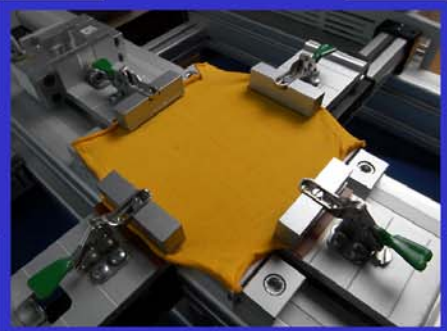
# Benefits of the Nanotechnology Revolution for Textiles

Dr. Stefan Mecheels (CEO), Hohenstein Institutes (Germany)

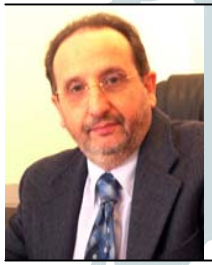

# At a Glance

- Textile research, testing, certification, consultancy, training
- Accredited test and certification laboratories
- Assessment of product performance
- Innovation motor for the entire textile sector
- 4000 clients and customers, 180 employees
- Germany, Turkey, Hungary, China, USA, Brazil, Mexico, Peru & others


# Branches & Offices

***Hohenstein Institutes Germany** (since 1946)*

***Hohenstein Turkey***



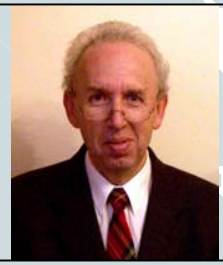
*Feyyaz Akbay (since 1996)*

***Hohenstein Brazil***

*Frits V. Herbold (since 2004)*

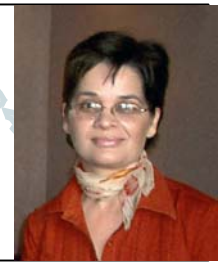
*Dr. Stefan Mecheels*

***Innovatext Hungary***



*Dr. Pal Pataki (since 2004)*

***Hohenstein Romania***



*Dr. Fiz. Iuliana Cohea (since 2005)*

***Hohenstein USA***

*Prof. Dr. M. Wentz (since 1999)*

***Hohenstein Peru***

*Graciela Cordova (since 2002)*

***Hohenstein Mexico***

*Antonio Bazan (since 2003)*

***Hohenstein Vietnam***

*Doan Manh Thang (since 2004)*

***Hohenstein Bangladesh***

*Md. Kamruzzaman (since 2004)*

***Hohenstein China***

*Rachel Huang (since 2005)*

# Hohenstein World-wide

# Textile Testing


Dr. Rainer Weckmann

Barbara Schrobsdorff

## Activities

- Textile materials and quality testing
- Advice on ensuring the quality of textiles, drawing up minimum requirements
- Measuring product performance and legal compliance
- Testing for harmful substances and production audit (Oeko-Tex Standard 100)

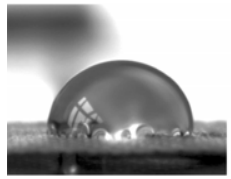
Test center for Personal Protective Equipment

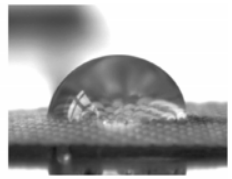
# Textiles and Nanotechnology

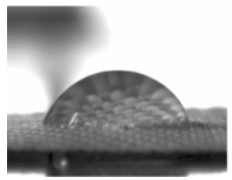
Dr. Jan Beringer

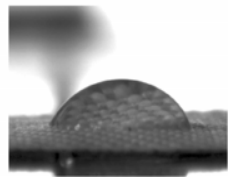
## Activities

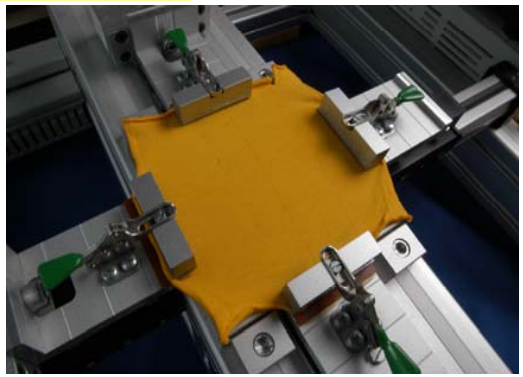
- Innovative products
- New effects and product performance
- Textile finishing and surface treatment
- Product evaluation
- Health and safety aspects
- Quality testing and certification









HOHENSTEIN
INSTITUTES

# Benefits of the Nanotechnology Revolution for Textiles

# TOPICS

## 1. Targets and Definition

## 2. From Functional to Intelligent & Smart Textiles

## 3. Textile Nano-applications (Examples)

## 4. Environment, Health and Safety Aspects

## 5. Product Requirements and Test Methods

## 6. Relevant Products on the Market

## 7. Outlook

# 1. Nanotechnology Targets

- To achieve new functions on existing products that cannot be reached with traditional methods

- To exploit interdisciplinary know-how (from other sectors) and apply it to textile materials

# 1. Nanotechnology - Definition

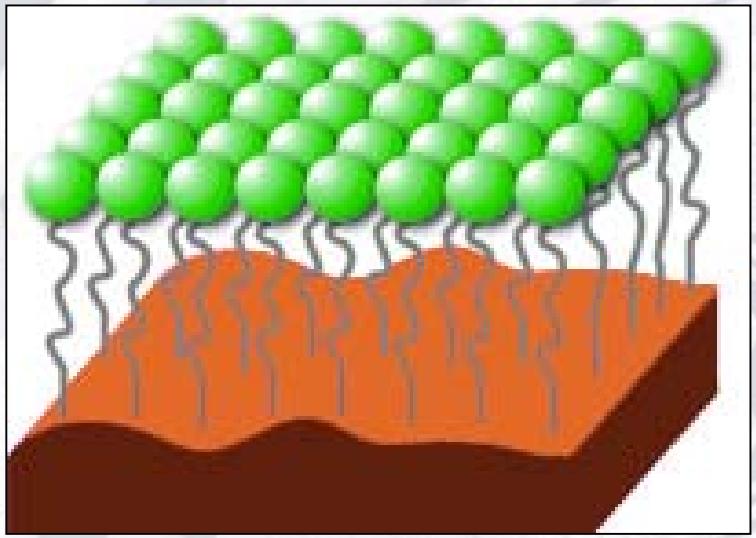
**Richard Feynman (1959) "*There's plenty of room at the bottom*"**

## Classic Definition:

Dimensions of layers or particles with a size between 1nm and 100 nm. 1 nm is $10^{-9}$ m (a billionth part of a meter).

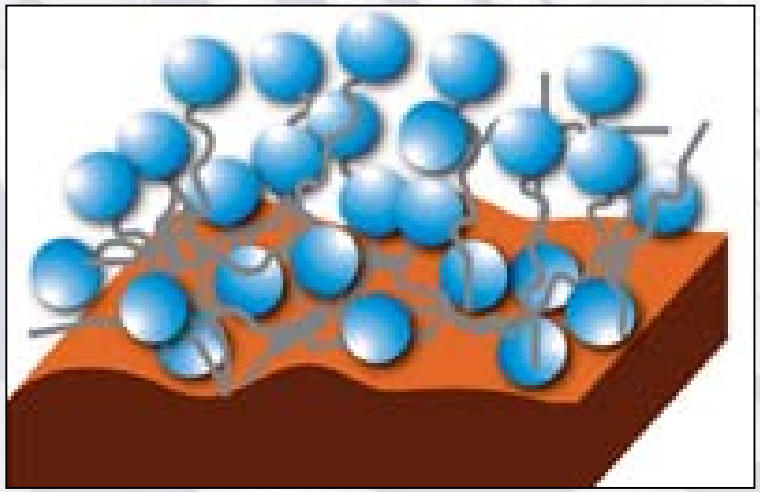
## Hohenstein & NanoMat Definition:

- Dealing with functional systems
- Based on the use of sub-units
- Nanoparticles systematically arranged
- With specific size-dependent properties
- Products with new or better functions
- Textile properties not being affected



## Nanotechnology

**Nanoparticles as a sub-unit are systematically adjusted to a functional system.**



## No Nanotechnology

**Molecules are nanoparticles. No functional system due to the lack of a systematical alignment.**

# TOPICS

1. Targets and Definition
2. From Functional to Intelligent & Smart Textiles
3. Textile Nano-applications (Examples)
4. Environment, Health and Safety Aspects
5. Product Requirements and Test Methods
6. Relevant Products on the Market
7. Outlook

# 2. From Functional to Intelligent & Smart Textiles

## FUNCTIONAL - INTELLIGENT - SMART TEXTILE MATERIALS

### Functional Material (on the market)

- Waterproof, wind-proof materials with good breathability and moisture trans-port etc.
- Optimized material properties, e.g. color fastness, tear strength and rubbing strength, heat and cold resistance etc.

### Intelligent Materials (new on the market)

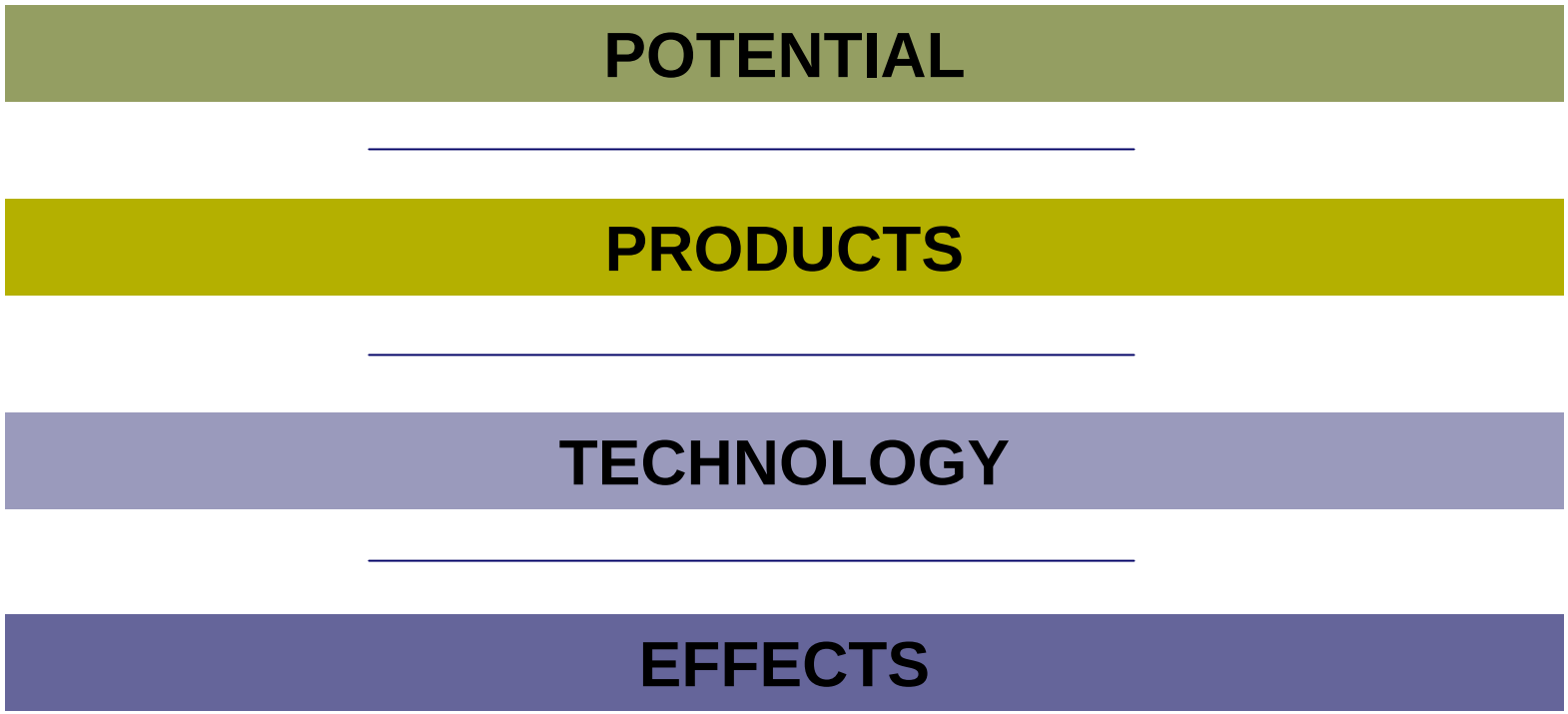
- Odor release or odor prevention
- Advanced wear comfort
- Individually adjustable heat insulation
- Microcapsules, Phase change materials
- Reflection materials
- Protection from environmental stress
- Protection from UV-radiation

### Smart Materials (under development)

- Completely new raw materials with new functions and benefits
- Textile materials with embedded electronic or microsystems tech-nology
- Materials that auto-matically adjust their properties according to internal / external influences

# TOPICS

# 3. Textile Nano-applications (Examples)



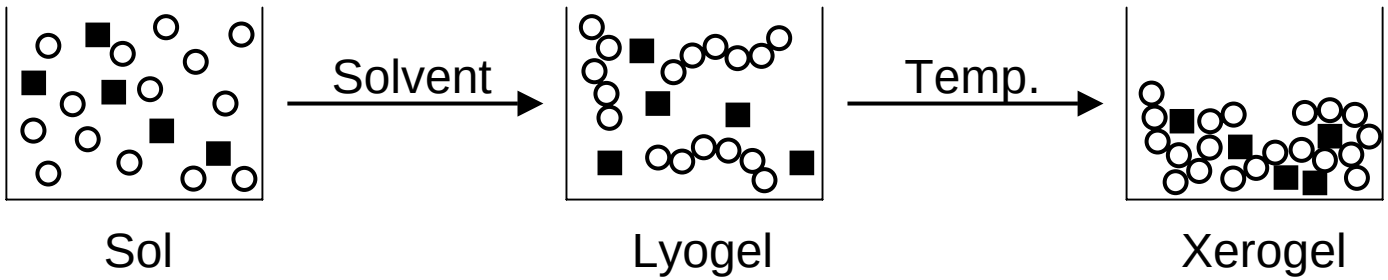
# 3. Textile Nano-applications (Examples)

