Functional Textiles:
Nanotechnology Approaches

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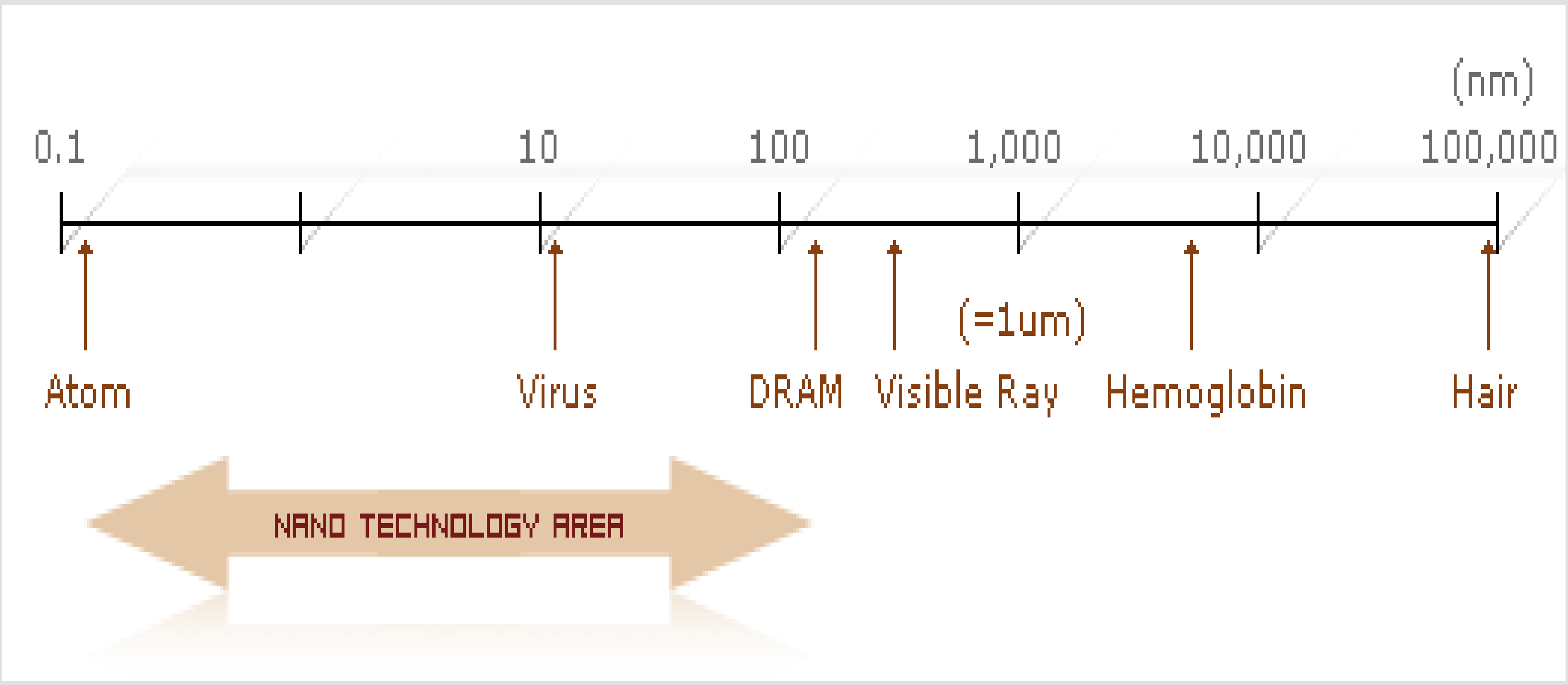
Assistant Prof. Dr. Apichart Sonthisombat
Rajamangala University of Technology Thanyaburi

What is Nanotechnology?

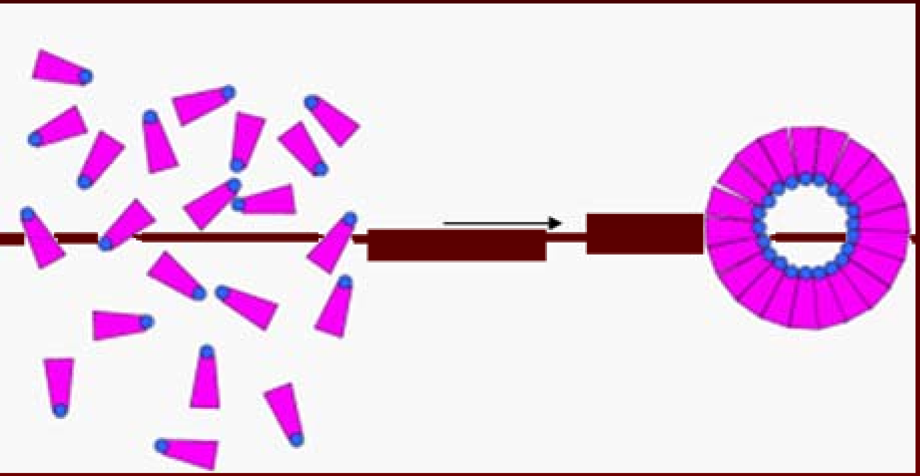


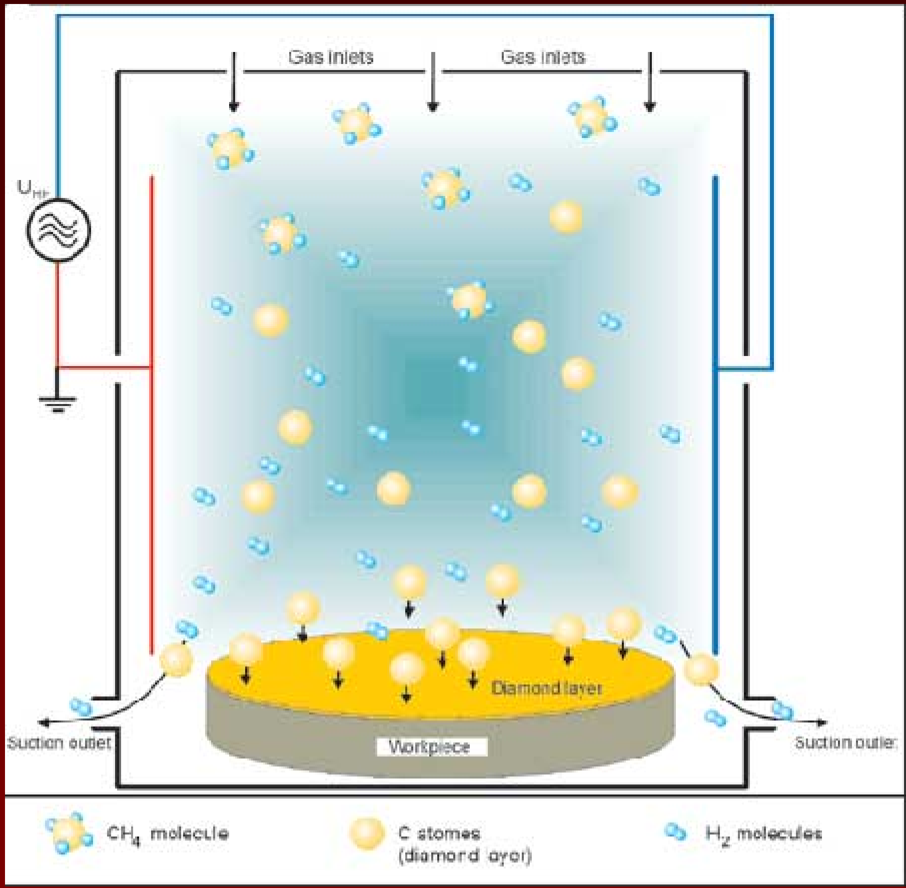
http://www.nano-silver.net/eng/index.php

Ways to Produce Nanomaterials

- **Bottom-Up Technique**
  - Self-Assembly
  - Sol-gel
  - Chemical Vapor Deposition
  - Nanomanipulation
  - 3D Printing
- **Top-Down Technique**
  - Milling
  - Plasma Particles

Self-Assembly





Chemical Vapor Deposition

http://www.csacs.mcgill.ca/selfassembly.htm

http://www.ieee-virtual-museum.org/collection/tech.php?taid=&id=2345958&lid=1

An Example of Direct Preparation of Silver Nanoparticles in Textiles

Ag^+ Silver Nitrate Solution (Exhaustion)

↓ Ammonia + Reducing Agent (Hydrazine, Glycerol, Glucose)

Ag Silver Nanoparticles Grown in Textiles

Note: Main Problem is how to make them evenly coated on fabric

US PATENT 6,979,491

Nanopowders by a modified sol-gel method (Institute of Advanced Energy, Kyoto University, Japan)

Metal Alkoxide + Acetylacetone (ACA)

0.1 M Laurylamine Hydrochloride (LAHC)

Aqueous Solution

Stirring at room temperature for 1 h

Stirring at 40^{O}C for 24 h

Nanopowders by a modified sol-gel method (Institute of Advanced Energy, Kyoto University, Japan

Keep at 80^{o}C for 1 week

↓

Dry at 80^{O}C for 24 h

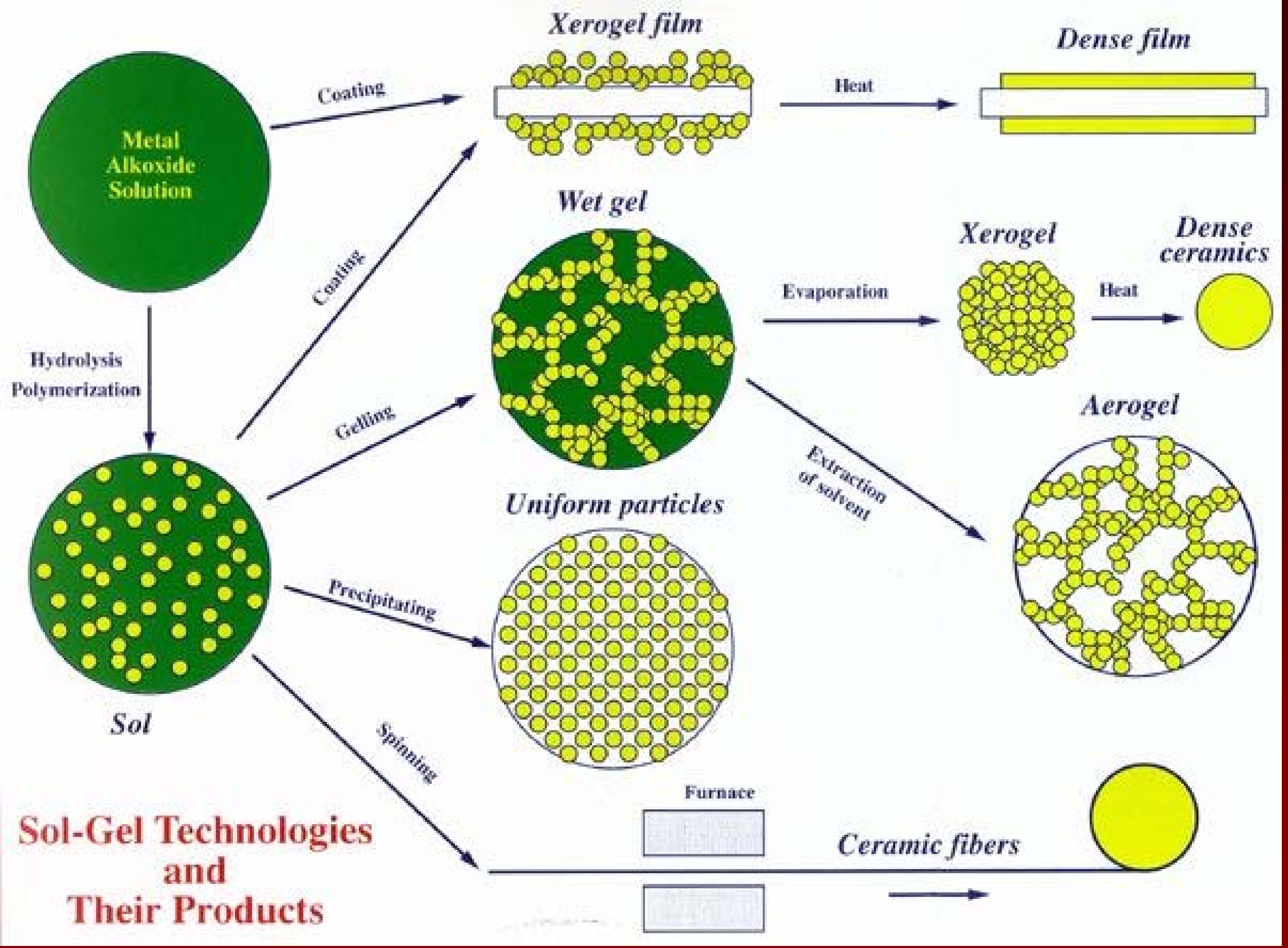
↓

Calcinations at 400^{o}C for 4 h

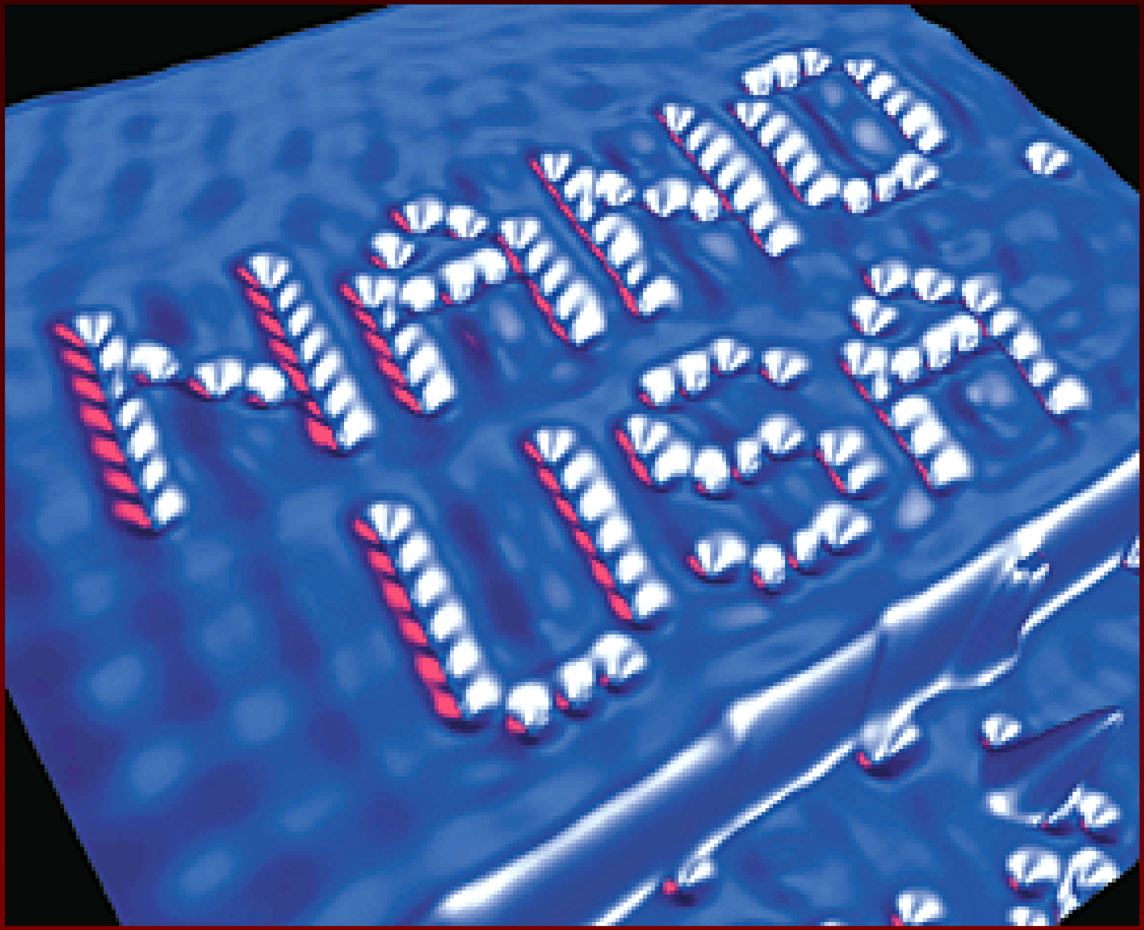
↓

Characterization

Results: The modified sol-gel process using a surfactant enabled to fabricate various metal oxides possessed high crystallinity with <u>crystal size about 5-15 nm</u>, high surface area (44-80 m^{2}/g) and average pore diameter about 3-6 nm.

