Nanotechnology in cleaning: future, foe or fiasco?

TNO | Kennis voor zaken

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ISSA/Interclean
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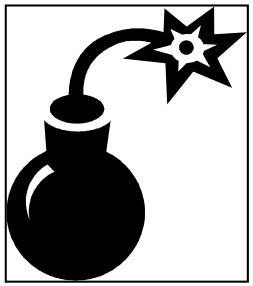
Nanotechnology in cleaning

- Is it the future

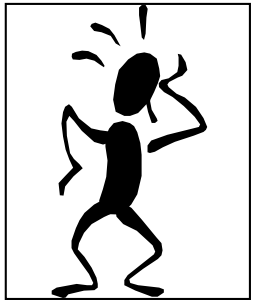
e.g. nano-detergents

- Is it a foe



e.g. self-cleaning

- Or a fiasco



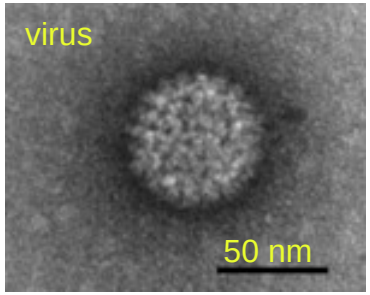
e.g. not functional

a critical analysis of recent developments

(size of symbol reflects my interpretation of the relative success of the *type* of products, not of individual products or trademarks)

Nanotechnology: what is it?

- Nano: structures of 1-100 nanometer (nm)
  - 100-1000 nm: submicron
  - < 1 nm: chemistry
  - Well controlled

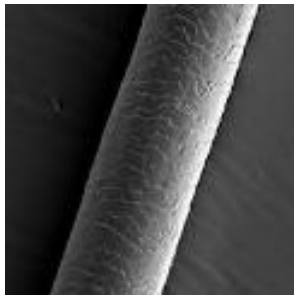


- Technology: mass production and use

→ Nanotechnology = mass production and use of controlled structures of 1-100 nm

Nanometer: what is it?

4 nm dot : football (22 cm) = football (22 cm) : earth (27 km)



nanotube (~1 nm) : human hair (~60 µm) = human hair (~60 µm) : main sewer pipe (4 m)

Nanotechnology: any news?

- No! China ware (pottery)

  start: 9000 BC;

  glass-like appearance: ~600

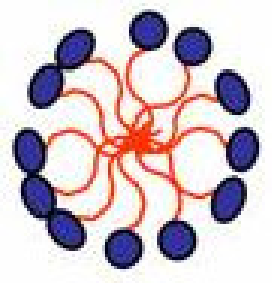
early copies in Europa (e.g. Delftware)
much cruder, poor clay technology

clay particles: platelets,
diameter: hundreds of nm
thickness: tens of nm

Nanotechnology: any news?

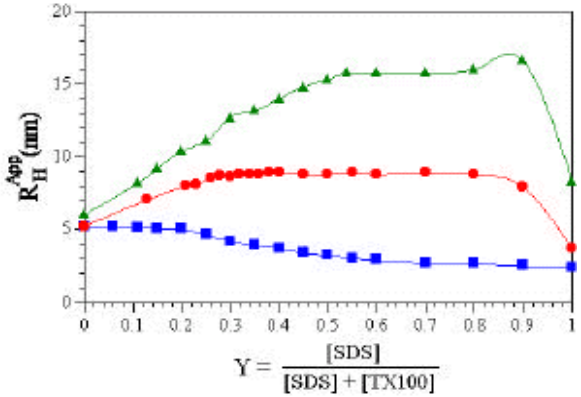
- No! Micelles in detergents

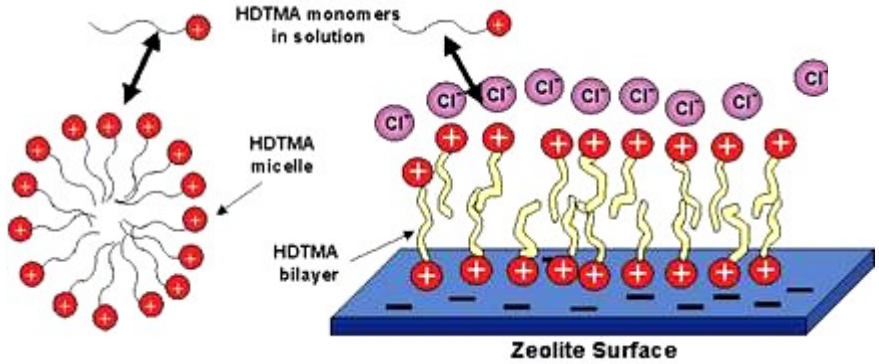
  Many surfactants form micelles
  above critical micelle concentration (CMC)
  micelle: spherule with water-loving parts
  of molecule on the outside



- Typical micelle diameter: 2-15 nm

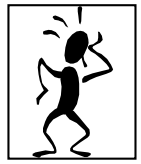
  bilayers on surfaces of same thickness





Conclusion on nanotechnology in cleaning:

- No future
- No foe
- No fiasco



but FAKE !?

Or is it?