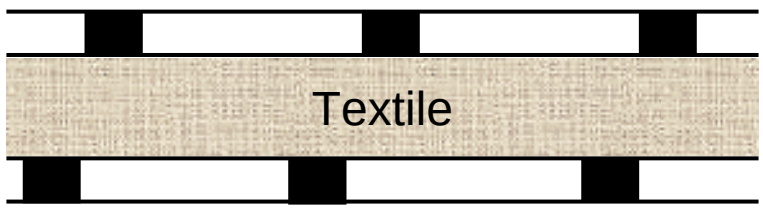
- **A** Ceramic Nano-coating
- **B** Antimicrobial Fiber Modification
- **C** Micro- and Nanoparticles for Textile UV-protection
- **D** Micro- and Nanocapsules Application
- **E** Cyclodextrine Finishing
- **F** Stain-repellent Coating
- **G** Block Copolymers (Switchable Surfaces)
- **H** „Ultrablack“ through „Light Traps“
- **I** Carbon Nanotubes

# A Ceramic Coating (Sol-Gel-Process)

- **Matrix** forming excipients: $SiO_2$-Nanoparticles together with cross-linking silicon compounds with -$Si(OEt)_3$-groups

- **Functional Additives**

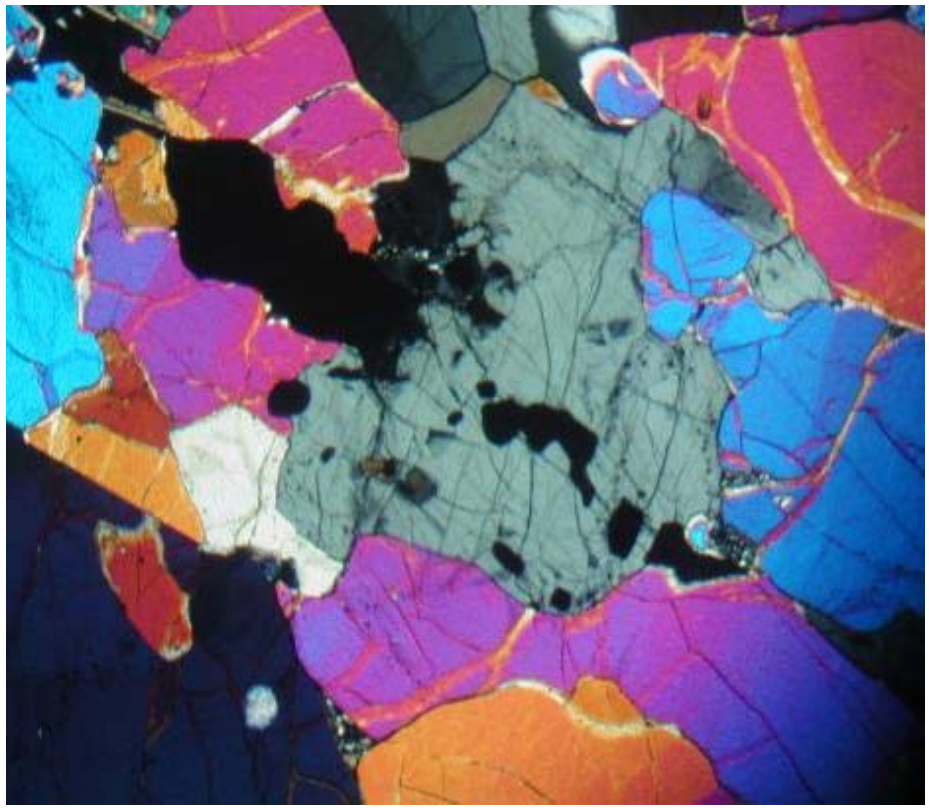


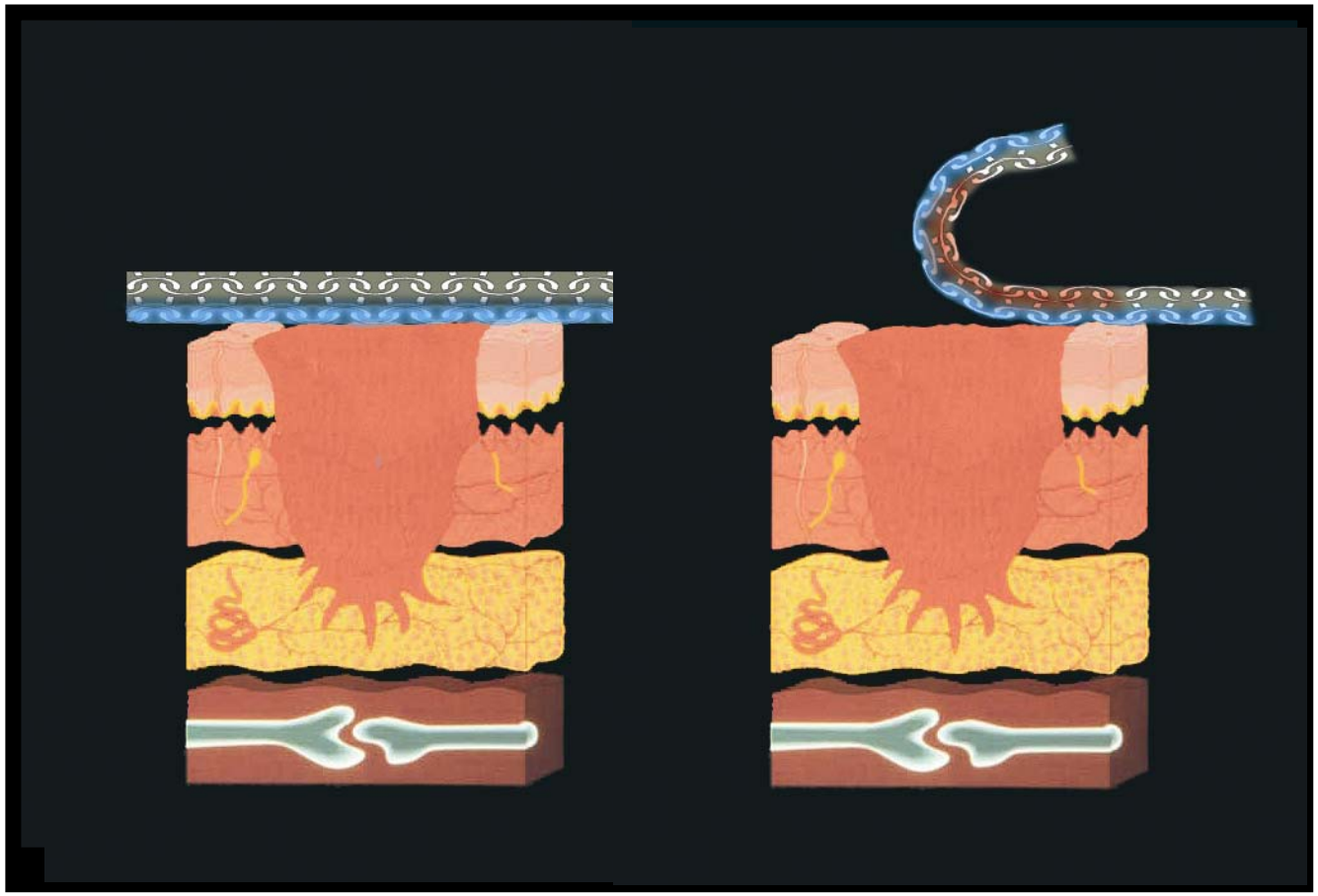
# A Ceramic Nano-coating (Sol-Gel-Process)

## Effects and properties:

- **Physical / mechanical:**
  Strain hardening, antistatic, anti-adhesive
- **Optical:**
  Interference colors, UV-protection, IR-absorption
- **Bioactive:**
  Antimicrobial, medical applications



# A Ceramic Coating of Wound Dressings



# A Ceramic Nano-coating

| EFFECTS | TECHNOLOGY | PRODUCTS | POTENTIAL |
|---|---|---|---|
| ◆ Strain harde-ning<br>◆ Antistatic<br>◆ Anti-adhesive<br>◆ Interference colors<br>◆ UV-protection<br>◆ IR-absorption<br>◆ Antimicrobial | ◆ Sol-Gel Process | ◆ Wound dressings and other medical applications | ◆ Very high, ready for market |

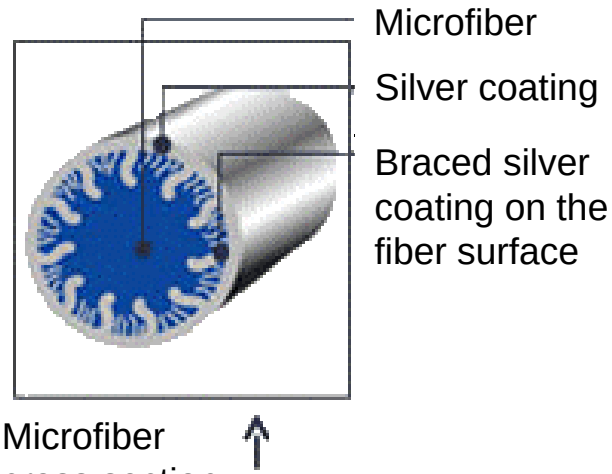
# B Antimicrobial Fiber Modification with Nano-particles (Biochemical Effect with Silver)

**Antimicrobial properties**

- Medical applications (e.g. atopic dermatitis)
- Odor control

**Technology**

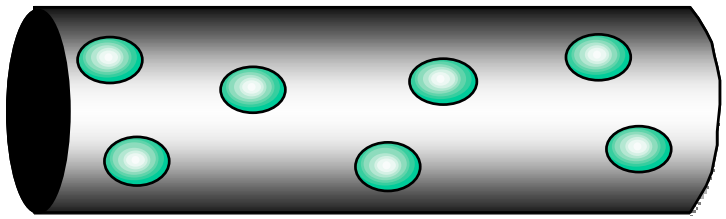
- Silver particles in the fiber
- Silver coating



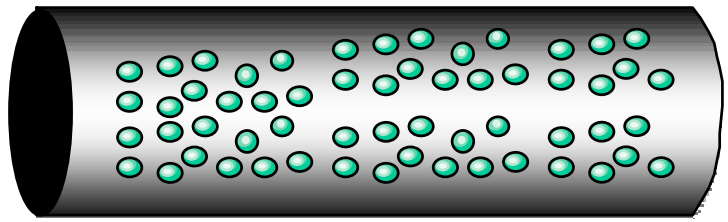

**Antimicrobial body wear**

*Source: Padycare ®*

# B Fiber Modification by Doping with Particles



**Microparticles**



**Nanoparticles**

There are much more particles in the fiber with the same mass.

➔ **larger surface area**

➔ **greater effect is reached**

# B Antimicrobial Fiber Modification with Nanoparticles

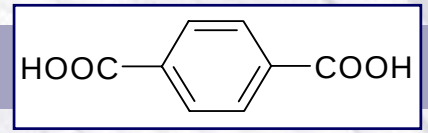
| EFFECTS | TECHNOLOGY | PRODUCTS | POTENTIAL |
|---|---|---|---|
| ◆ Antimicrobial | ◆ Placement of particles during spinning of synthetic fibers<br>◆ Silver coating onto the fiber | ◆ Body wear alle-viating atopic dermatitis<br>◆ Medical textiles<br>◆ Hospital textiles<br>◆ Active clothing for sports and leisure<br>◆ Socks<br>◆ Shoes (lining) | ◆ Very high<br>◆ State-of-the-art |

# C Micro- & Nanoparticles for Textile UV-protection

*Source: Hyphen, Piz Buin, Nivea*

# C Textile Fibers and UV-protection

## Polyester (PET, PPT, PBT)




- Terephthalic acid absorbs in UV-spectrum
- Better protection through fiber delustering ($\mu$/n-$TiO_2$)
- **Both together offer the best UV-protection!**

## Polyamide (PA 6, PA 6,6)

- Only matt-finished types (nano-$TiO_2$) provide good protection

## Natural fibers (CO, WO, LI) + man-made cellulosic fibers (CV, CLY)

- Low to no protection
- Viscose types doped with $TiO_2$ were once on the market

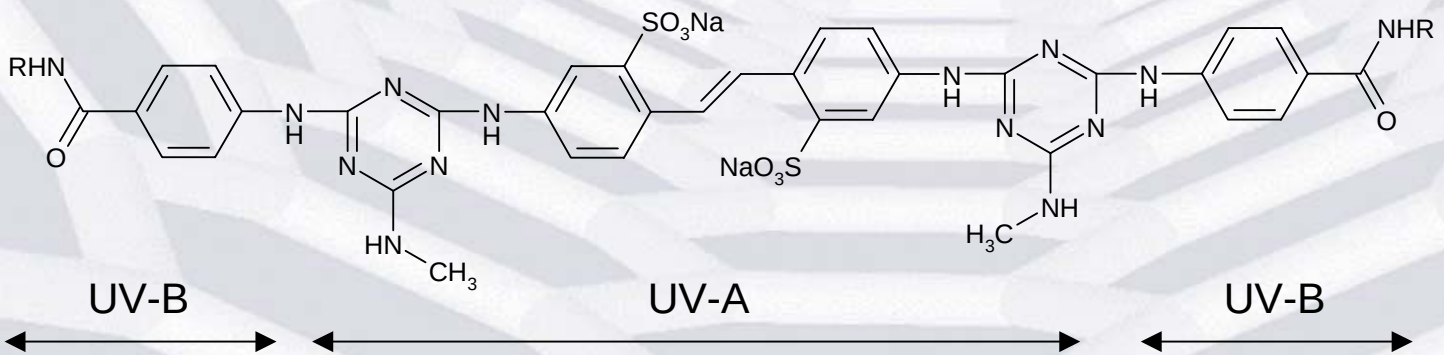
# C Textile UV-protection - Fiber Modification