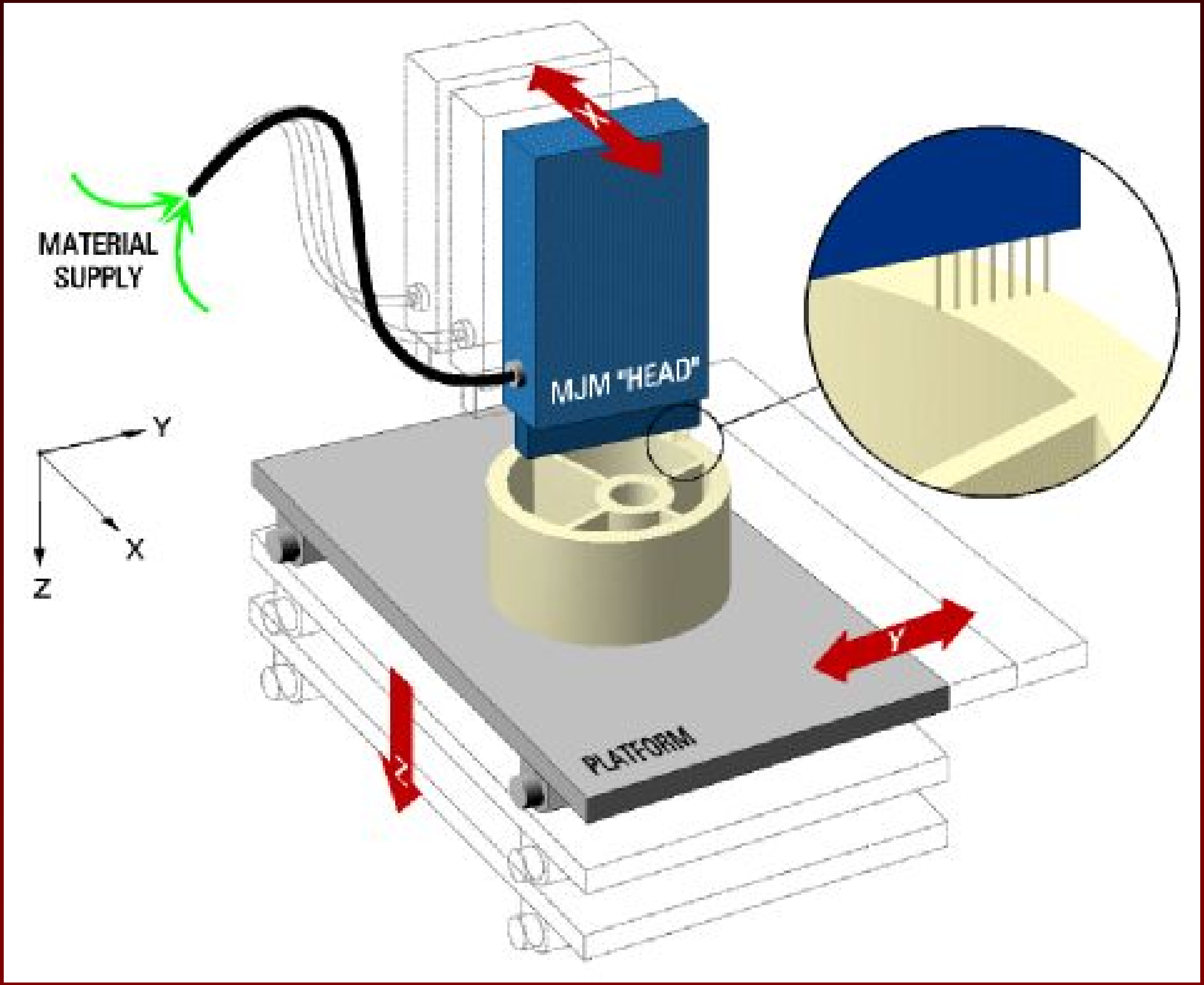


http://www.chemat.com/assets/images/Flowchat72.jpg



An Example of Nanomanipulation

http://www.georgehernandez.com/h/xzMisc/Science/media/nano/112COMoleculeMsgByIBM.gif



An Example of 3D-Printing Machine

http://www.warwick.ac.uk/atc/rpt/Techniques/3dprinting.htm

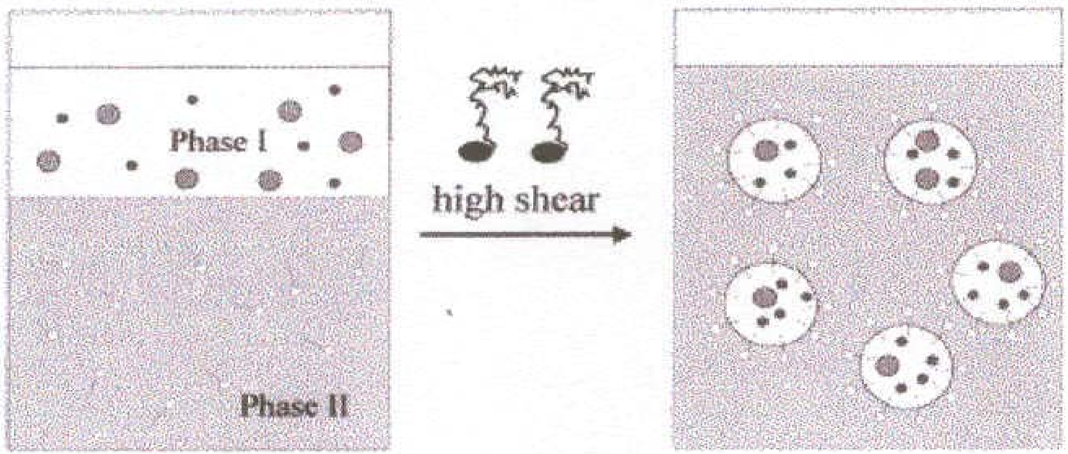
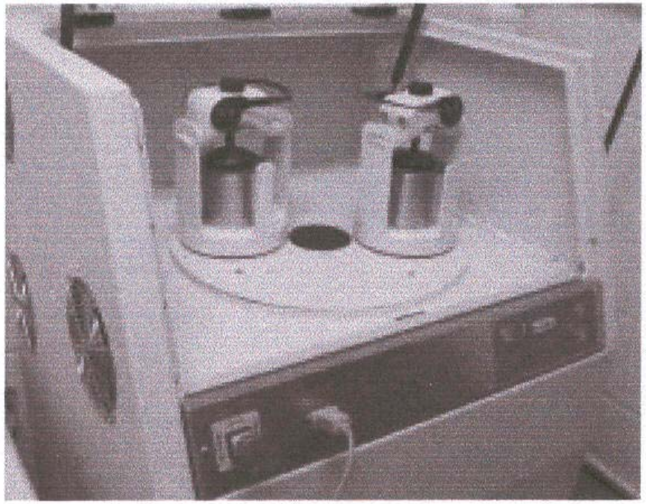
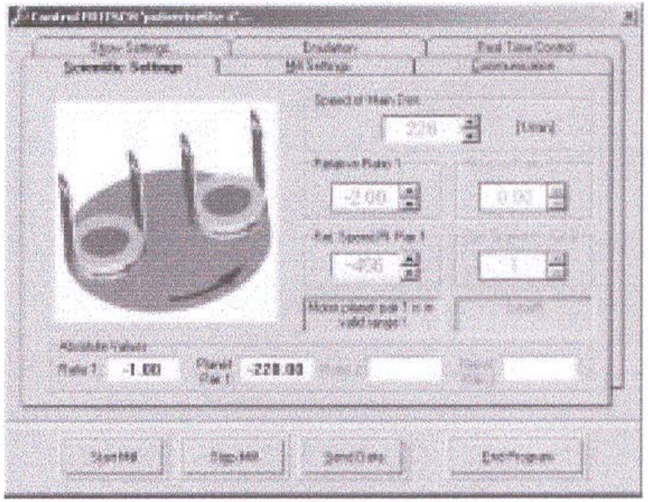


Fig. 1. The miniemulsion principle.

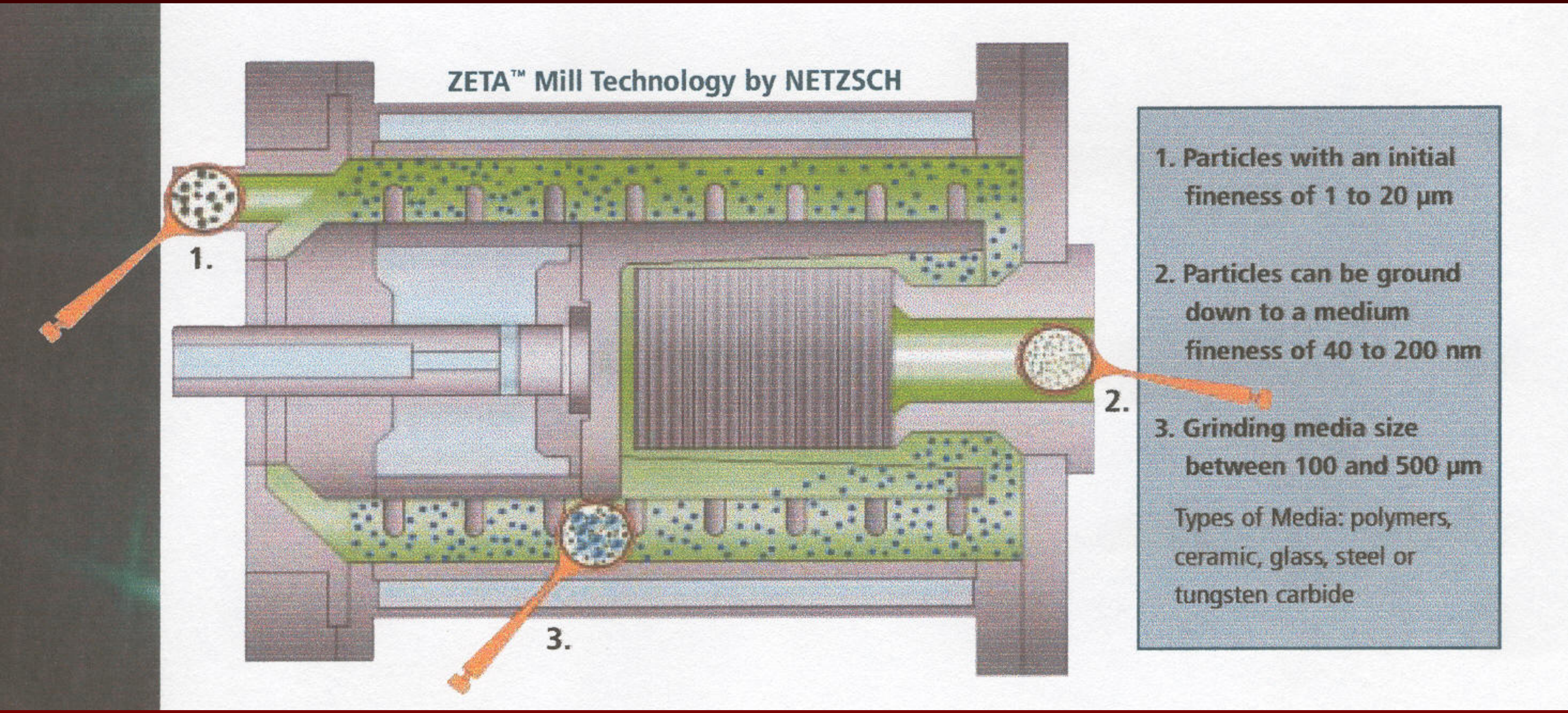
Encapsulation





Ball Milling Machine for Nanoparticle Preparation

http://www.fritsch-heidolph.co.jp/page01.html



Milling Machine for Nanoparticle Preparation

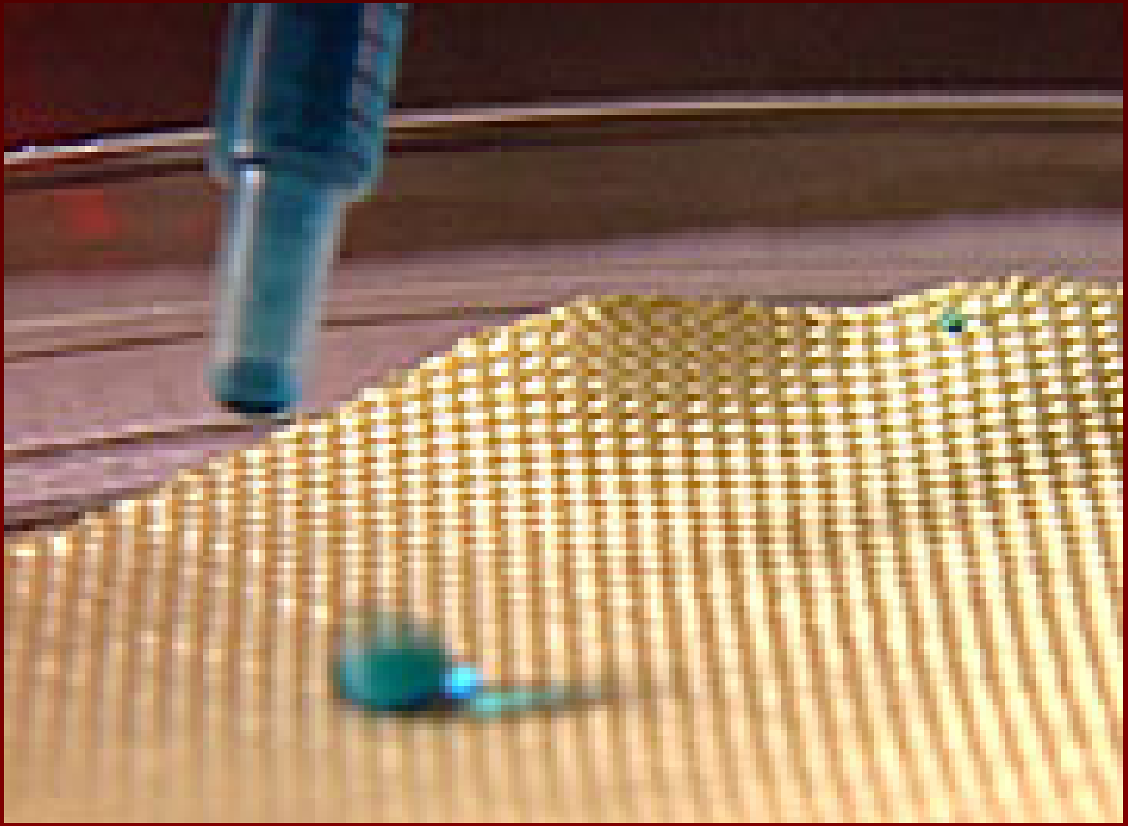
http://www.netzschusa.com

Nanotechnology for Textiles

1. Water Repellent Effect
2. UV-Protection Effect
3. Antimicrobial Effect
4. Antistatic Effect
5. Wrinkle Resistance Effect

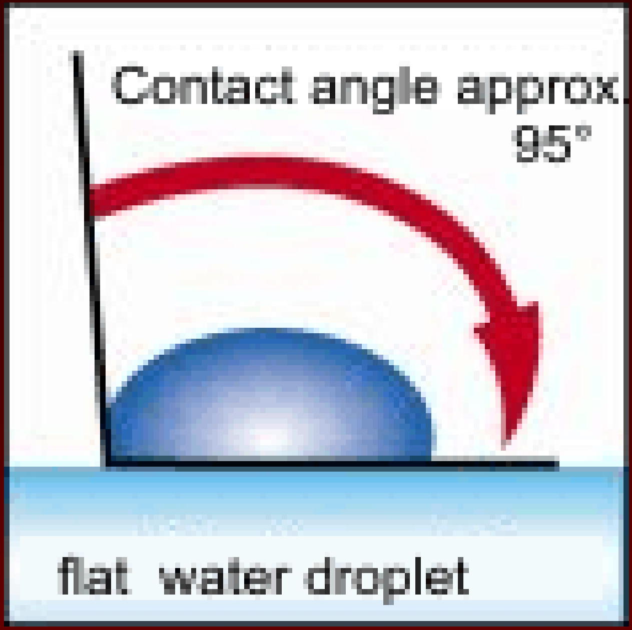
Nanotechnology for Textiles

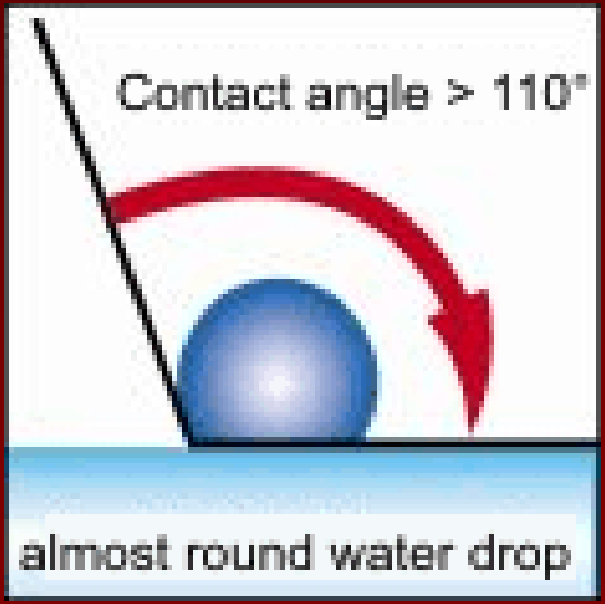
1. Water Repellent Effect



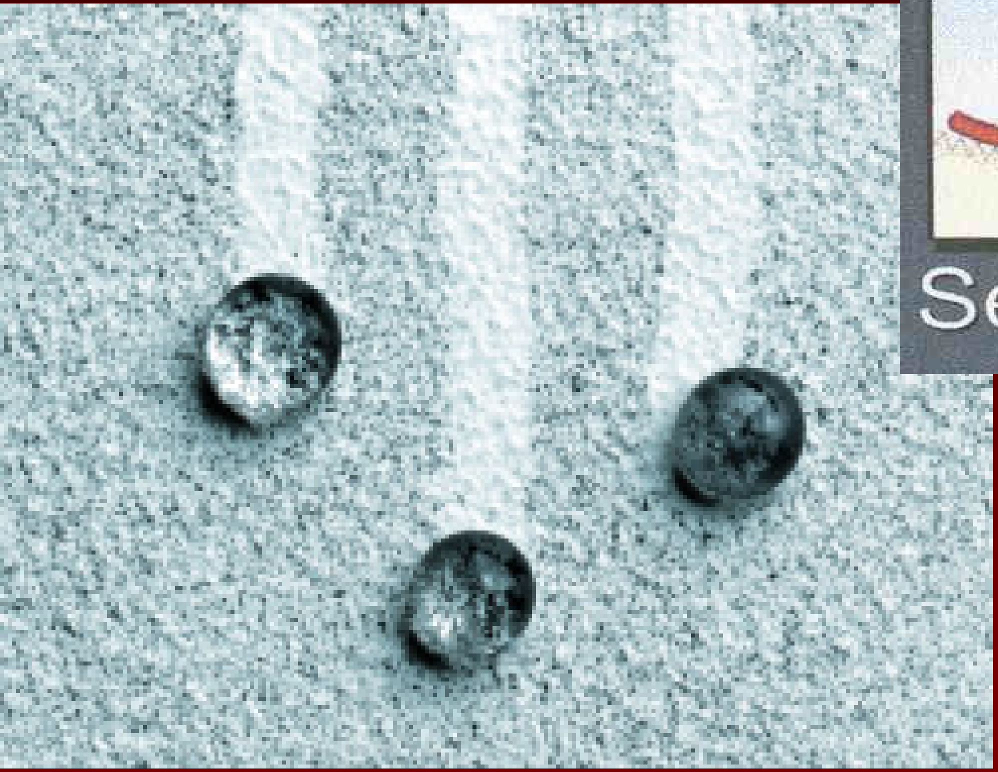
http://www.corporate.basf.com/en/innovationen/felder/nanotechnologie/?id=Opz3Z56hHbcp-kb#7