Let us examine some recent developments

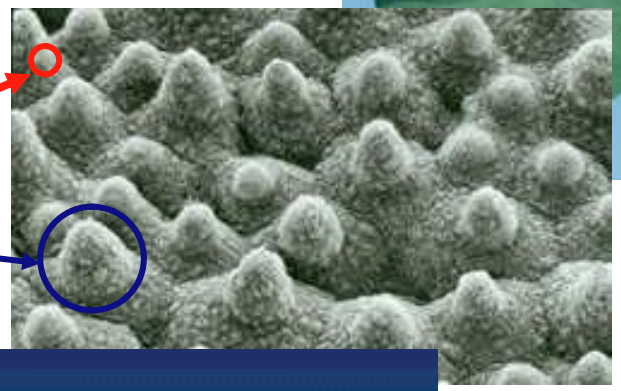
Nanotechnology with relevance to cleaning

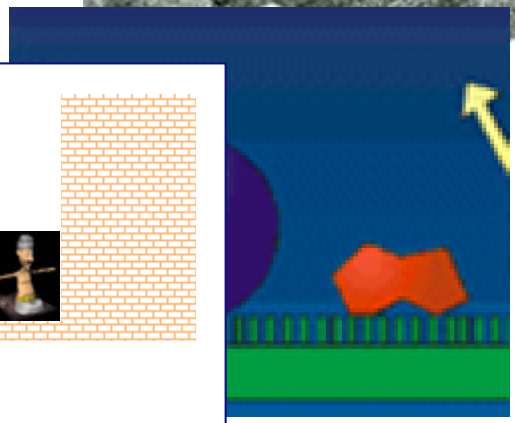
A. Coatings
- Soil-repellant coatings
- Soil-removing coatings
- Disinfecting coatings

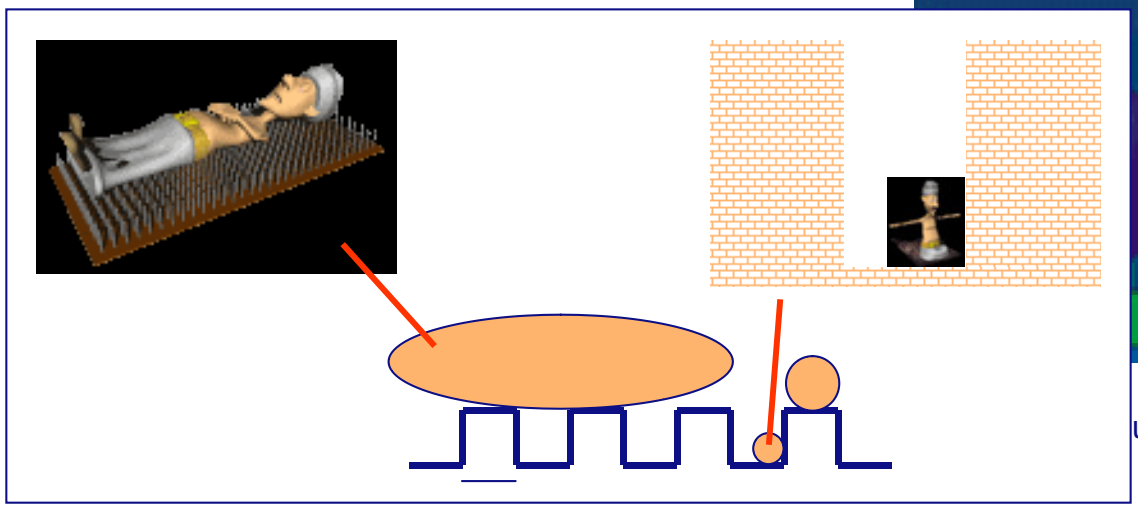
B. Cleaning agents
- Nanogreen
- Nanofibers
- Nanospray
- Electrically activated water

Coating technology: lotus effect

- Lotus-effect first understood by Bartlett & Neinhaus, Univ. Bonn, Germany
- Asian symbol of purity, rises clean from muddy water
- Due to structure of nanospheres on microcones
- Particles and droplets sit on the ‘lotus-coat’ as fakirs on nail-bed



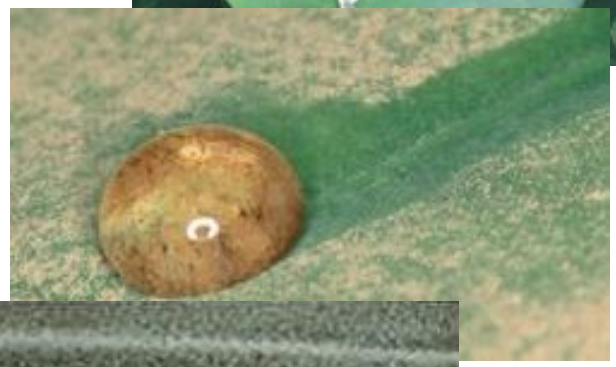


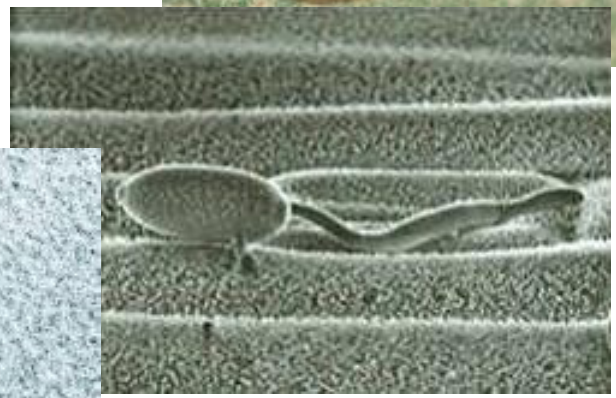


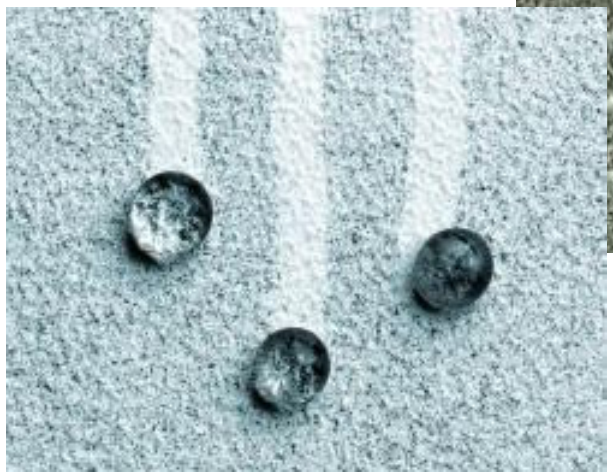
urce of images: www.lotus-effekt.de

Coating technology: lotus effect (2)

- Liquids runs off very quickly
  (water repellant wax + very low friction)
- Water running of drags dust particles,
  bacteria, fungi et cetera
- Thus, the leaves become
  cleaned and sanitized
- Effect can be mimicked,
  e.g. with Lotusan® of Bartlett c.s.