## Inorganic pigments

- Micro- and Nanopigments ($TiO_2$, ZnO)
- Placement of pigments **into** the fibers during spinning process (delustering)
- Placement of pigments **afterwards onto** textiles (finishing or coating) (Hohenstein research project)

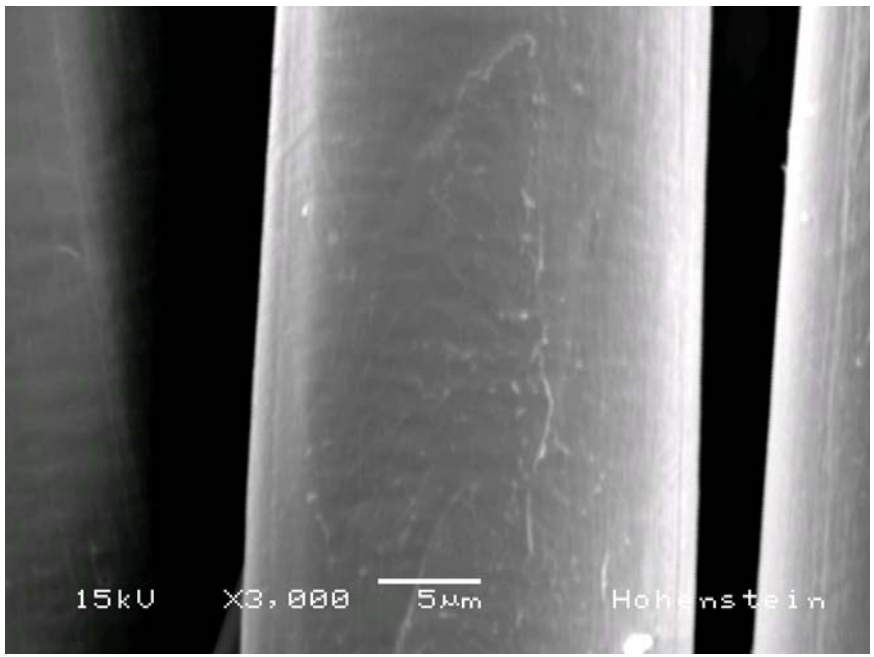
## Organic molecules

- Detergents with UV-protection (UV-absorbers)

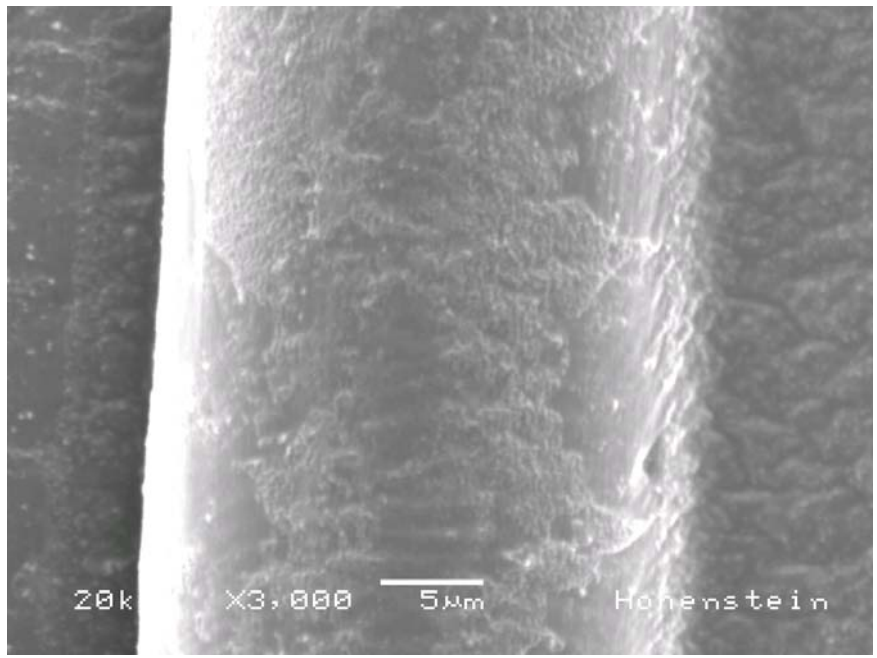



Source: CIBA, TINOSORB FD®

# C Application of Nano-$TiO_2$ onto Polyamide



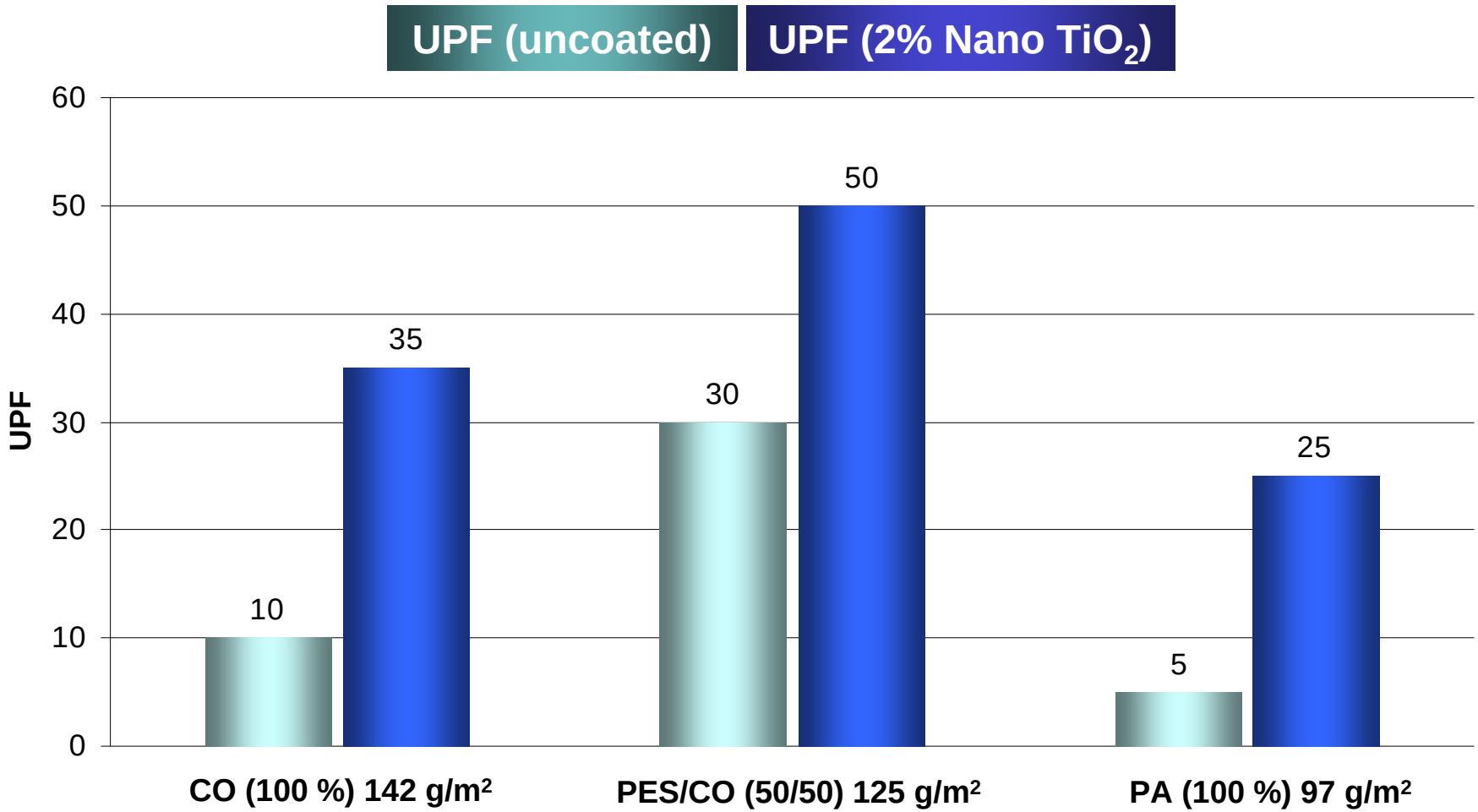

PA uncoated




PA 2 % nano-$TiO_2$ coated

# C UV-protection Factor (UPF) after Coating

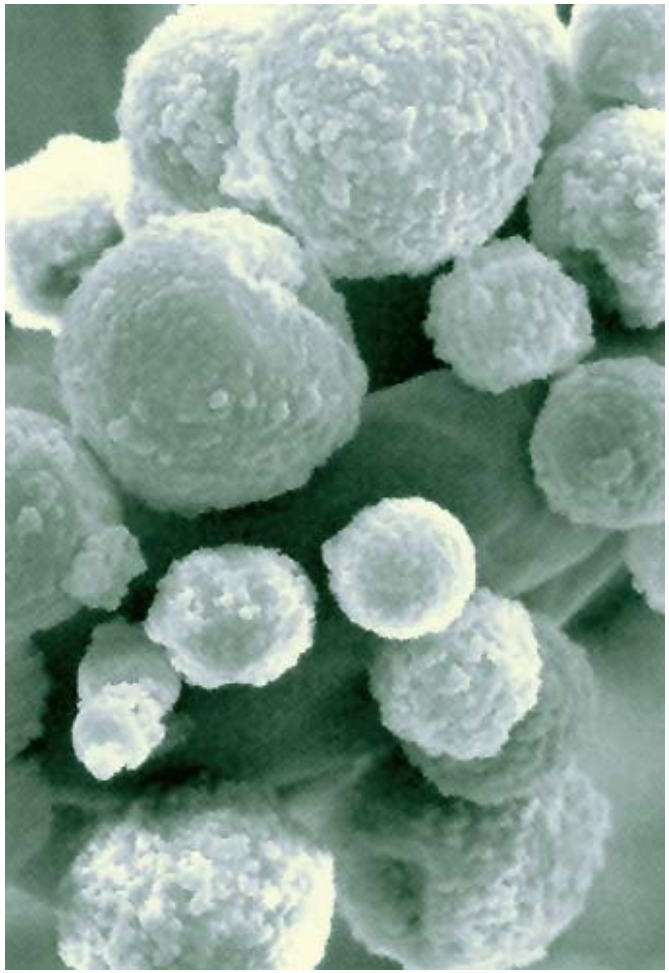
## UPF Rating according AS/NZS 4399:1996



# C Micro- & Nanoparticles for Textile UV-protection

| EFFECTS | TECHNOLOGY | PRODUCTS | POTENTIAL |
|---|---|---|---|
| ◆ UV protective properties<br>◆ Protecting skin cancer | ◆ Fiber deluste-ring at spinning process of synthetic fibers (particles **in** the fiber)<br>◆ Application of UV-protection finishing or coating (parti-cles **onto** the textile) | **UV protective wear:**<br>◆ Swimwear<br>◆ Children‘s wear<br>◆ Sportswear<br>◆ Businesswear<br>**Other textiles protecting against sun:** e.g. sunshades, awnings | ◆ Very high<br>◆ State-of-the-art<br>◆ Standard in certain countries<br>◆ Important for sensible skin |

# D Micro- and Nanocapsules (Wellness, Therapeuticals)



## Product Spectrum

Micro- and nanocapsules that are able to enclose active agents inside:

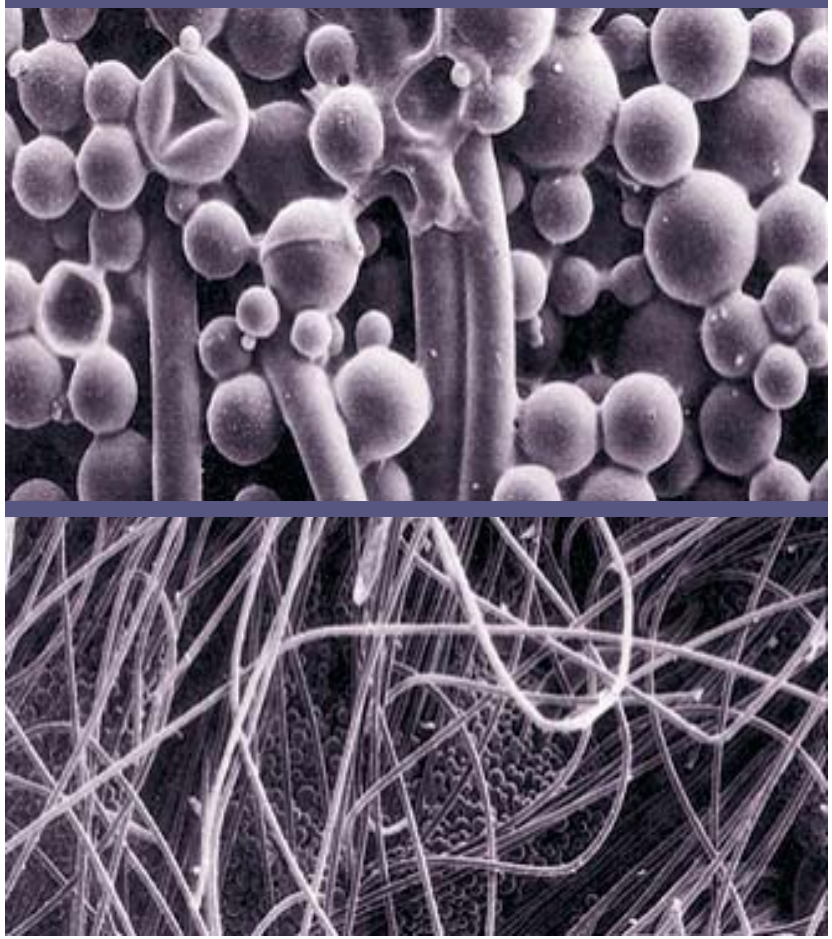
- Skin care substances (Aloe Vera etc.)
- Perfumes / fragrances
- Therapeuticals, drugs
- Phase Change Materials (PCM)