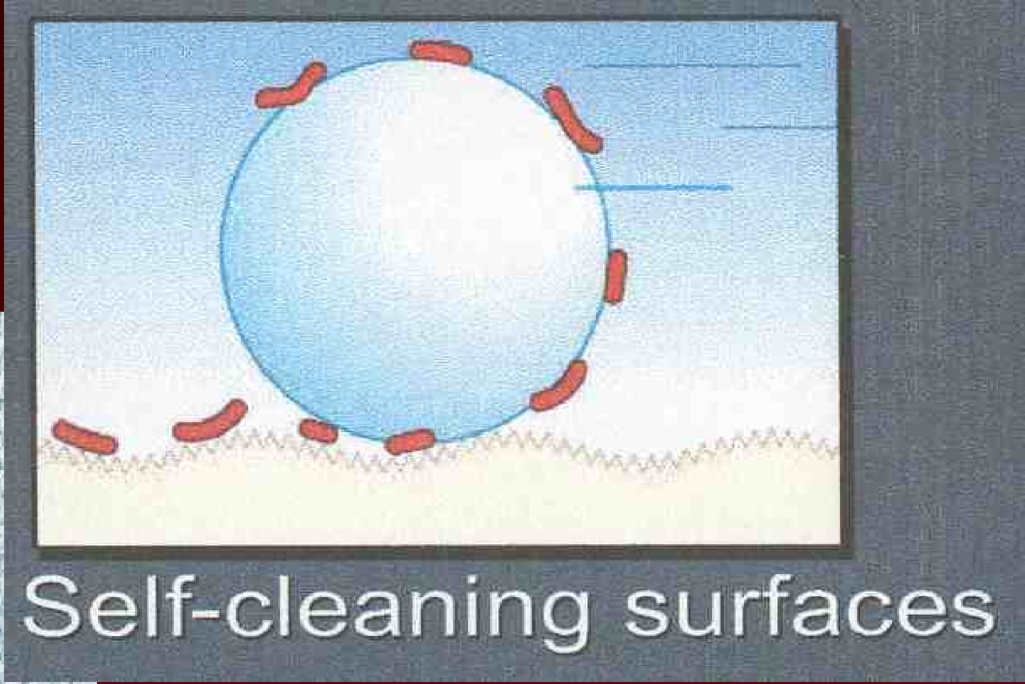
http://www.sciencentral.com/articles/view.php3?article_id=218392046&language=english

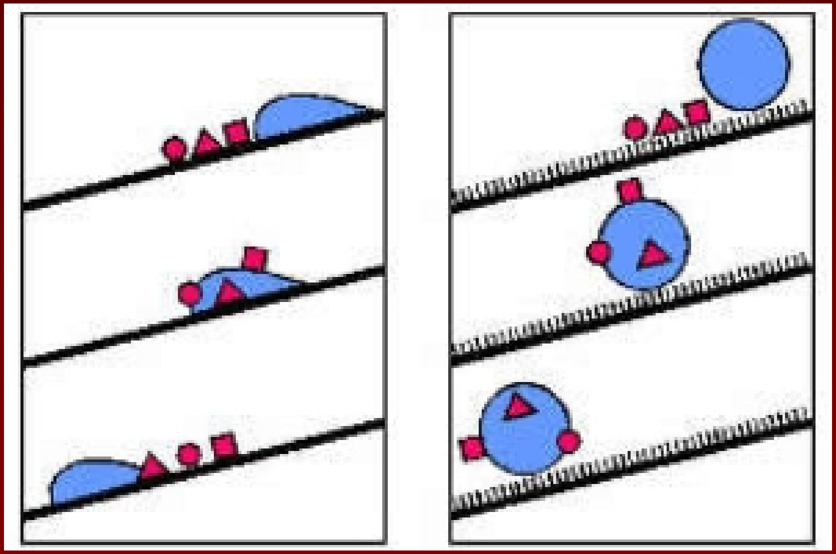




http://www.zeiss.de/4125680F0053A38D/ContentsWWWIntern/FE6774D035ABB49CC1256DF3003C7B36

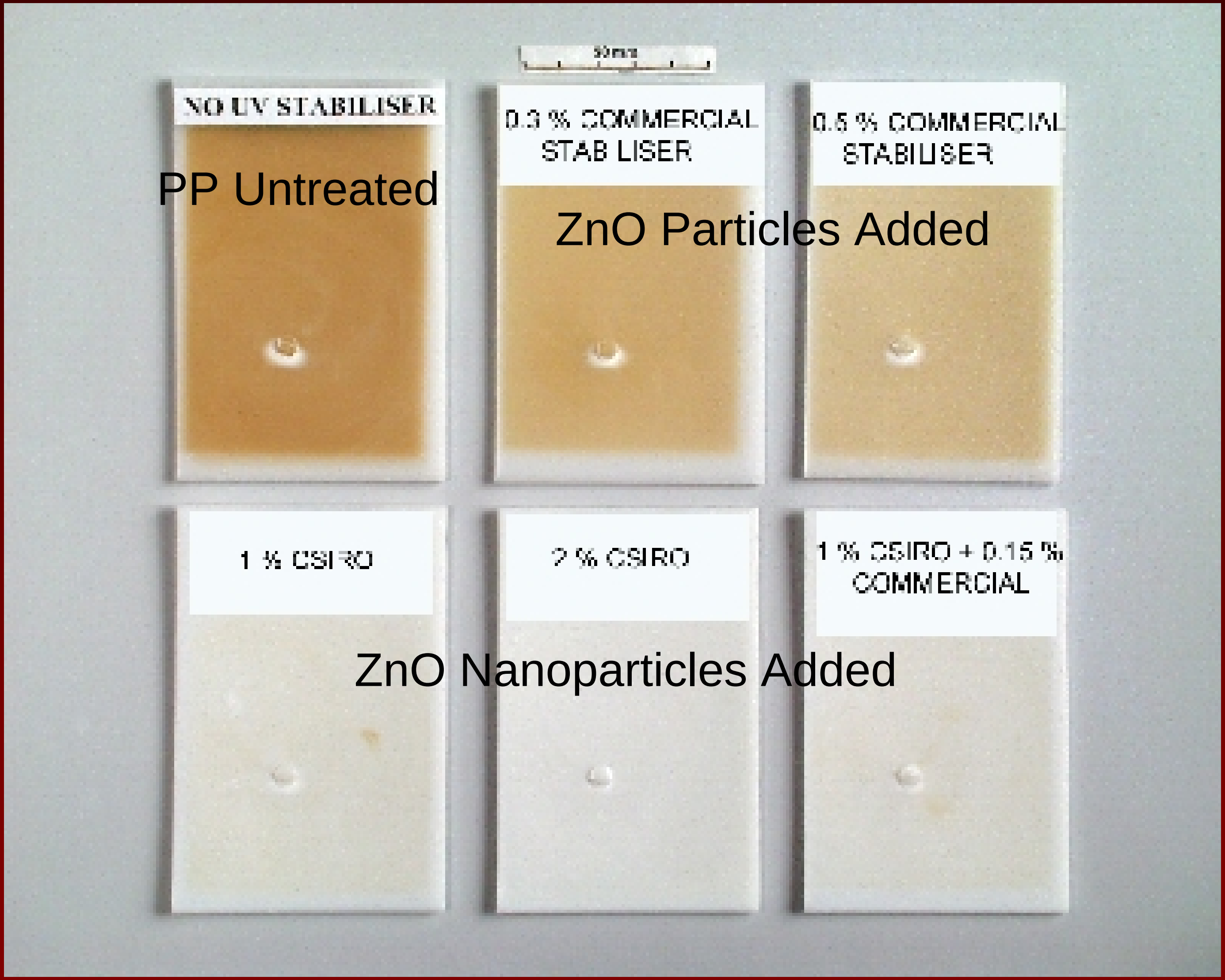




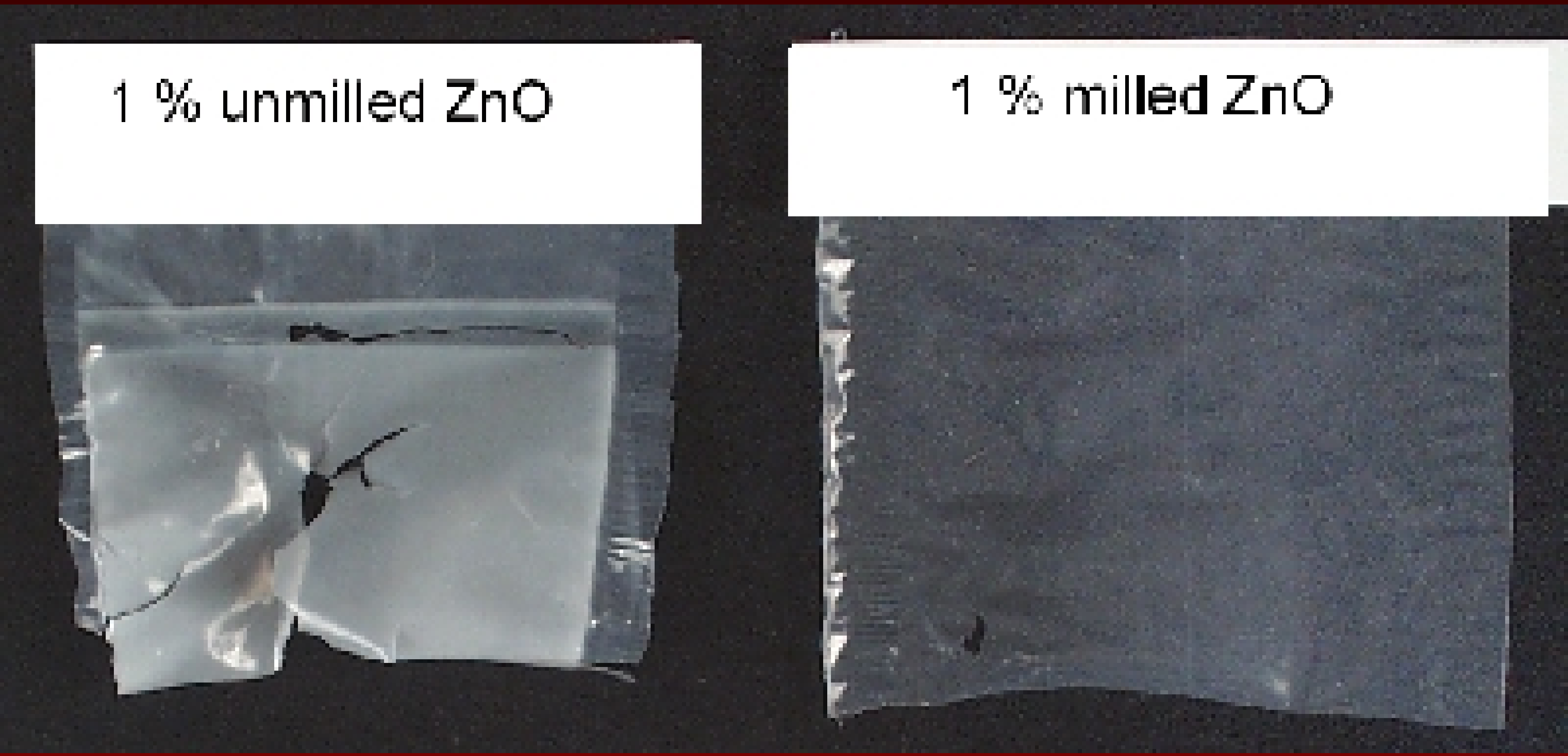


http://www.wupperinst.org/FactorFour/best-practices/lotus-effect.html

2.UV-Protection Effect



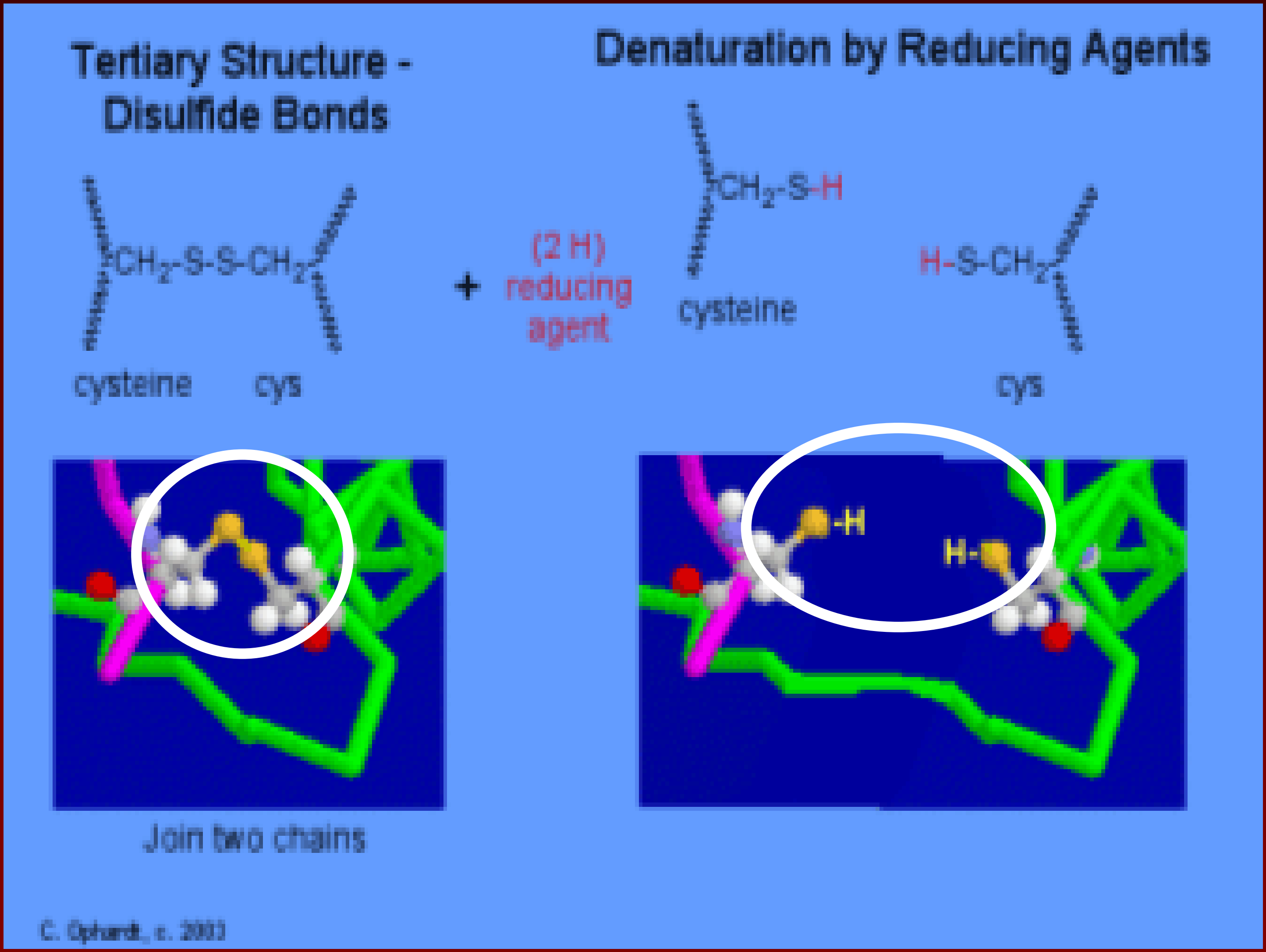
http://www.cmst.csiro.au/nanotech/polymers.htm