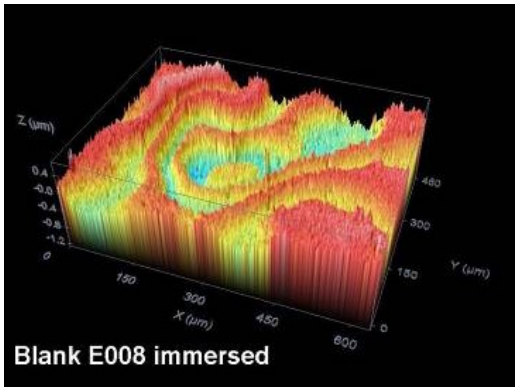


Source of images: www.lotus-effekt.de

Coating technology: lotus effect (3)

- Many different ways of producing ‘lotus-surface’
  - Waxy product sprayed on surface
  - Paint like product (e.g. Lotusan®)
  - Laser structuring
  - Polymeric reactions (‘raspberries’)
  - Polymeric layer with nanoparticles
  - Carbon nanotubes
  - Sol-gel method with clay particles (TNO)

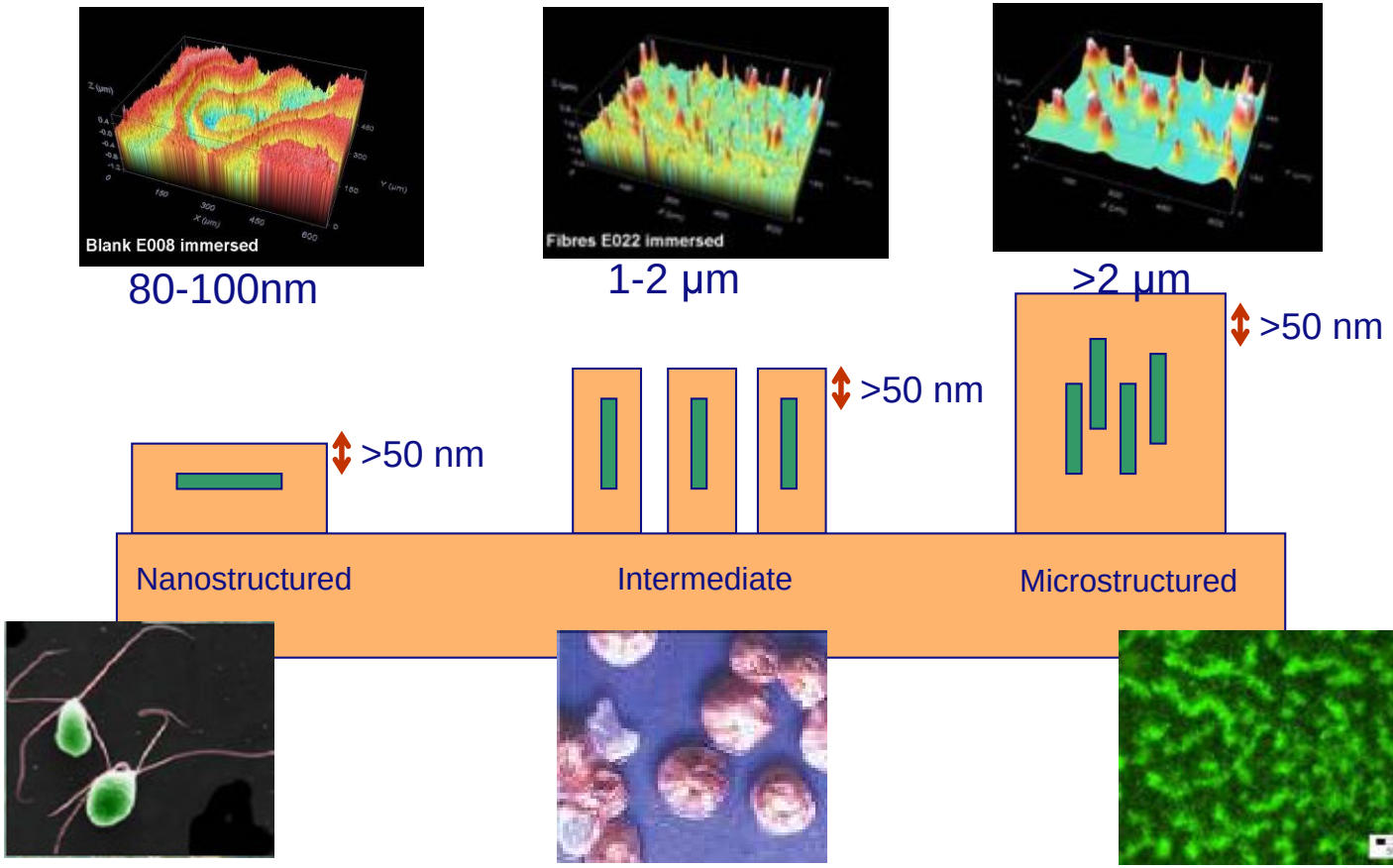
StoCoat™ Lotusan® enables simple, seamless application.



Raspberry coatings

Coating technology: lotus effect (4)

- Nanoparticles are modified and added to a sol-gel coating
- Different structures affectthe growth of different types of organisms.