## Textile Application

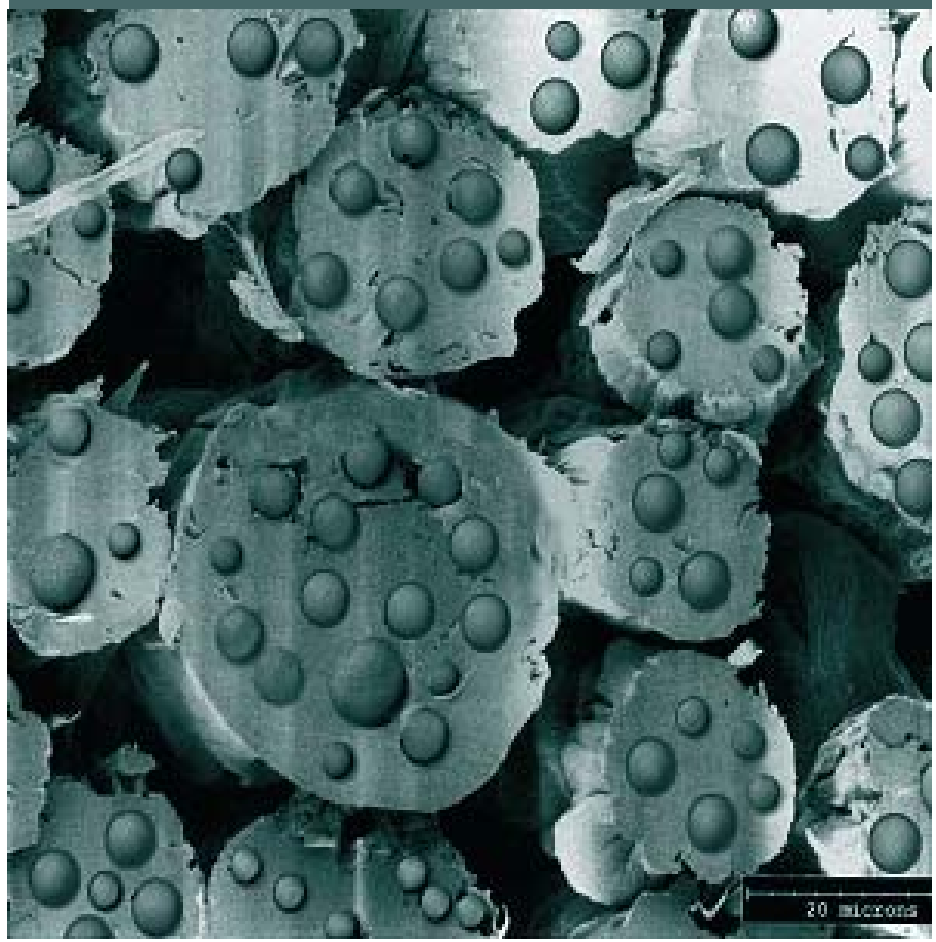
- Acrylic fibers during wet spinning process
- Fixation on textile surfaces with binding agent
- In PU-foam with open pores as calendar coating on textile material

# D Micro- and Nanocapsules

## on the fiber



## in the fiber

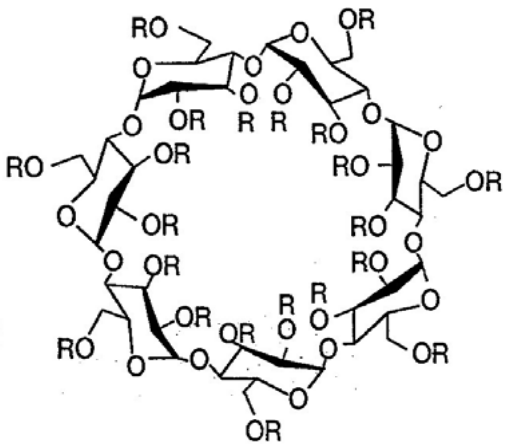


# D Micro- and Nanocapsules Application

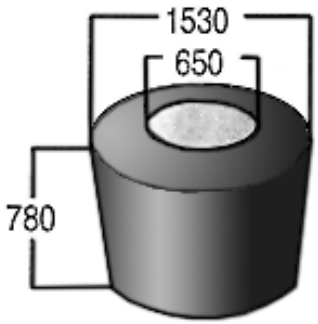
| EFFECTS | TECHNOLOGY | PRODUCTS | POTENTIAL |
|---|---|---|---|
| **Wellness:**<br>◆ Skin care<br>◆ Fragrance release<br>◆ Aromatherapy<br>◆ Therapeuticals and drug release<br>◆ Thermoregulation | ◆ Particles in the fiber during spinning (**in** the fiber)<br>◆ Finishing or coating of textile materials (**on** the textile) | **Wellness textiles:**<br>◆ Tights with Aloe Vera<br>◆ PCM coated articles<br>◆ Drug release textiles<br>◆ Cosmeto-textiles<br>◆ etc. | ◆ Very high<br>◆ First products on the market<br>◆ Huge potential |

# E Cyclodextrine Finishing (e.g. “Fresh-effect”)

## β-CD




## Spatial structure (measurements in pm)




- Cyclic **sugar-molecules** forming depots
- Structure of a **depot**: Odor molecules being deposited and locked away
- Works until all depots are **filled up**
- Washing **empties** the depots; Using a softener, perfumes are deposited in the depots

# E Application of Cyclodextrines

| EFFECTS | TECHNOLOGY | PRODUCTS | POTENTIAL |
|---|---|---|---|
| ◆ **„Fresh-effect”:** bad odor, sweat locked away<br>◆ **Embedded perfumes:** slowly released, actuated by pressure, temperature or moisture | ◆ Cyclodextrines permanently anchored ana-log to a dyeing process in textile finishing | ◆ Clothes with fresh-effect<br>◆ Home textiles with embedded perfumes<br>◆ Toys with embedded perfumes | ◆ High<br>◆ State-of-the art<br>◆ Products on the market, especially with fresh-effect |

# F Stain-repellent Coating

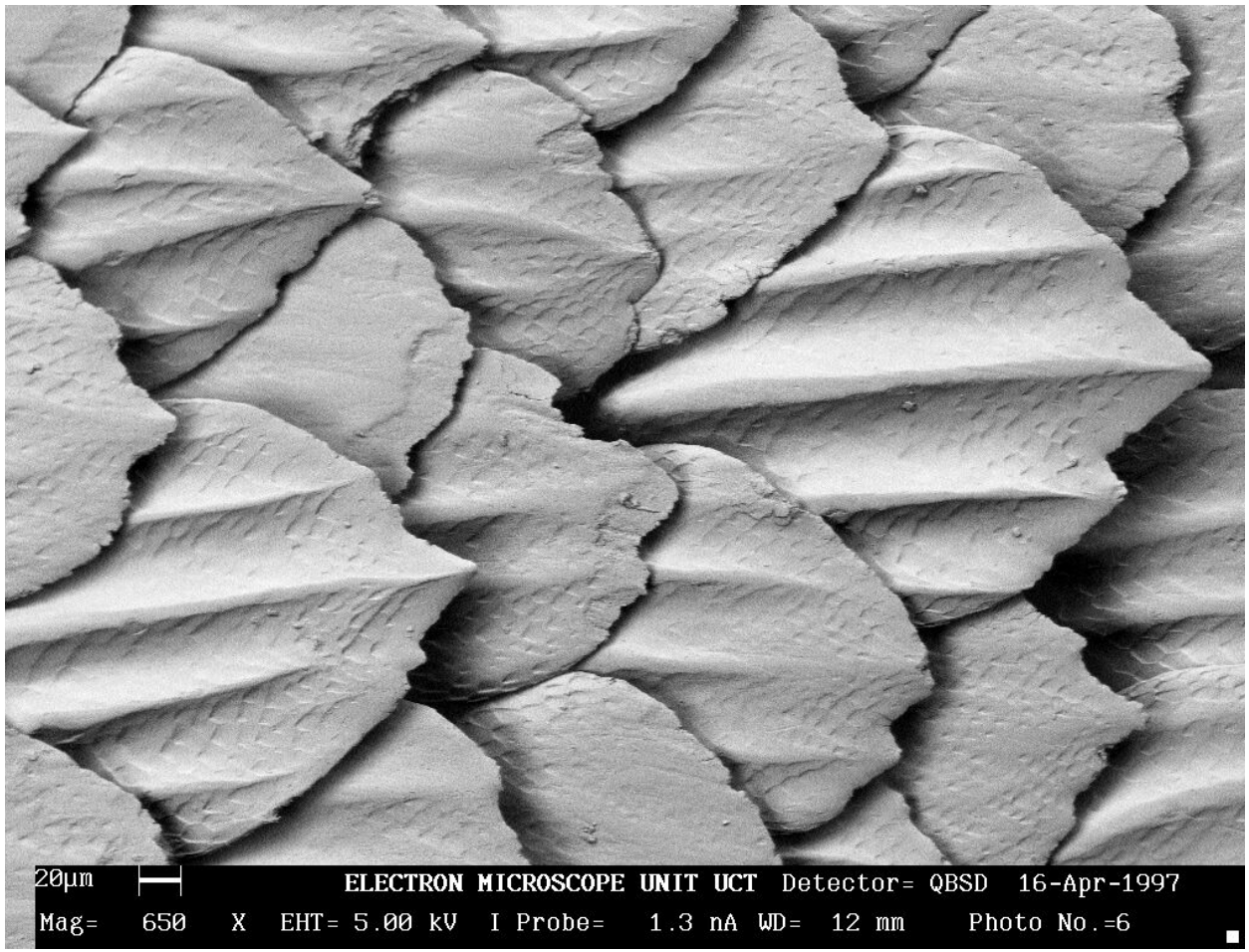
**Marketing terms:**

- „Soil-repellent“, „stain-resistant“
- „Self-cleaning surfaces“
- „Lotus leaf effect“

Nanotechnology in combination with textiles is often being reduced to these effects, although nanotechnology is more than that.

Learning from **„Bionics“**, learning from nature:
Application of biological principles to the design of engineered products.

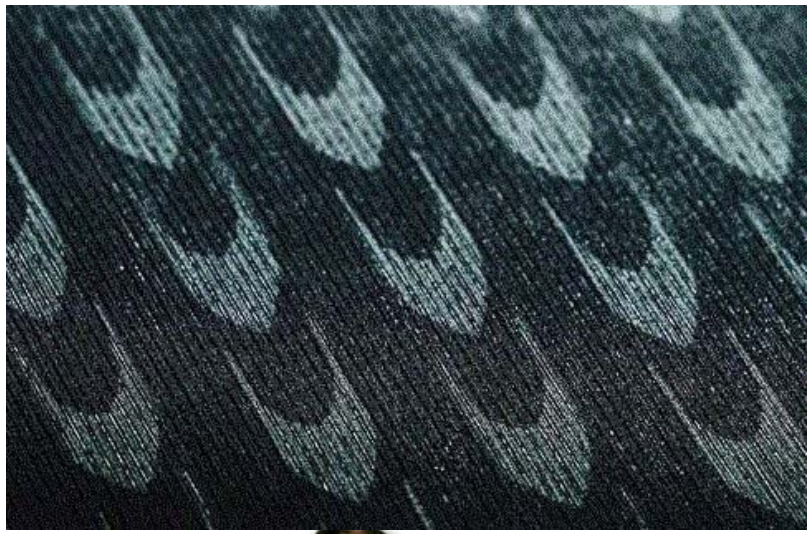
# Nature as a Model: Sharkskin with extremely low Flow Resistance

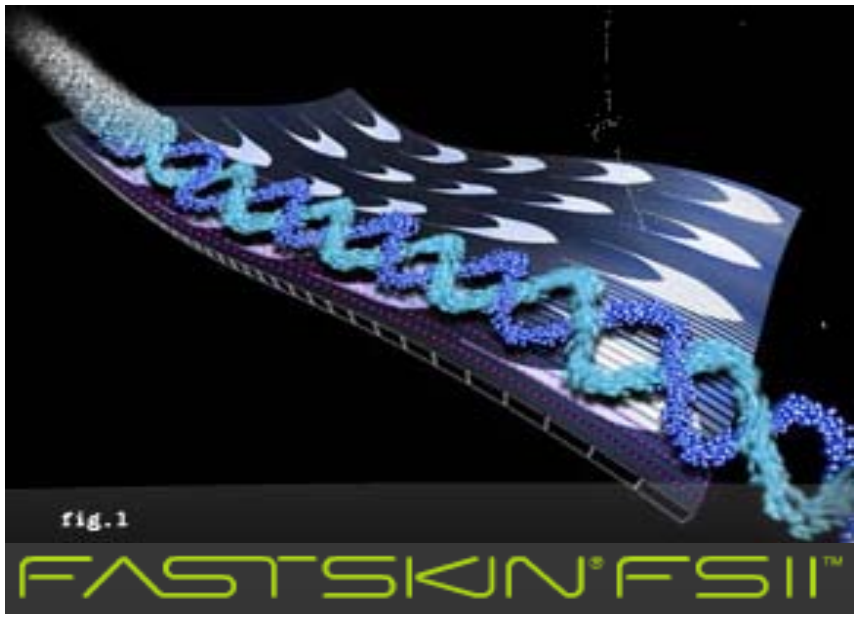



Source: speedo

# F Bionics: Swimsuits with Sharkskin-effect

- Different friction coefficients on the textile (printed or knitted)
- Creation of micro-vortices





