

Funktionale Textilien dank Nanotechnologie

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Nanotechnologie, ihre Produkte und Risiken für den Verbraucher

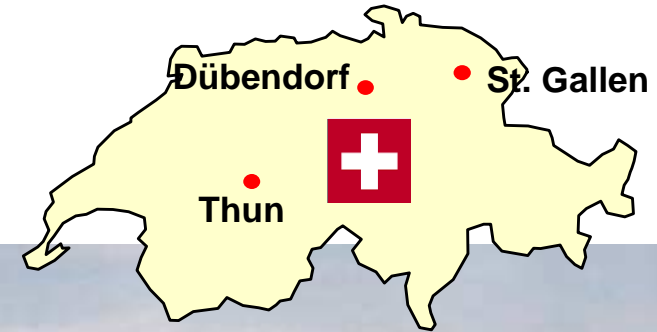
28. März 2006, BfR, Berlin



EMPA – Materials Science & Technology

Member of the ETH Domain in Switzerland
820 employees at three sites

→ R&D for SMEs



Empa Laboratory

Functional Fibers and Textiles

% Fiber and Textile Chemistry

- finishing, wet-chemical treatment



% Fiber Development

- bi-component fiber spinning device



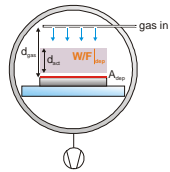
% Plasma-modified Surfaces

- cleaning, activation, deposition



Outline

Functional Textiles thanks to Nanotechnology



% Dimensions

% Nanoscaled coatings

% Nanostructuring with particles

% Incorporation of nano particles

% Applications

Functional Textiles thanks to Nanotechnology

Nanostructures and dimensions (<100 nm)

1-dimensional

%nanoscaled coatings on fibers and textiles

(by plasma coating or wet-chemical grafting)

2-dimensional

%nanostructures on fibers and textiles

(by etching, embossing or nanoparticle incorporation at the surface)

%nanofibers (by electrospinning)

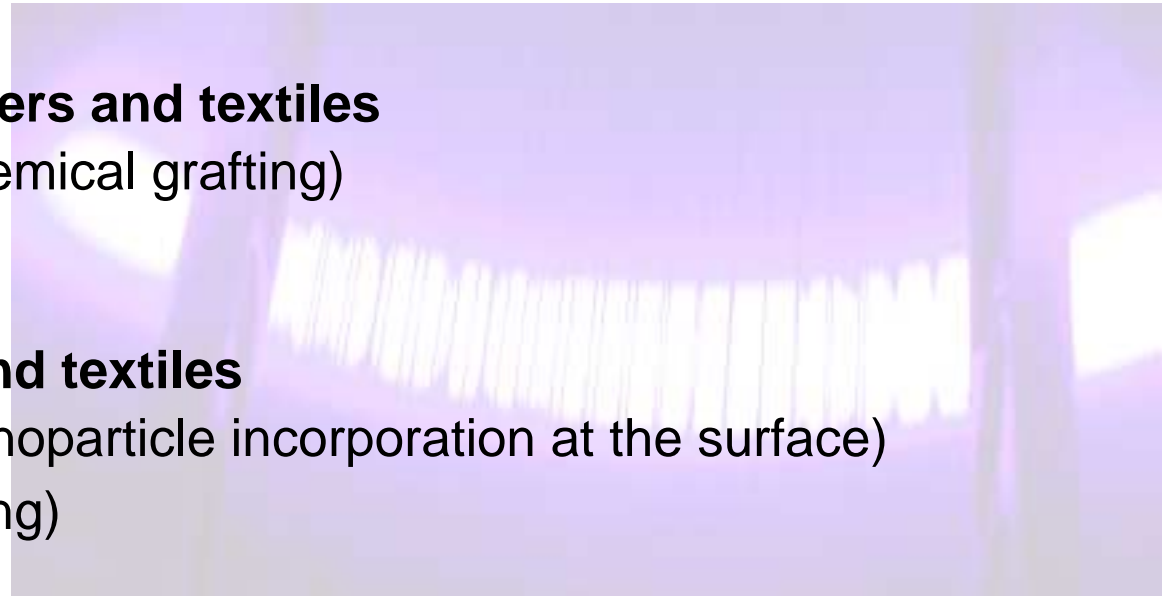
3-dimensional

%nanoparticles in fibers and textiles

(by incorporation in plasma coatings or during fiber spinning)

%nanoporous coatings

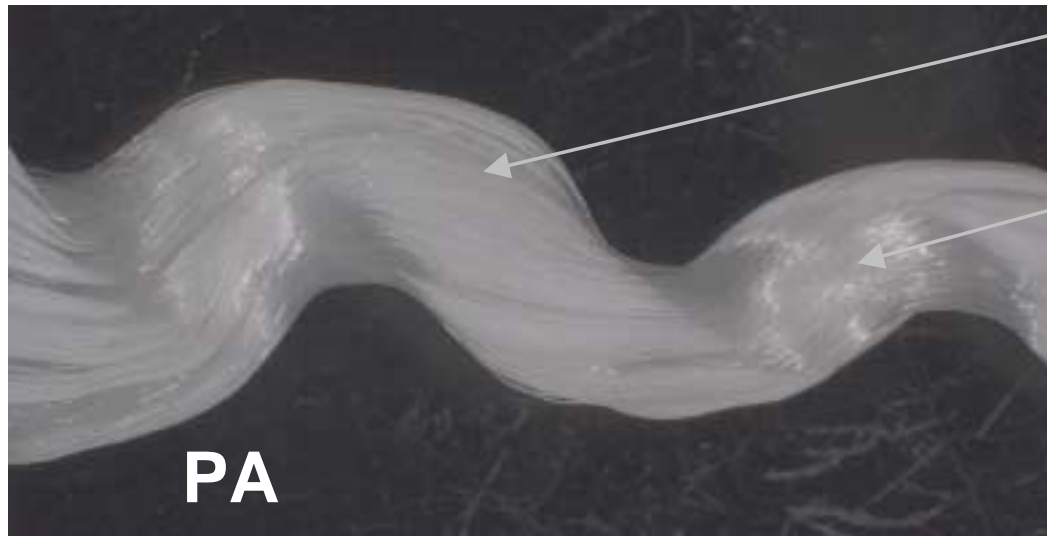
→ New material properties of textiles



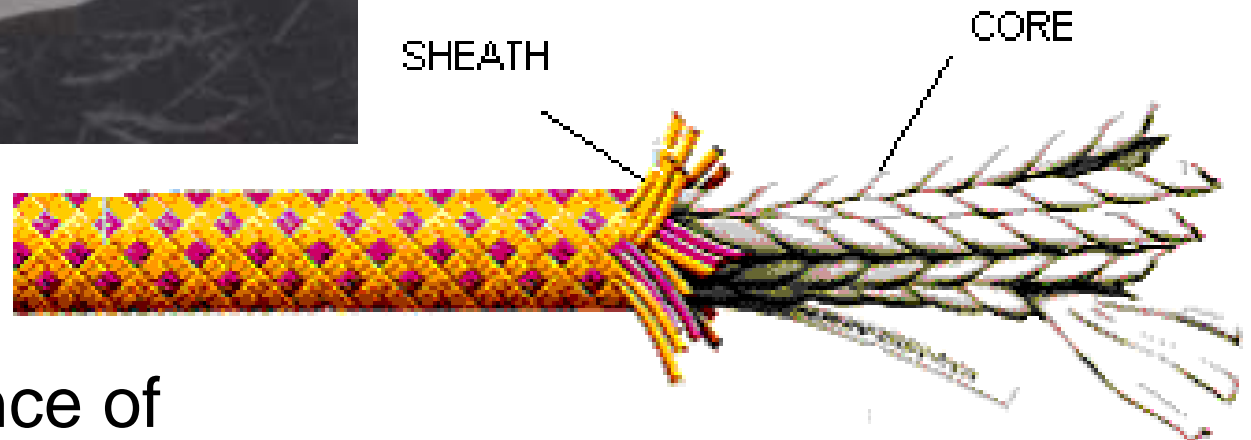
Nanoscaled Coatings

Self-assembled monolayers (SAMs) on ropes

Grafting of fluoroalkyltrichlorosilanes



? water repellency



Loss of the performance of wet climbing ropes can be avoided.

