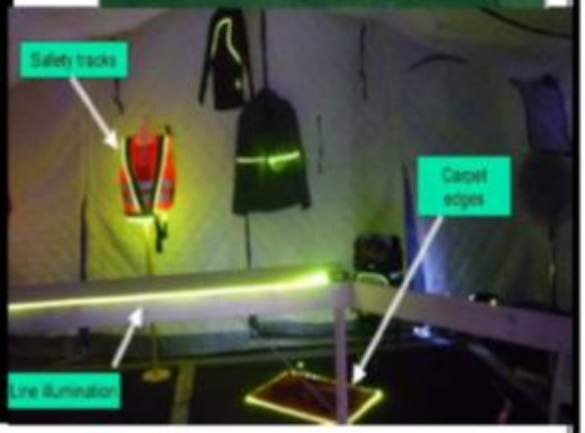
Mirror- optional

Light and Textiles


- Illumination
- Design
- Indication
- Warnings
- Safety
- Highlight
- Light transfer



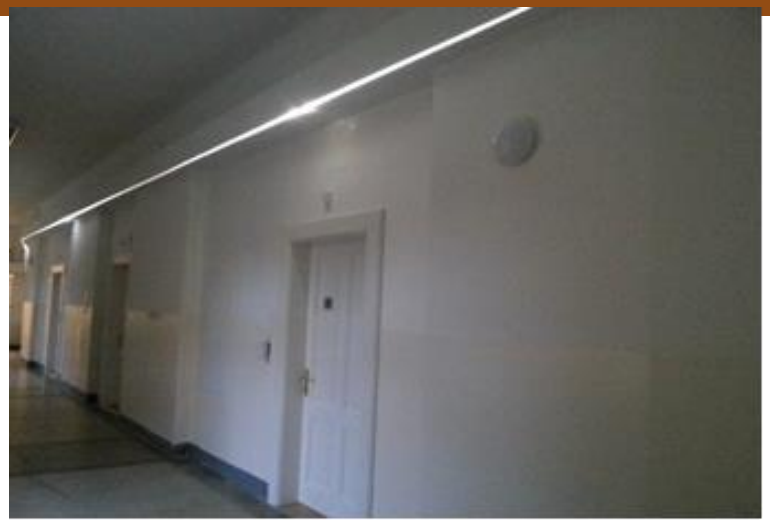


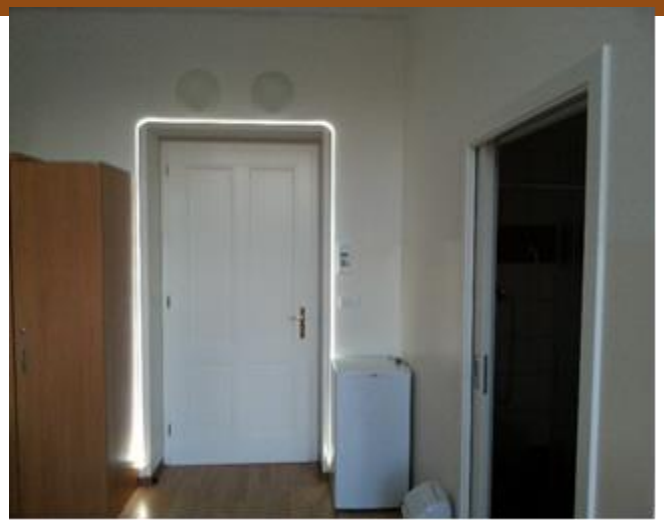



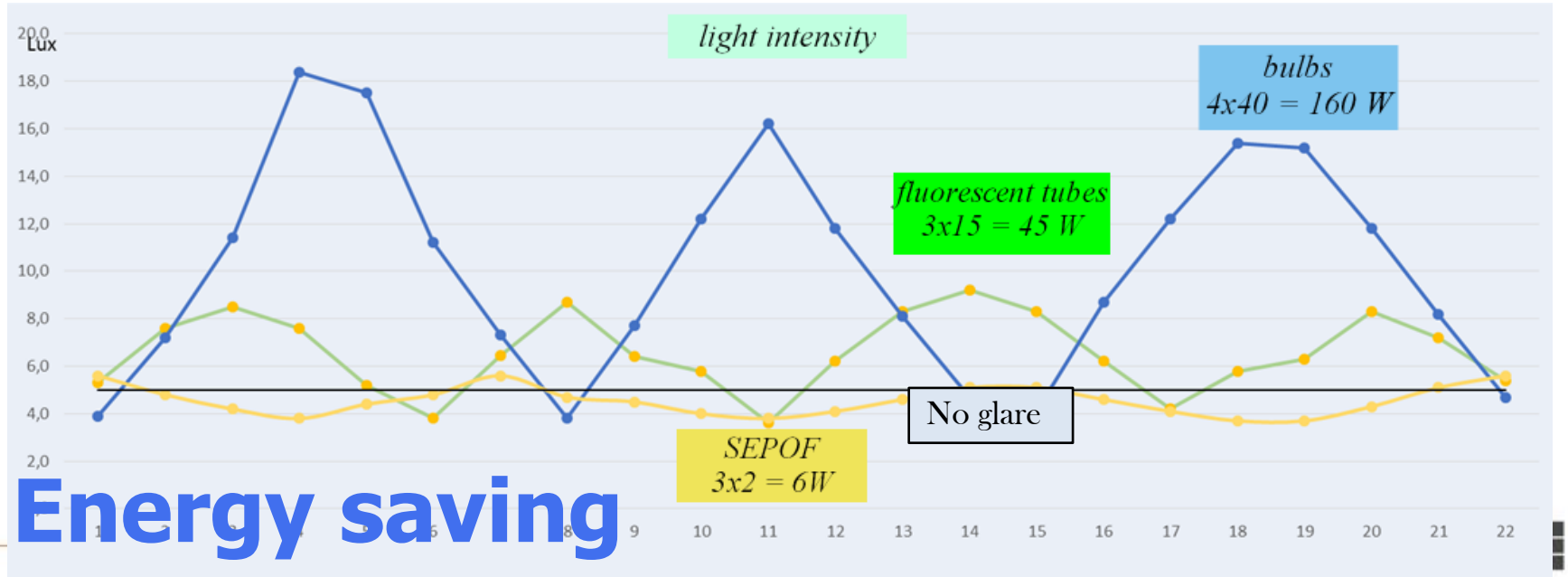

R. Friedman: Smart textiles for Designers, London 2016

Night lighting

Technical applications

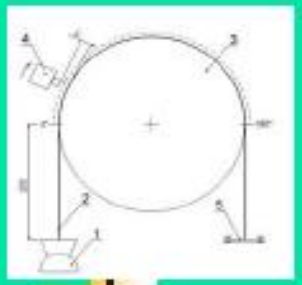


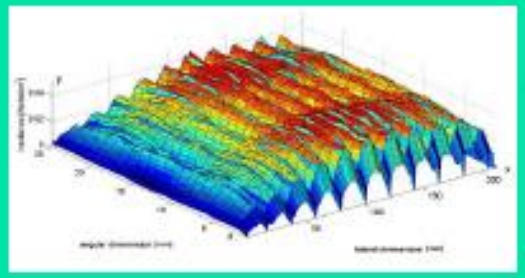


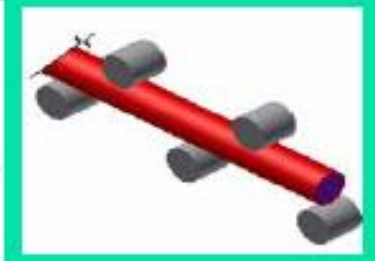


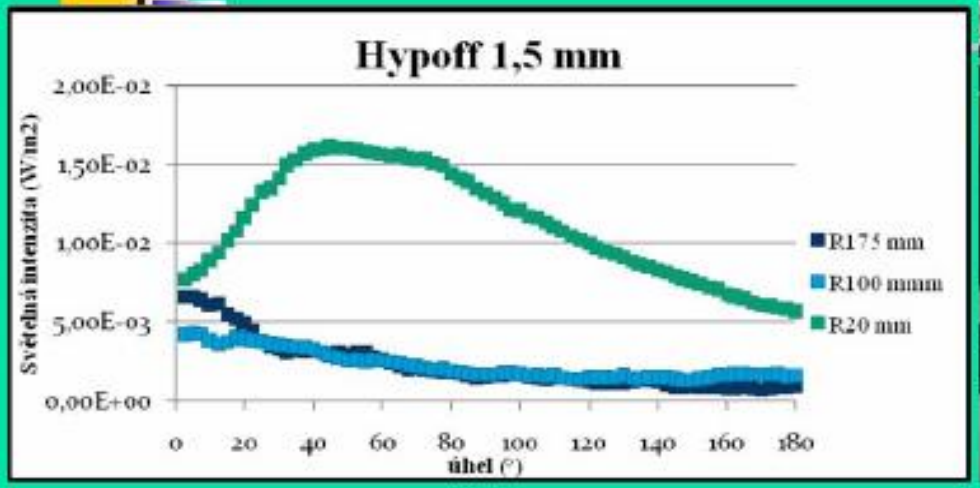
Energy saving

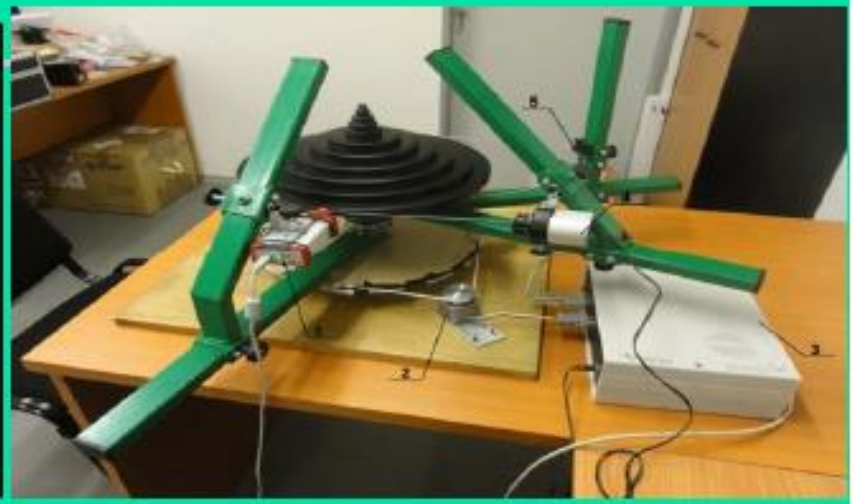
Measurement of illumination intensity in bend state

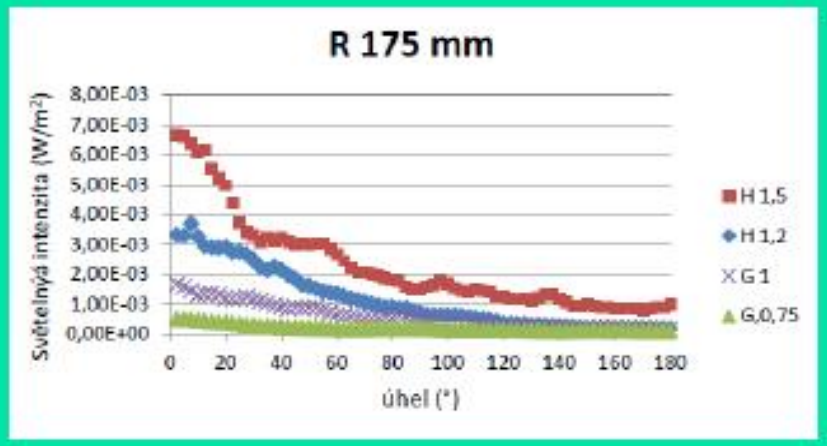


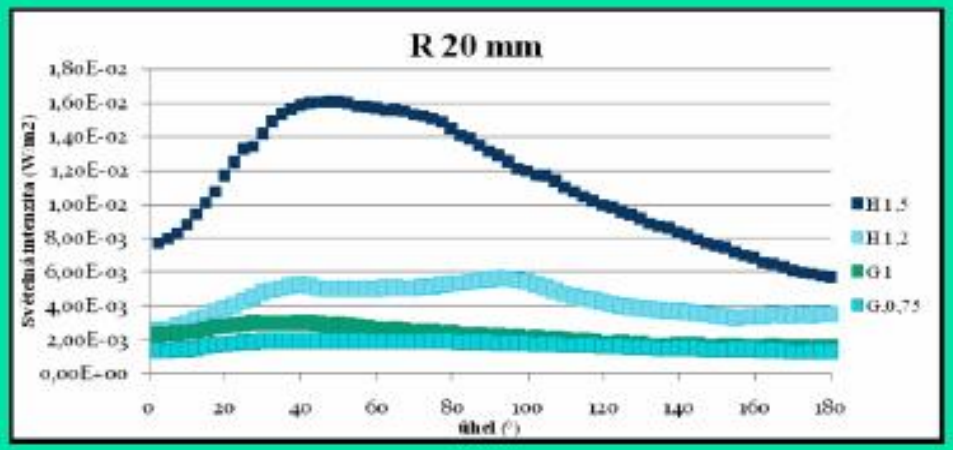