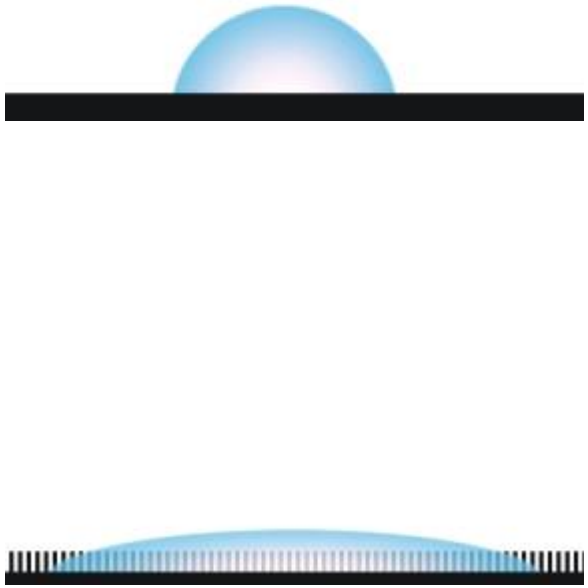


Source: speedo

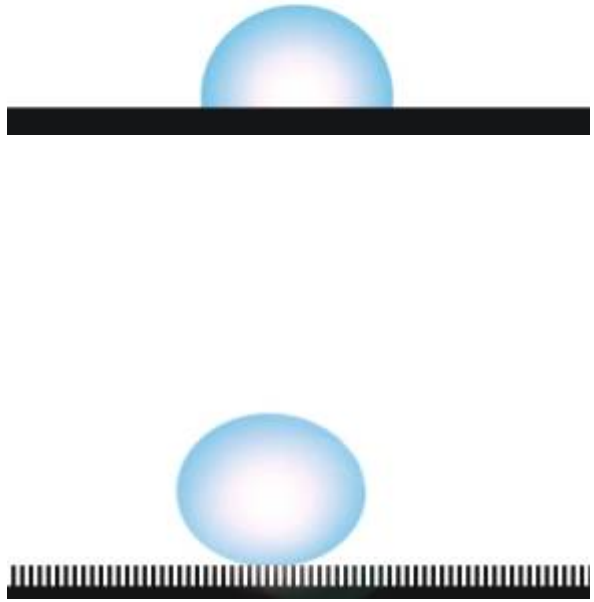
# F Self-cleaning Principle in Nature (1)



## Hydrophilic surfaces

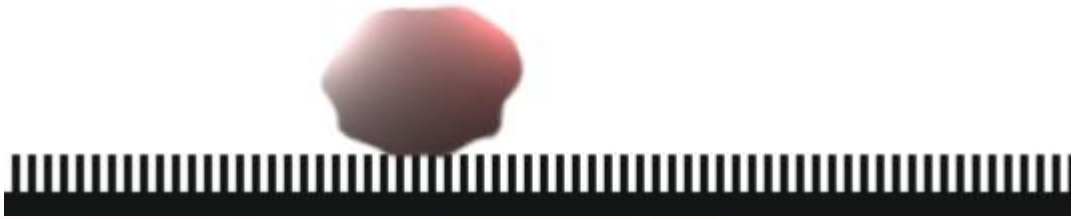


## Hydrophobic surfaces



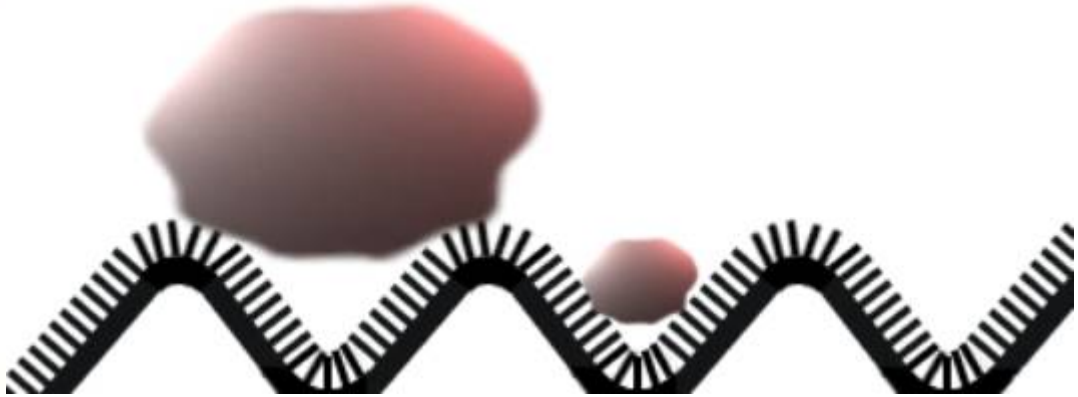
# F Self-cleaning Principle in Nature (2)





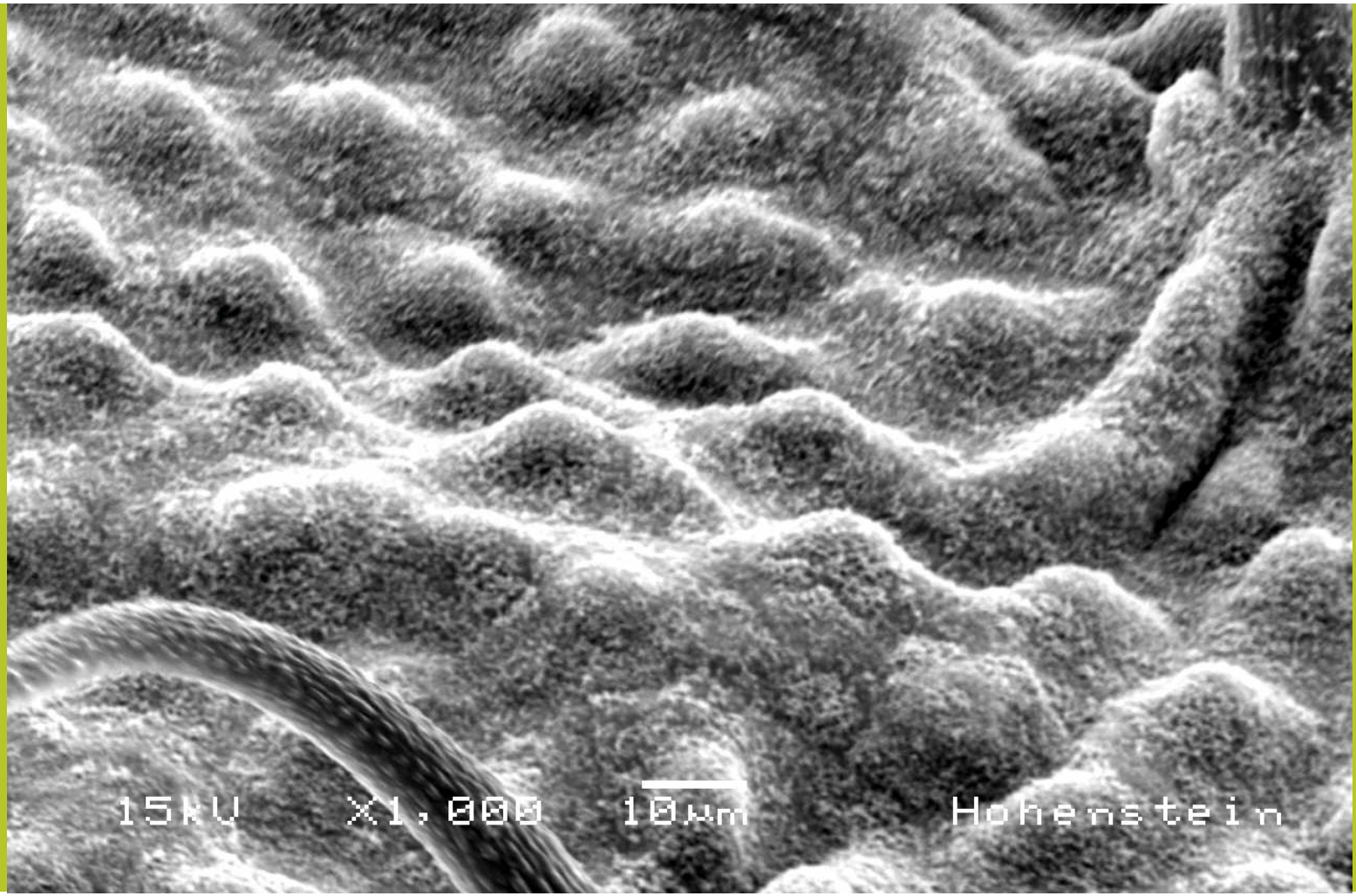
Nano-structure

Micro-structure



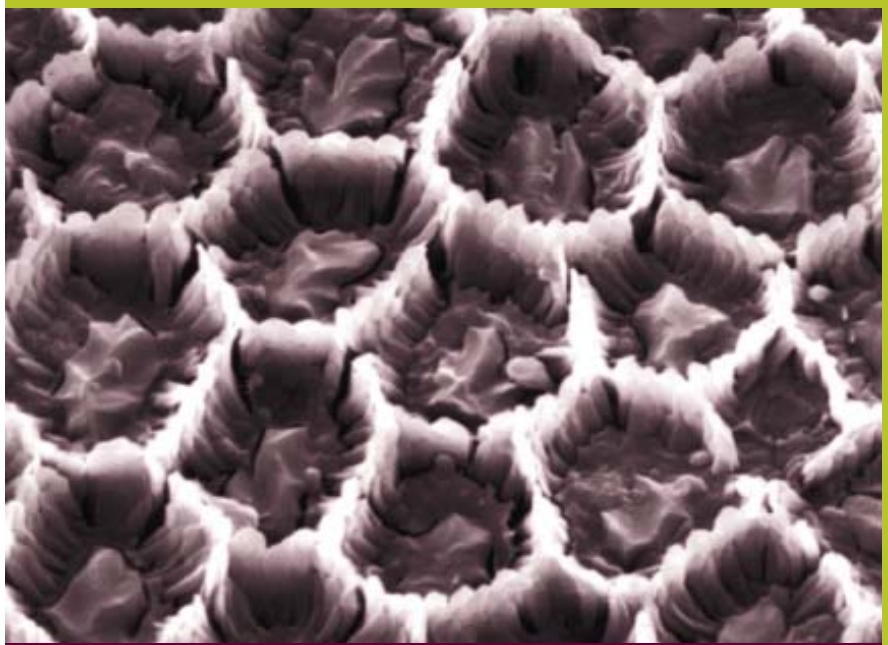
# F How Plants organise the Self-cleaning