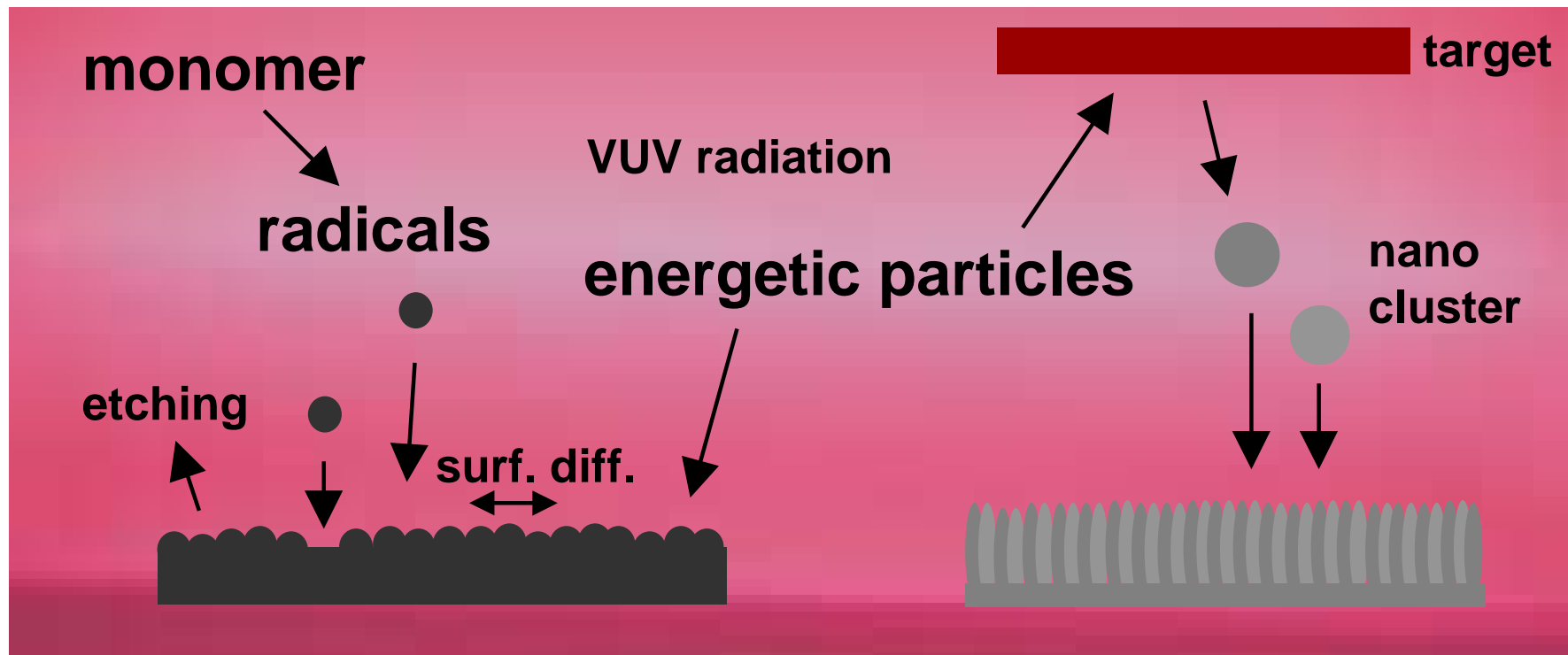


Nanoscaled Plasma Coatings

Plasma CVD and PVD – layer by layer growth

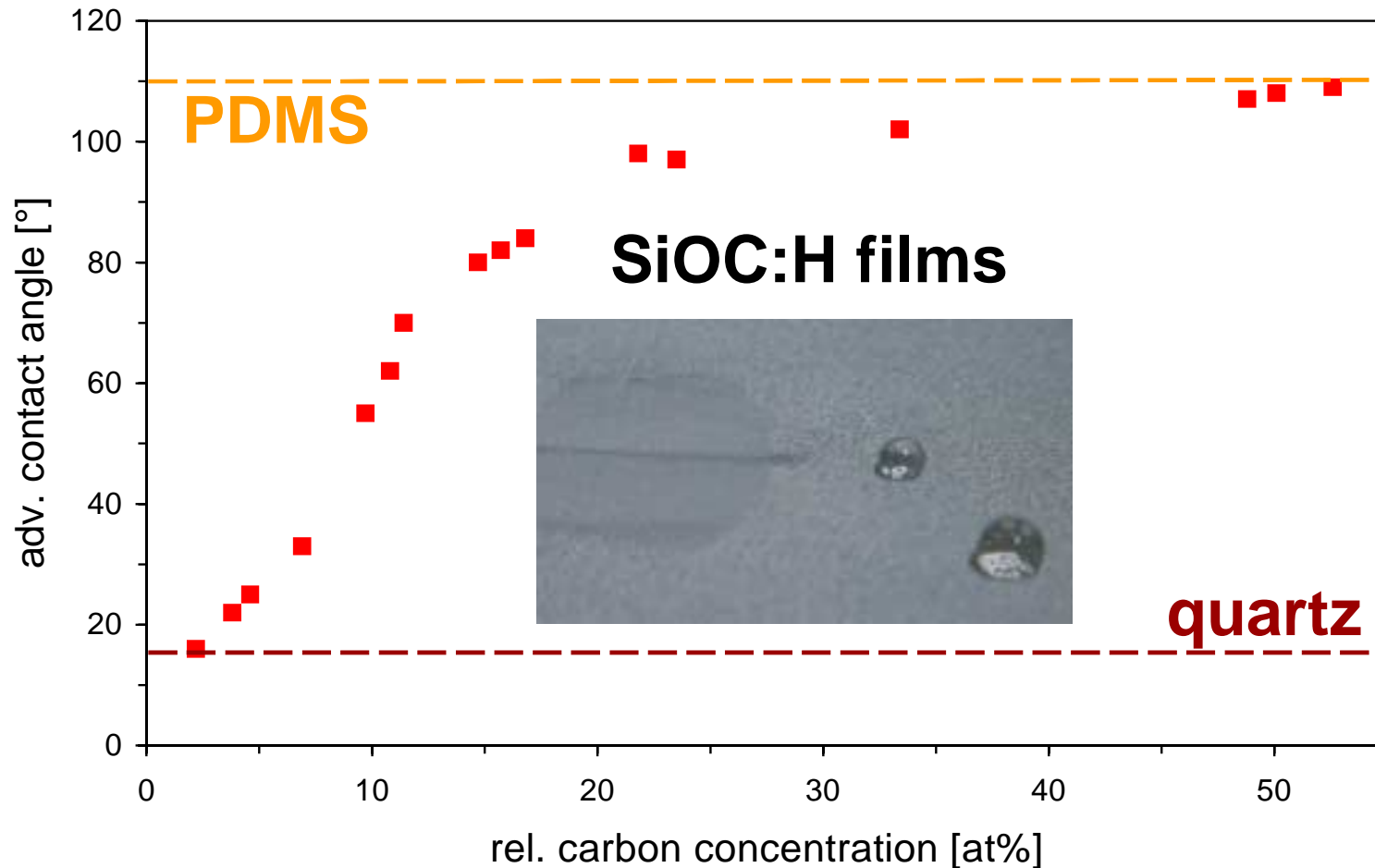
plasma polymerization

sputtering

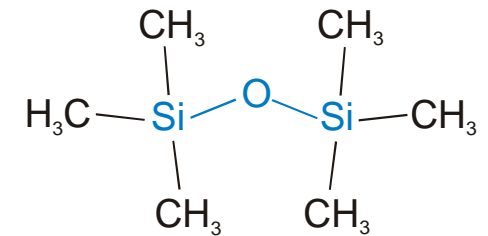


Plasma Polymerization

Control of wetting properties by O₂/HMDSO coatings



O₂/HMDSO



The residual C concentration also scales with the crosslinking and thus the permeability

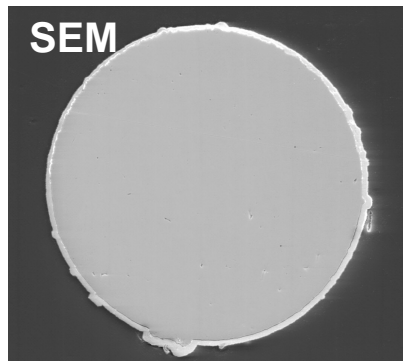


Plasma Sputtering

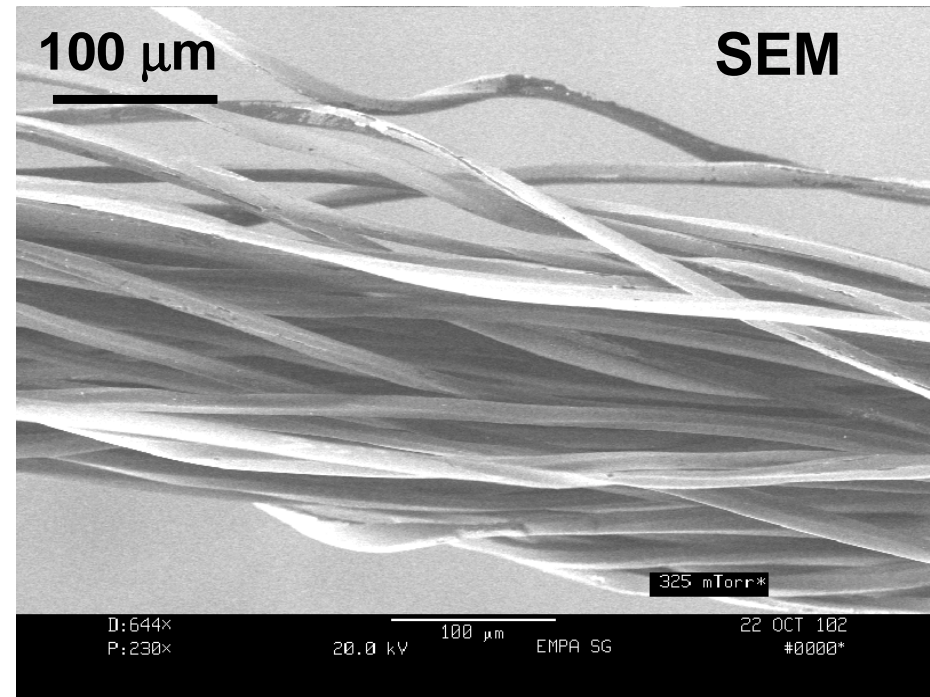
Nanoscaled metallization of fibers

Development of electrically conducting, anti-static fibers:

- metallization with Ag, Al, Ti etc.
- homogeneous coatings
- textile properties are unaffected



→ **medical textiles, occupational safety & health, wellbeing**



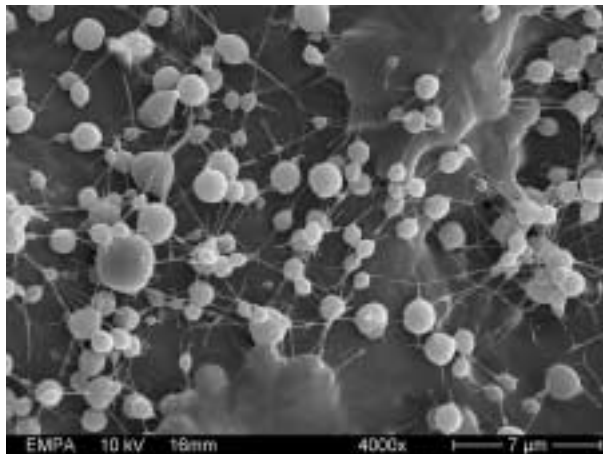
metal-coated multifilament

$\rho = 10..10^5 \Omega/\text{cm}$ (coated)

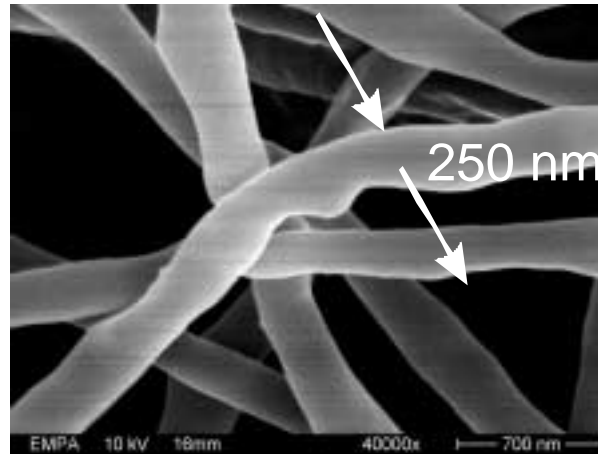
$\rho \sim 10^{11} \Omega/\text{cm}$ (non-coated)