Coating technology: lotus effect (5)

+ Water and soil repellent
+ ‘Self cleaning’ (if wetted by rain or other method)
+ Invisible
+ Several types commercially available

- Not very durable
  - Easily mechanically damaged
  - Does not repel graffiti
  - Interstices become dirty, greasy; then impossible to clean
- Not always easy to repair
- Not all types applicable on existing surfaces
  - Metal surfaces hard to treat with most systems
  - Care must be taken to apply the coating correctly
- Needs (regular and even) rain or other water source
- Matt appearance sometimes seen as drawback

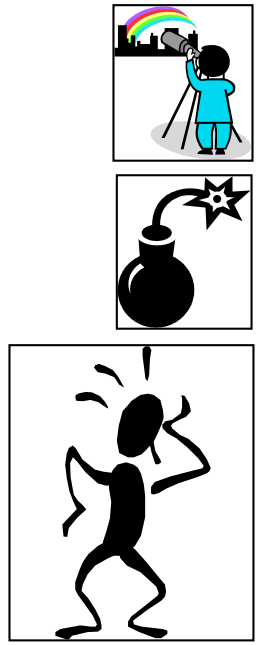
Coating technology: lotus effect (6)

Applicable on

+ Façades that receive rain
+ Windows; Car screen windows and mirrors
+ Bathrooms, sanitary appliances
+ Clothes (?)
+ Road signs, et cetera

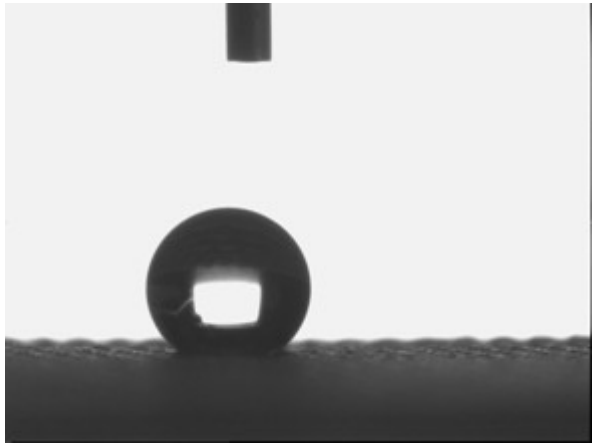
Not applicable on

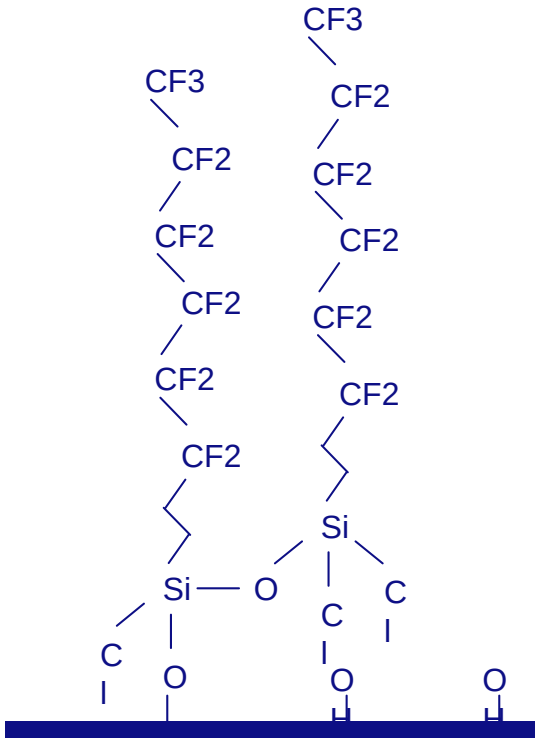
- Flooring
- Dry in and outdoor surfaces
- Façades that may be probe to graffiti
- In house walls



Coating technology: soil-repellant layer (1)

- Water repellent layers containing fluorine and/or silicon
  - Self assembly monolayers
  - Modifying surface with reactive groups
  - Applying through gas phase





- Familiar applications:
  - Carpets, furniture
  - Ceramics

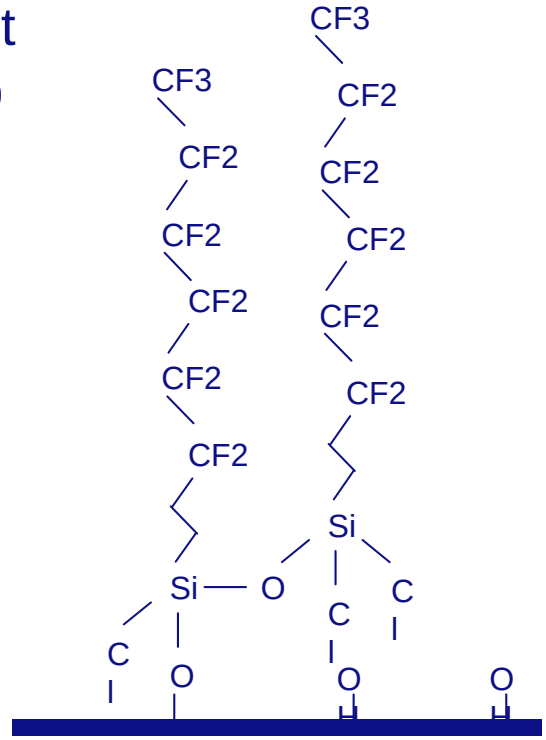
Coating technology: soil-repellant layer (2)

PRO's and CON's

+ Water and soil repellant; can be grafitti repellant
+ Easy to clean (but cleaning of dust still needed)
+ Invisible
+ Several types commercially available

± Fairly durable
  - Easily mechanically damaged;
  - sometimes vulnerable to sunlight

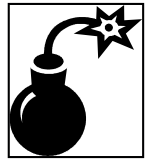
- Not always easy to repair
- Not all types applicable on existing surfaces
  - Care must be taken to apply the coating correctly
- Needs (regular and even) water source