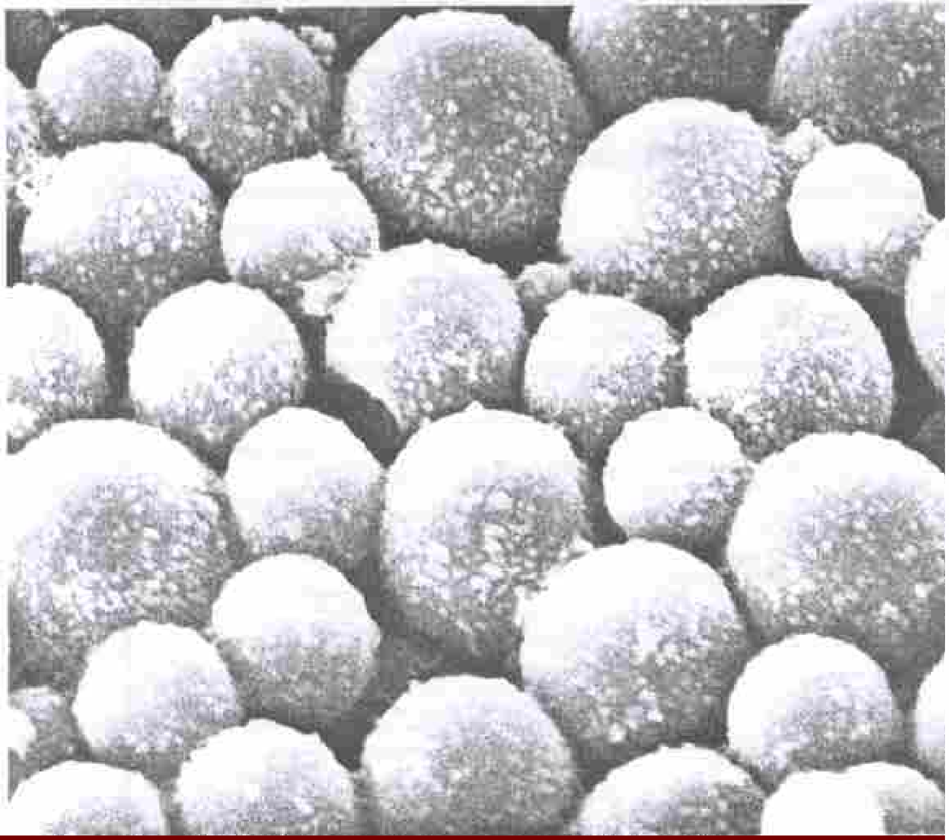
ZnO Nanoparticles for UV Protection

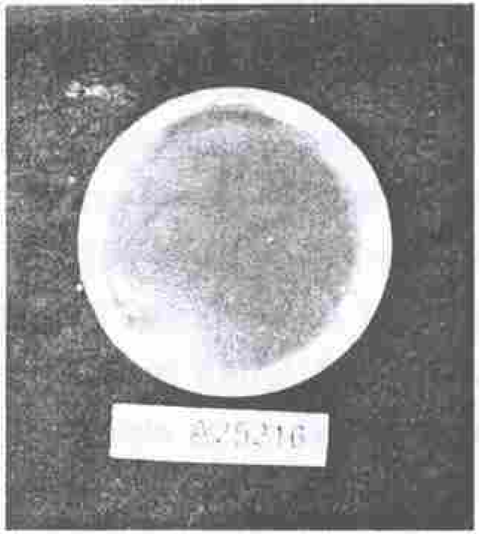
http://www.cmst.csiro.au/nanotech/polymers.htm

3. Antimicrobial Effect



http://www.nano-silver.net/eng/index.php





Used organism	Staphylococcus aureus (ATCC 6538P)	Klebsiella pneumoniae (ATCC43652)
Bacteriostatic Activity Value	5.3	4.6
Biostatic rate(%)	99.9	99.9

(KOTITI ; Korea Textile Inspection & Testing institute)

NanoSilver for Anti-microbial Effects

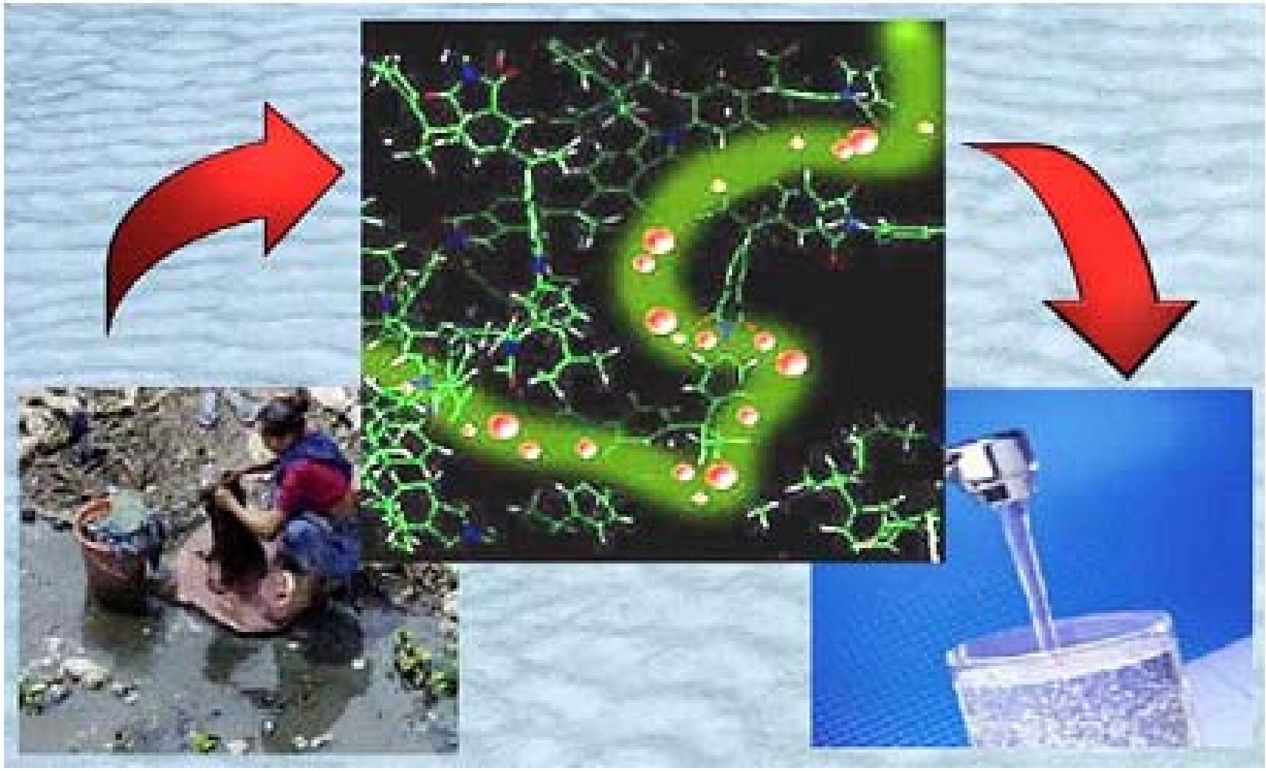
http://www.polychrom.com

4. Antistatic Effect

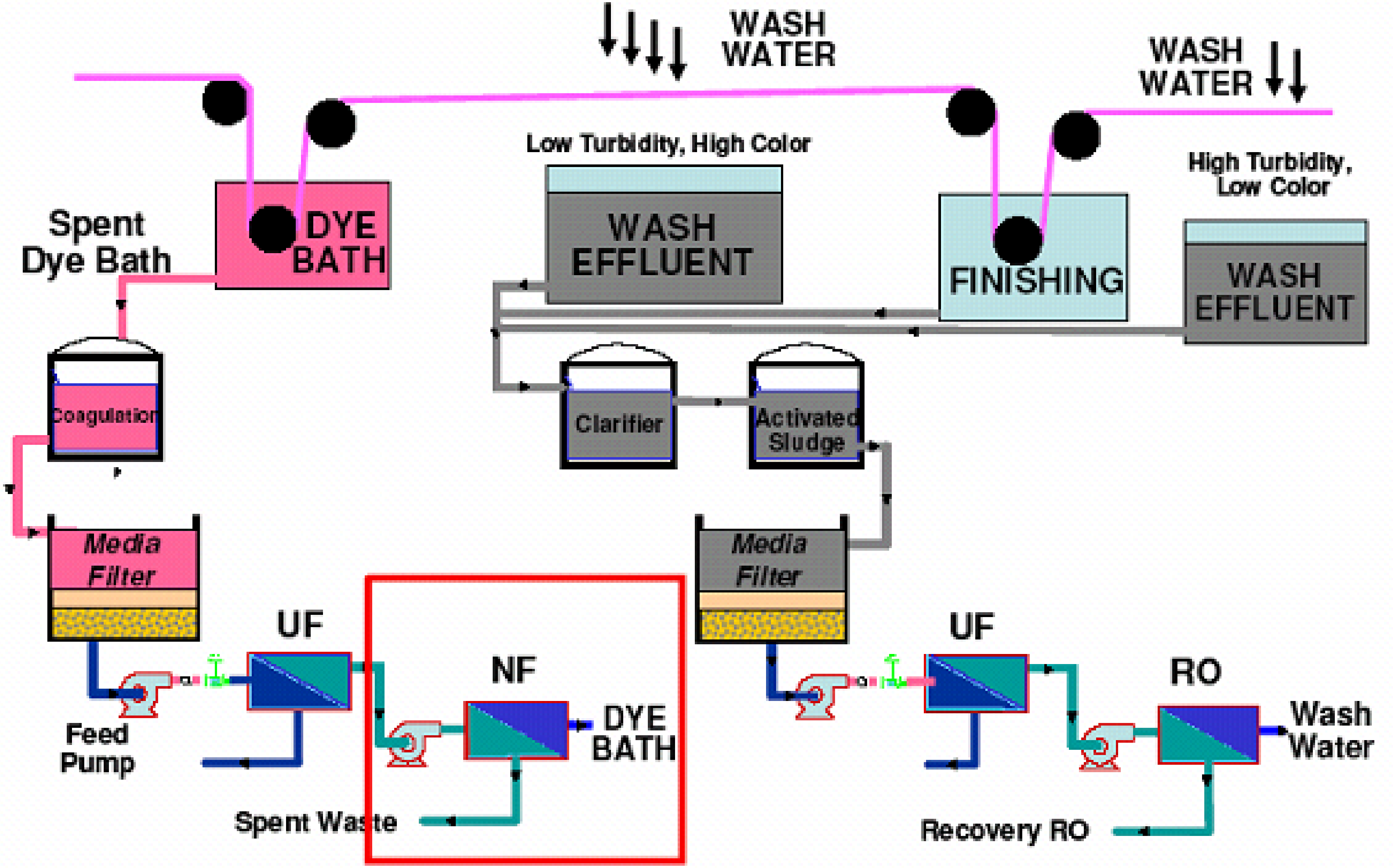
5. Wrinkle Resistance Effect

http://www.garments.globalsources.com/MAGAZINE/GAT/0607/IMAGES/ECFCNYUA.JPG

6. Water Filter

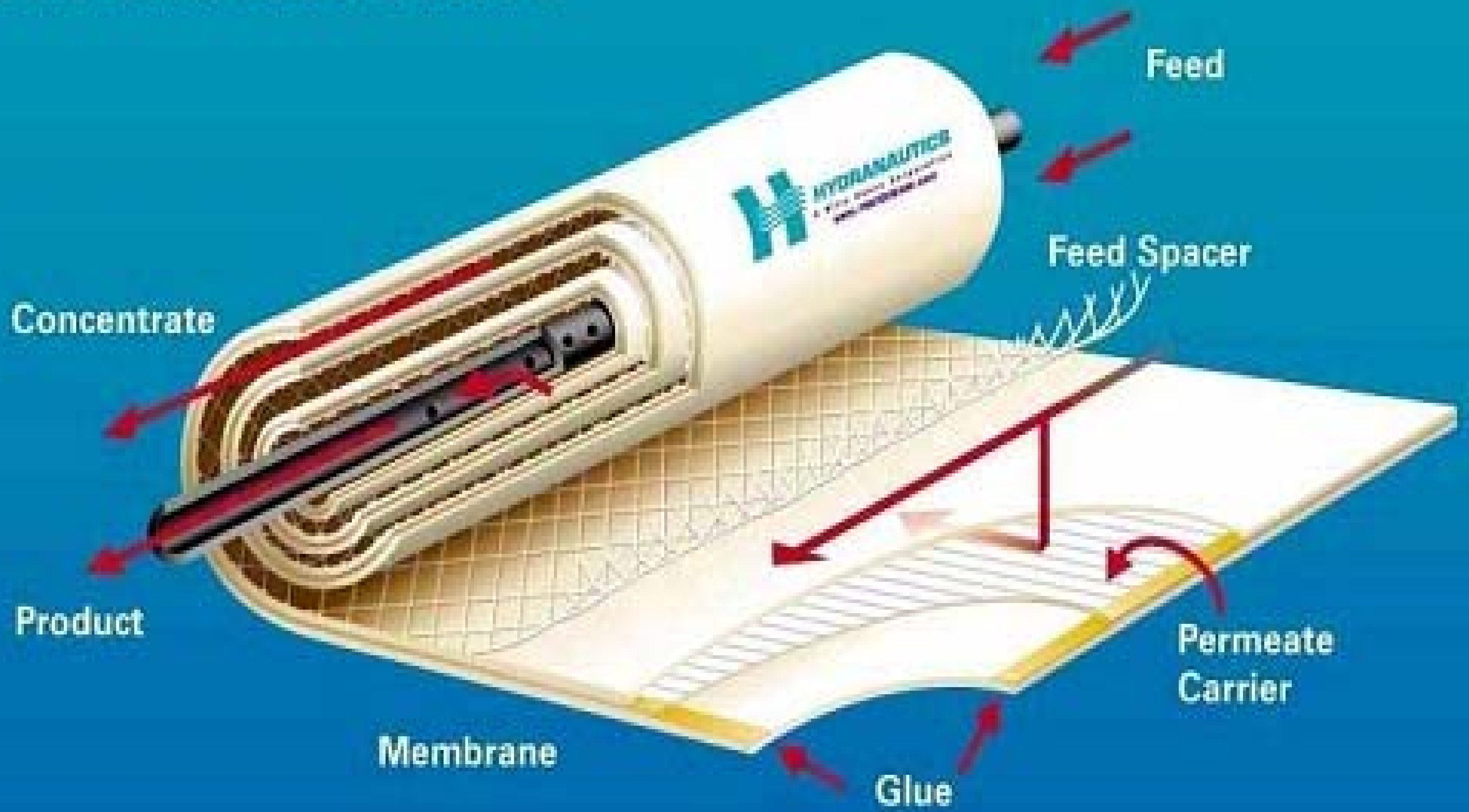


Clean, safe water passes through microstructured membranes.

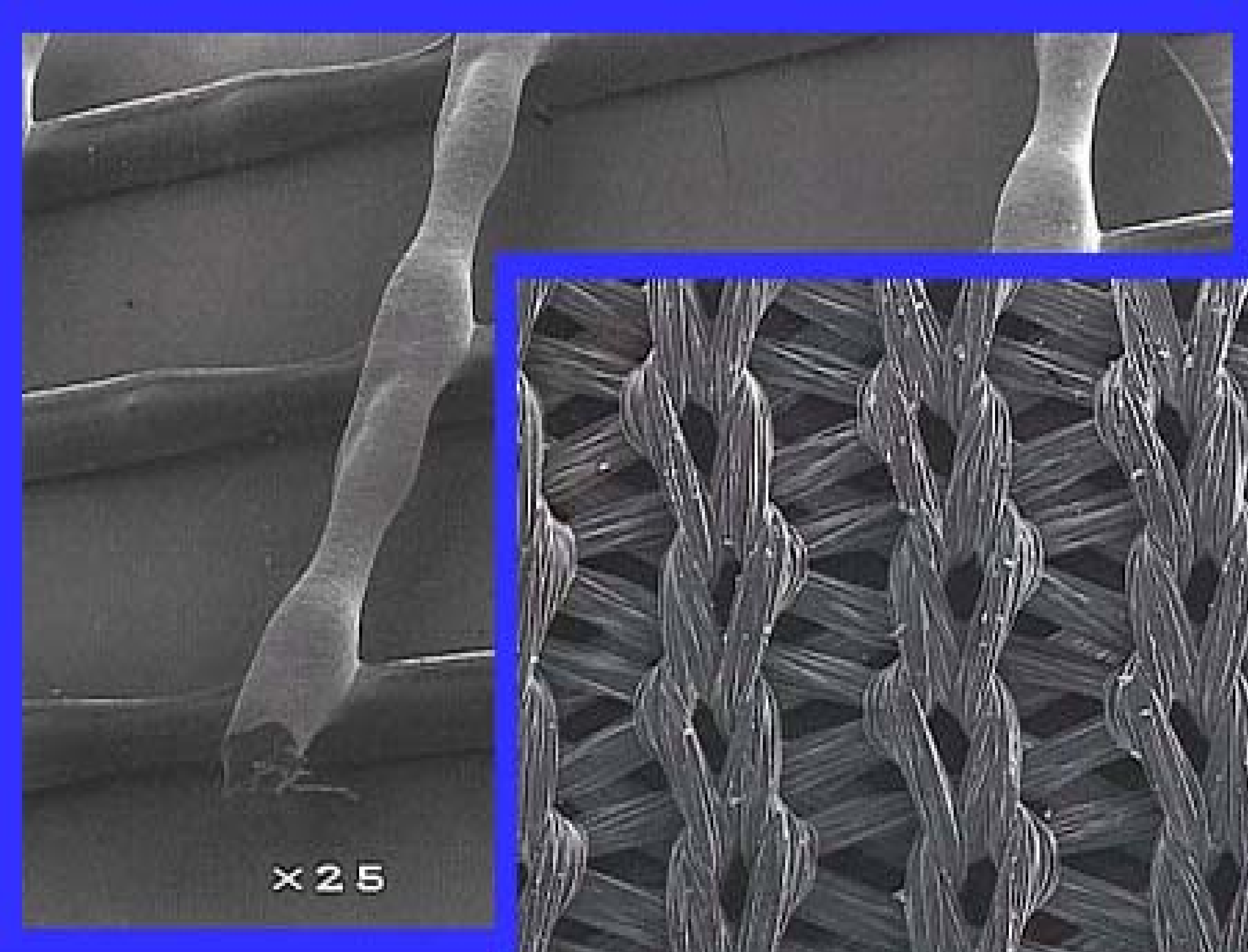

WASH WATER
WASH WATER
Low Turbidity, High Color
High Turbidity, Low Color
Spent Dye Bath
DYE BATH
WASH EFFLUENT
FINISHING
WASH EFFLUENT
Coagulation
Clarifier
Activated Sludge
Media Filter
Media Filter
UF
NF
DYE BATH
Feed Pump
Spent Waste
UF
RO
Wash Water
Recovery RO

http://membranes.com/docs/papers/New%20Folder/HYDRACoRe70%20pHT%20Sugar%20Refining.pdf