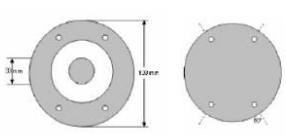


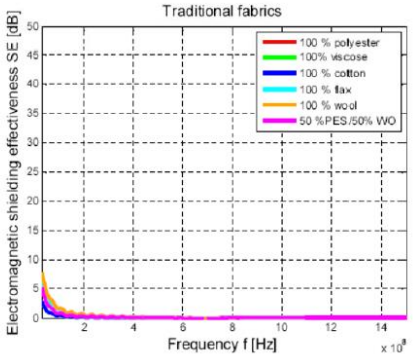


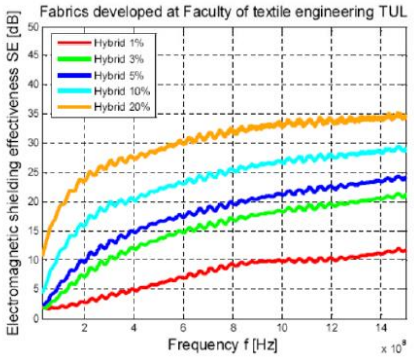


Electromagnetic pollutions

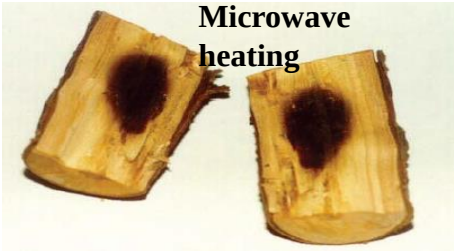
Offered components:
Gray or finished woven fabrics with prescribed shielding effectiveness and comfort.
Benefits: textile character, simple combination with other textile materials, simple maintenance, no adverse effect on comfort and hand, color design.
Price: approx. 10 EURO per 1 meter of colored woven fabric.
Delivery: Czech companies (already produced).
Partner role:
1. Design and fabrication of cloth for pregnant women containing woven textile shield .
2. Fabrication of cloth for pregnant women based on the TUL design.