Nanofibers by Electrospinning

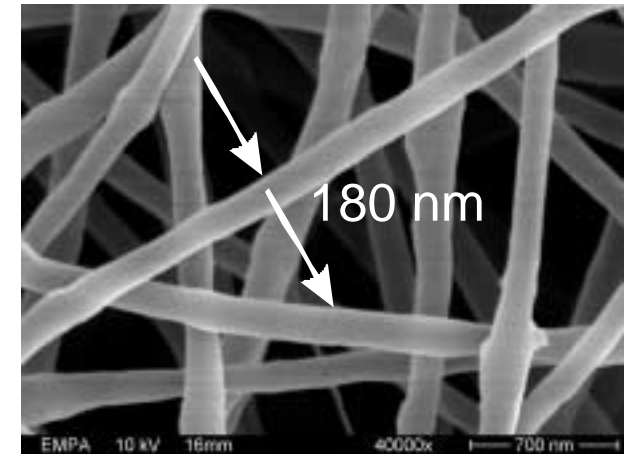
Influence of solvent and voltage



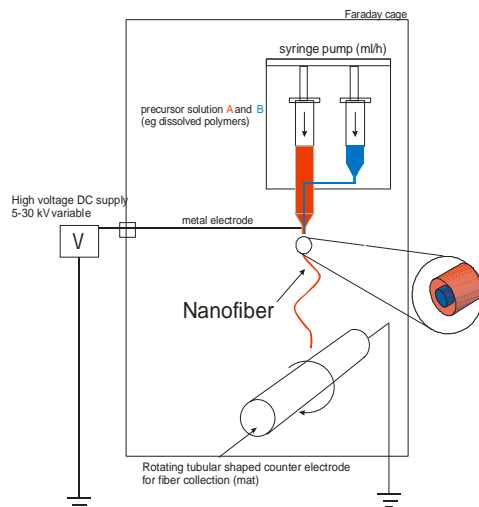
2.5% PEO in H₂O, 15 kV



7 % PEO in H₂O, 15 kV



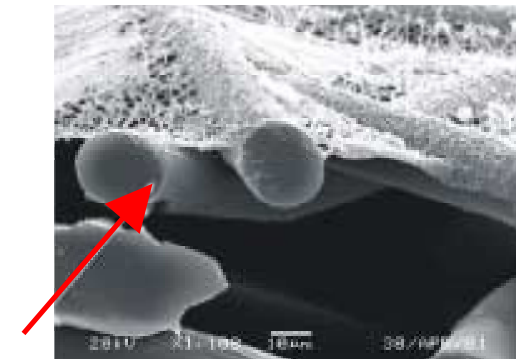
7 % PEO in H₂O, 25 kV



possible application

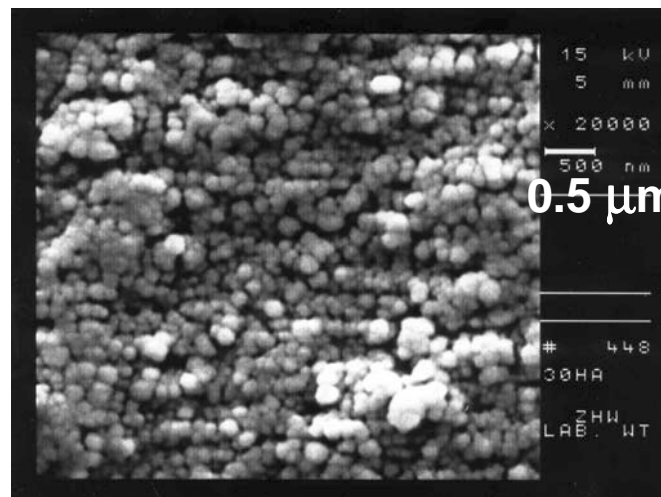
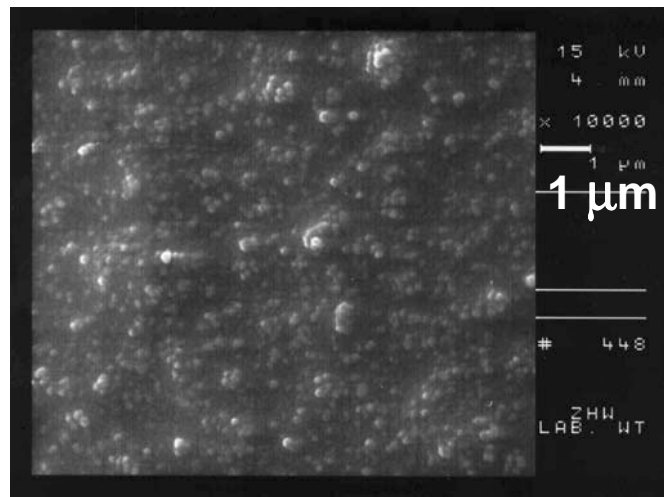
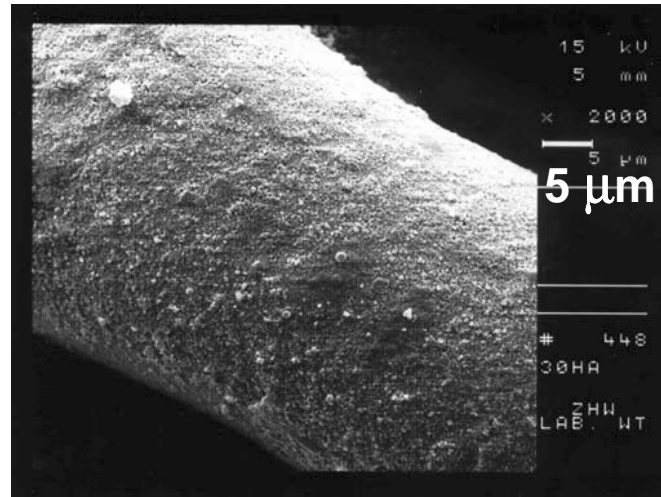
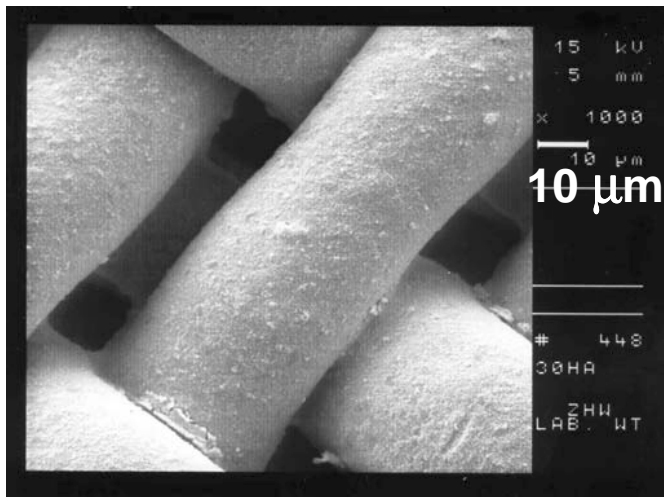
air filtration