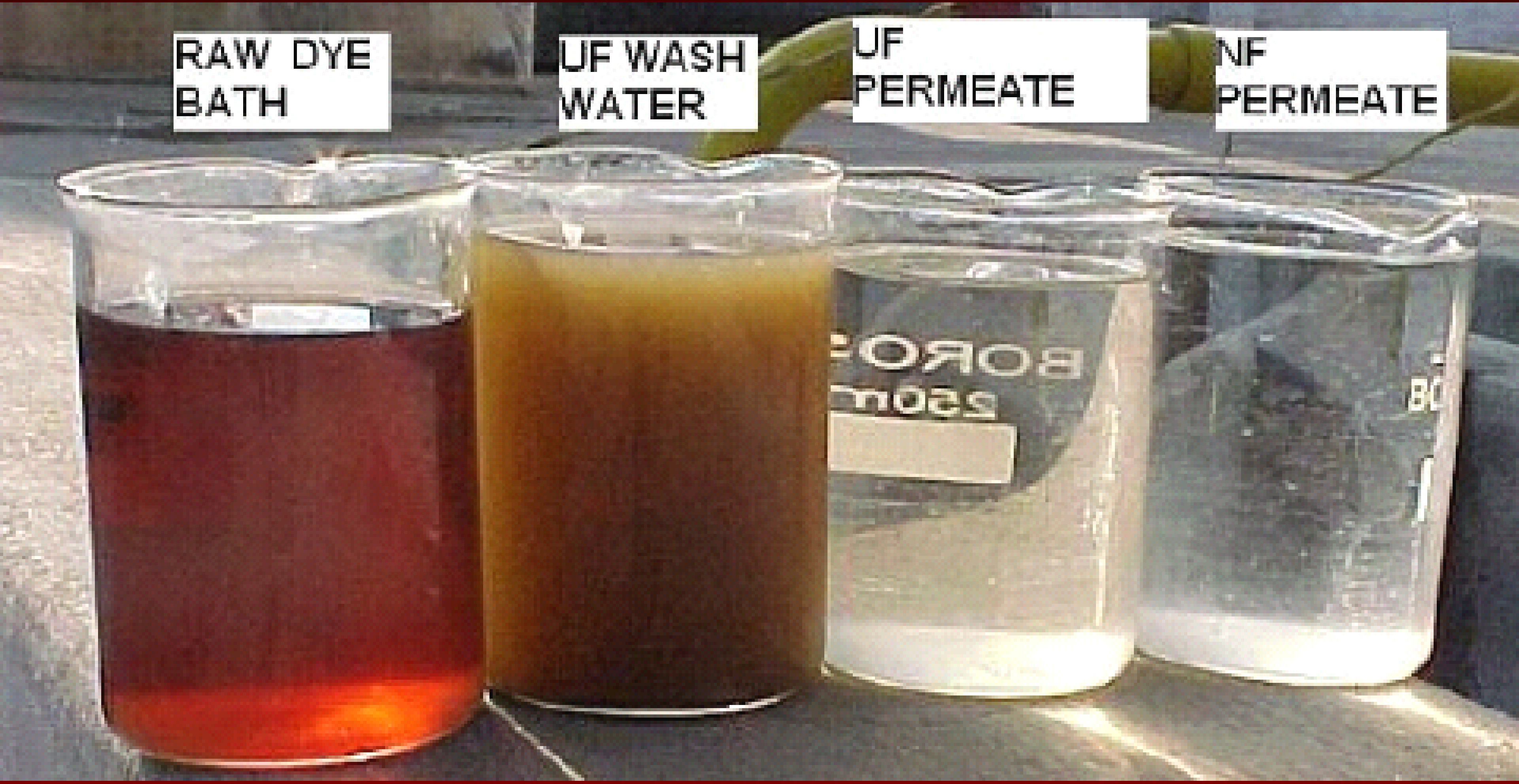
1. Membrane (Fabric, Barrier Layer)
2. Leaf Glue
3. Permeate Carrier



http://membranes.com/docs/papers/New%20Folder/HYDRACoRe70%20pHT%20Sugar%20Refining.pdf



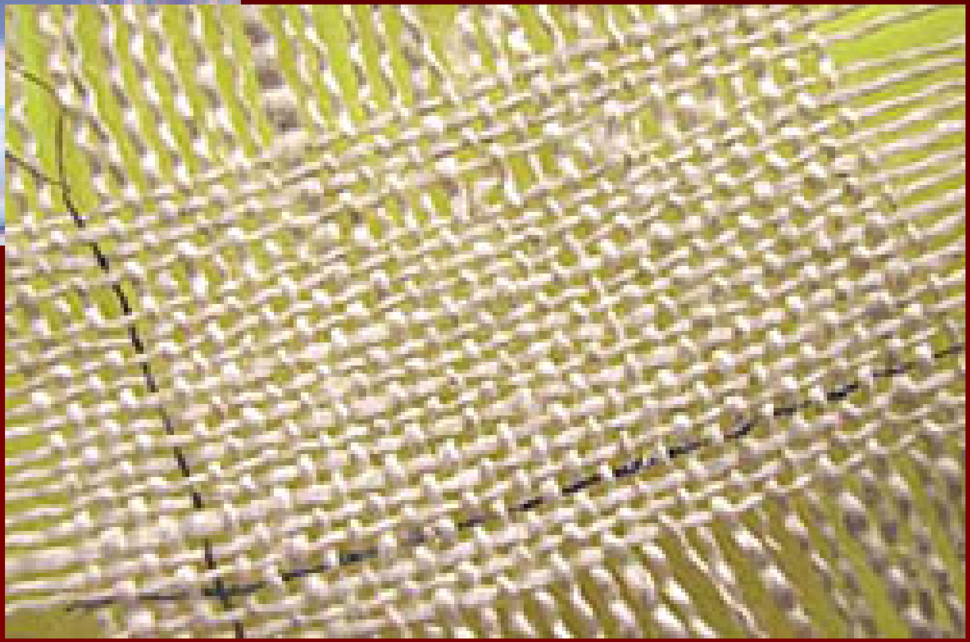
http://membranes.com/docs/papers/New%20Folder/HYDRACoRe70%20pHT%20Sugar%20Refining.pdf



http://membranes.com/docs/papers/New%20Folder/HYDRACoRe70%20pHT%20Sugar%20Refining.pdf

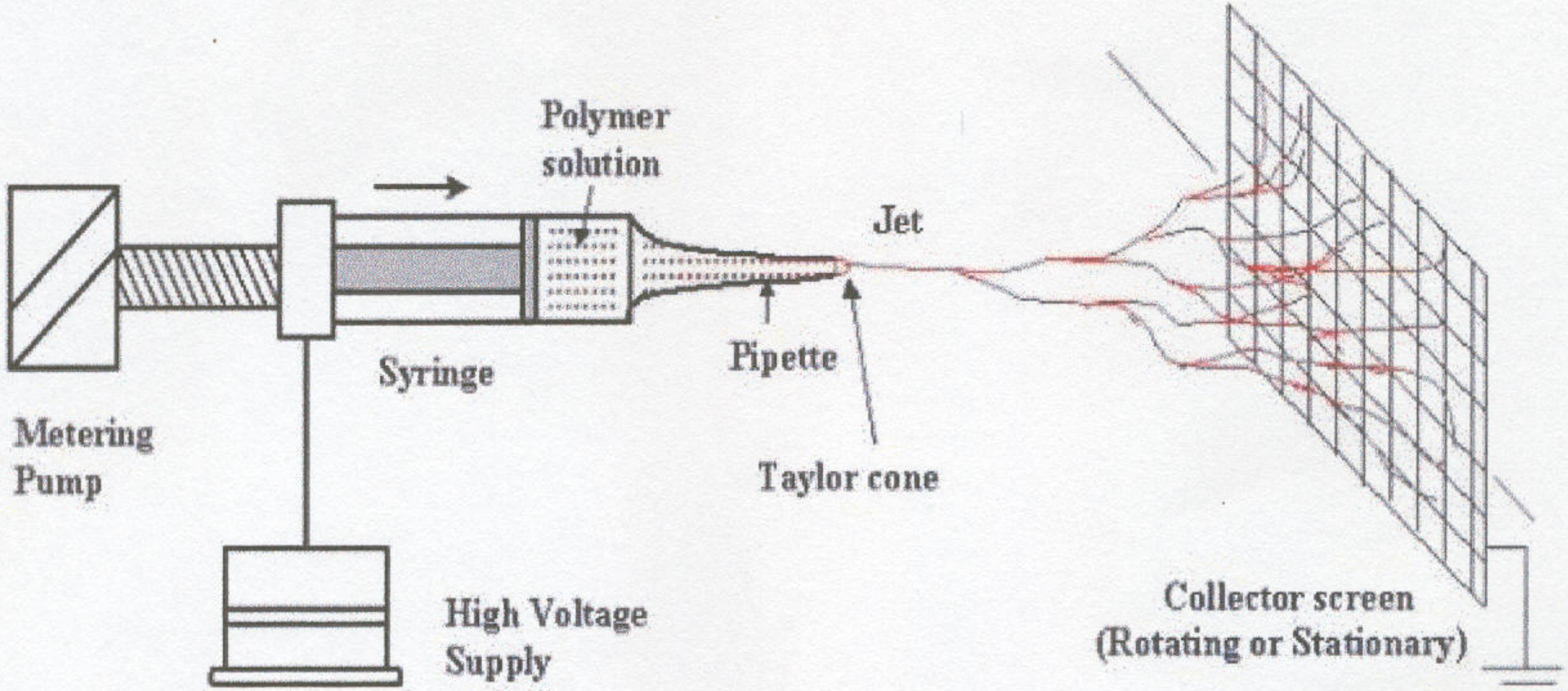

PRESSURE VESSEL 1
MF-1B
PERMEATE CIP RETURN
ACCEPTED
ACCEPTED
CT-2
CIP TANK
CT-1
CHEMICAL TANK
CIP FEED

7. Carbon Nanotube



http://www.sciencentral.com/articles/view.php3?article_id=218392016&language=english

8. Luminescent Polyester Fiber
9. Nanofibers via Electrospinning



Polymeric Nanofibers and Nanofiber Webs: A New Class of Nonwovens

Timothy Grafe * , Kristine Graham Donaldson Co., Inc., PO Box 1299, Minneapolis, MN 55440

Table 1. Comparison of Fiber Diameters from Various Fiber / Nonwoven Web Processes

Fiber Type	Fiber Size Range, microns	Fiber Size Range, denier
Electrospun Nanofibers	0.04 – 2	0.00002 – 0.06
Meltblown Fibers	2 – 10	0.03 - 1
Spunbond Fibers	15 - 40	1.5 - 12

Denier Calculation based on fiber specific gravity = 1. Specific gravity values of common fiber polymers range from 0.92 (PP) to 1.14 (PA66) to 1.38 (PET).

Table 2. Fiber Surface Area per mass of Fiber Material for various Fiber Sizes

Fiber Type	Fiber Size, microns	Fiber Surface Area per mass of fiber material, m^2/g
Electrospun Nanofiber	0.05	80
Electrospun Nanofiber	0.2	20
Small Meltblown Fiber	2.0	2
Spunbond Fiber	20	0.2

Specific Surface area calculations based on fiber specific gravity = 1.

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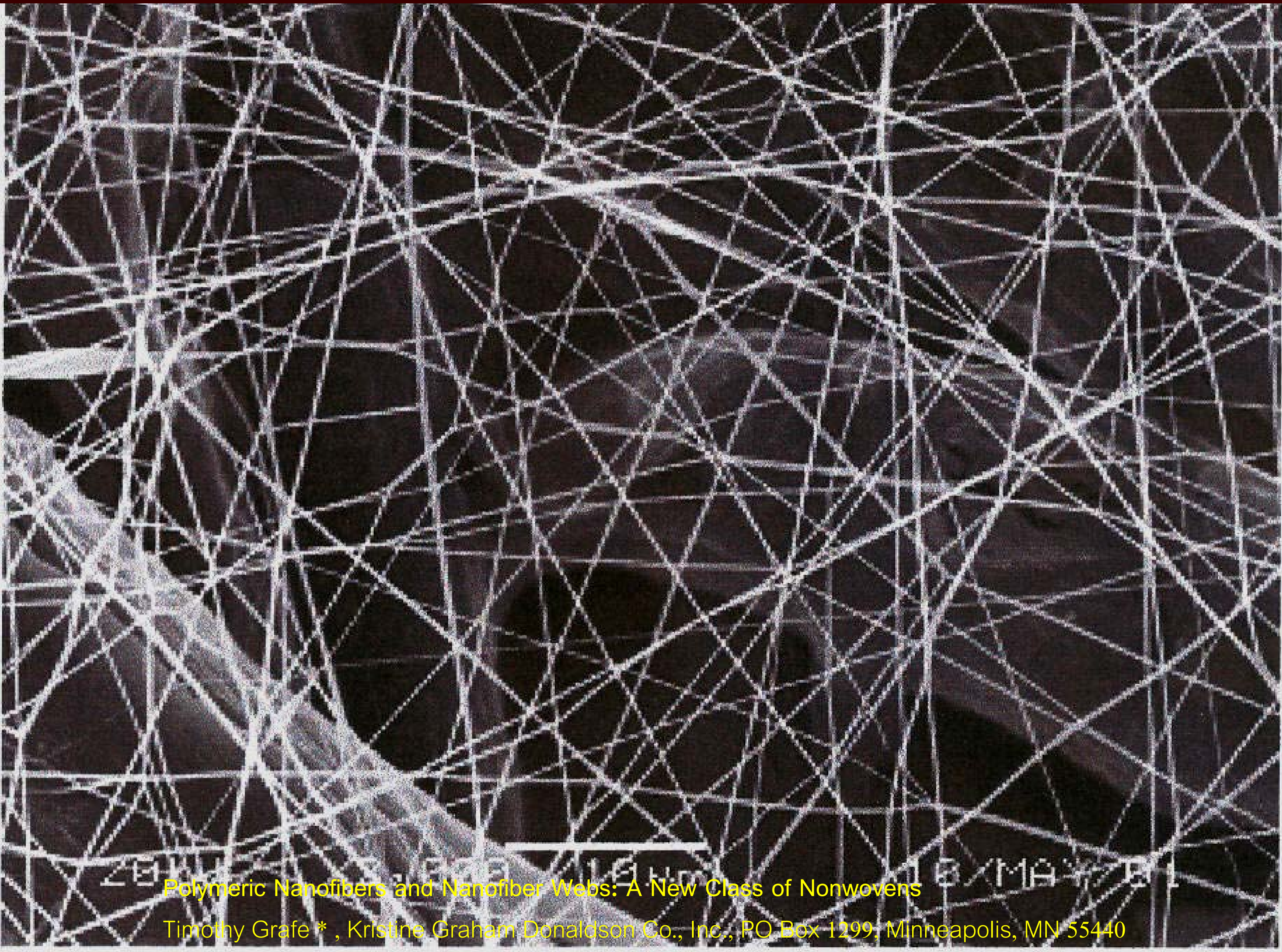