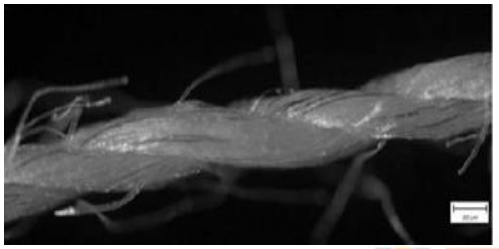






Woven textile shield containing hybrid yarns with optimal percentage of fine metallic fibers in blended with standard fibers having EMI shielding effectiveness more that 10 dB.

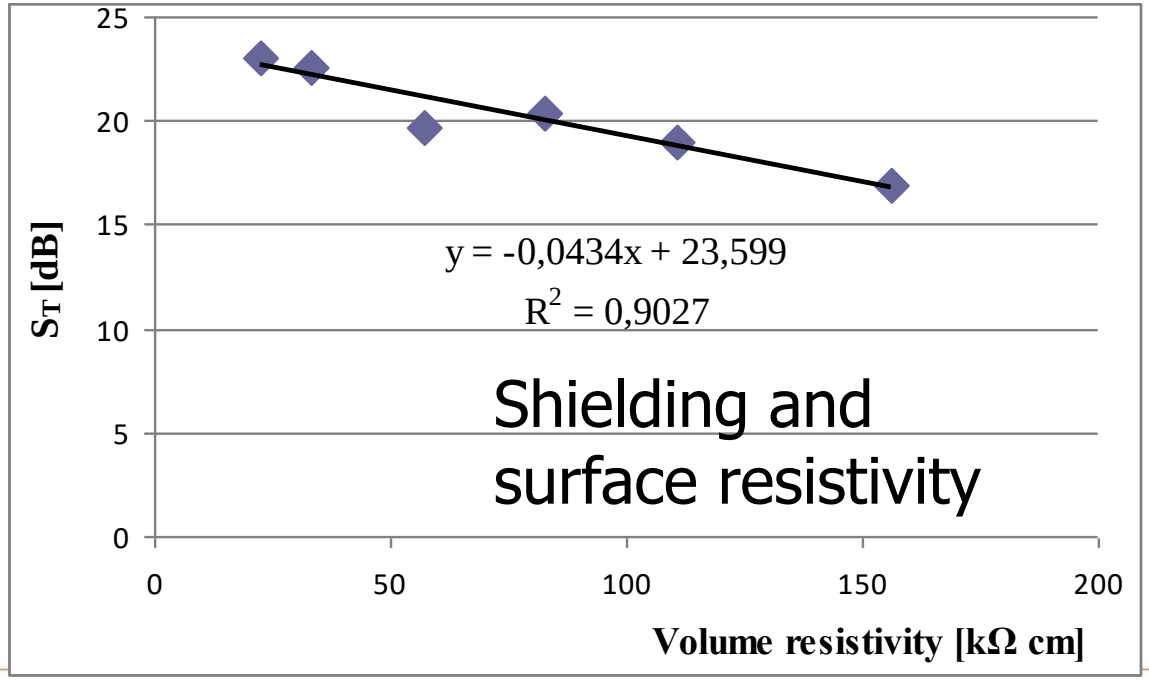


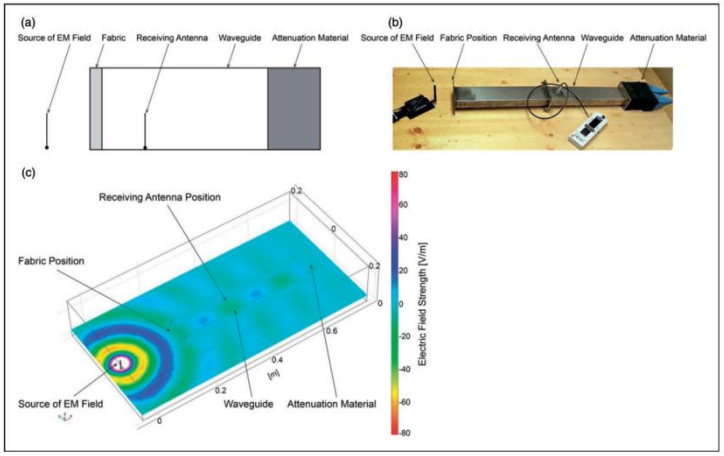


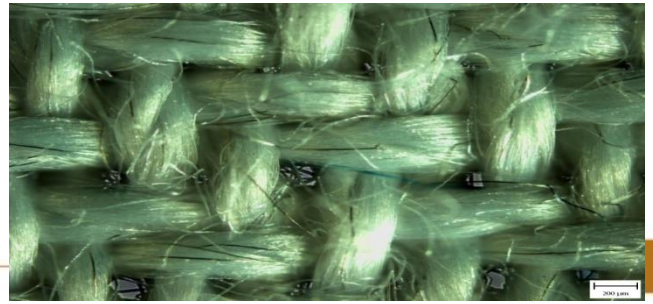
Transmitting antenna is placed in front of first waveguide input. As source of electromagnetic field the ZigBee module working at frequency 2.4 GHz is used

Electromagnetic shielding

Electromagnetic (EM) fields **below 10 GHz** (to 1 MHz) penetrate exposed tissues and produce *heating* due to energy absorption. The depth of penetration depends on the frequency of the field and is greater for lower frequencies.



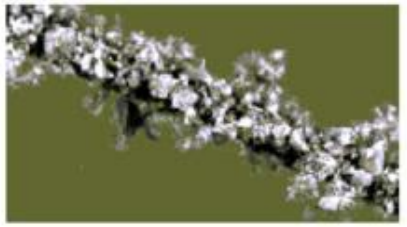




Focus Areas @ Department of Material Engineering - I

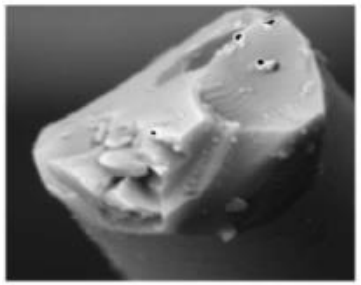
Fibers

- High performance fibers (Kevlar, Nomex, etc,.)
- Side emitting optical fibers
- Special Inorganic Fibers (Basalt, Carbon)
- Properties of modified PET and other fibers
- Thermally adaptive fibers (hollow, special profiles)



Composites and Nanocomposites

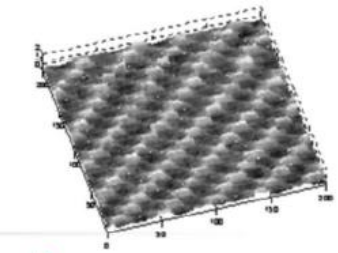
- Computer modeling of textile structures
- Textile composites based on the carbon fibers
- Nano-reinforcements for composites
- FEM modeling of composites properties
- 3D fabrics preparation and properties for composites