nano-fibrous web on fabric



Nanostructuring of Surfaces

Nano particles embedded in wet-chemical coatings



SEM pictures

possible application
stain repellency

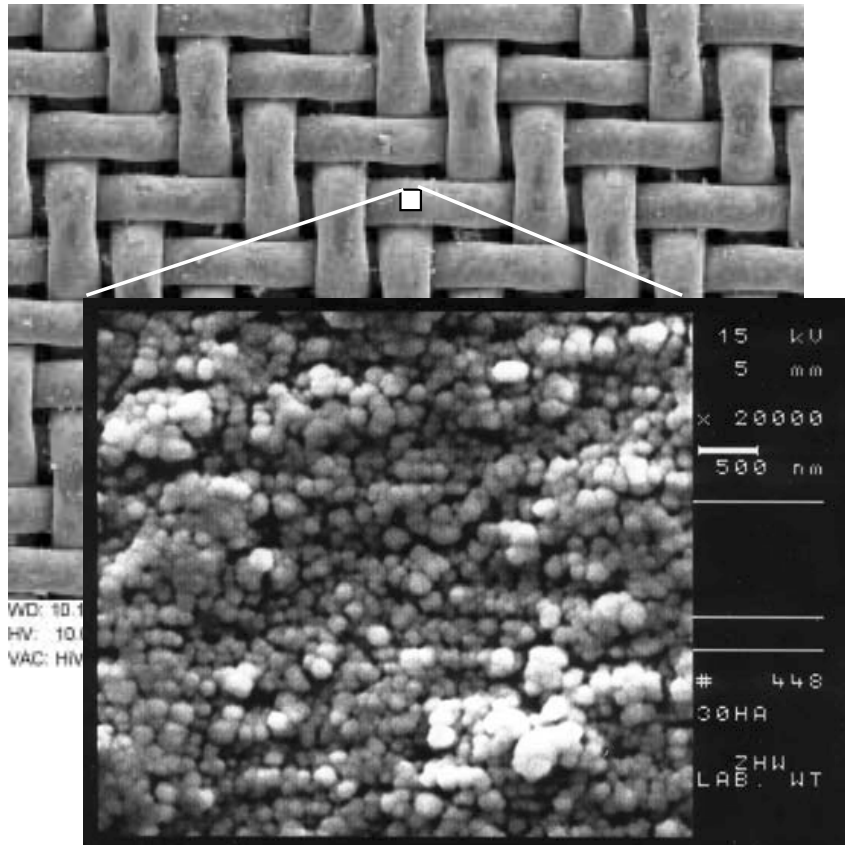


Zürcher Hochschule Winterthur
Z:W

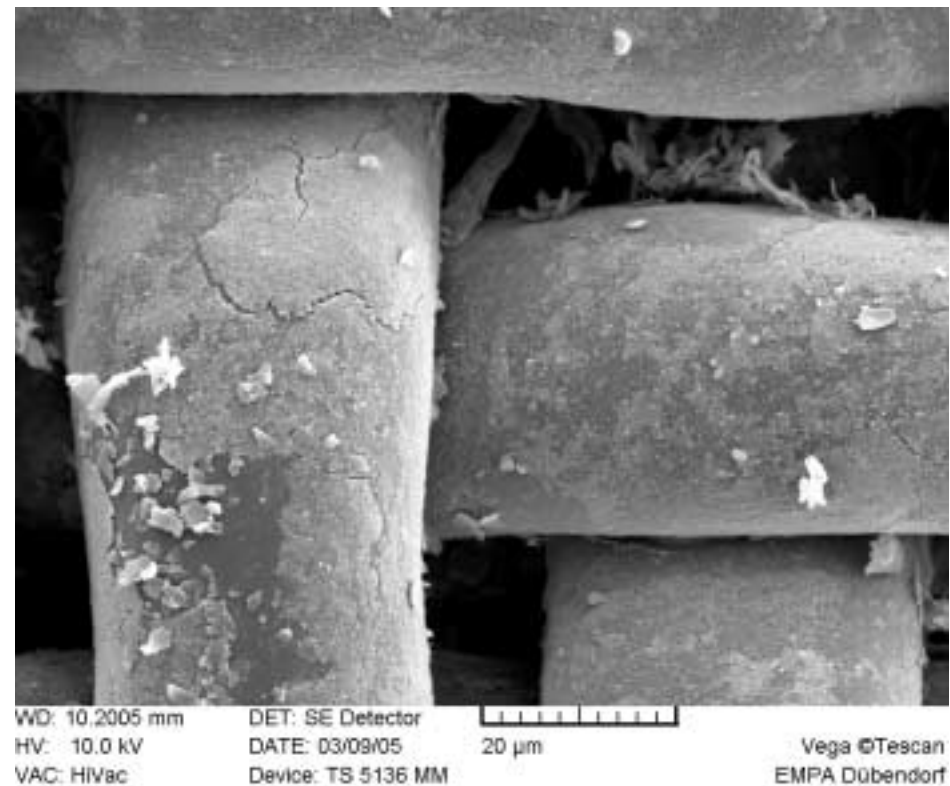
EMPA 

Nanostructuring of Surfaces

Coating failure with a high content of nano particles

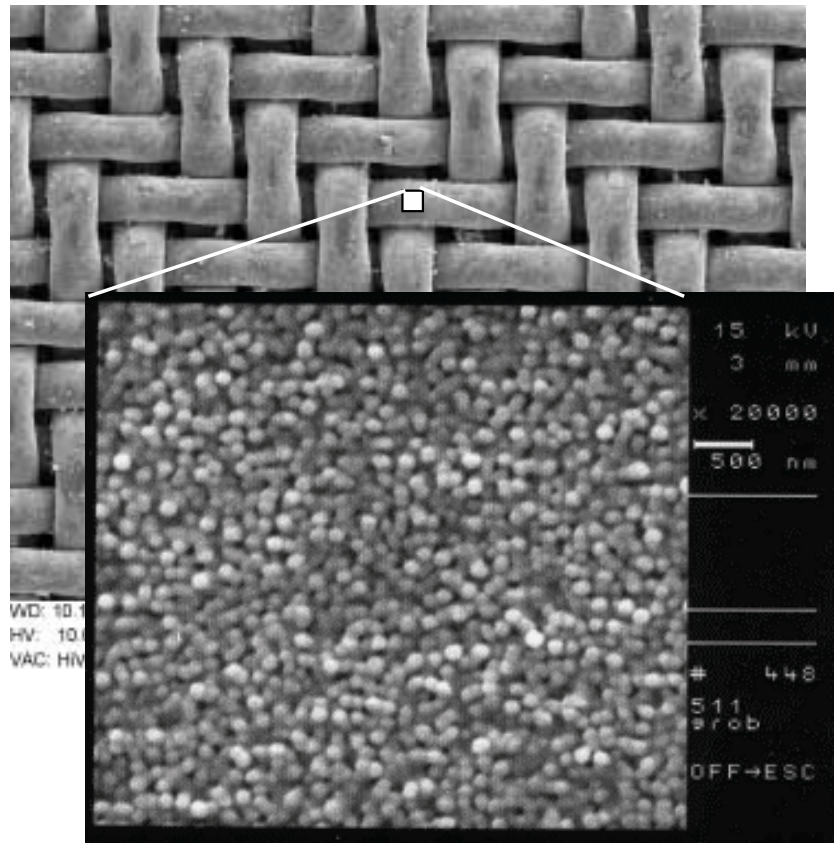


SEM pictures

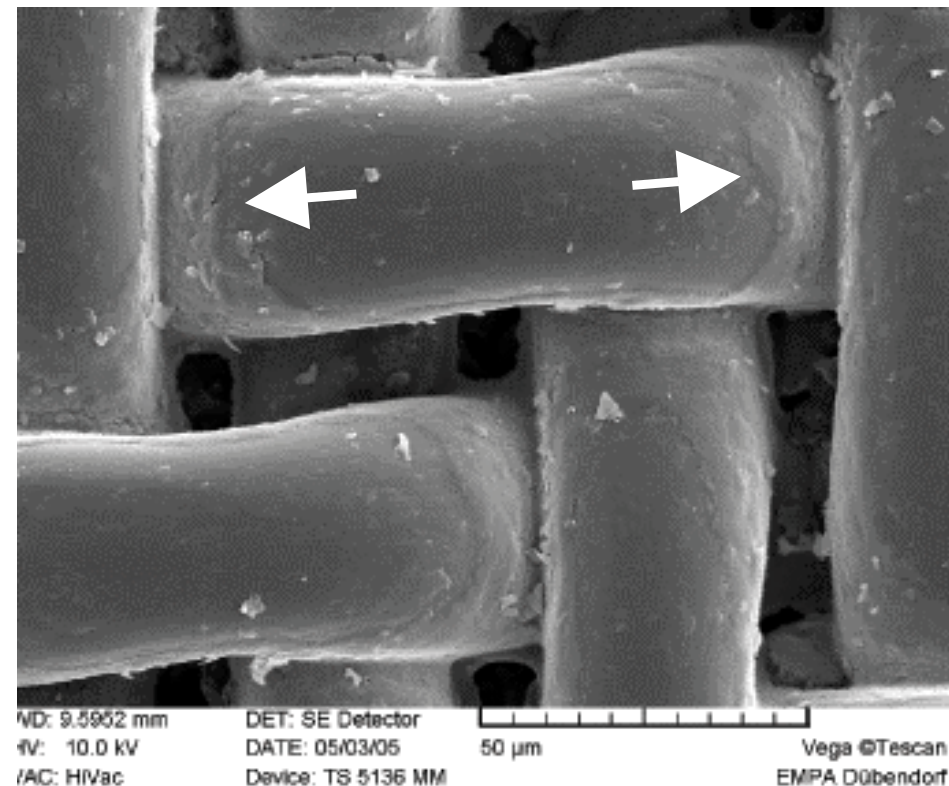


Nanostructuring of Surfaces

Abrasion of nano particle containing coatings

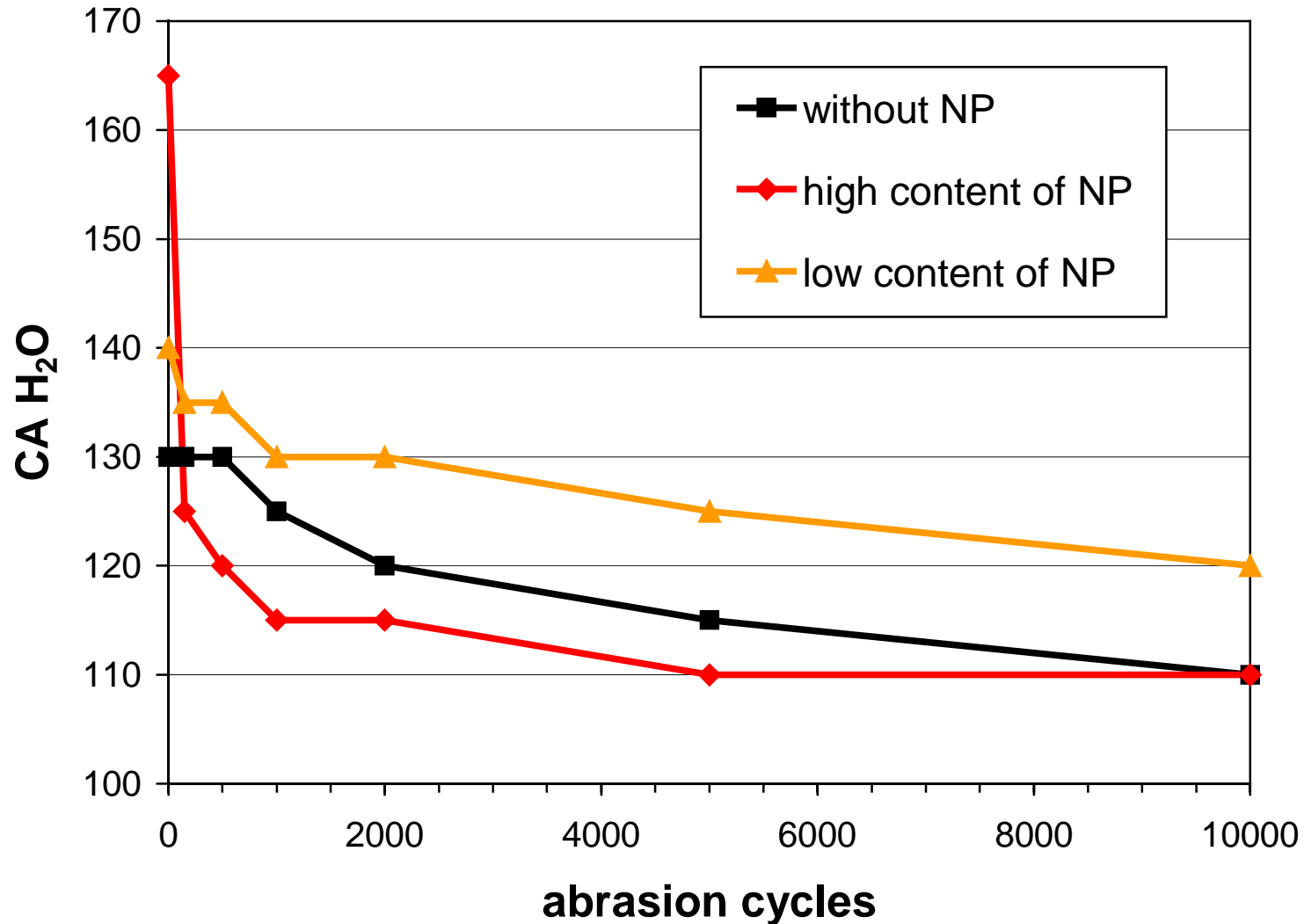


SEM pictures



Nanostructuring of Surfaces

Abrasion of nano particle containing coatings



A suitable content of nano particle incorporation can enhance the abrasion resistance of water repellent coatings.