## (Hedge Leaf - Spirae)

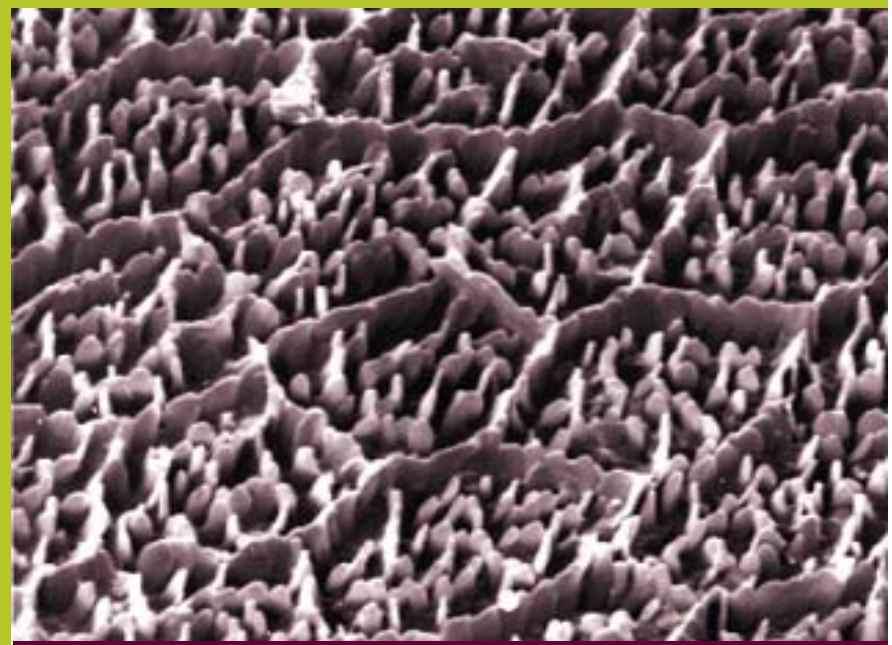


# F How Animals organise the Self-cleaning

## (Rose Beetle - Cetonia aurata)

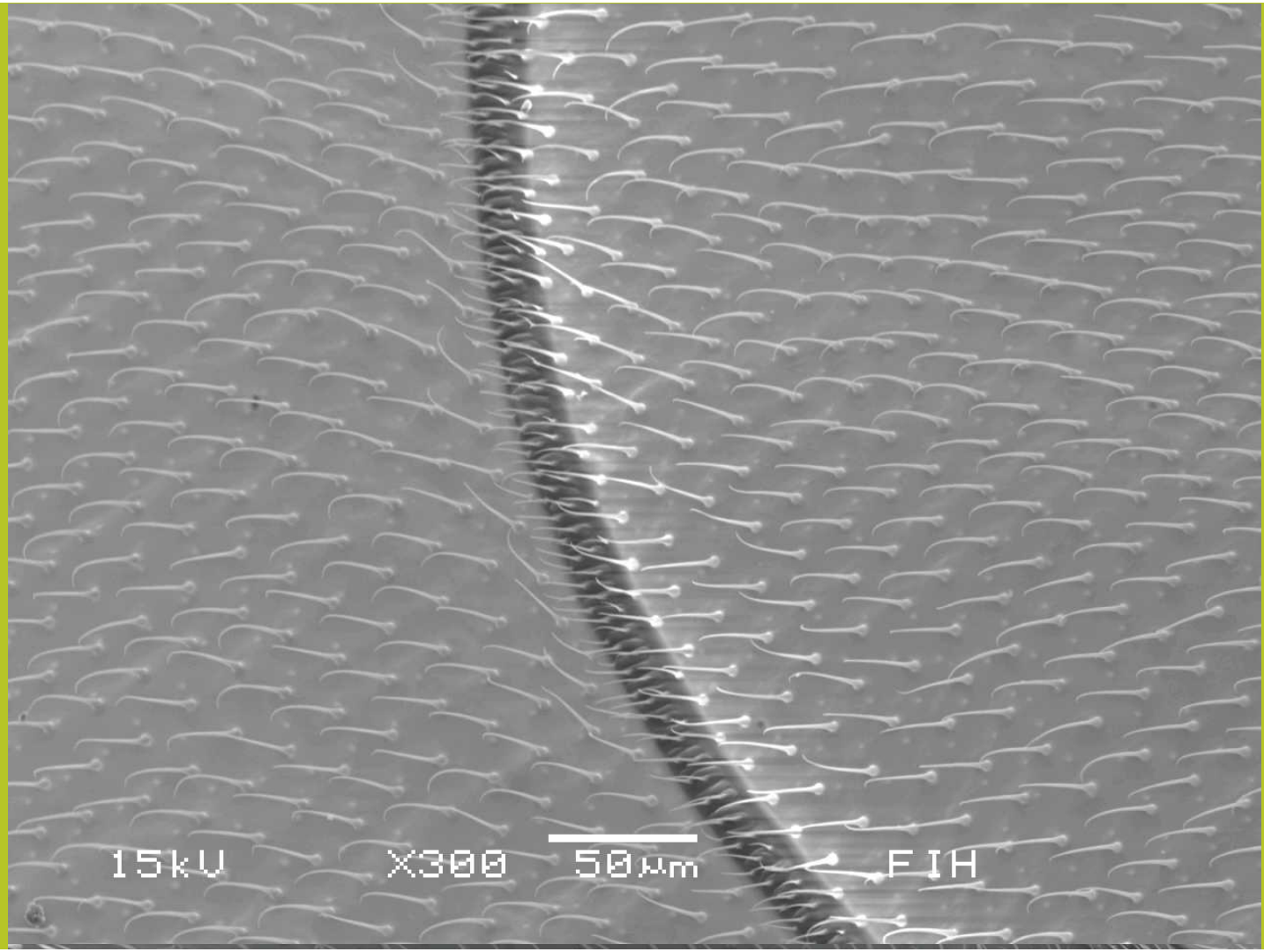


Art 1



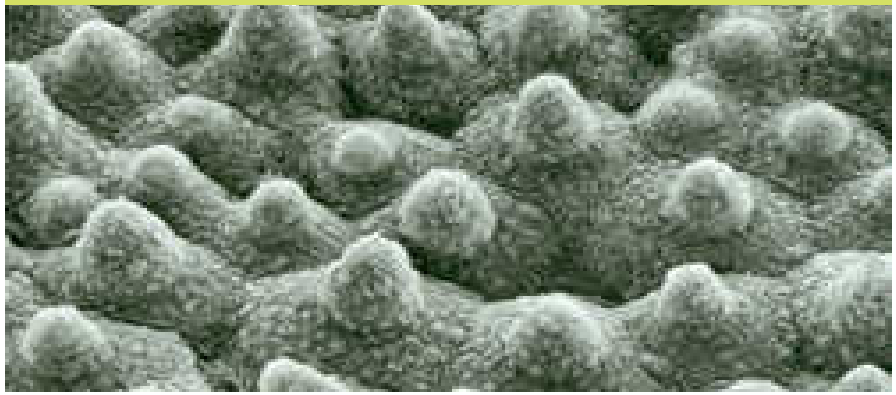
Art 2

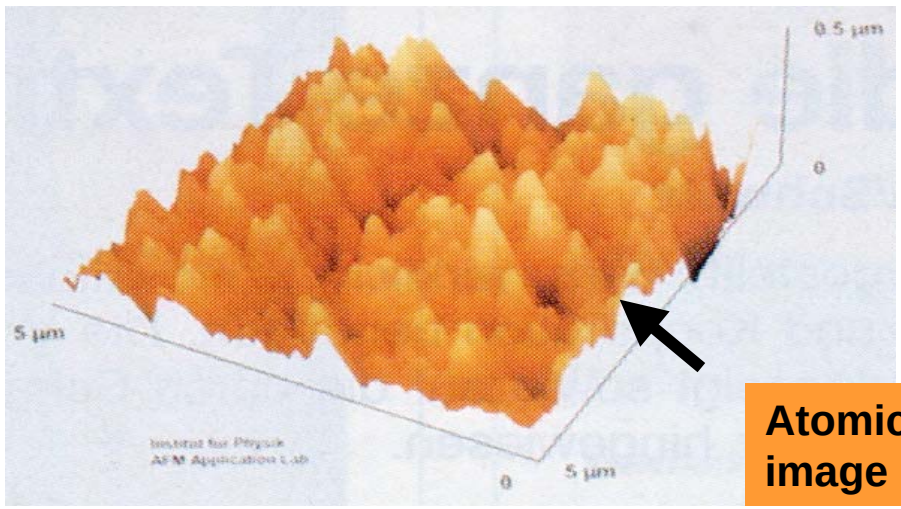
# F Self-cleaning - Wing of the Common Housefly



# F Self-Cleaning (Lotus leaf effect) - Structure on Plants / Textiles

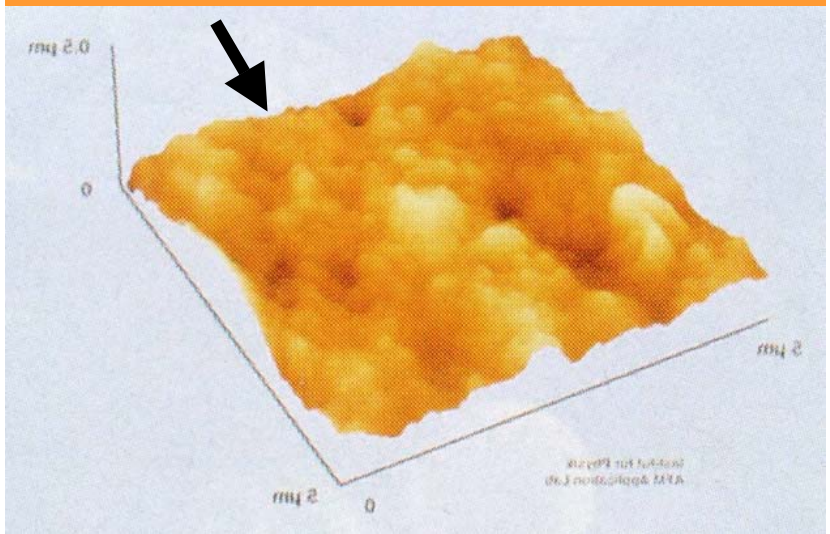
**Scanning Electron Microscope**






**Atomic Force Microscope (AFM) image of the lotus leaf**

**New hydrophobic properties of a textile with nano-structured surface**




*Source: Schoeller Textiles*

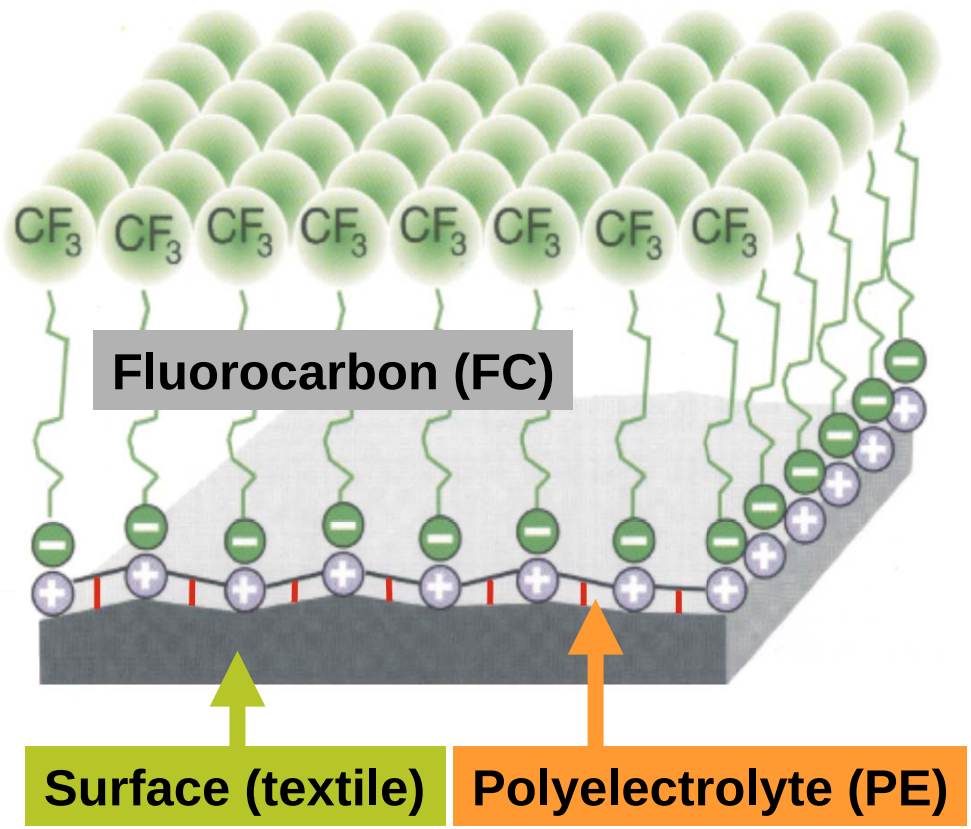
# F Stain-repellent Properties considering Fluorocarbon-finishing as an Example

**Surface Energy $\gamma_c$:**

- Water: approx. 73 mN/cm
- Oil: 20 - 35 mN/cm

- FC ($-CF_3$) approx. 9 mN/cm
- PTFE ($-CF_2-$) approx. 18 mN/cm
- Wax ($-CH_3$) approx. 24 mN/cm
- Silicone ($-SiO_2-$) approx. 24 mN/cm
- PE ($-CH_2-$) approx. 31 mN/cm

**For good effects $\Delta\gamma_c$ > 10 mN/cm**




*Source: Thünemann, Lochhaas*

# F Soil Repellent Finishes / Coatings

| EFFECTS | TECHNOLOGY | PRODUCTS | POTENTIAL |
|---|---|---|---|
| ◆ Soil-repellent<br>◆ „Self-cleaning“ | ◆ Fluorocarbon (FC) coating with nano-particles<br>◆ Sol-Gel-Nano-Finish without fluorine | ◆ Suits<br>◆ Ties<br>◆ Outdoor jackets<br>◆ Technical tex-tiles, e.g. awnings | **FC:**<br>◆ Very high<br>◆ State-of-the-art<br>**Sol-Gel-Nano-Finish:**<br>◆ Middle to high<br>◆ From research to product<br>◆ First products with nano-particles on the market |

# F Fluorocarbon Finish vs. Silicon Nano-finish

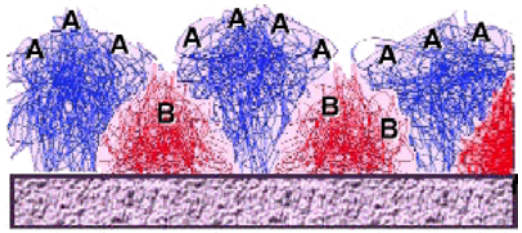
**Fluorocarbon finish:**

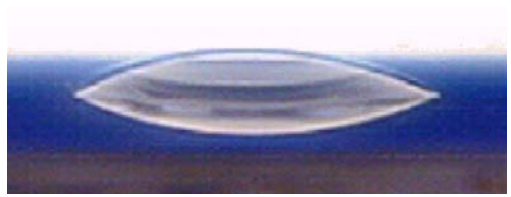
- State-of-the-art
- Excellent hydrophobicity
- Excellent oleophobicity
- Excellent wash-permanence
- **Minus: fluorine (not biodegradable)**

**Silicon Nano-finish:**

- Just in the market
- Excellent hydrophobicity
- Moderate oleophobicity
- Moderate wash-permanence
- **Plus: fluorine free**

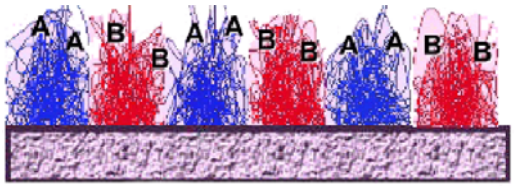
# G Block Copolymers (Switchable Surfaces)

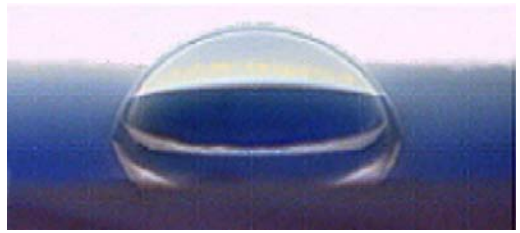


$H_2O$ THF (Regeneration)

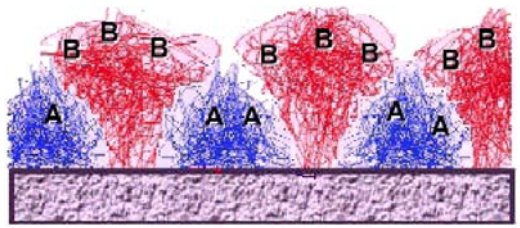
**Polymer Brushes**

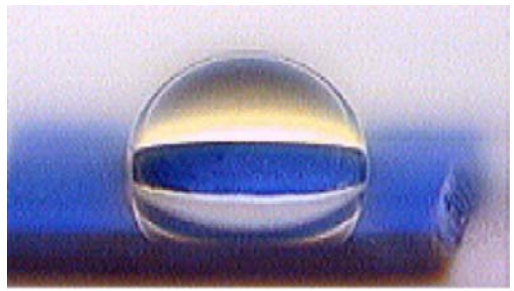


Toluene THF (Regeneration)