Coating technology: soil-repellant layer (3)

Applicable on

+ Carpet, furniture
+ Façades
+ Windows; Car screen windows and mirrors
+ Bathrooms, sanitary appliances
+ Clothes
+ Road signs, et cetera

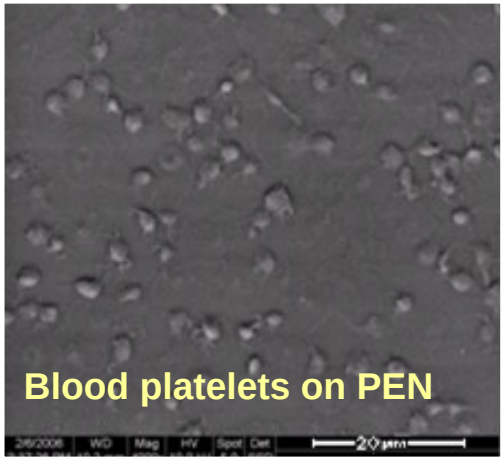


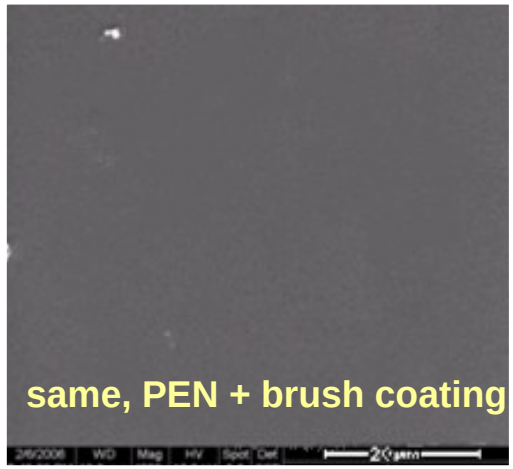
Not applicable on

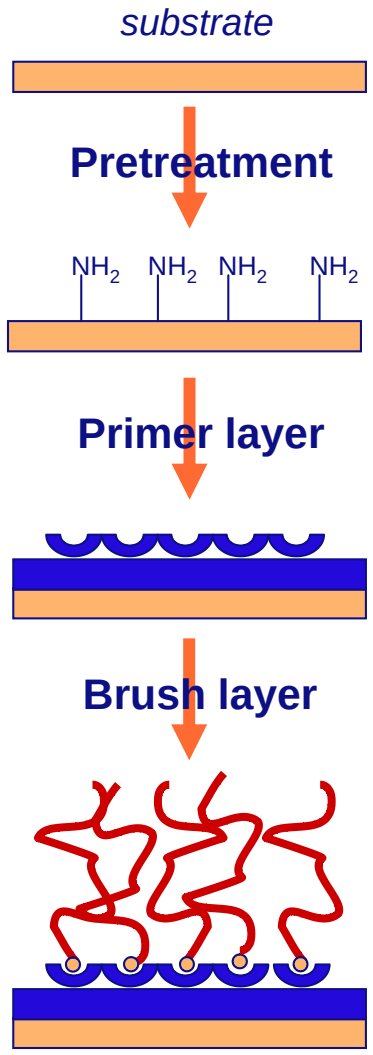
- Hard flooring
- Existing surfaces

Coating technology: brush coatings (1) (by TNO)

- Wide range of substrates: polymers, silicon, glass, metal oxides, textile, fibres, metals
- Large variety of polymers can be used
- Low adhesion of micro-organisms to surface







- Practical applications under investigation

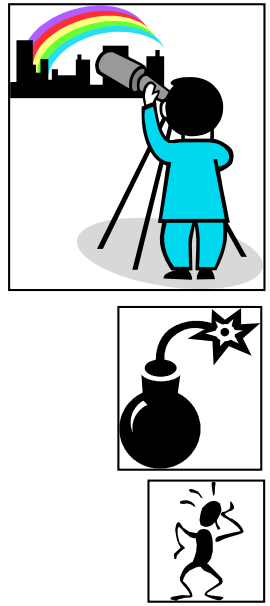
Coating technology: brush coatings (2) (by TNO)

PRO's and CON's

+ Water and soil repellant; can be grafitti repellant
+ Applicable on many surfaces
+ Good repellancy of bacteria etc.
+ Biocompatible
+ Invisible

± Easy to clean?
± Durability currently limited
± Unkown whether repairs can be made

- Not commercially available at this moment

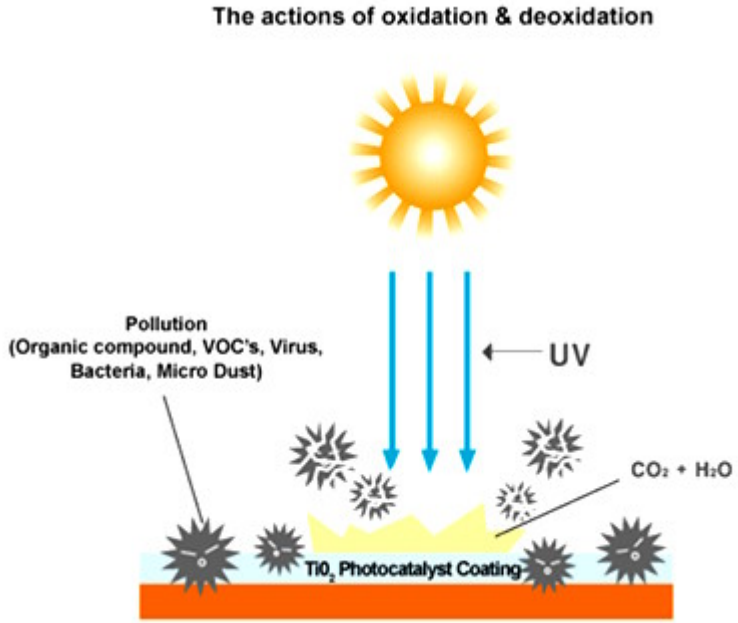


APPLICATIONS

- Medical instruments and textiles, ships, …??