Focus Areas @ Department of Material Engineering - II

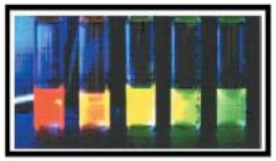
Metrology and Quality Control

- Surface and hand of flat textiles
- Thermal and Mechanical properties of materials
- Electrical properties and EMI shielding
- Application of image analysis for special testing
- Complex evaluation of textile quality
- Spatial variability of textile properties



Colorimetry

- Evaluation of color and color differences
- Color changes based sensors
- Measurement of UV protection



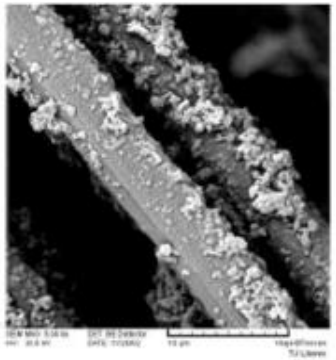
Focus Areas @ Department of Material Engineering - III

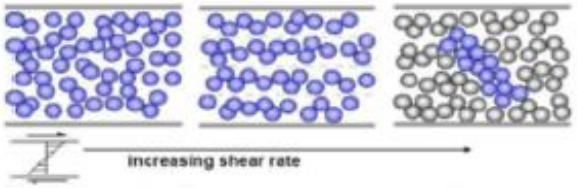
Functionalization of Surfaces

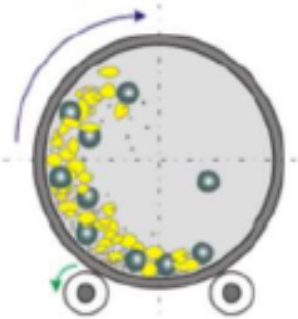
- Application of plasma microwaves, laser and ozonation
- Chemical modification of surfaces
- In situ deposition of active agents
- Analysis of foreign materials composition (dust, spots)
- Special finishing techniques(felting, shear thickening)

Nanoparticles

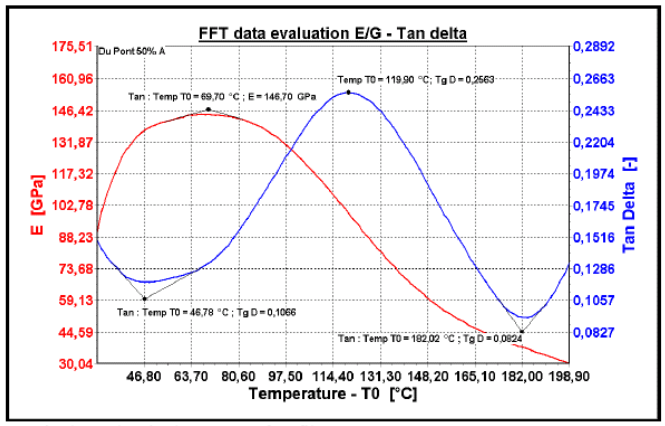
- Preparation of nanoparticles by milling or in situ deposition
- Nanoparticles for functionalization of textiles
- Characterization of nanoparticles effects

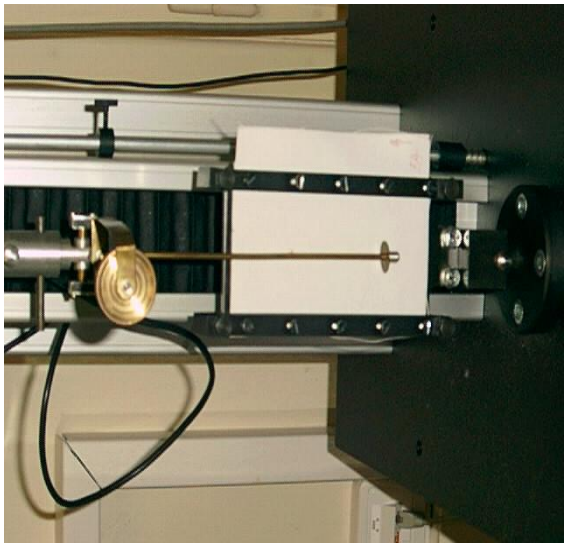






Measurements @ KMI, FT

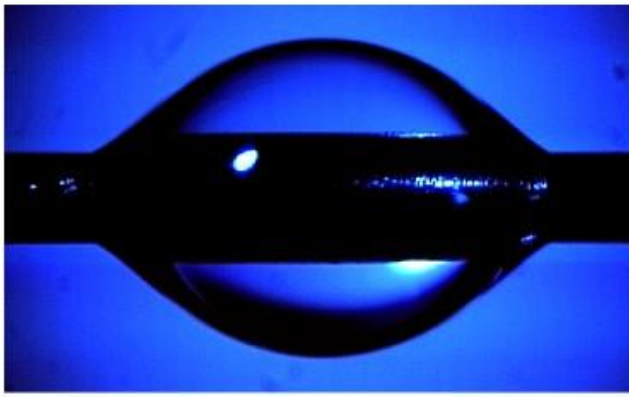


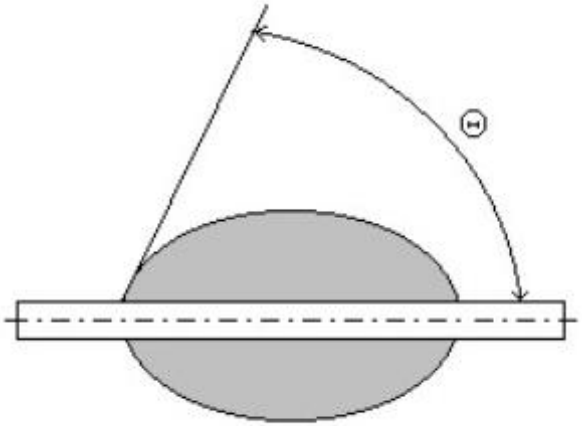


- Thermo mechanical spectroscopy
- Environmental microscopy and image analysis
- Surface roughness
- Hardness and micro hardness
- Light attenuation
- Nanoindentation
- EMI shielding

Special microscopy - image analysis

Pacini Compound Microscope (circa 1845)





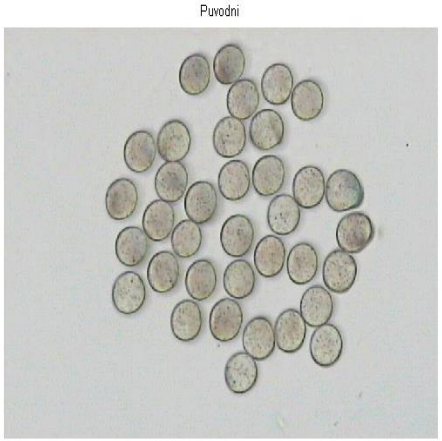
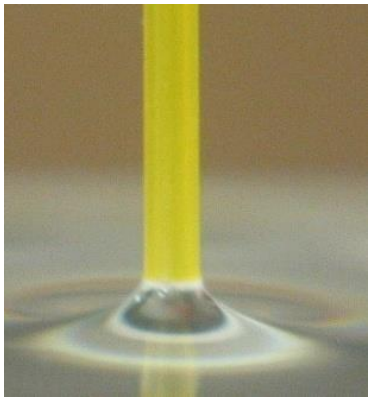
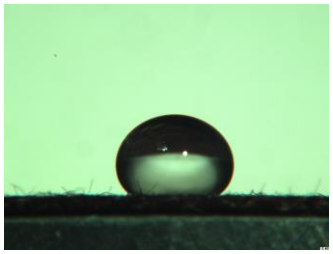
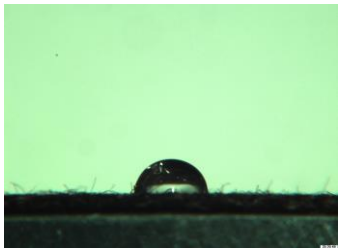