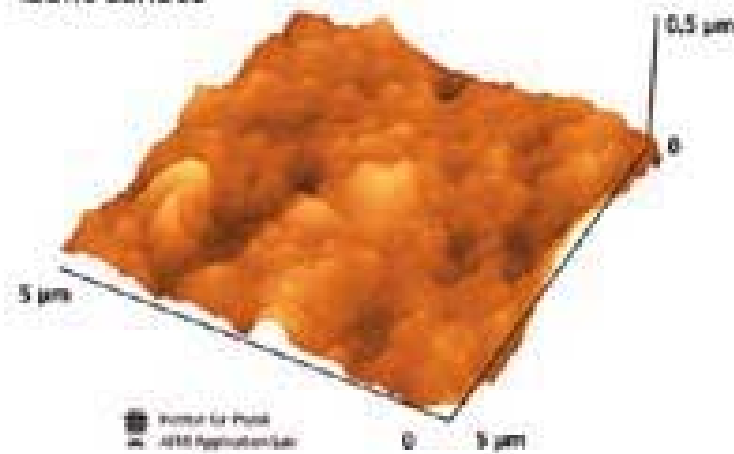
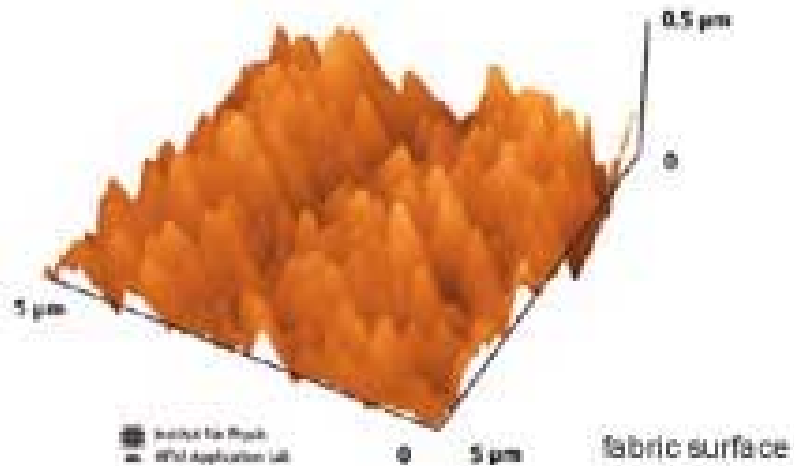
Martindale test



schoeller® Switzerland

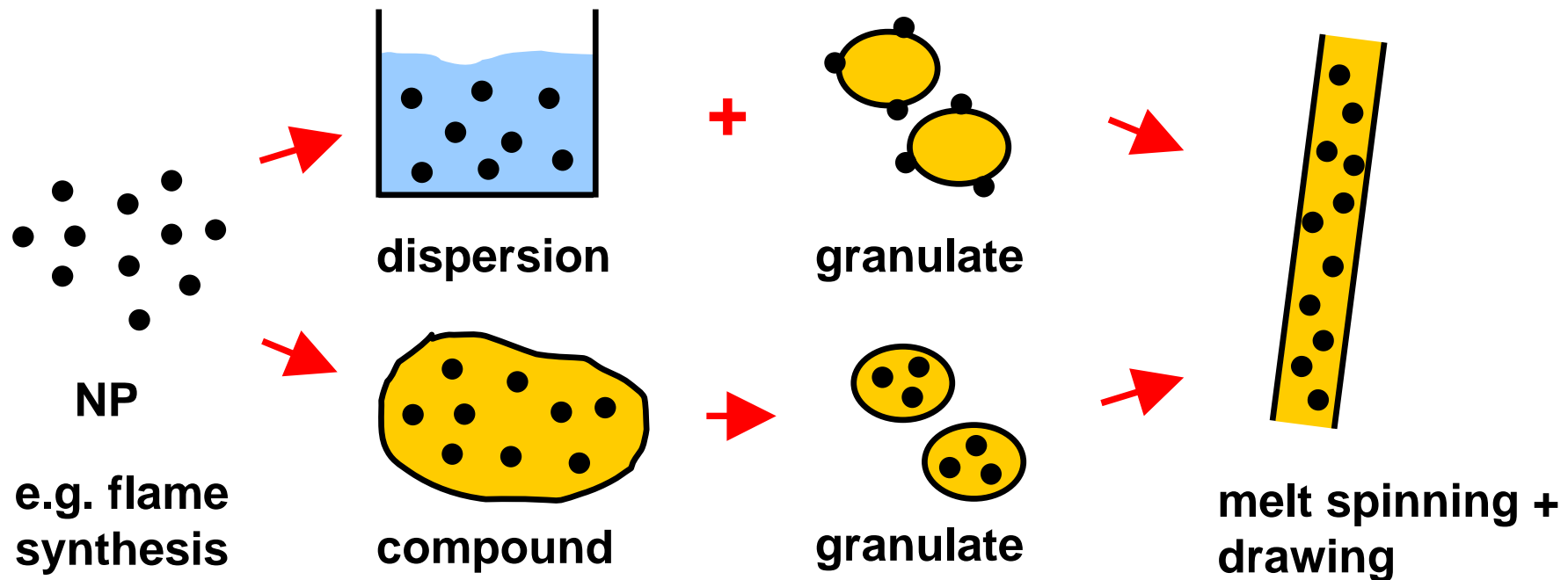
Patented technology

- NanoSphere® it's naturally selfcleaning



Incorporation of Nano Particles into Fibers

Handling of nano particles



SiO_2 : stiffness

ZnO : UV blocking agent

TiO_2 : photocatalysis

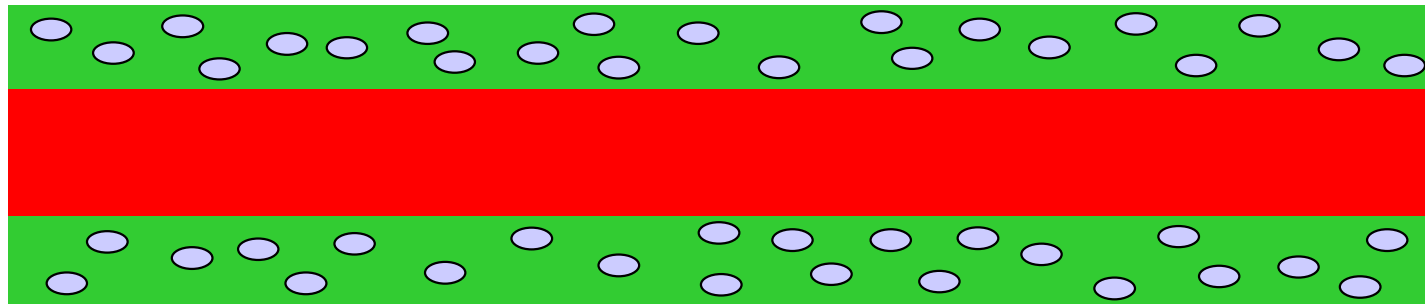
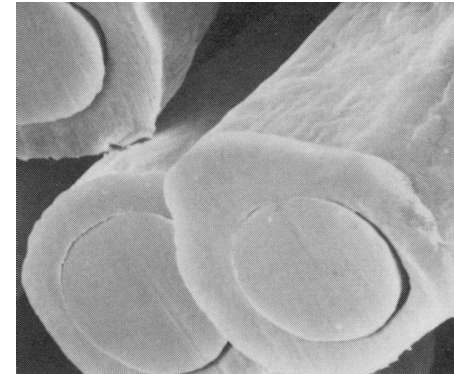
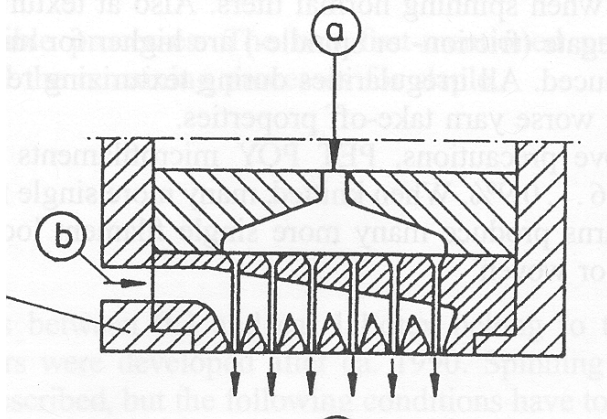
Ag: anti-odor, antimicrobial agent

nano clay: FR

CNT: strength, FR

Bi-component Fiber Spinning

Core/sheath structures loaded with nano particles



○ nano particle ■ degradable polymer ■ durable polymer

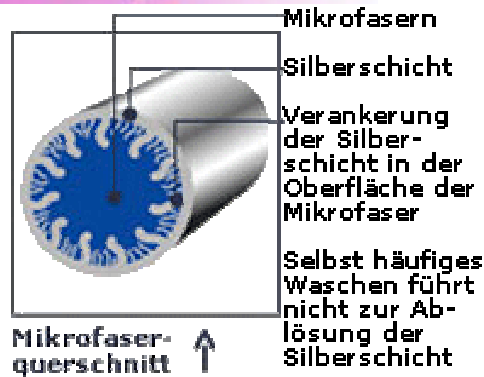
possible applications

Drug release; Flame retardancy

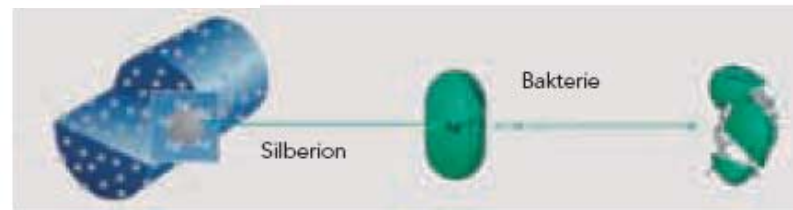


Ag Nano Particles and Coatings

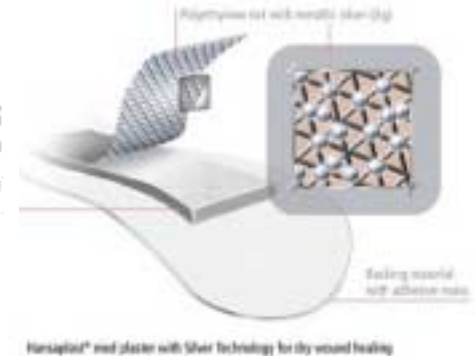
Wound dressings, socks, underwear etc.