Coating technology: catalytic layers (1)

- TiO_2 (titanium dioxide) in specific crystalline form
  - With UV-light catalyses the decomposition of organics, killing micro-organisms, removing odours
  - Keeps glass, metals very hydrophilic
  - (Rain) water runs of in even film (theoretically)



Source: nanopower.co.kr

Source: Pilkington Glass

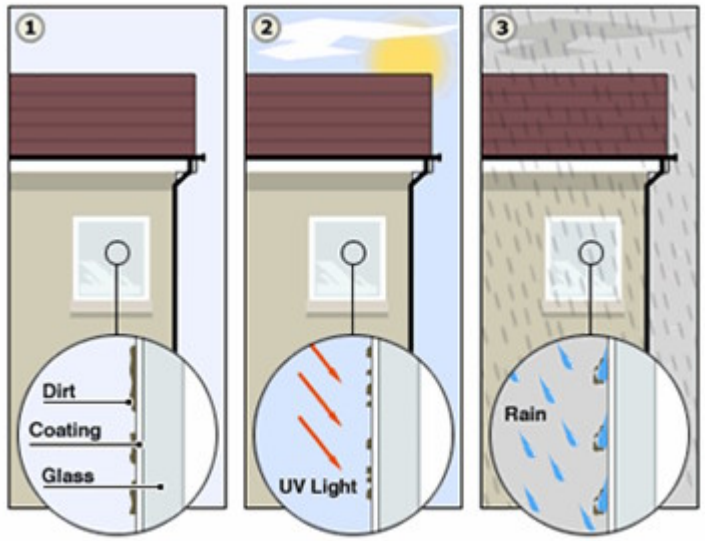
- Familiar applications:
- Glass (building, cars, mirrors)
  - coating for all kind of materials
  - Air cleaning systems (with UV source)
- Under investigation: clothing, textiles

Coating technology: catalytic layer (2)

PRO's and CON's

+ Removes odour, greasy components
+ Kills bacteria, viruses
+ Easy to clean (with water)
+ Invisible
+ Several types commercially available

- Not easy to repair (on glass)
- Non durable
  - Chemical attack by bird dropping et cetera
  - Easily mechanically damaged;
- Not all types applicable on existing surfaces
- Needs UV (and water) source



Source: Pilkington Glass

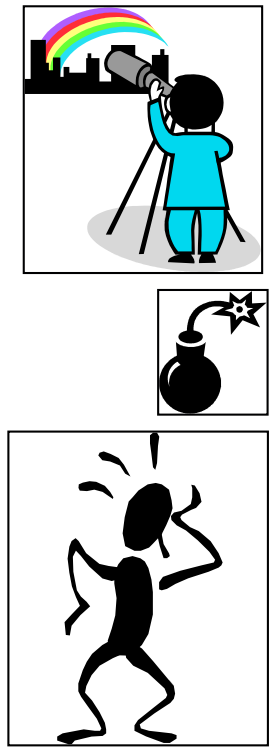
Coating technology: catalytic layer (3)

Applicable on

+ Façades, outer window
+ Car screen windows and mirrors
+ Air filter units (with UV source)
+ Clothes (?)
+ Road signs, et cetera

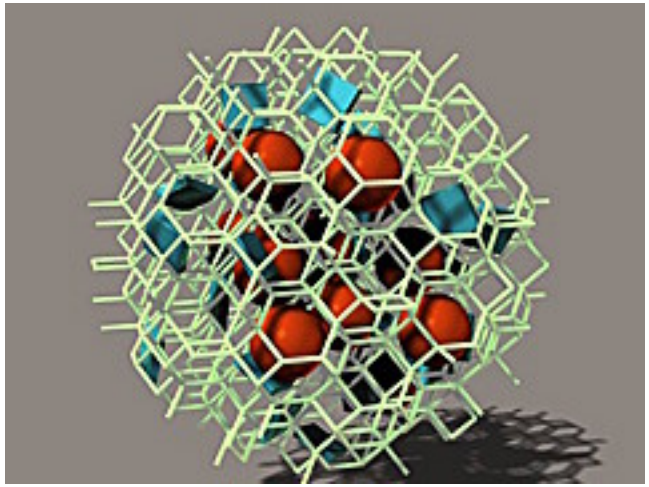
Not applicable on

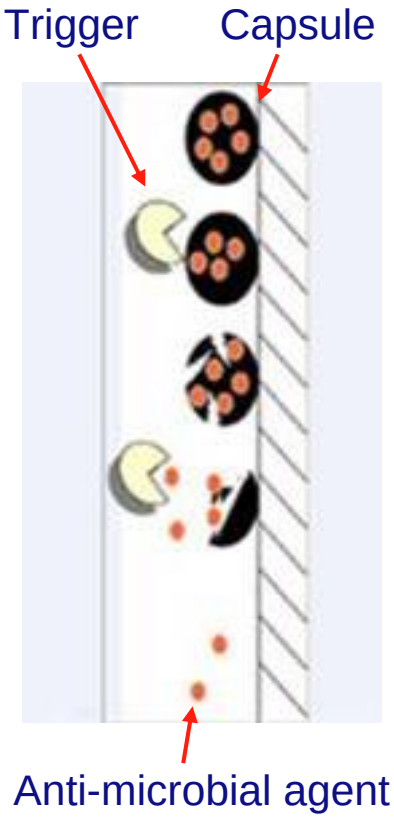
- Flooring
- In house surfaces



Coating technology: BioSwitch® (1) (TNO)

- Encapsulated anti-microbial agent
  - Biological trigger (e.g. specific enzyme) breaks the capsule
  - Anti-microbial agent is released
  - And destroys source of the trigger