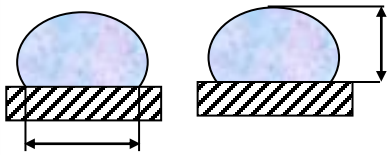
Image analysis based techniques

Wetting characterization

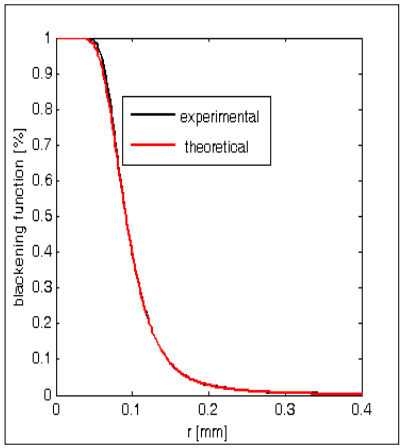


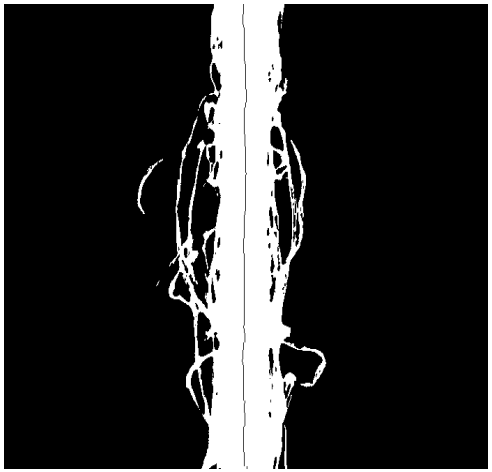


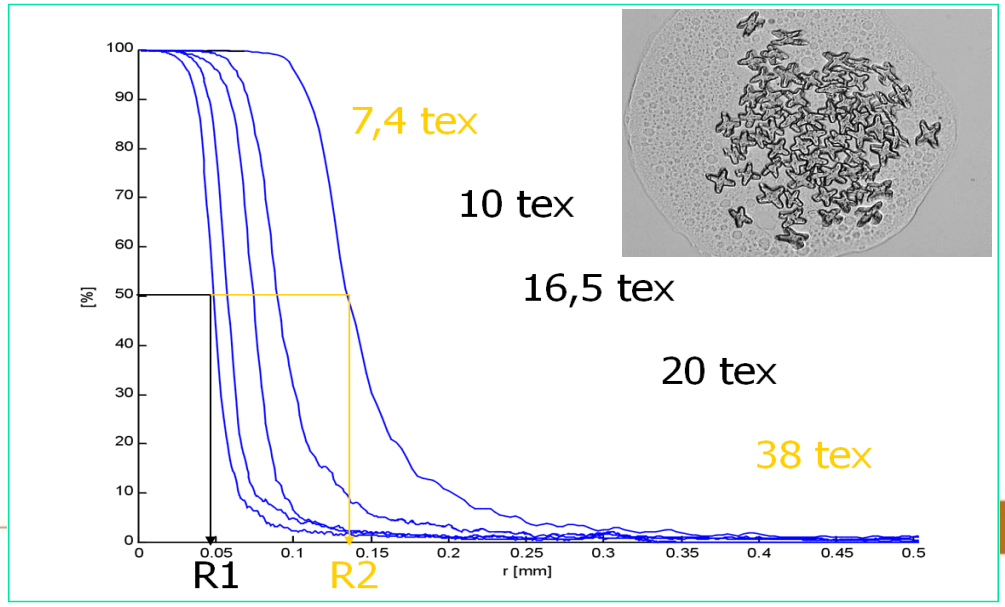




Yarn hairiness and packing density

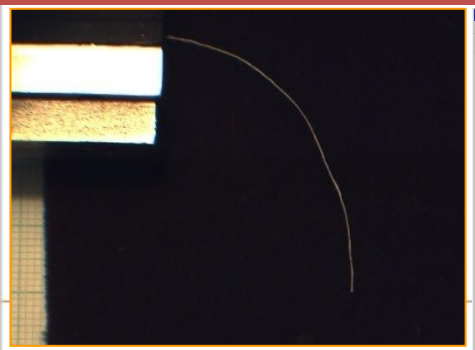






Bending rigidity

New device



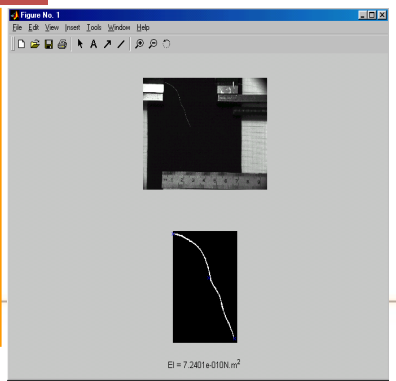
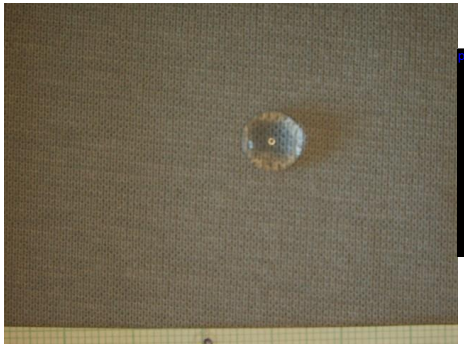
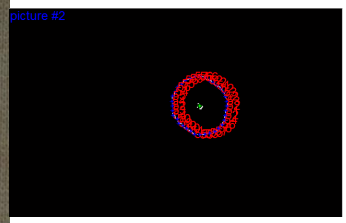