Trevira
THE FIBRE COMPANY



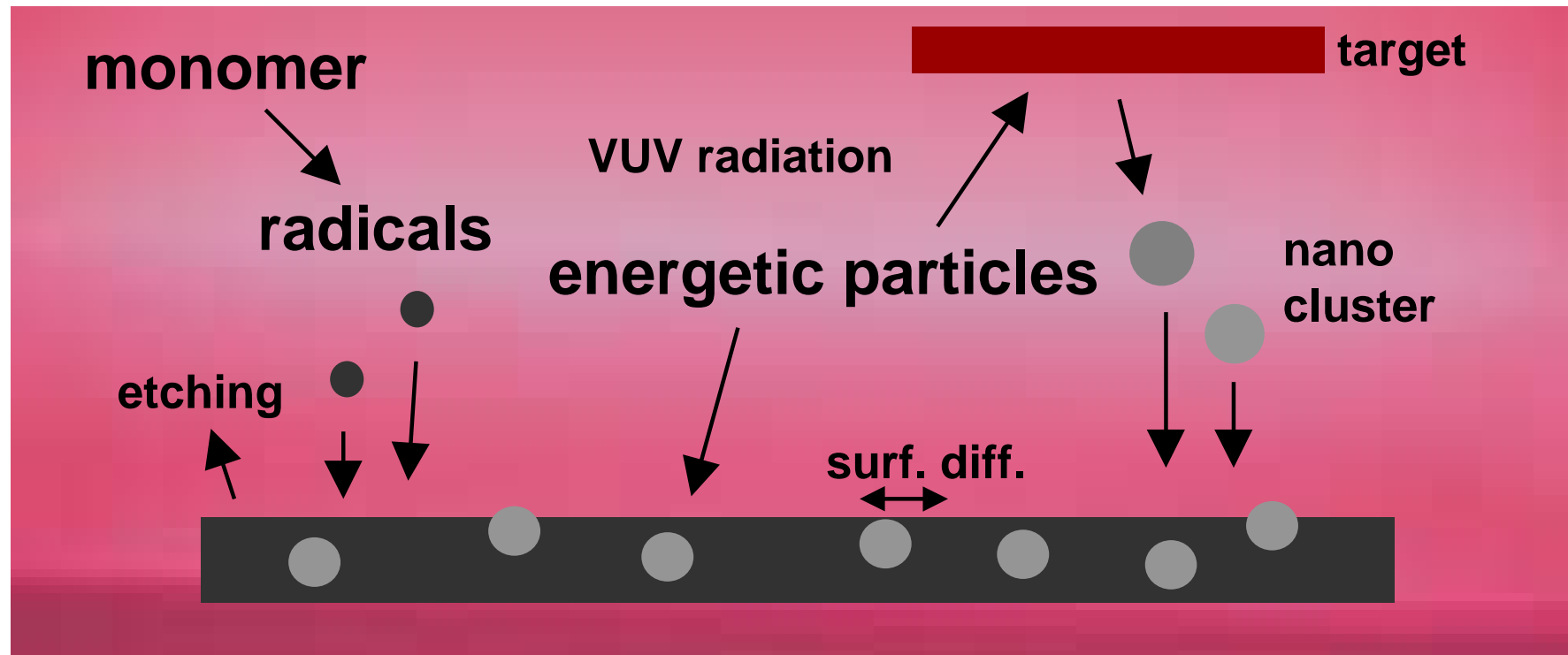
SoleFresh™
Nano-silver Socks
Click to purchase now



Nano Particle Containing Plasma Coatings

Combination of plasma CVD and PVD

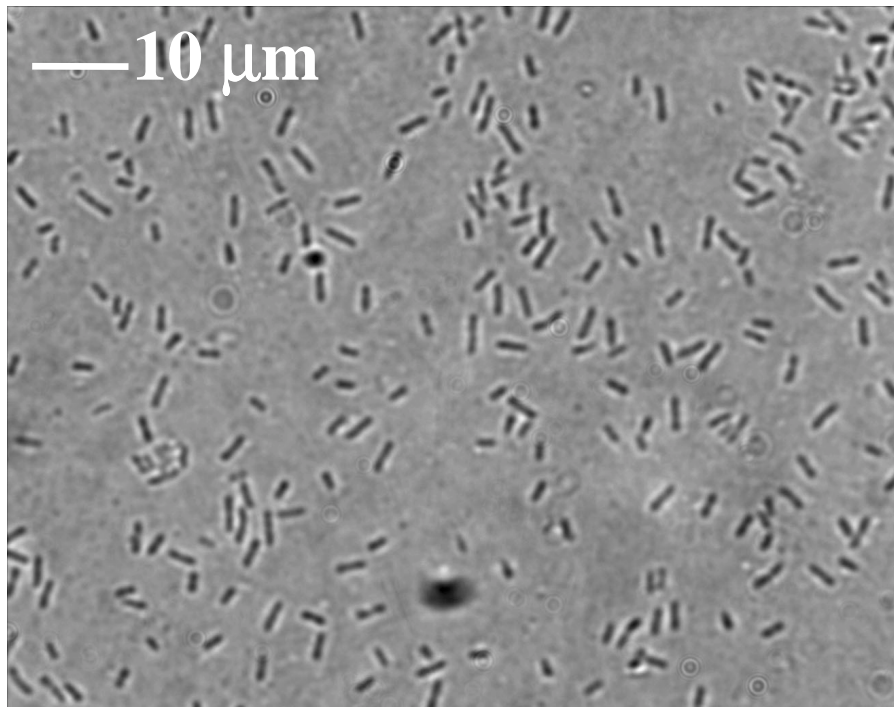
plasma polymerization + sputtering



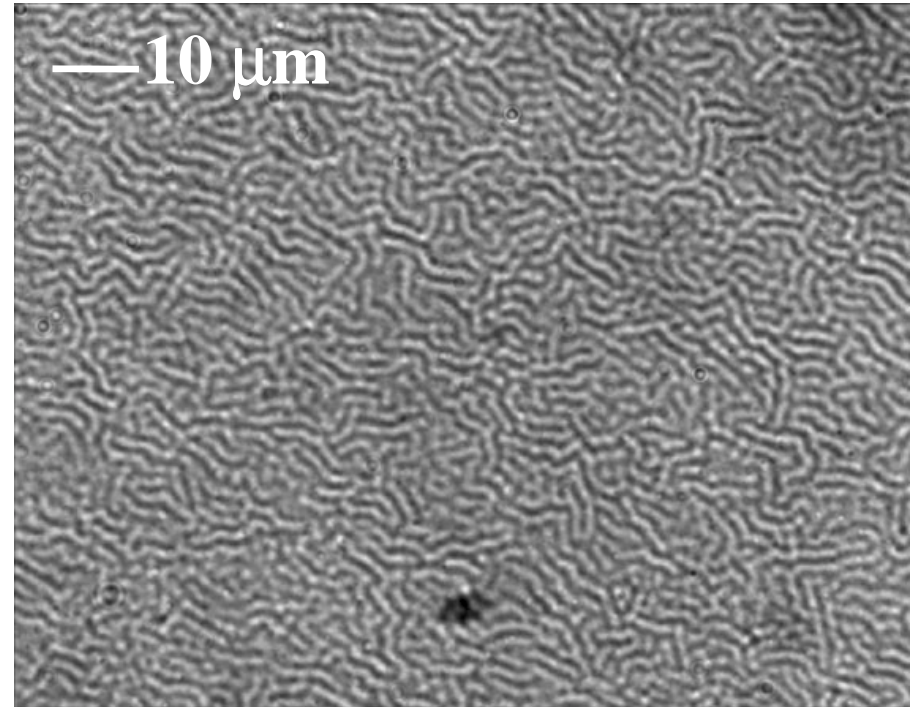
? in-situ incorporation of nano particles
(10..100 nm)

Ag/PEO-like Coatings

Anti-microbial treatment



adhesion of *P. aeruginosa*
on native PVC



non-fouling Ag/PEO-like
surface

D.J. Balazs et al., in: Plasma Processes and Polymers, ed. R. d'Agostino et al.,
Wiley-VCH, Weinheim, 2005, p. 351.



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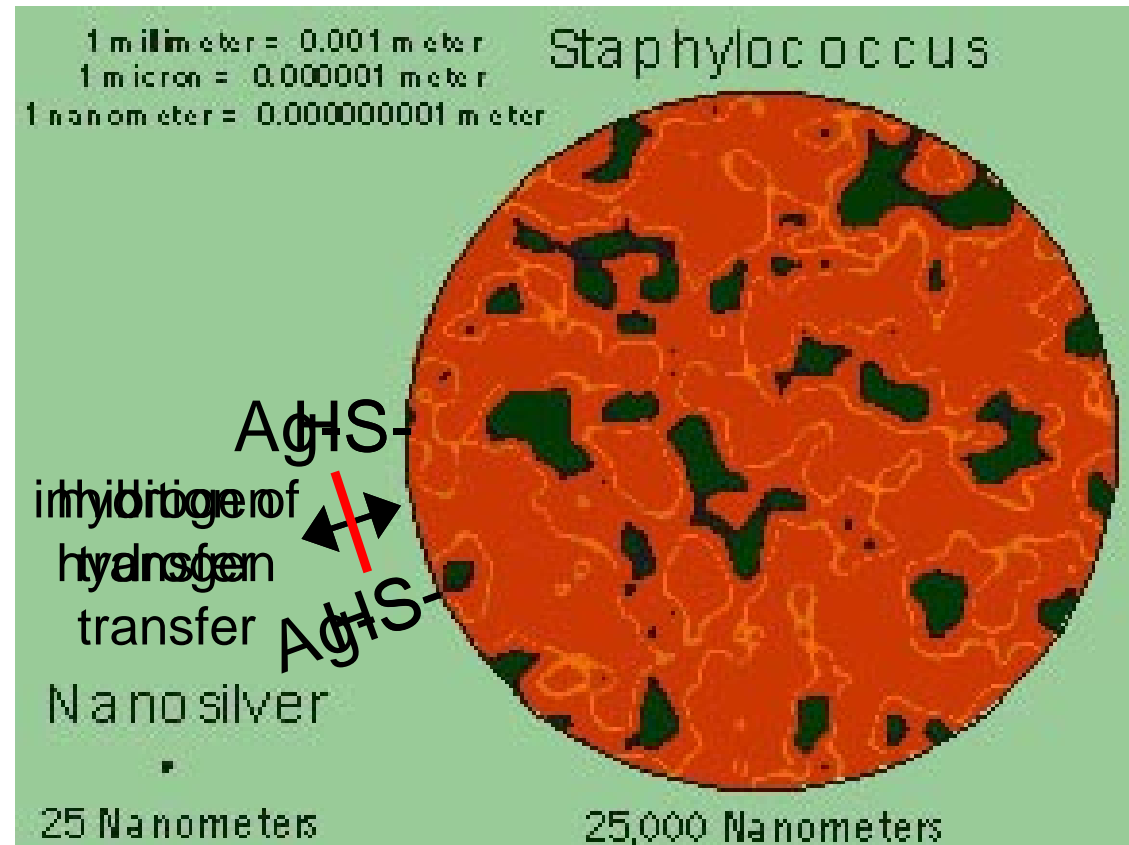
Ag/PEO-like Coatings