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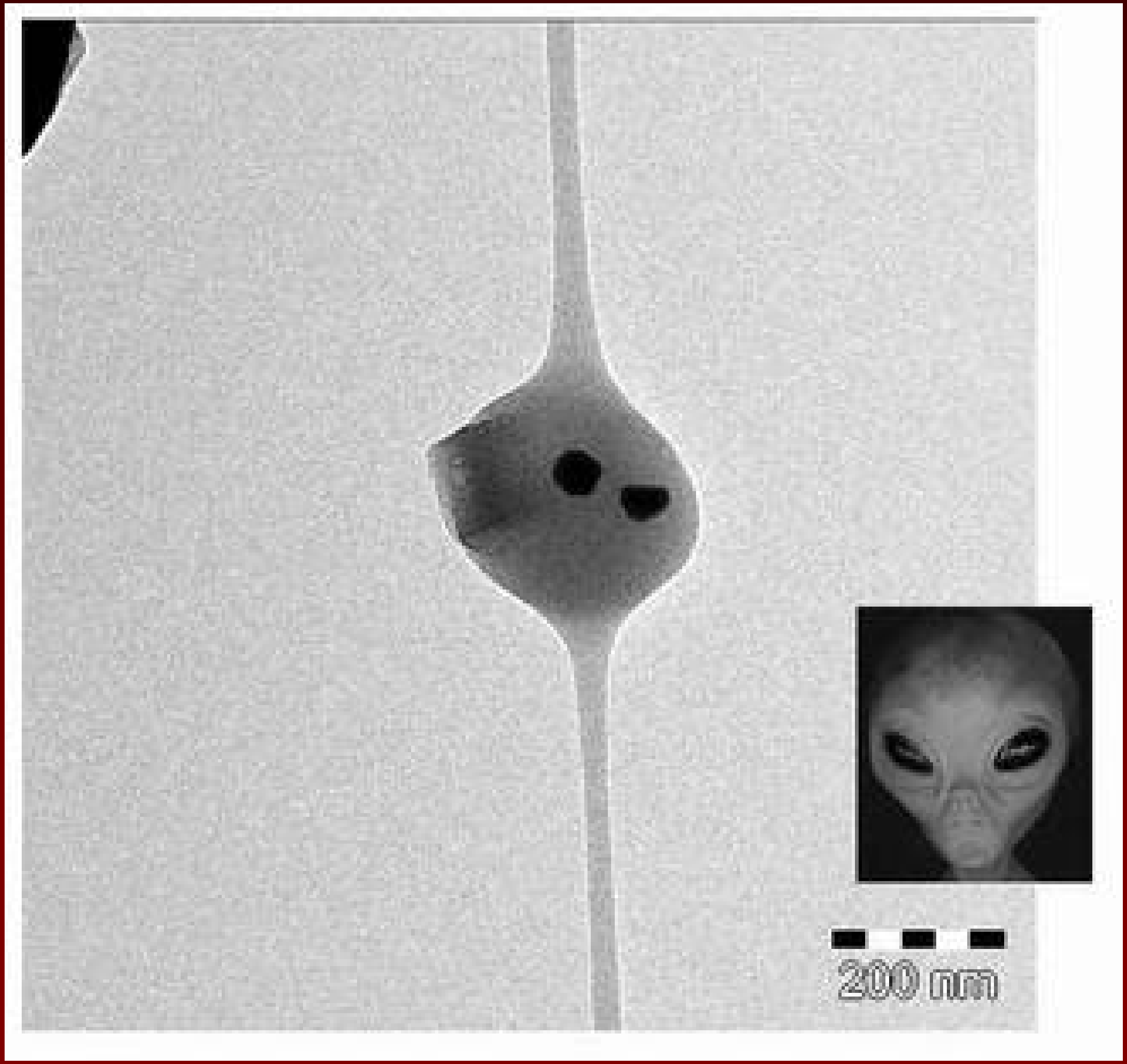
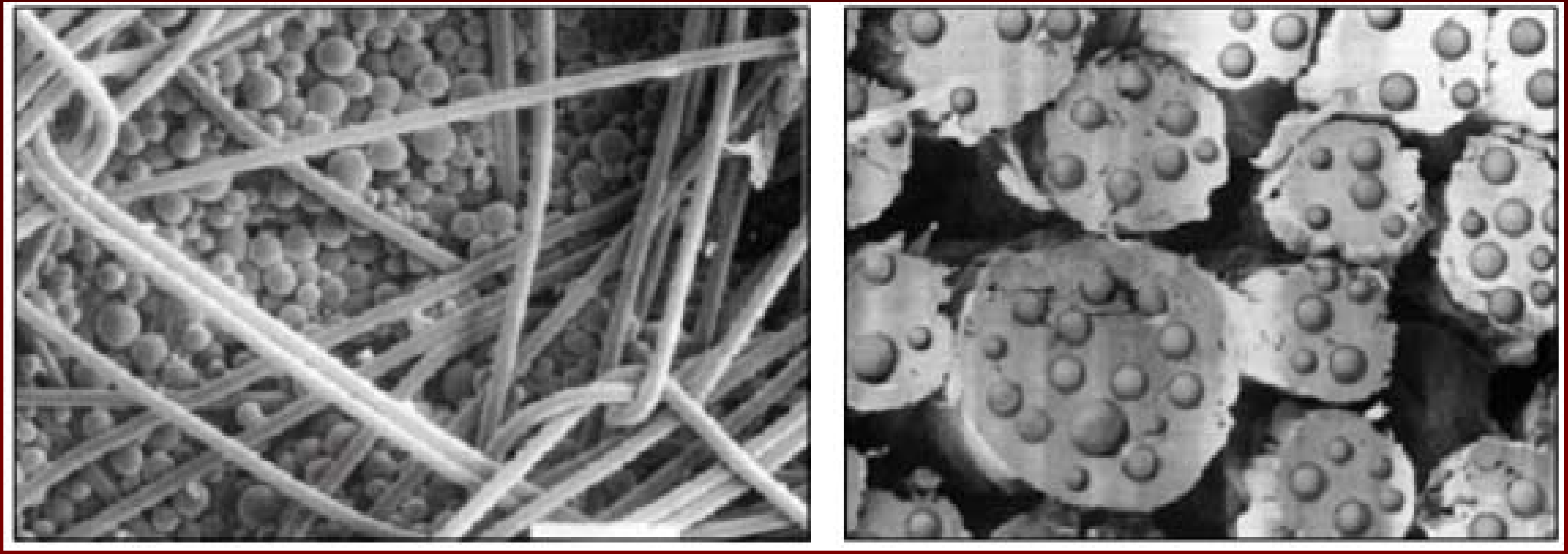
10. Counterfeit Nanofibers



http://www.physorg.com/news6152.html

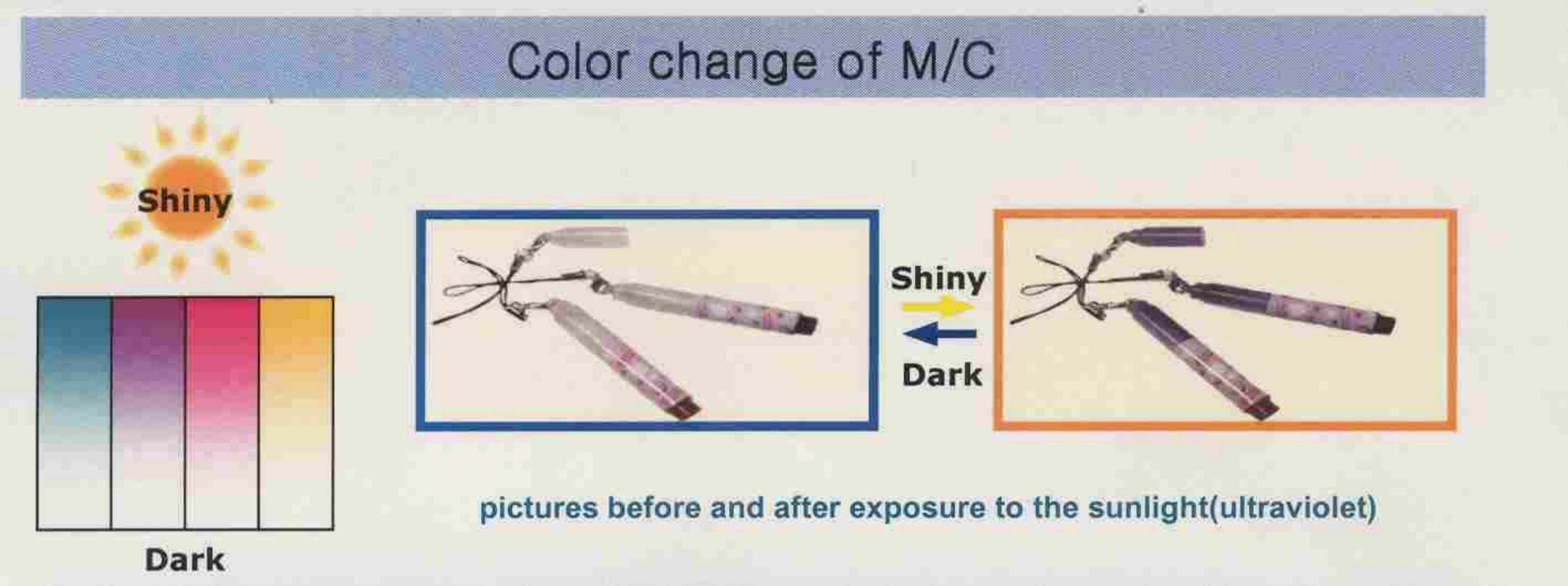
11. Fragrance Release Textiles

11.1 Microcapsules



Phase Change Materials

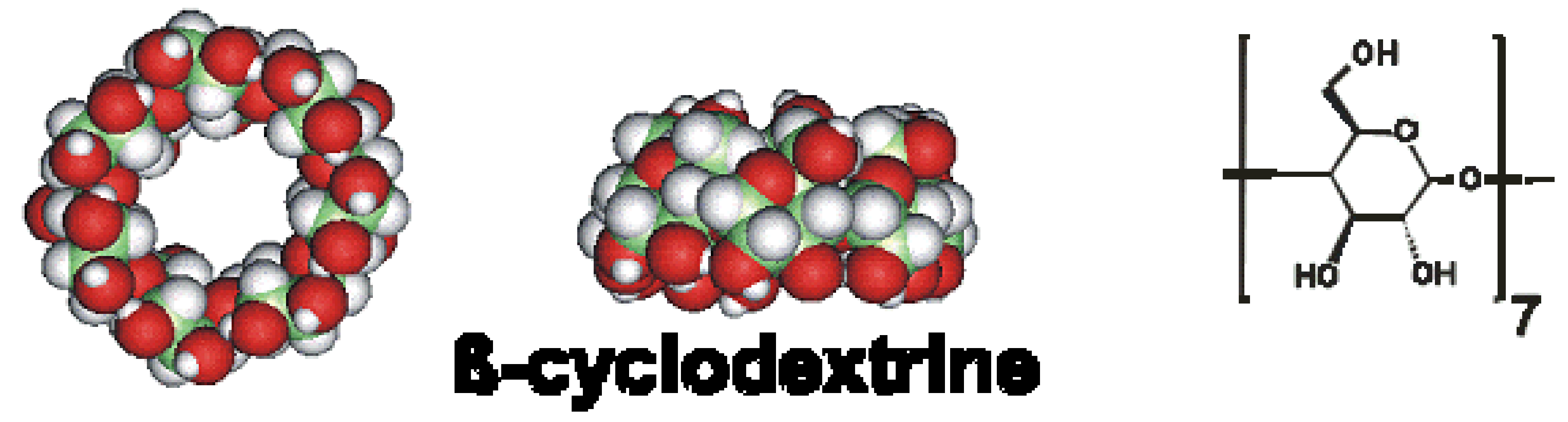
G.Nelson, Microencapsulation in Textile Finishing, *Reviews of Progress in Textile Coloration,* 31(2001), pp. 57-64.



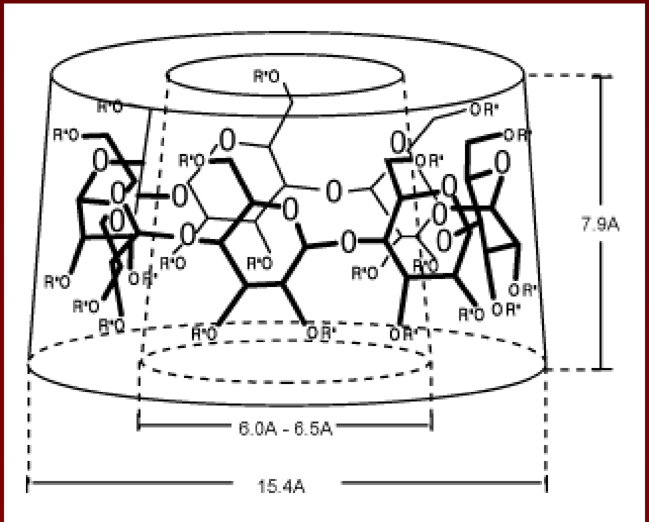
Thermochromic Dyes in Microcapsules

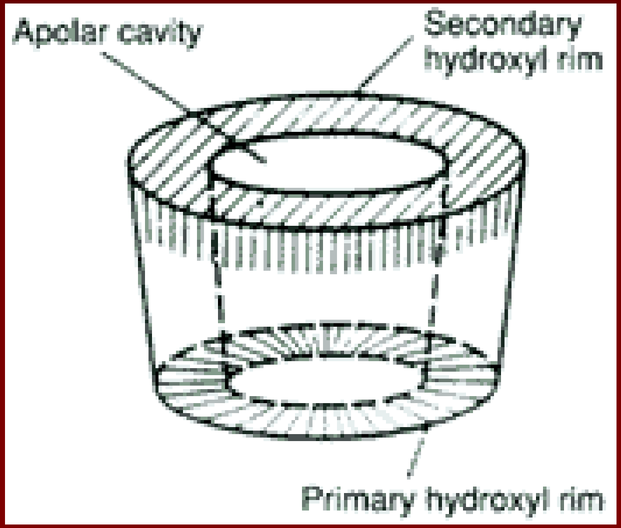
http://www.polychrom.com

11.2 Cyclodextrins

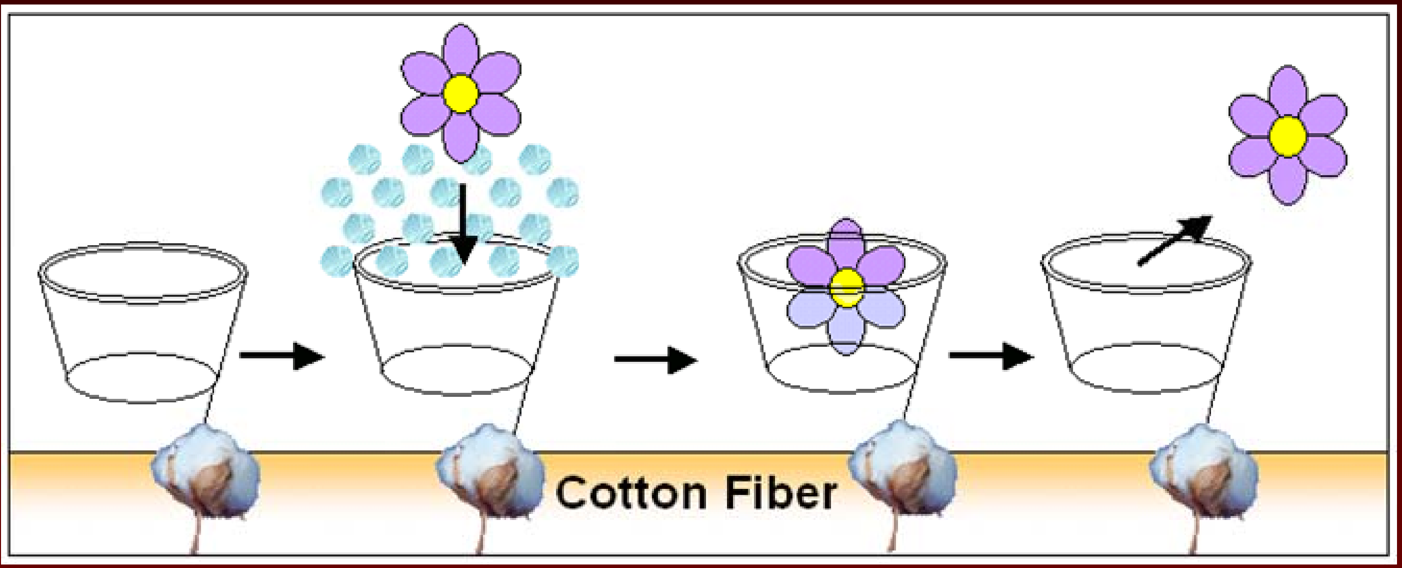


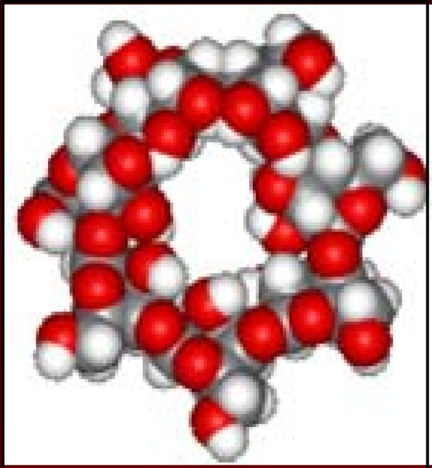
M.R. ten Breteler, V.A. Niestrasz and M.M.C.G.Warmoeskerken, Textile Slow-Release Systems with Medical Applications, *AUTEX Research Journal*, vol. 2 no. 4, December 2002, pp.175-189.





A.Tonelli, and P.Hauser, Delivery of Textile Additives with Inclusion Compounds, *National Textile Center Research Briefs-Chemical Processes Competency*, June 2001, pp.51-52.

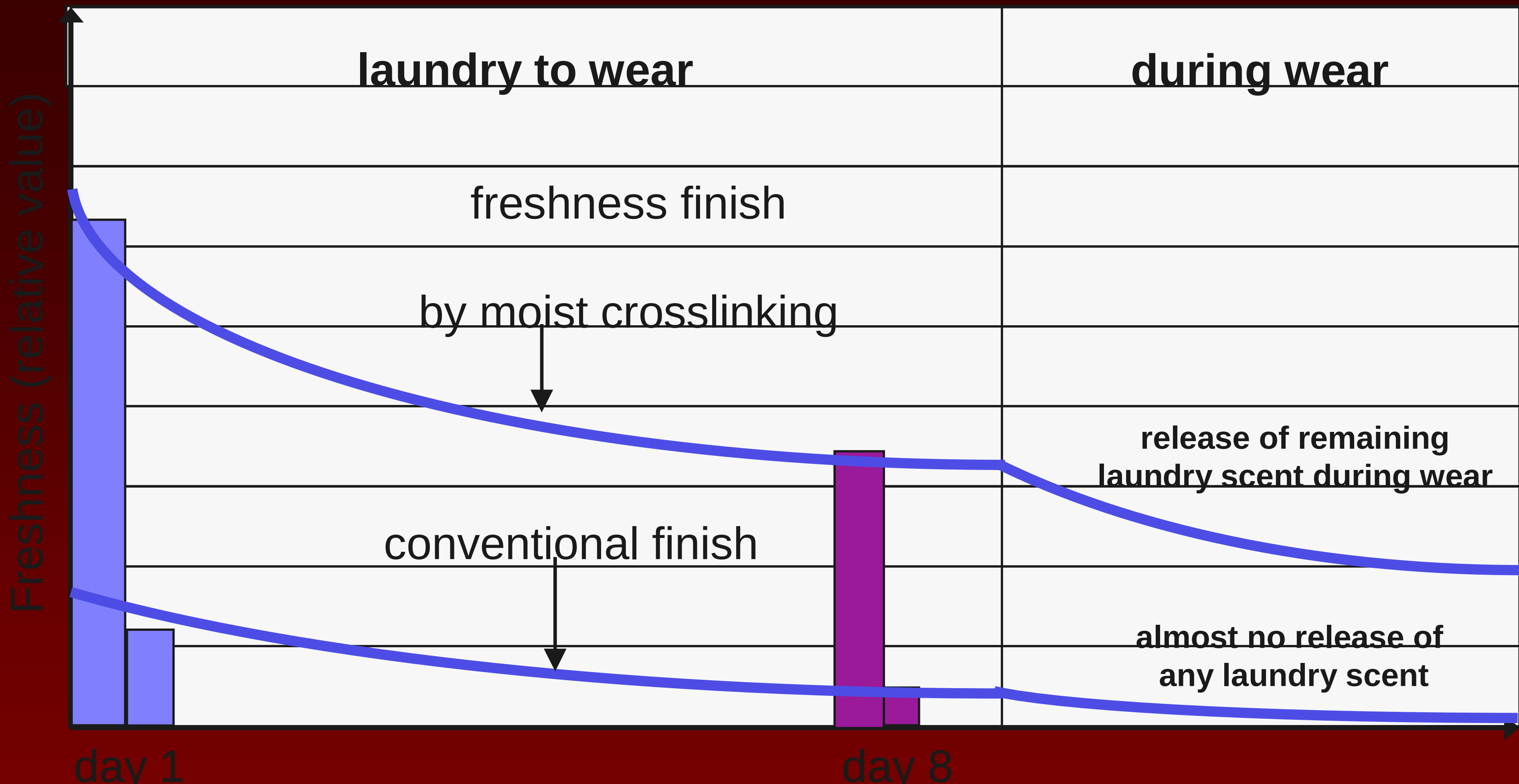




Cyclodextrin (CD)