A = PVP (hydrophilic)
B = PS (hydrophobic)



*(Source: Stamm, et al.)*

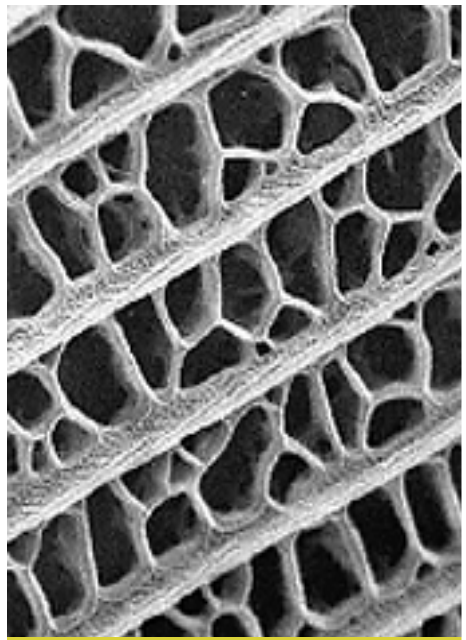
# G Application of Block Copolymers

| EFFECTS | TECHNOLOGY | PRODUCTS | POTENTIAL |
|---|---|---|---|
| ◆ Switchable surfaces | ◆ Application during textile finishing process | ◆ Textiles that adapt to the environmental milieu, e.g. medical textile applications like implants, wound dressings | ◆ Low<br>◆ At research stage, no products available up to now |

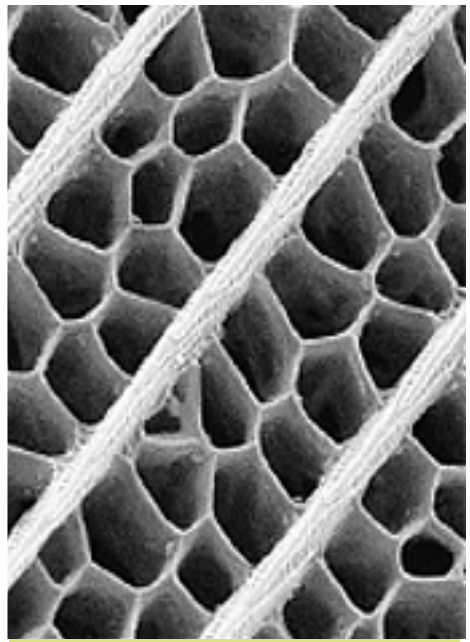
# Ultrablack Wings of a Butterfly reached by Structural Effects („Light Traps“)

**Physical absorption of light, no reflection.**
**Light being captured / swallowed up.**

**Papilio Ulysses**



**glossy**

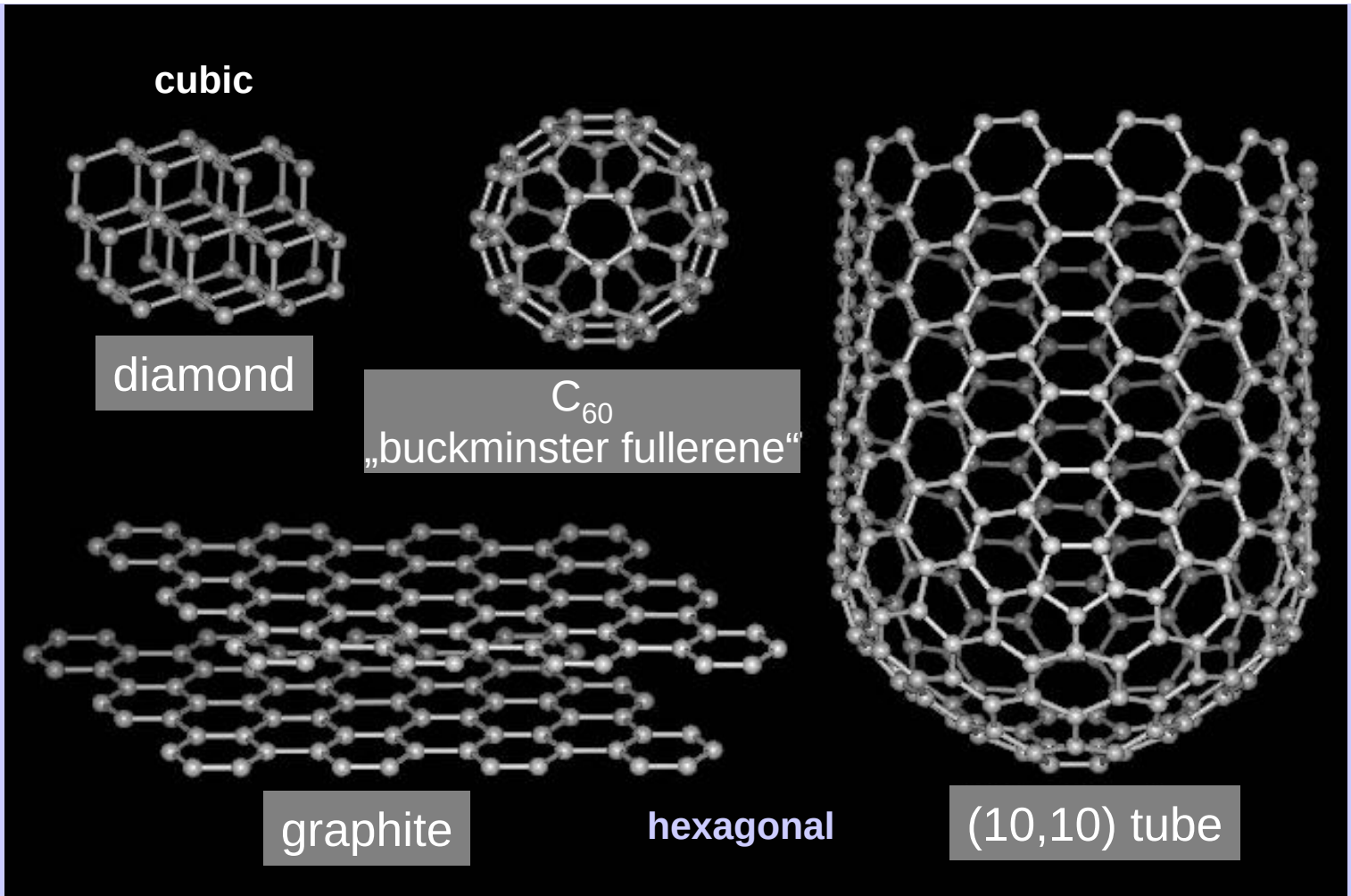


**matt**

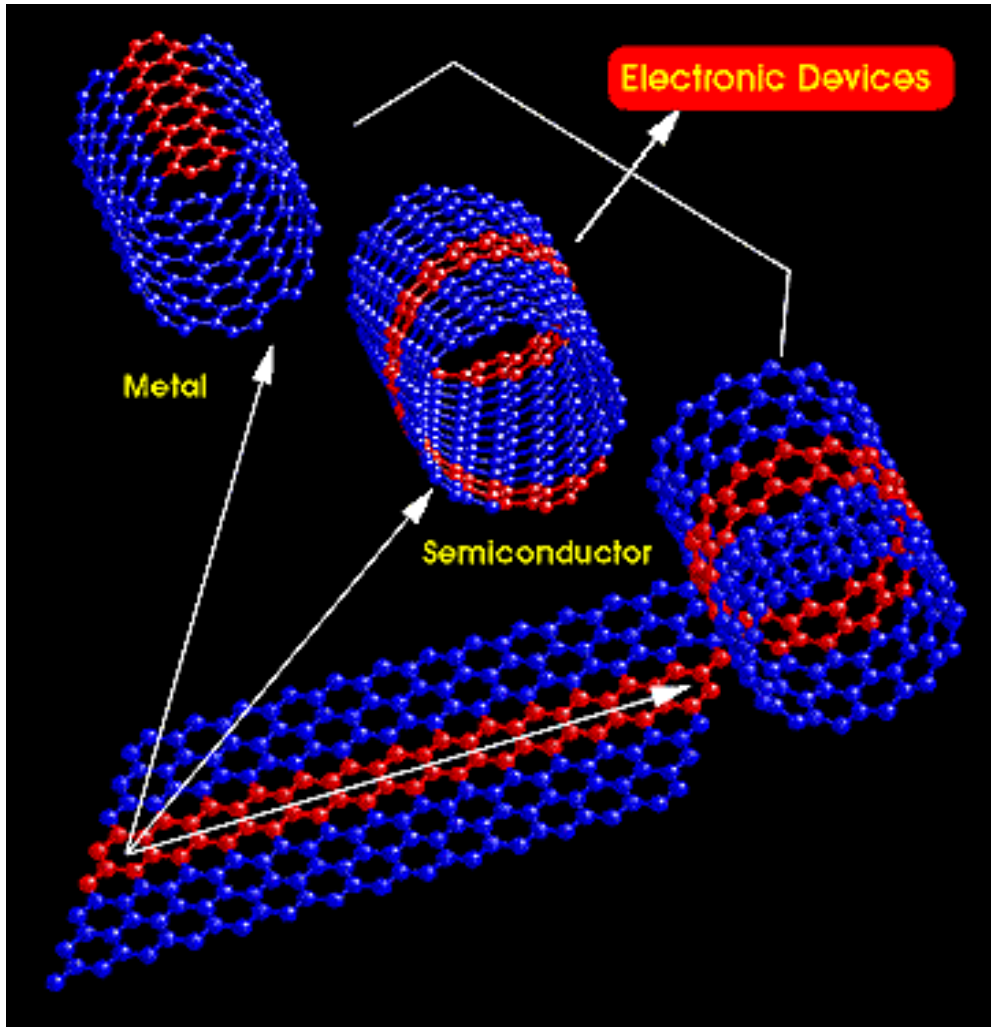
# Colour Effects by Nanostructures

| EFFECTS | TECHNOLOGY | PRODUCTS | POTENTIAL |
|---|---|---|---|
| ◆ Ultrablack<br>◆ Interference colors<br>◆ Color reached without dye-stuff | ◆ Nanostructu-ring of fibers | ◆ Textiles with intensive and exotic colors | ◆ Low<br>◆ At research stage, no products available up to now |

# Carbon Nanotubes - A New Modification of Carbon



# Carbon Nanotubes - A Revolutionary Discovery

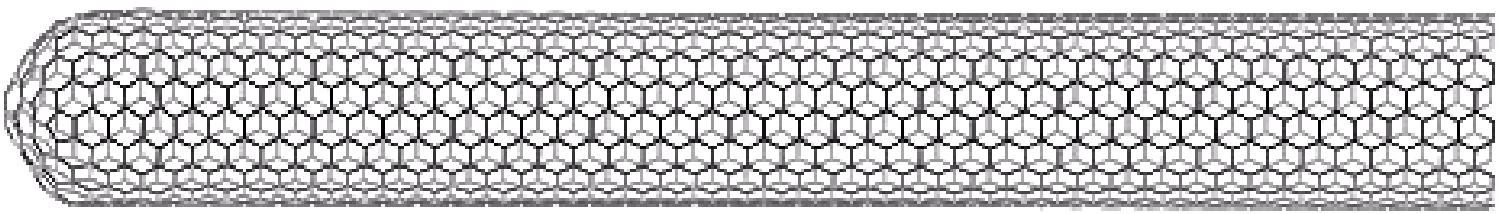



- **1991 Sumio Iijima (NEC)** on the occasion of fullerene synthesis
- **MWNTs** (**M**ulti **W**alled **N**ano **T**ubes)
- **1993 SWNTs** (**S**ingle **W**alled **N**ano **T**ubes)

# Carbon Nanotubes - Physical Properties

## SWNTs

- 100 x more solid than steel
- Extremely high thermal conductivity (~ diamond)
- Metallic properties (conductivity ~ copper)
- Semiconductor properties (~ silicon)
- Emission of electrons when voltage impressed
- Conversion of light into electricity (nature-online 09/2004)



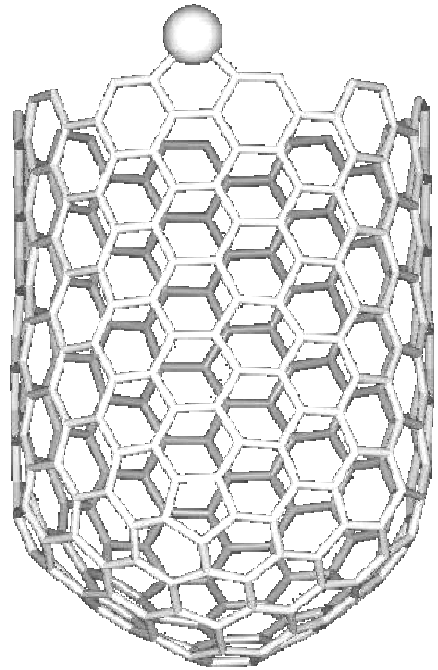
# Textile Application Fields for Carbon Nanotubes

## Compound materials with CNTs

- **Fibers:** Introduction into a spinning solution / melt for improved mechanical fiber strength and new properties
- **Materials:** 6 x more solid than conventional carbon fibers

## Fibers from CNTs

- **Requirements:** Continuous filaments or spun yarn (today: max. 20 cm)
- High-tensile metallic single nanofibers
- High-tensile metallic yarns for special applications
- Technical textiles, shot vests, ropes