- Practical applications under investigation

Coating technology: BioSwitch® (2) (by TNO)

PRO's and CON's

+ Agent only released when needed
+ Applicable on many surfaces
+ Good anti-microbial effectivity
+ Invisible

± For packaging only; one time use
± Sensitivity should be increased

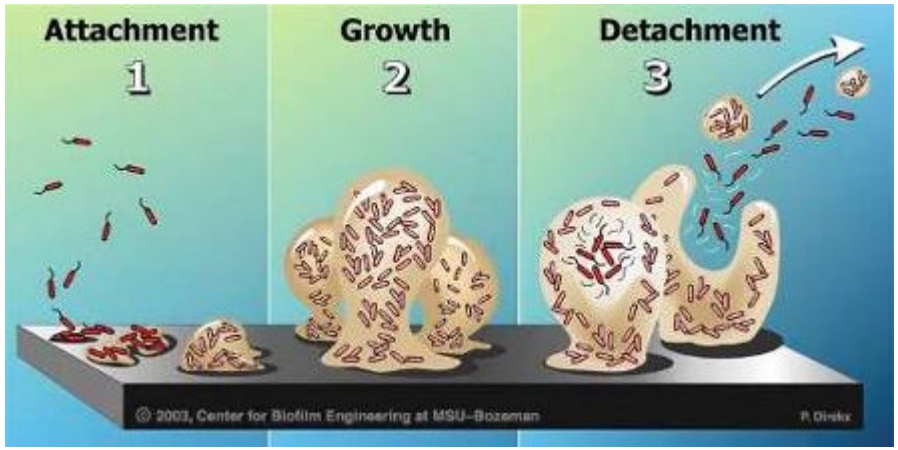
- Not commercially available at this moment

APPLICATIONS

- Packaging of food, pharmaceuticals, medical instruments
- Drug delivery

Coating technology: other anti-microbial (1)

- Loading of surface with antimicrobial agent, e.g. silver (nano)particles
  - Can kill microbes that try to attach
  - Metallic materials (copper, silver, even steel) good alternatives
  - Prevents biofilm formation



- Practical applications under investigation

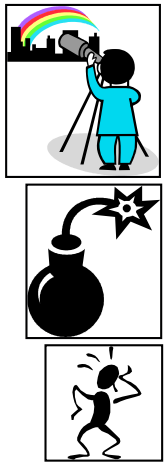
Coating technology: other antimicrobial (2)

PRO's and CON's

+ Applicable on many surfaces
+ Good anti-microbial effectivity
+ Invisible

± Durability problematic (e.g. 100-200 days for silver nanoparticles
± Concerns for human safety and environment (nanoparticles, metal ions)

- No cleaning effect, only anti-microbial



APPLICATIONS

- Medical

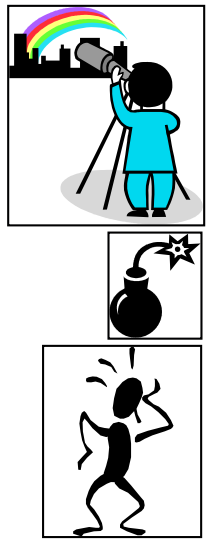
Coating technology: summary and conclusion

PRO's and CON's

+ Plethora of options available
+ Often affordable and fairly easy to apply

± Commercial success limited up to this time
± Number of (nanosized) companies booming

- Most if not all options have limited applicability
- Removal of gross dirt, residues often still needed
- Durability is often if not always problematic
- Concerns over health, environmental issues



Cleaning: Nano Green Sciences (1)

New detergent made from natural products (hence ‘green’)

Some claims:

- “unique nano-scale particle size of 1-4 nm”
- “The micelle is comprised of a collection of linear molecules or fatty esters and fatty acids”
- “biobased and biodegradable”
- “Its fatty acid content provides Nano Green with the added attribute of being antibacterial, antimicrobial and antifungicidal; it also possesses disinfecting and sanitizing capabilities”
- “Nano Green possesses a wide array of formulations, which are suitable for the varied and widely diverse applications of the Jan/San market”

Source: www.nanogreensciences.com

Cleaning: Nano Green Sciences (2)

However:

- All micelles have a *not so* “unique nano-scale particle size of 1-4 nm”
- Many products contain “a collection of linear molecules or fatty esters and fatty acids”
- The ‘greenness’ of fatty acids is controversial: potential food is made into detergent; substantial amounts of pesticides are used in the production
- All products containing fatty acids“biobased and biodegradable”
- And “posses disinfecting and sanitizing capabilities”
- Many companies market “a wide array of formulations, which are suitable for the varied and widely diverse applications of the Jan/San market”