Incorporation of silver nanoparticles

plasma copolymerization:

embedding of Ag
particles (by sputtering)
into a plasma-
polymerized PEO-like
matrix

→ germicidal properties
of Ag^+ ions in swollen
state



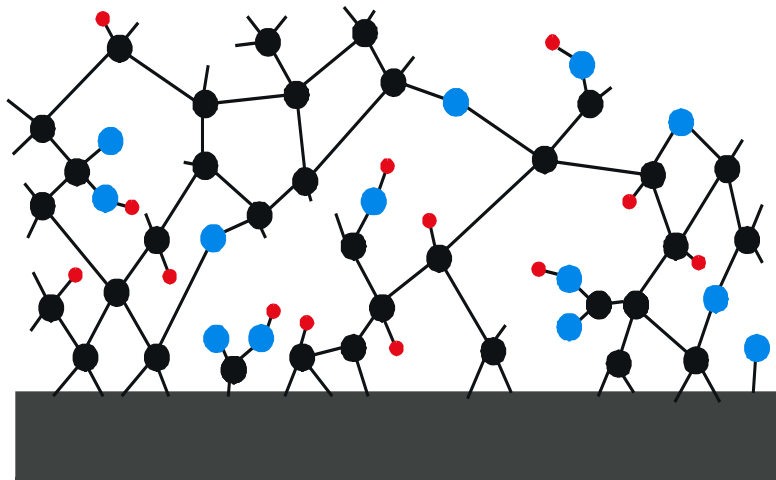
D.J. Balazs et al., in: Plasma Processes and Polymers, ed. R. d'Agostino et al.,
Wiley-VCH, Weinheim, 2005, p. 351.

Functionalized Coatings

Retention of functional groups during plasma deposition



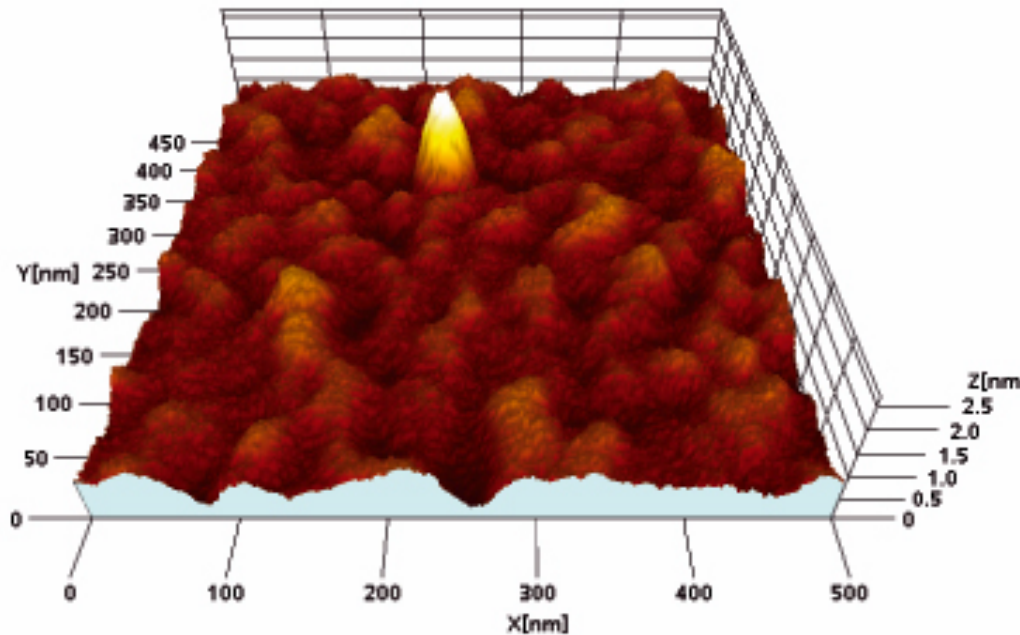
→ specific functionalization



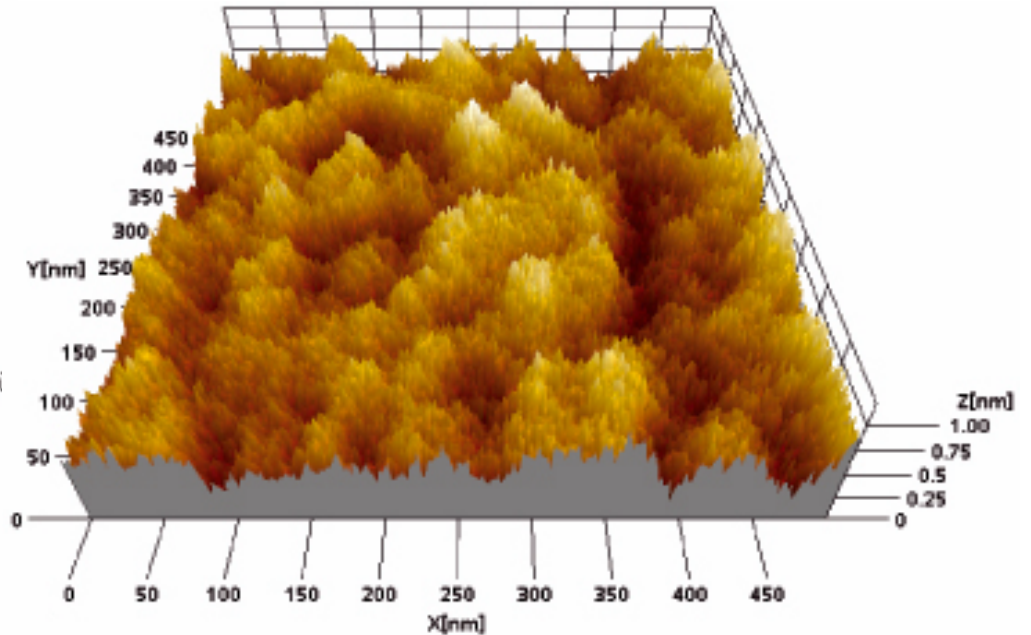
nanoscaled coatings
with accessible
functional groups
within nano-porous
structure

Deposition of Nano Porous Coatings

Functionalized coatings



amino-functionalized (65 nm thick)

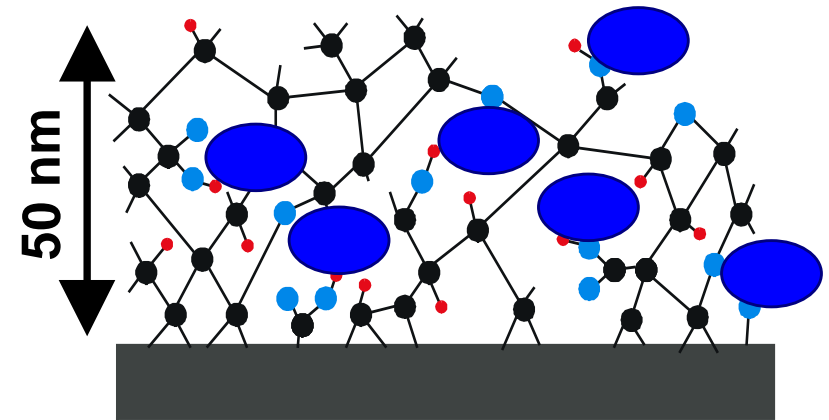
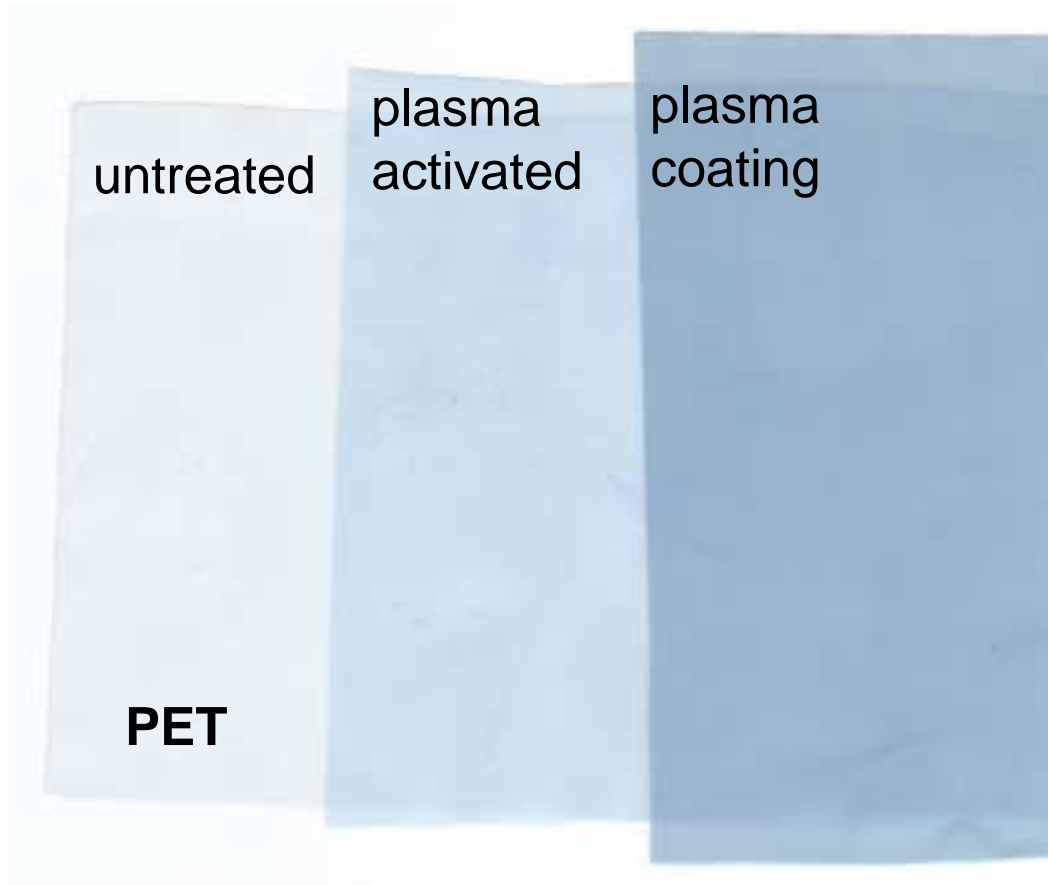


carboxy-functionalized (45 nm thick)