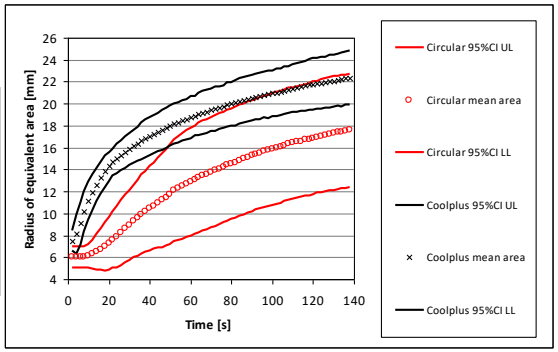
Image analysis and water spreading

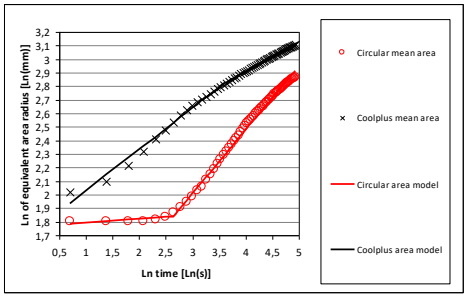
Moisture management tester

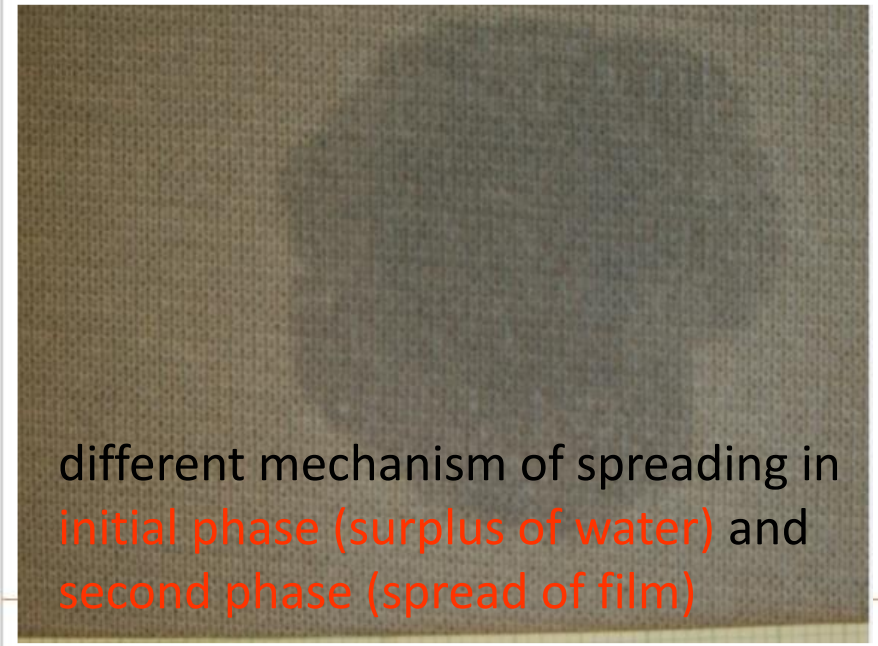
$$R_{Si} = \sqrt{S_i / \pi}$$



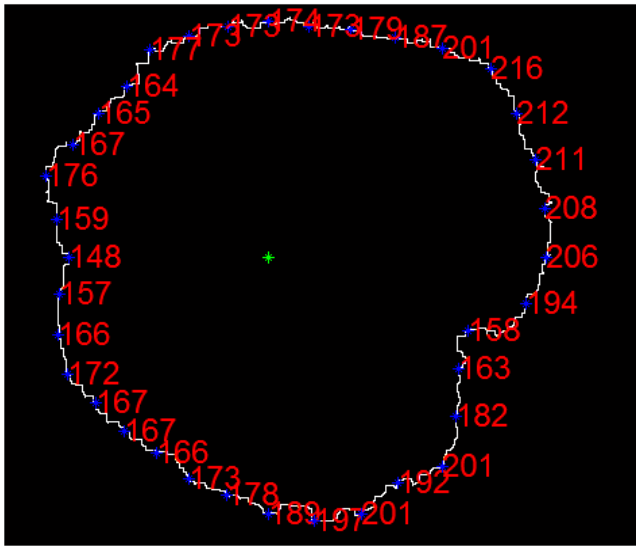


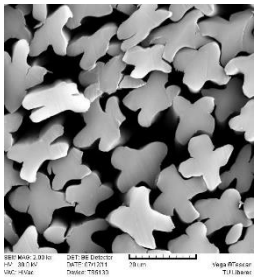


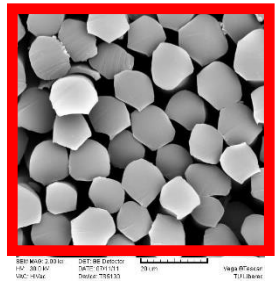




different mechanism of spreading in initial phase (surplus of water) and second phase (spread of film)



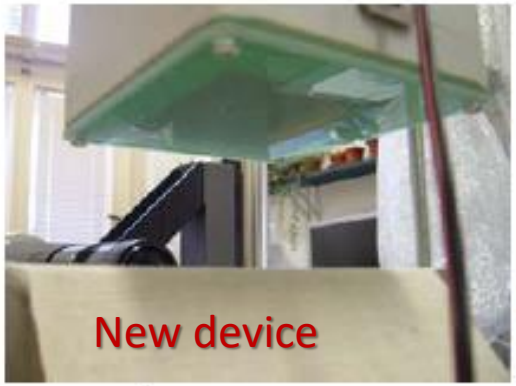


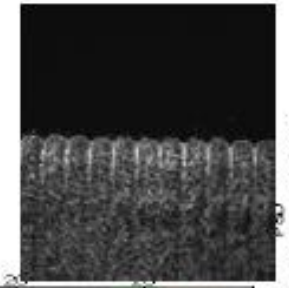


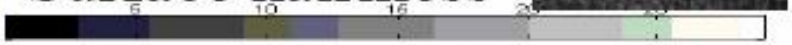
$$R(t) = R_1 t^n \quad \text{or} \quad \ln(R(t) = \ln(R_1) + n \ \ln(t)$$

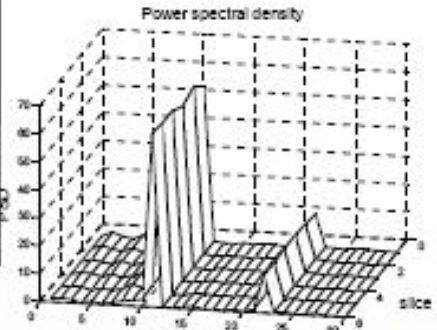
Textiles surface

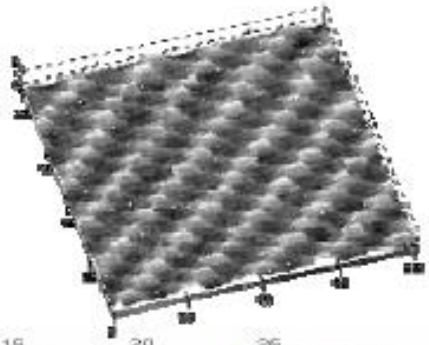
- Surface relief
- Surface roughness
- Surface evenness
- Surface faults
- Pilling
- Wearing
- Surface hairiness