CONCLUSION

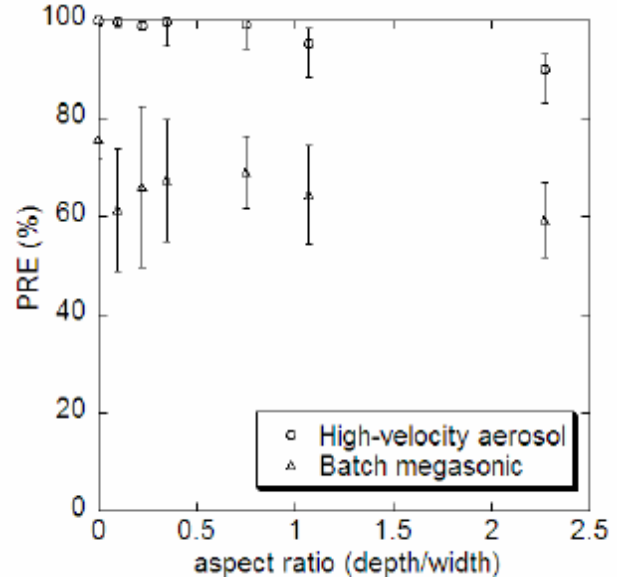
Cleaning: nanofibers

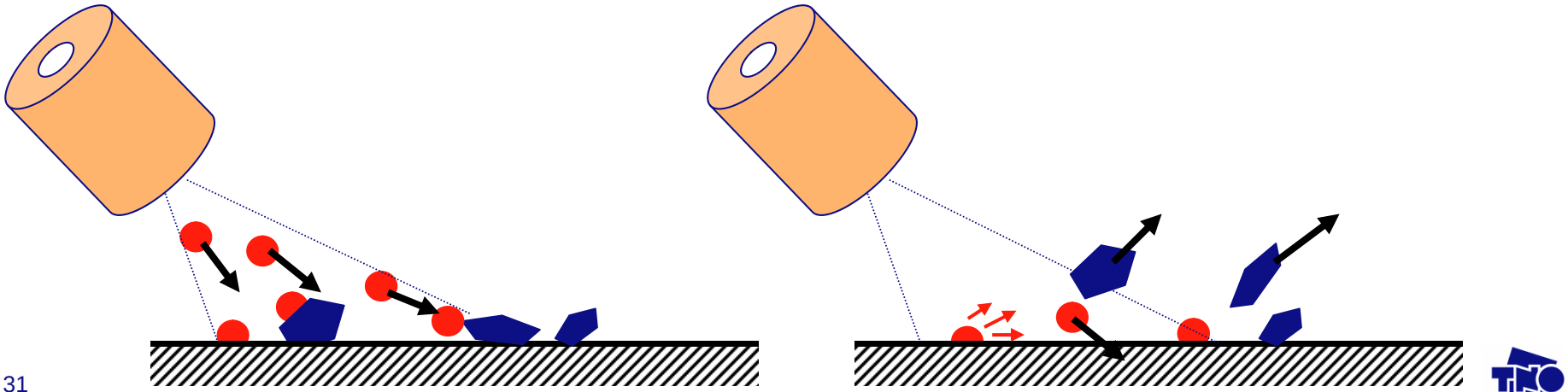
- Some producers market ‘nanofibre’ cleaning materials, with properties comparable to microfibres
- ‘Nanofibres’ appear to have diameter > 100 nm
- No real difference to microfibers !?
  No evidence for differences or smaller size.

CONCLUSION

Cleaning: nanospray

- Spraying water at very high pressure through minute nozzle
- Yields high velocity submicron droplets
- Droplets remove small particles by impact (nano-snooker)
  and evaporate directly, leaving dry surface





Cleaning: nanospray

+ 100% removal of nanoparticles, even from trenches
+ Little or no damage to nanostructures

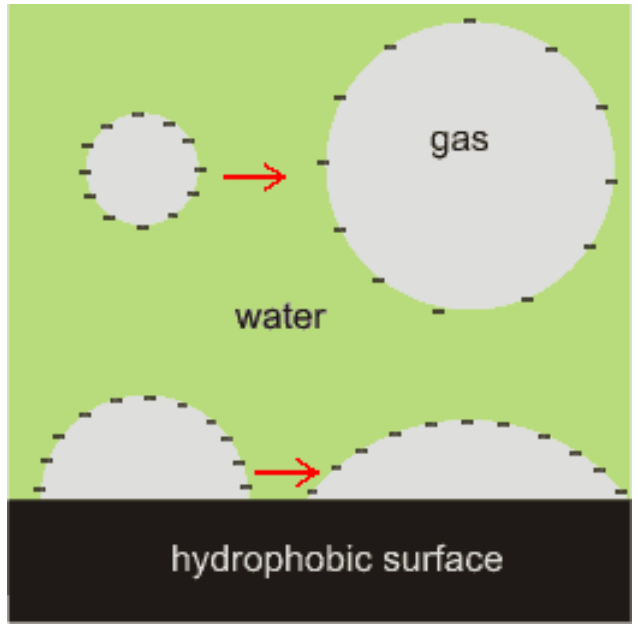
- Very low production rate, suitable only for wafer, reticle cleaning

CONCLUSION

FUTURE

Cleaning: Electrically activated water

- Growing evidence of cleaning effect of electrically activated water
- Some detergency noted after mixing anodic and cathodic water
- Possible explanation: nanobubbles stabilized by (negative) electric charge
- Nanobubbles would attach to dirt, causing them to charge and repel the surface
- More experimental, independent evidence needed

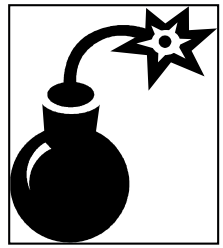


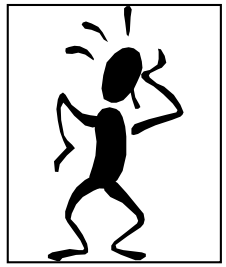
Source:
www.lsbu.ac.uk/water/nanobubble.html
(prof. M.L. Chaplin, London Southbank University)

CONCLUSION ???

Conclusion (with respect to jan/san cleaning)

- Nanotechnology holds some FUTURE:
  - Coatings: soil repellant, (catalytic), (antimicrobial)
  - Cleaning: electrically activated water?
    - Better understanding on nanoscale needed
- Nanotechnology is hardly a FOE:
  - Cleaning often still necessary, but easier
  - Limited applications for nanotechnology
- Nanotechnology is sometimes a FIASCO
  - Lotus effect
- And sometimes FAKE
  - Nanofibers, nano green, …





Conclusion

- Nanotechnology is no miracle, no cure-it-all, no revolution
- Nanotechnology is part of a continuous technological development that can make our lives easier, better
- ‘Nano inside’ does not really matter: (cleaning) products should be effective, efficient & safe for man, material and environment
- Claims should always be substantiated, preferably by independent research bodies