# TOPICS

1. Targets and Definition
2. From Functional to Intelligent & Smart Textiles
3. Textile Nano-applications (Examples)
4. **Environment, Health and Safety Aspects**
5. Product Requirements and Test Methods
6. Relevant Products on the Market
7. Outlook

# 4. Environmental, Health and Safety Aspects

## Concerning use of nanoparticles - facts & environmental impacts

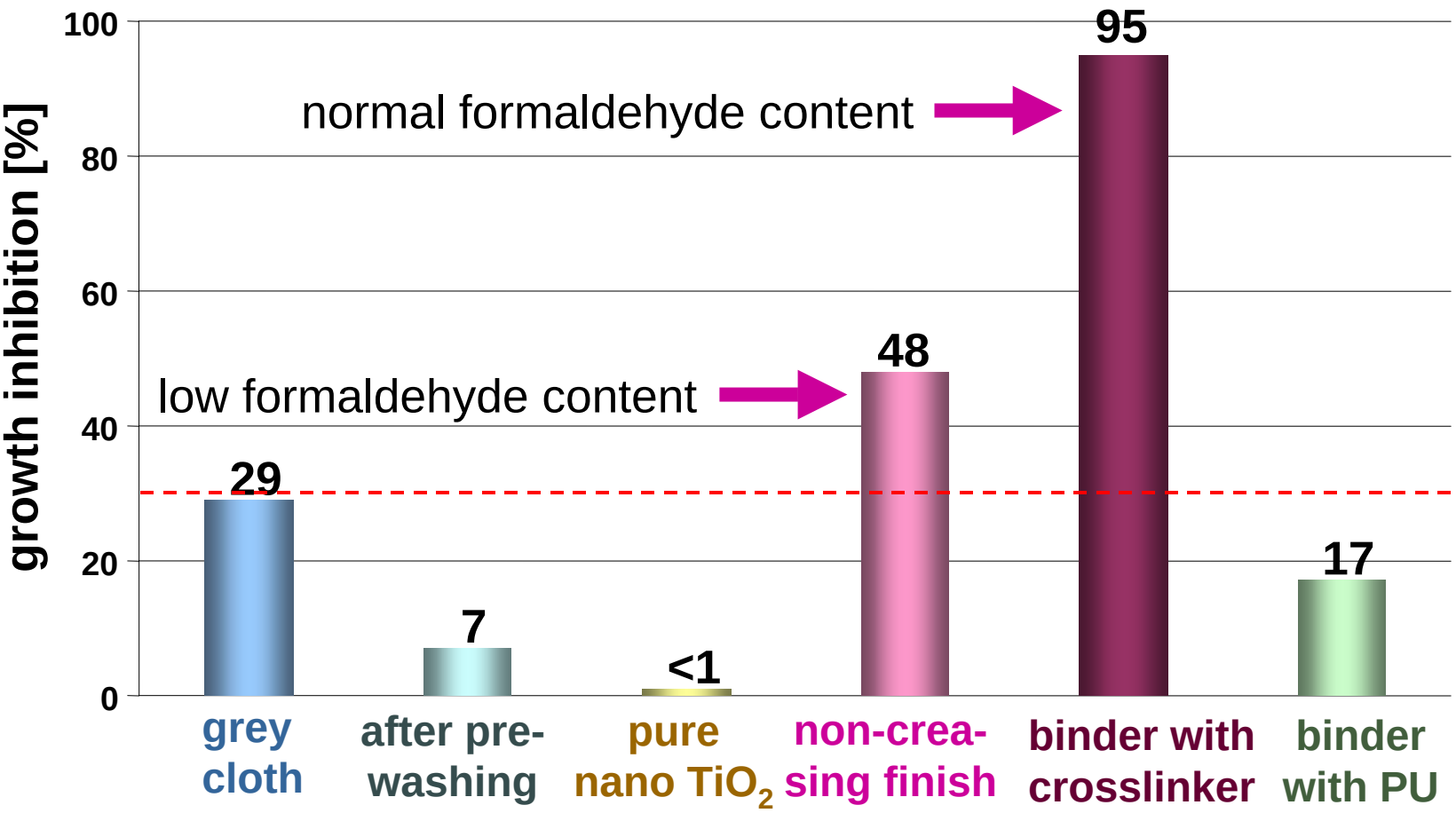
- Coarse, fine and ultra-fine particulates are potentially harmful to health
- Combustion processes (exhaust gases, diesel soot)
- Volcanic eruptions (since millions of years)
- Tobacco smoke (since hundreds of years)

## Article „Nanoparticles in the brain“ in Nature-online, 01/2004

- Rats were exposed to carbon nanoparticles (35 nm)
- After one day the particles could be found in their brains (smell center)
- Path taken: olfactory receptors → olfactory nerves → brain
- No panicking necessary, but precautionary measures are advisable!

# 4. Skin Irritation Potential of $TiO_2$-Nanoparticles

## Cytotoxicity of Cotton in different Finishing Levels



# 4. Environmental, Health and Safety Precautions

- Precautions to be taken in the production process while dealing with nanoparticle powder (otherwise dust, fine particulate)
- Nanoparticles to be adequately fixed onto the textile (immobile)
- Nanoparticles to be embedded in the fiber (immobile)
- High permanence under use conditions (wearing and washing)
- Good values in skin compatibility, genotoxicity

**Further research necessary.**

# TOPICS

# 5. Product Requirements

- New or better **functions** to be offered
- **Textile properties** not being affected
- Good **thermal physiological properties** (e.g. breathability, sweat transport)
- **Permanence:** Long lasting resistance to washing, rubbing
- **No cell-damaging** potential

# 5. Test Methods (1)

**Textile functions**

- Contact angle measurement with different liquids

- Antimicrobial activity

Institute for Hygiene and Biotechnology
at the Forschungsinstitut Hohenstein

Certificate

antimicrobial

According to test report No. 03.8.0579 dated July 16th, 2005
the fabric / fibre

**SAMPLE FIBRE**

produced by: Company
Street
P.O.Box
Town

shows **antimicrobial activity**

provided that it is applied correctly.

The tests were carried out with reference to JIS L 1902 : 2002 „Testing for antibacterial activity and efficacy on textile products" with the test strains Staphylococcus aureus ATCC 6538 and Klebsiella pneumoniae ATCC 4352.

The evaluation of the antimicrobial activity is based on the Hohenstein evaluation scheme (Rev. 1, February 2001).

The certificate is valid until **May 23rd, 2006.**

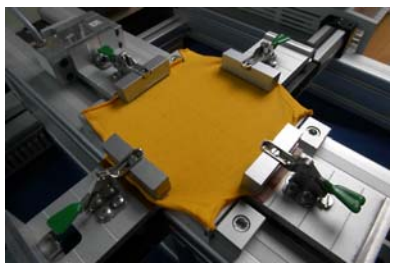
Schloss Hohenstein · D-74357 Bönnigheim, June 24th, 2005

The Director of the Institute for
Hygiene and Biotechnology

Dr. med. habil. Dirk Höfer

# 5. Test Methods (2)

## Textile functions



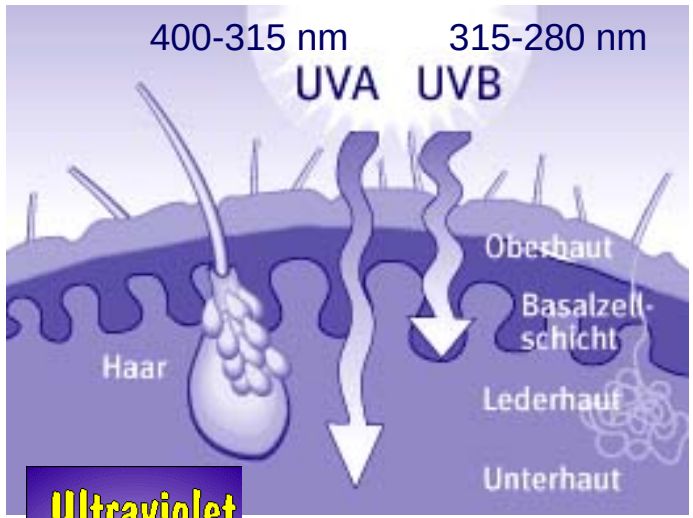
## UV-protection factor

**AS/NZS 4399: 1996, EN 13758-1**

- Testing only done on new product
- No practical suitability!

## UV Standard 801 (Hohenstein):

- New product dry and wet
- Washed product dry and wet
- Rubbed product dry and wet
- Stretched product dry and wet
- “Worst case” being certified
- Practical suitability is given!




Ultraviolet Protection Factor
UPF 50+
Excellent Protection
AUSTRALIAN RADIATION LABORATORY UPF RATING

UV
PROTECT 40
UV STANDARD 801
Prüf-Nr. FI Hohenstein

EN 13758
30+

# 5. Test Methods (3)

**Textile properties**

Conventional textile tests (physical and chemical properties)

**Thermal physiological properties**

Quantitative measurement and assessment of the wear comfort (e.g. $R_{et}$ value, sweat transport, comfort vote)

# 5. Test Methods (4)

## Permanence

## Certain numbers of care cycles

Household washing

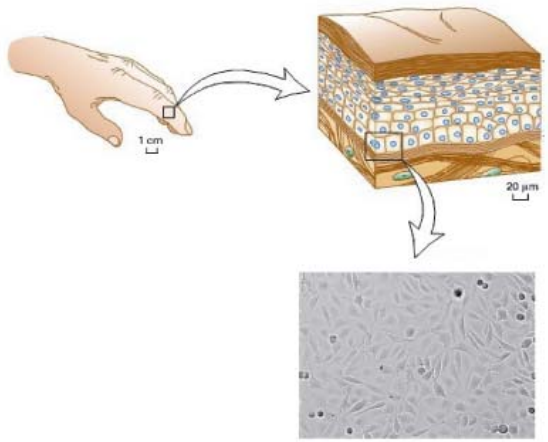
Commercial laundry

## Test Report

# 5. Test Methods (5)

## Health properties

## Cytoxicity test




## Test report

## Total product evaluation

"Hohenstein Quality Label for Nanotechnology"

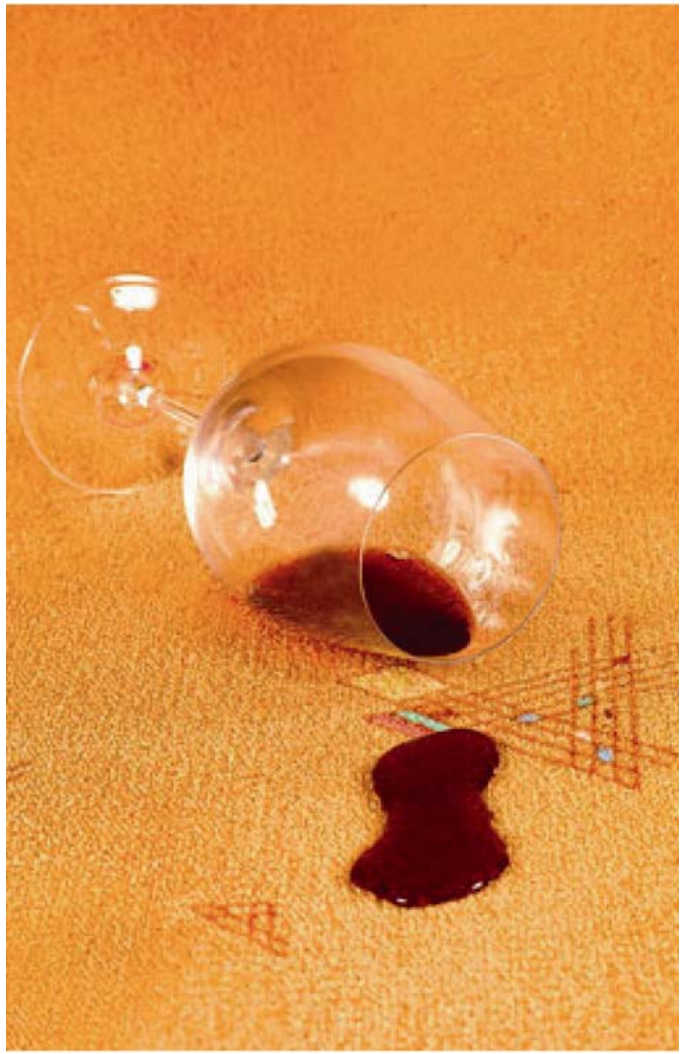
(new)

# TOPICS

# 6. Relevant Products on the Market - Promotion Arguments

| |
|---|
| “Fresh-effect, “Anti-smell” |
| Teddies “that heal” |
| Stockings that “care the skin” |
| “Self-cleaning” jackets / shoes |
| Textiles doped with fragrance |
| “Textiles that encourage wellbeing” |
| Drug release textiles / drug delivery systems |
| Catalytic conversion of noxious substances, nicotine, formaldehyde or other nasty odors |
| Dirt-repelling |
| Anti-dust |
| Stain-repelling |
| Water-repelling |

# 6. Relevant Products on the Market



*(Sources: Schoeller, Nanopool, bugatti, Eterna, Trevira, Hefel, Drapilux, Hyphen, 3sat)*

# 6. Relevant Products on the Market







*(Sources: Schoeller, Nanopool, bugatti, Eterna, Trevira, Hefel, Drapilux, Hyphen, 3sat)*

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# 7. Outlook

Nanotechnology with infinite opportunities.
These high-tech-fibers are like a “revolution”
for the textile sector.

---

The coming years will be like firework with an unbelievably high number of textile innovations.

---

Brazil as well should invest in textile nanotechnology, in order to find its own way against countries with lower production costs.

# I never think of the future.
# It comes soon enough.

*Albert Einstein*

**Technology is dominated by two types of people:**

**those who understand what they do not manage,**

**and those who manage what they do not understand.**

***Putt's Law***

# Thank you very much for your attention!

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