? nano porous structure (<30 nm)

Functionalized Coatings

Dyeing of plasma coatings on textile fabrics



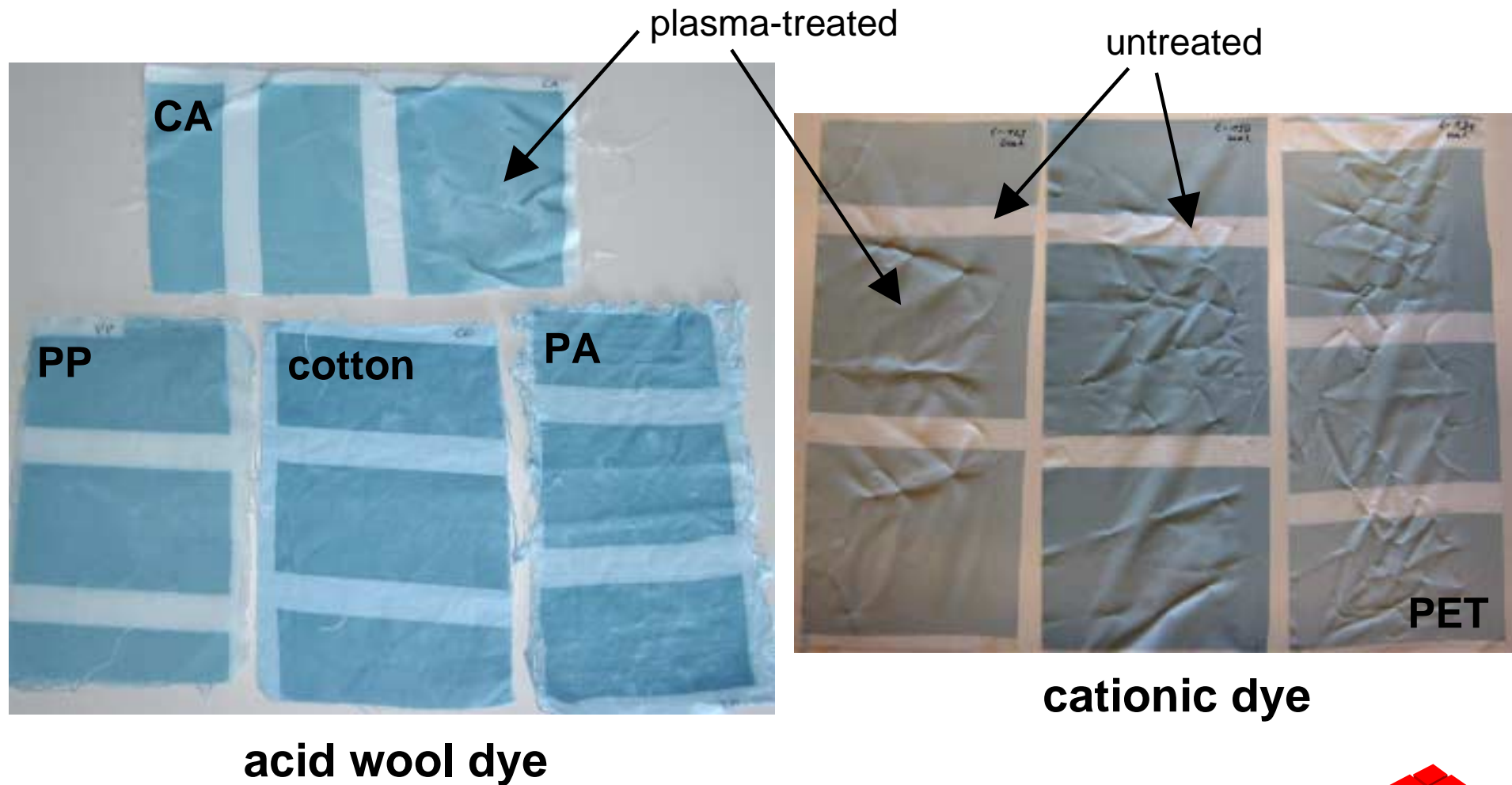
Stability:

>50 000 cycles in
Martindale test

dyestuff: Sandolan walk blue N-GLN 180

Functionalized Coatings

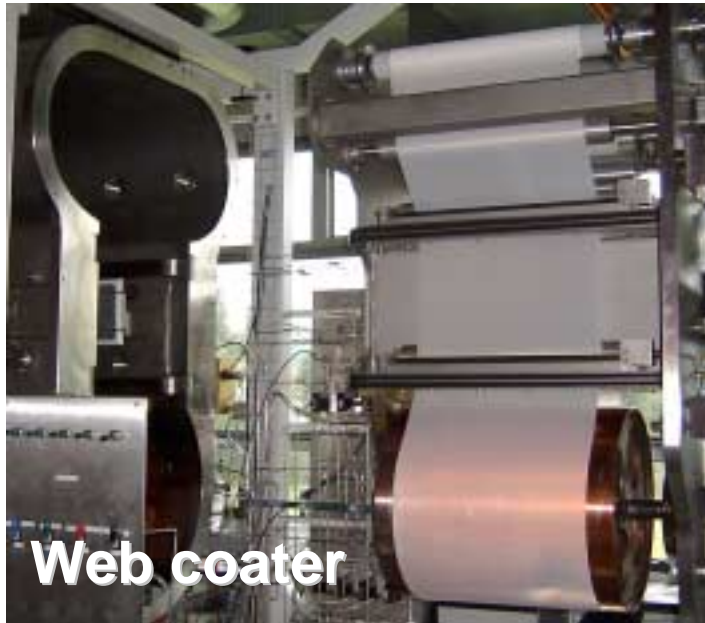
Substrate independent dyeing



Plasma Reactors

Continuous reactors @ Empa St.Gallen

demonstration of industrial scale-up



width = 65 cm

velocity = 0.1..100 m/min

RF + MW, magnetron sputtering

one-step processing (of 3 processes)



mono- and multifil fibers (0.01..2 mm)

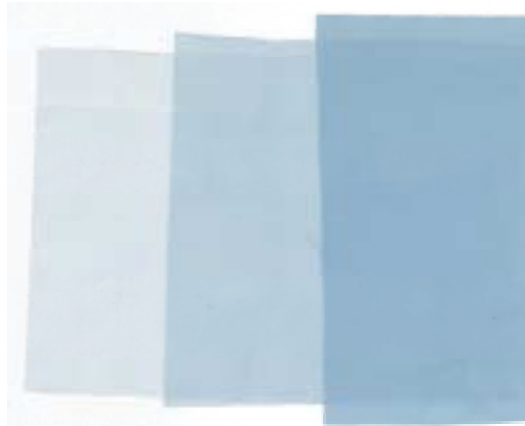
velocity = 0.1..100 m/min

RF, magnetron sputtering

one-step processing (of 2 processes)

Applications

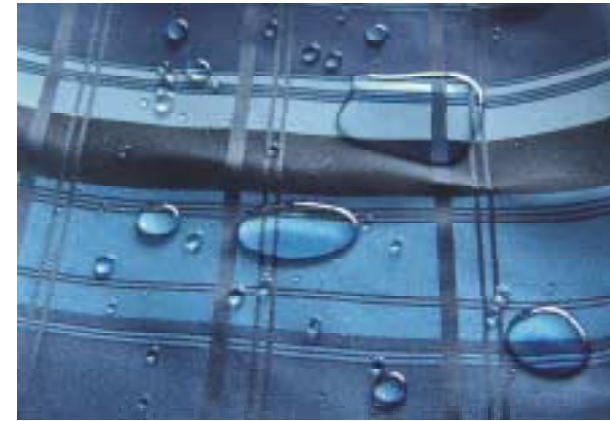
dyeability



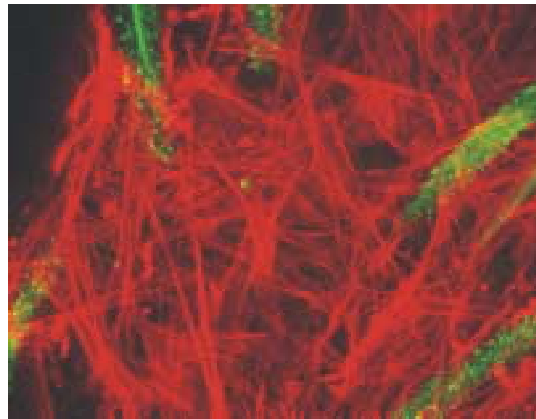
reinforced composites



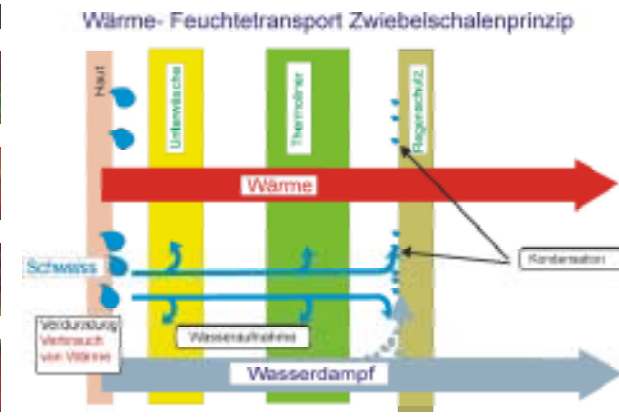
hydrophobicity



metallizations



biocompatibility



moisture/heat management

D. Hegemann, A. Fischer, D.J. Balazs, *Textilveredlung* 3/4, 2005, 14.



Outlook

Functional Textiles thanks to Nanotechnology

% Nano particles in use:

SiO₂: nano structuring ? stain repellence

Ag: incorporation ? anti-bacterial treatment

nano clay: incorporation ? flame retardance

% Nanoscaled coatings

% Nanoporous coatings

? container systems



Acknowledgment

Laboratory for Functional Fibers and Textiles

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