Fragrance Can Be Trapped with Cyclodextrin Which is Cross-linked (Resin Finish) with Cotton Fibers

http://www.textil.monforts.de /t3/mxl.455.0.html?&L=2

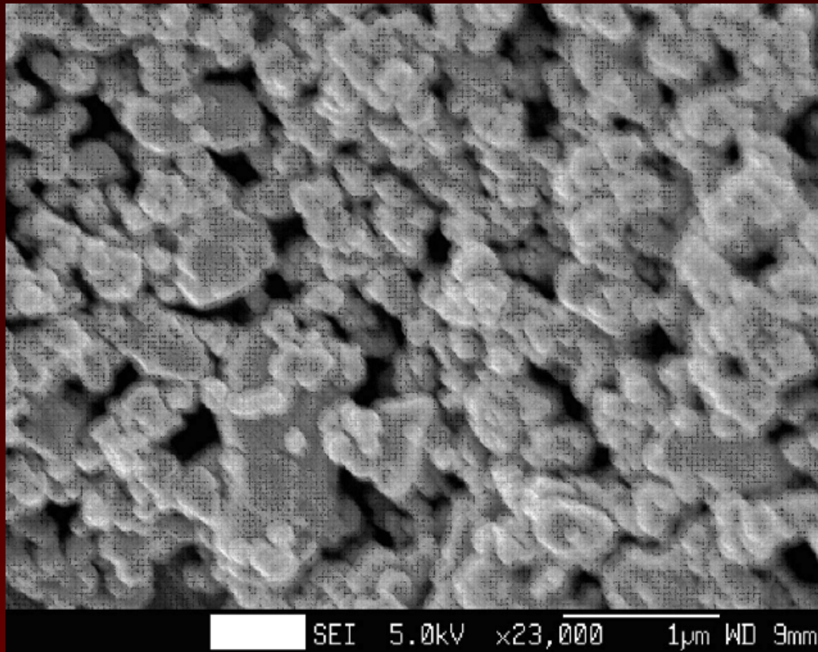


Slow Released Fragrance in Garments with Different Kinds of Finishing Processes Comparisons of Untreated and Treated Fabrics

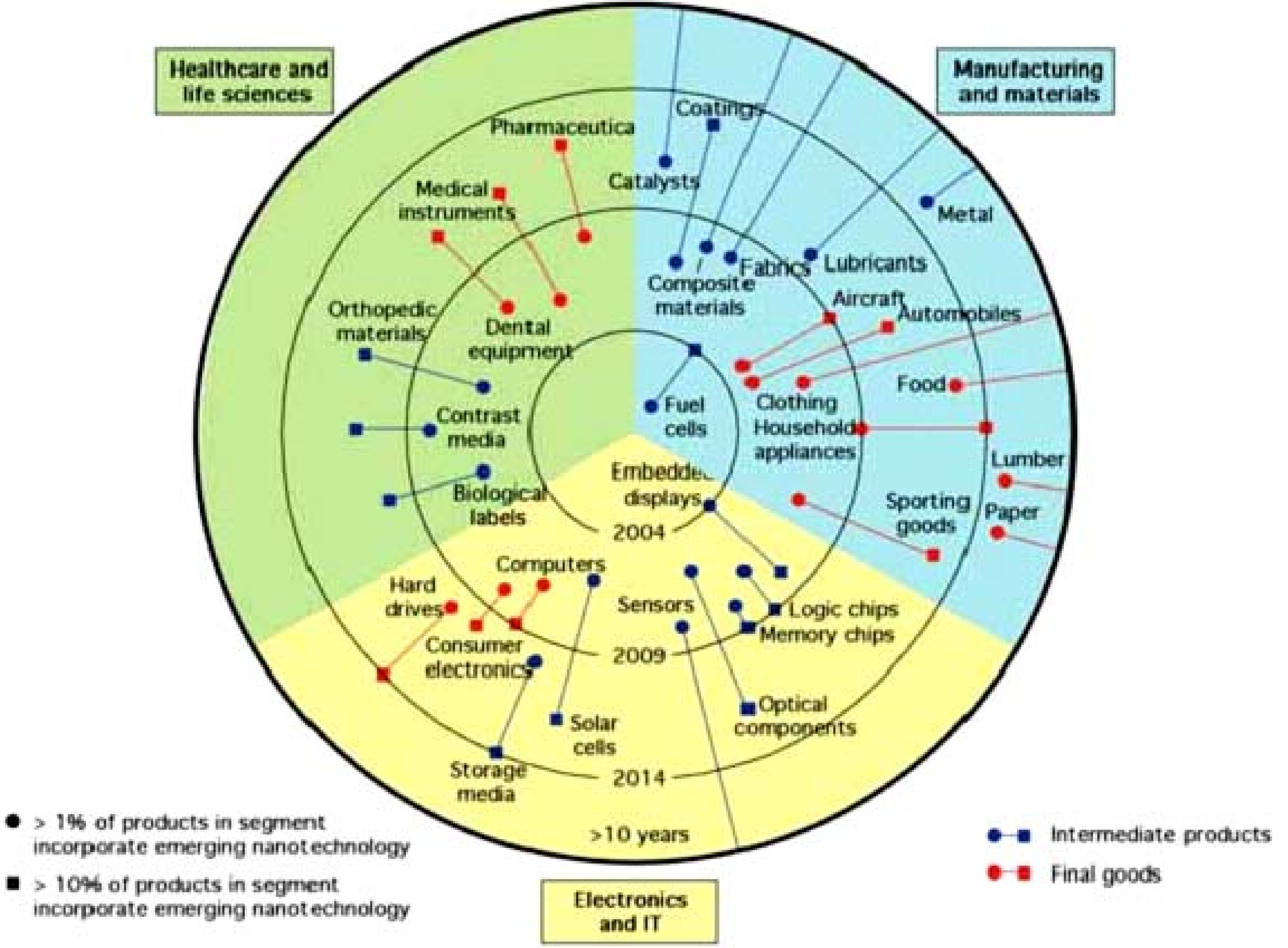
http://www.textil.monforts.de /t3/mxl.455.0.html?&L=2

Product Applications

Anti-microbial	Textile Fibers, Thermoplastics, Permanent Coating, Wood Preservation
Catalysts	Environmental Catalysts, Fuel Cells
Performance Coating	UV-Attenuating Coating, Abrasion-Resistant Coating, Charge Dissipating
Personal Care	Sunscreen Formulations, Foot Powder, Deodorant/Antiperspirant, Shaving Products, Oral Care
Polishing	Glass Polishing, Semi-conductor Polishing



An Example of Using TiO2 Microparticles Mixed With Concrete for Road Building



http://www.futuretechnologycenter.nl/downloads/nanobook.pdf

Nanotechnology for Military and Civil Purposes

1. Human Centrics
2. Vehicles
3. Marine
4. Aerospace
5. Space

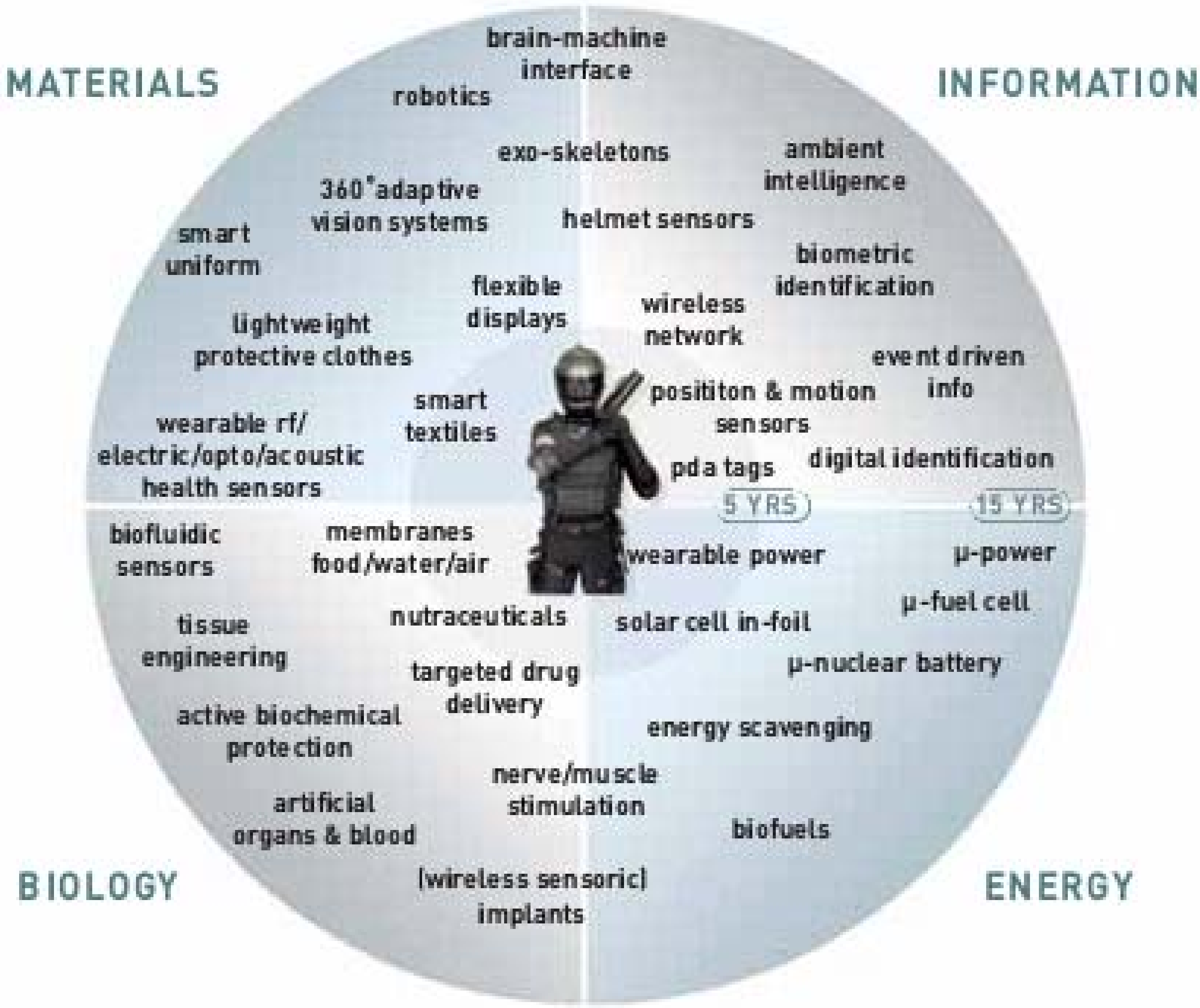
6. Weapons and Law Enforcement

7. Logistics

8. Security and Surveillance

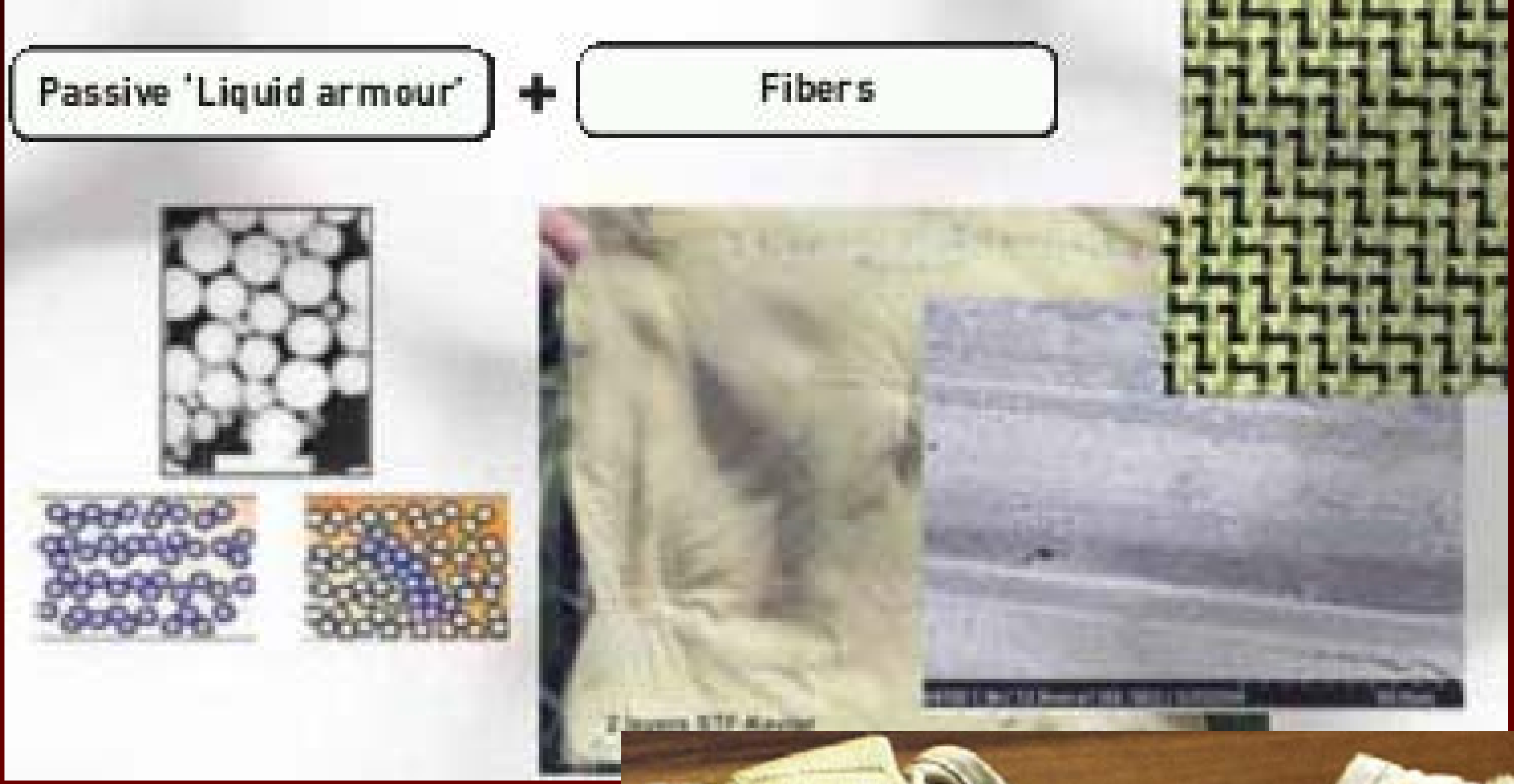
Human centric

- Self supporting
- Connectivity
- Mobility
- Ambient intelligence



Technology radar

http://www.futuretechnologycenter.nl/downloads/nanobook.pdf

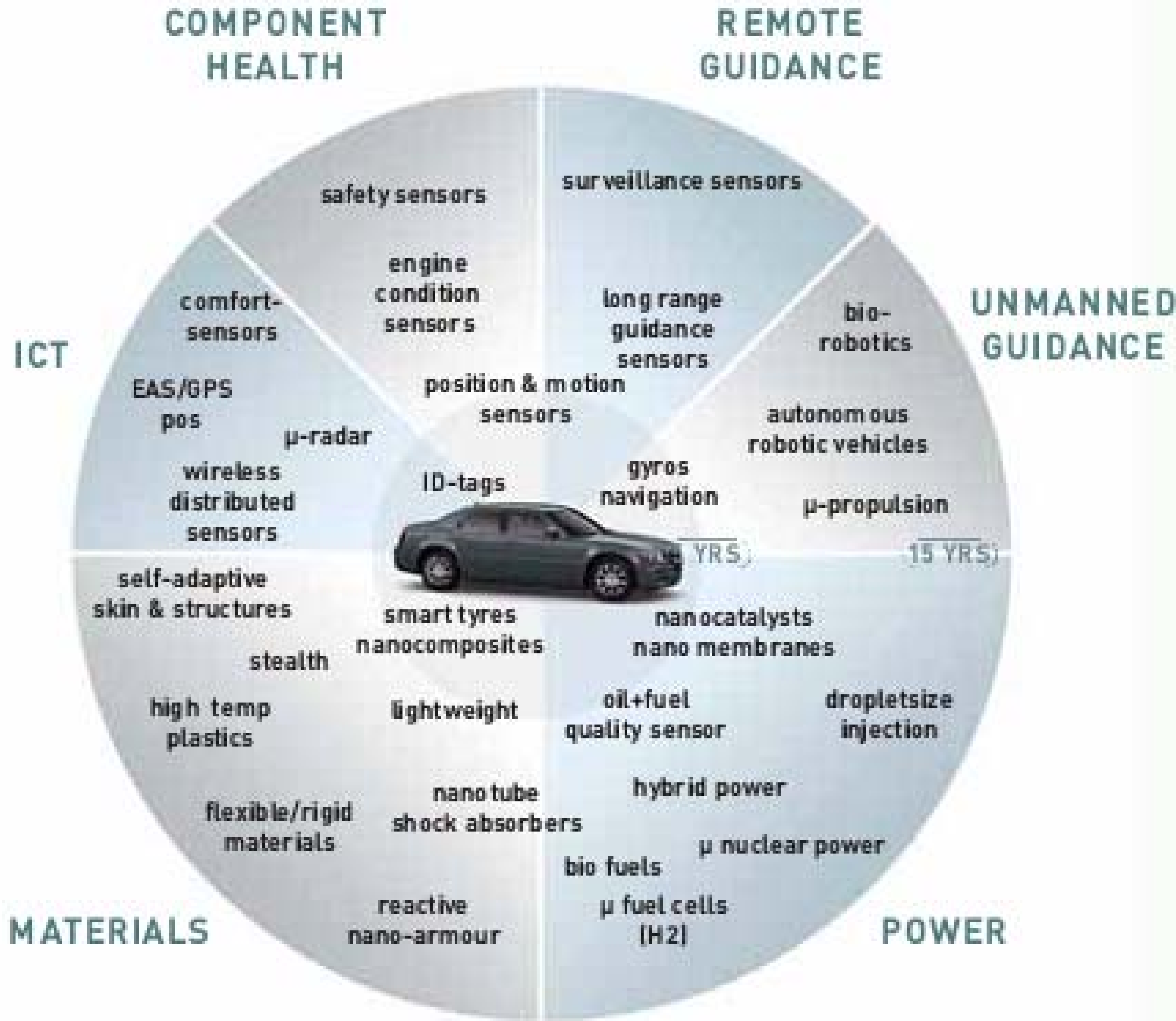


http://www.physics.ucla.edu/research/biophysics/pubs/pdf/ap_nanotube_fabric.pdf

http://www.futuretechnologycenter.nl/downloads/nanobook.pdf

Vehicles

- Lightweight
- Multi-purpose
- Intelligence-guided
- Protection
- Low energy
- Comfort