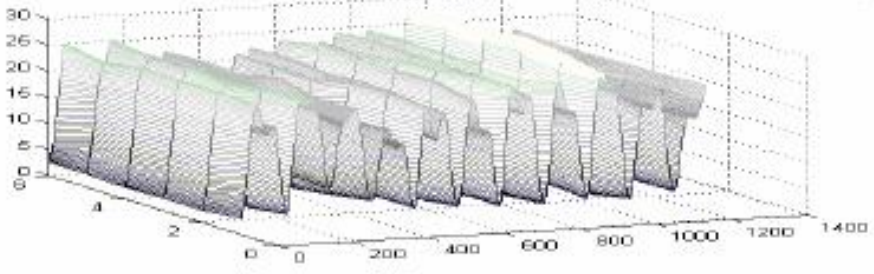


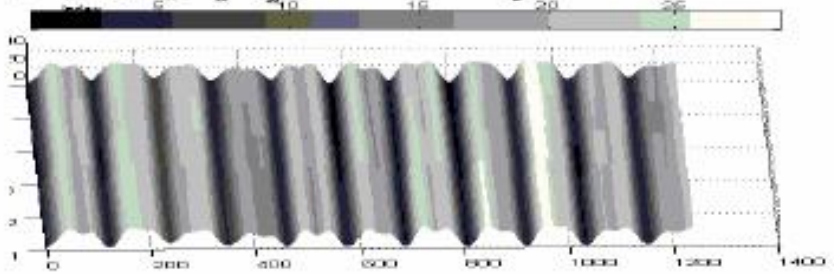


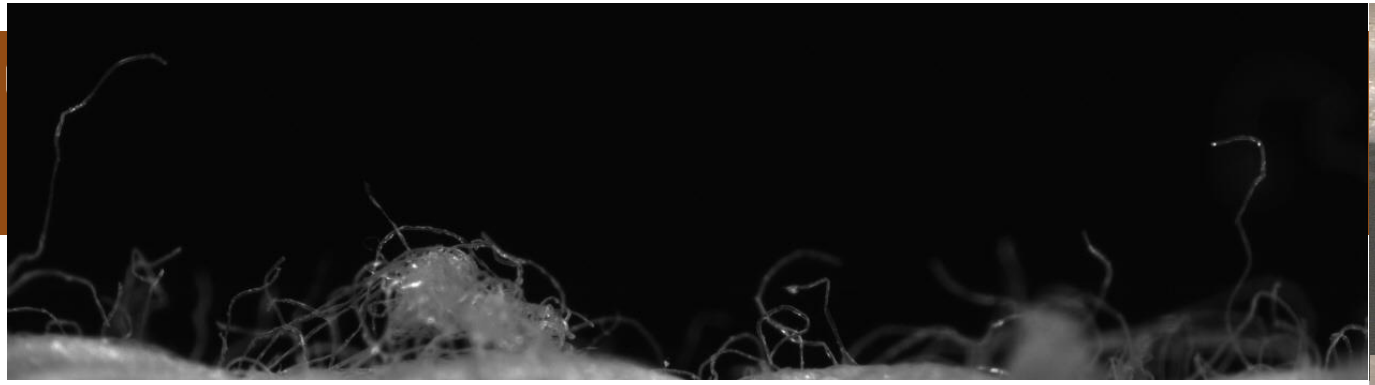


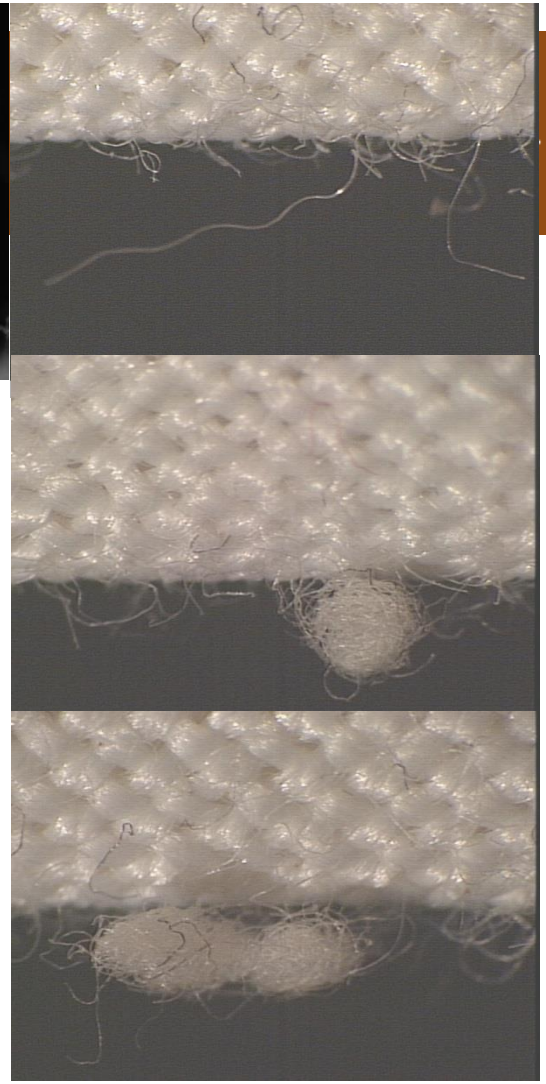




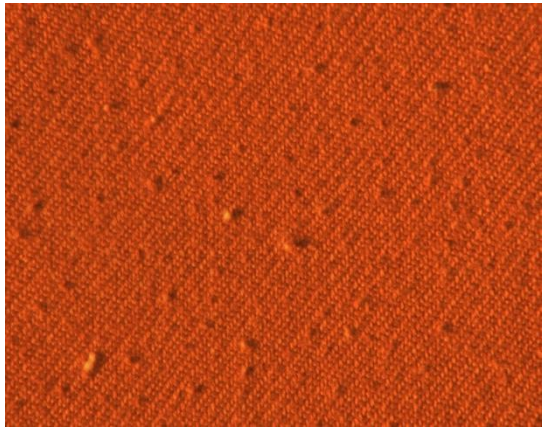


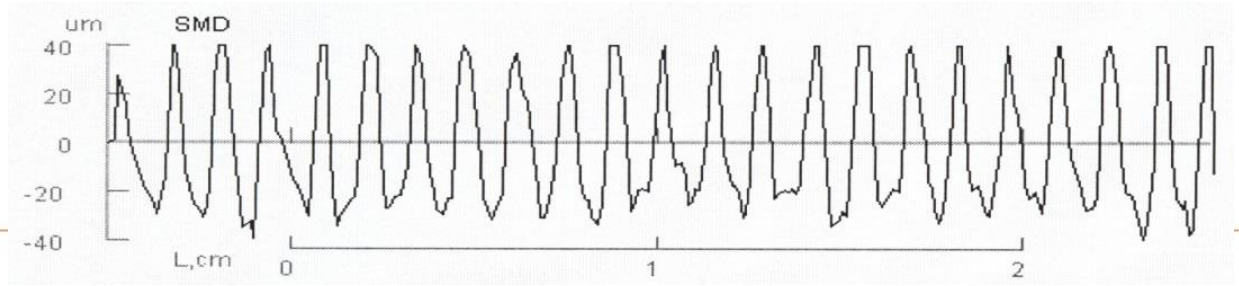




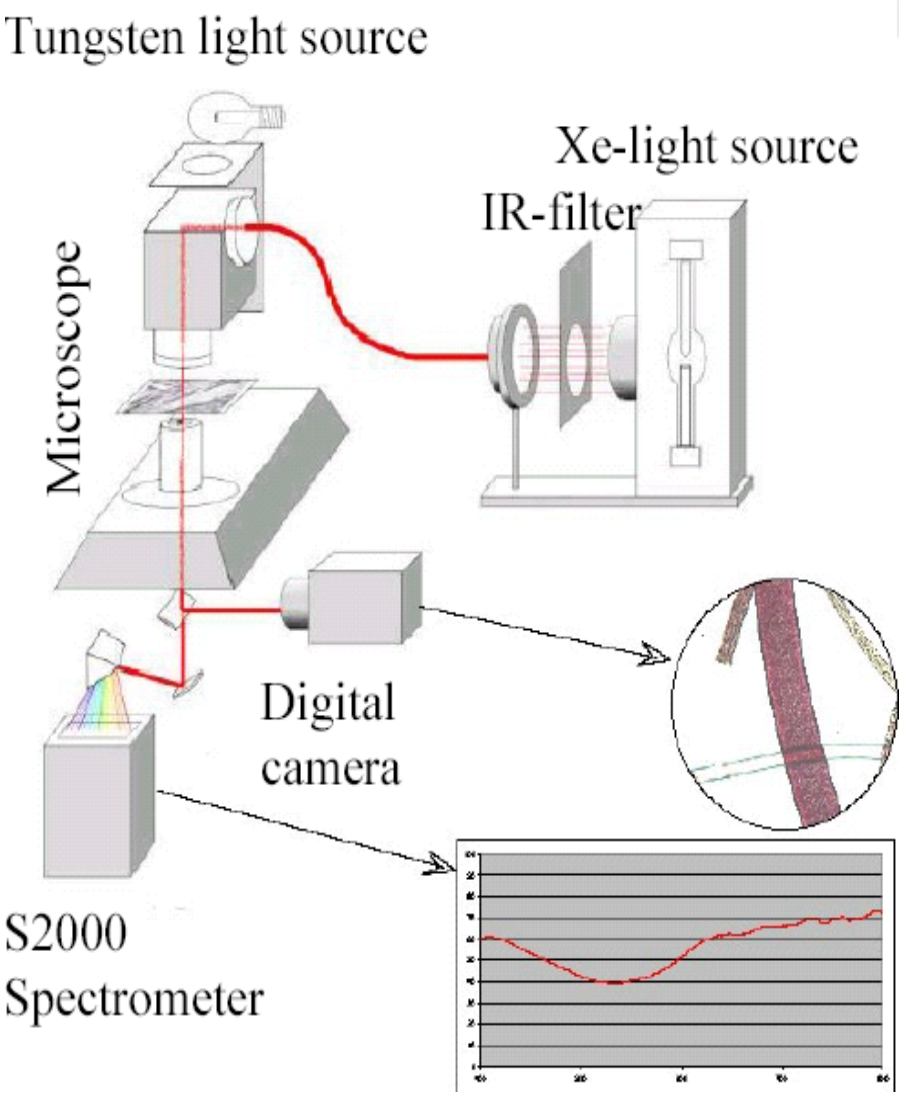


Fabric surfaces





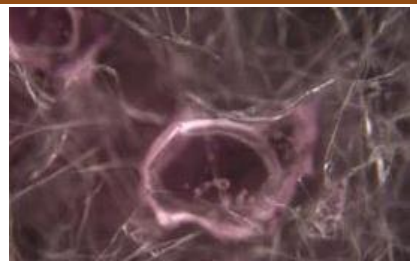
Objective color measurement

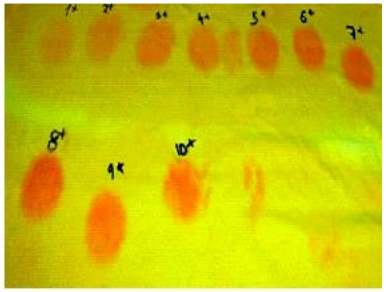


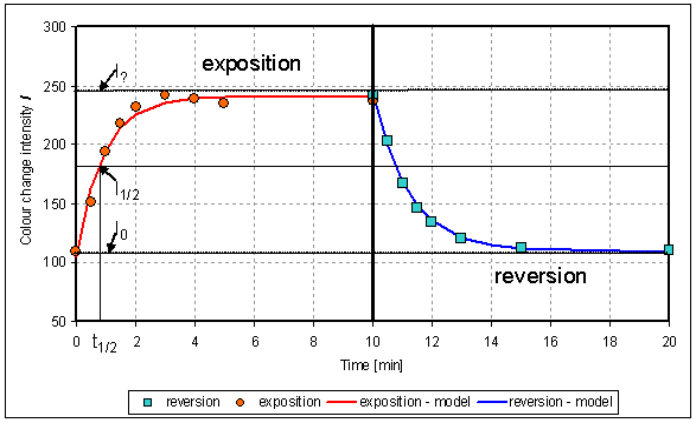
- Microspectrocolorimetry
- Camouflage materials
- Gas and UV color sensors
- Visual perception
- Spectroscopy from UV to IR range

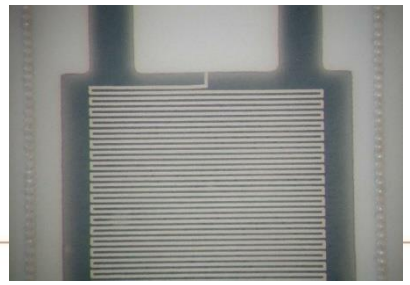
Textile sensors

- Properties of sensors and their selectivity (humidity, temperature).
- The ways of installation of sensors into textile structures.
- Testing the utility of sensors considering the wear and maintenance of textiles.
- Selection, verification and testing of chosen dyestuffs and filters for the design of textile UV radiation dosimeters.
- Selection, verification and testing of dyestuffs or substances for indication of bacteria and toxic agents.









Combined sensor of humidity and temperature

Controlled surface destruction

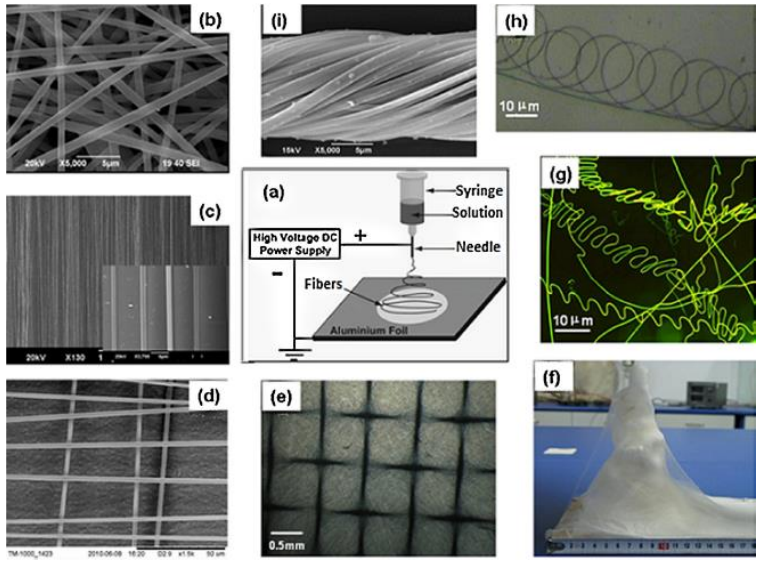
New measurements

Pattern creation, local yellowing, cutting of shapes

Smart microporous membranes with tunable structure prepared in electrostatic field

Main aim is to design and preparation of smart multilayered structures with mesoporous tunable porosity active membrane created in high voltage electrostatic field.

The nanoparticles based on TiO_2, SiO_2, POSS, metallic salts, milled basalt, activated carbon and aerogels mainly will be used for activation and achieving of special effects. The inner and outer layers of membrane system will be optimized according to protection against environment and according to comfort. The measurement methods for thermal comfort evaluation at extreme conditions, barrier functions and adaptive particle transport will be modified.



(b) electrospun polymer nanofiber mesh without orientation, (c) parallel and (d) crossed fiber array, (e) patterned fiber web, (f) 3D fibrous stack, (g) wavy and (h) helical fibers, and (i) twisted fiber yarns

Birth of Nanofibers

https://www.youtube.com/watch?v=Hr9qWgFmii0

Nanospider

https://www.youtube.com/watch?v=8xptinM9qn4

References

- A. Richard Horrocks and Subhash C. Anand, Handbook of Technical Textiles, Woodhead Publishing Series in Textiles, 2016, 2nd edition, ISBN 9781782424581, https://doi.org/10.1016/B978-1-78242-458-1.10000-7.

Textile Engineering

KMI-TEN (Practice)

Part 1: *Introduction and Textile Structures*

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