Technology radar

http://www.futuretechnologycenter.nl/downloads/nanobook.pdf

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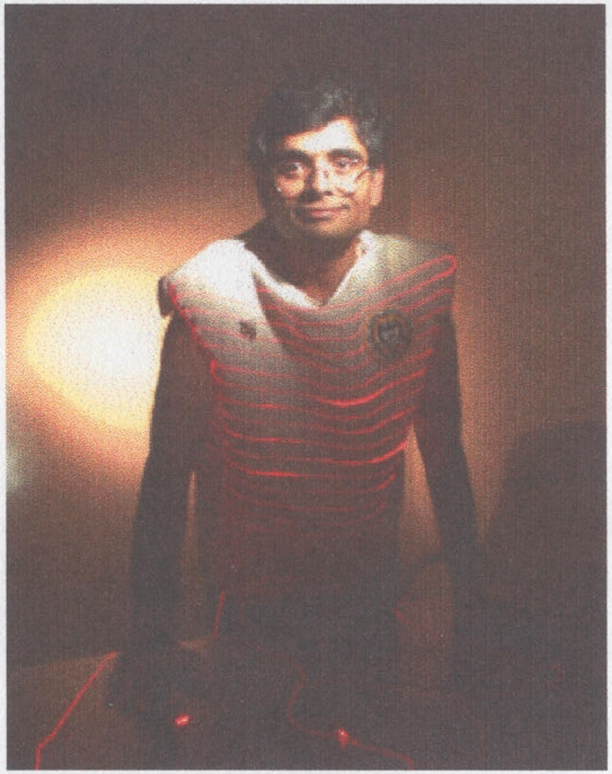
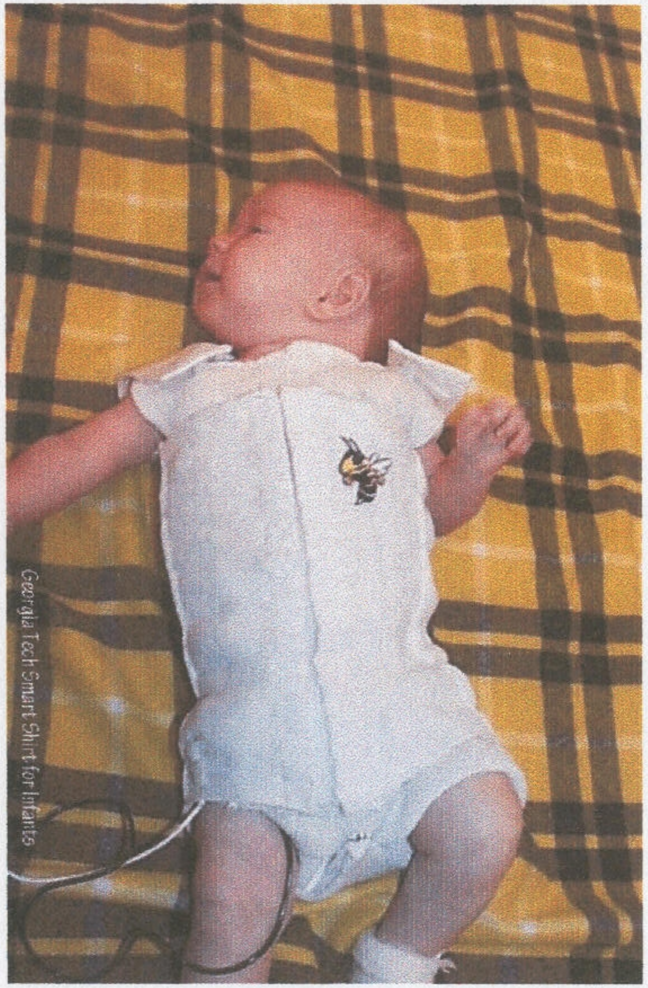
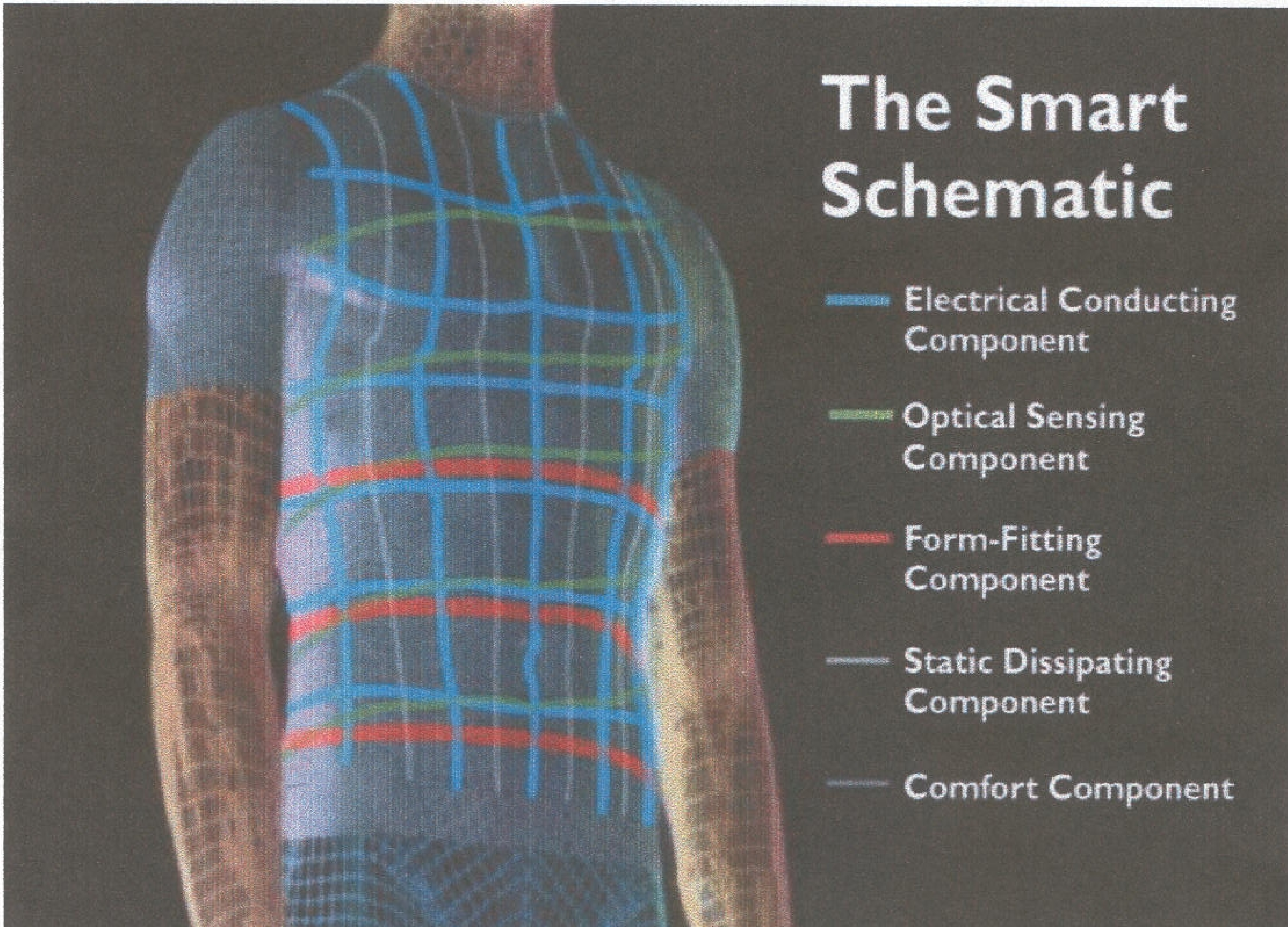




http://www.smartshirt.gatech.edu



http://www.smartshirt.gatech.edu

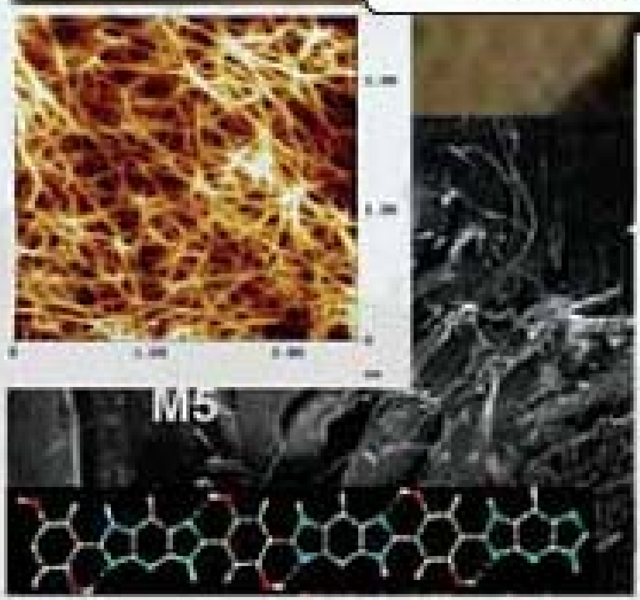
http://www.futuretechnologycenter.nl/downloads/nanobook.pdf

Nanoparticles + Fibers + Polymer

Nanoceramics

Polymer + nanoparticles

CNT buckypaper



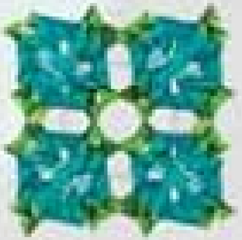
Options
1. Fibers + composite of polymer & nanoparticles
2. Fibers + mixture of polymer & nanoparticles in fibers
3. Fibers filled with nanopowder

Fibers
Dyneema, Kevlar, M5 (magelaen), nanofibers

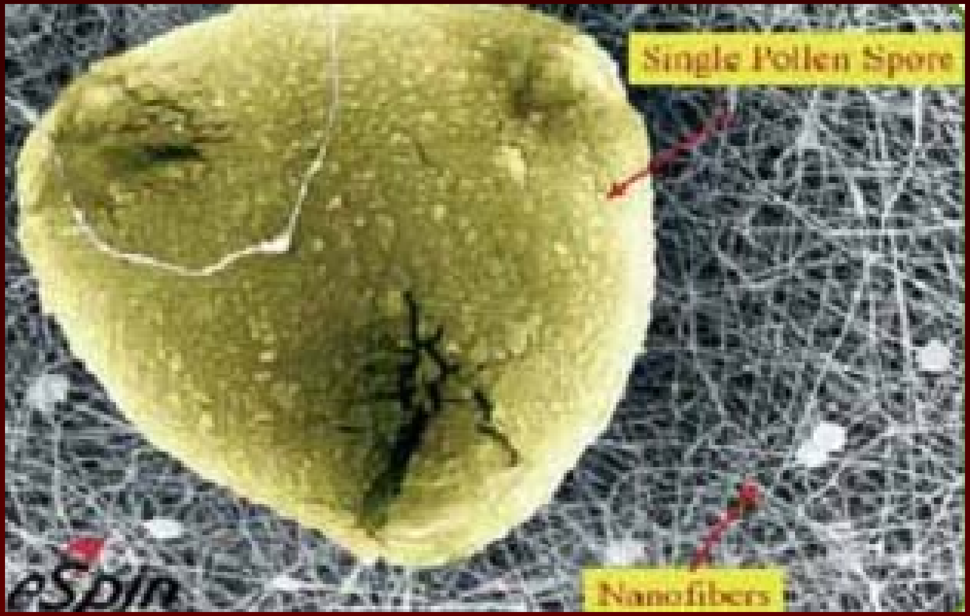
Particles
Nanotubes, al si zeolytes, cubicles, nanoclay platelets, hexagons, chitosan, nanocoated metal/ ceramic particles etc.

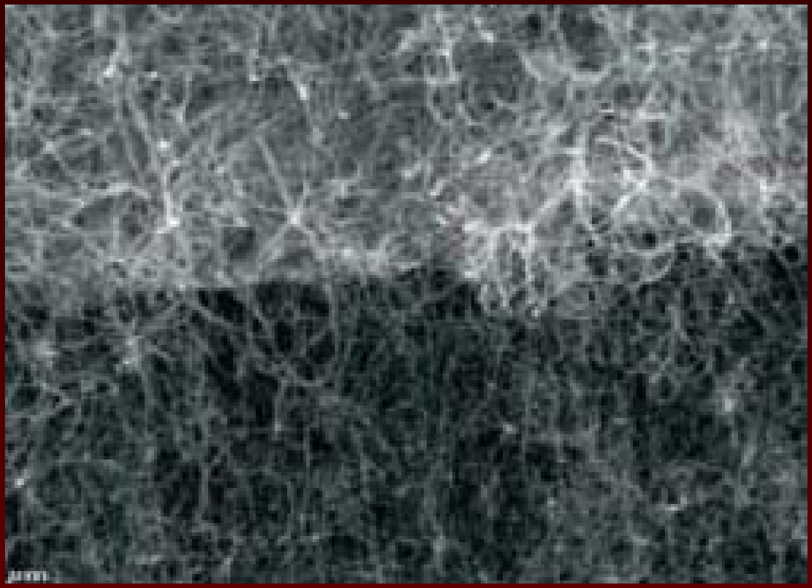
Nanoclay

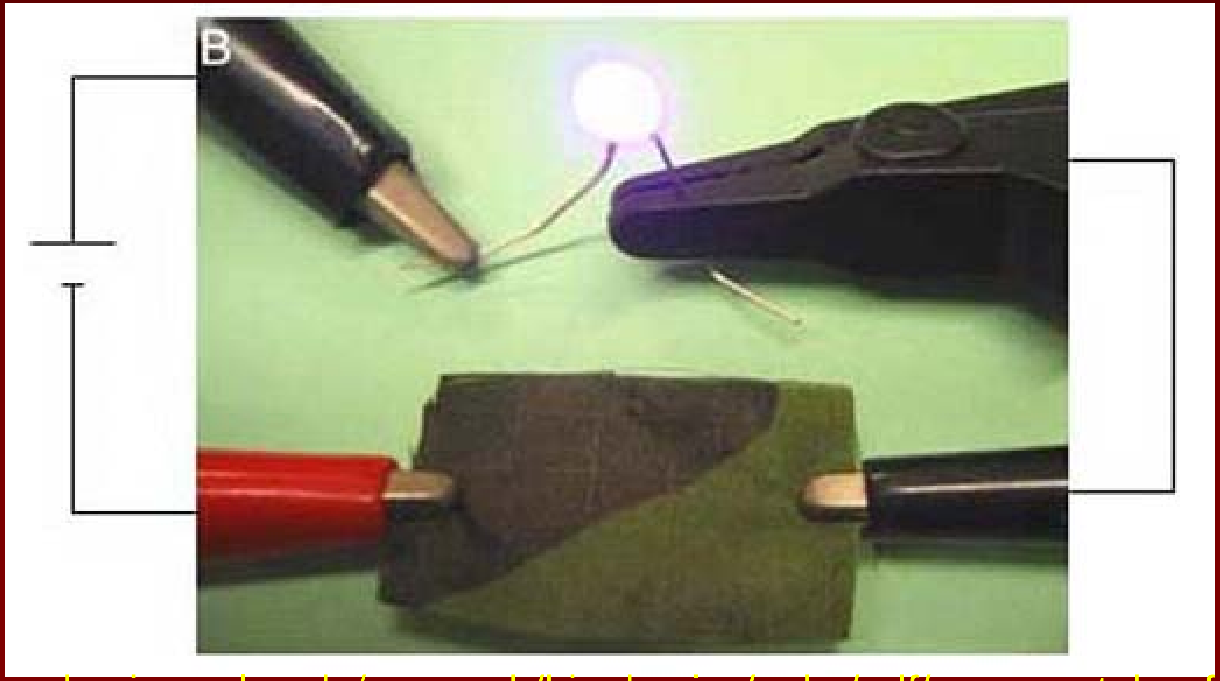
Nanoparticles



http://www.futuretechnologycenter.nl/downloads/nanobook.pdf



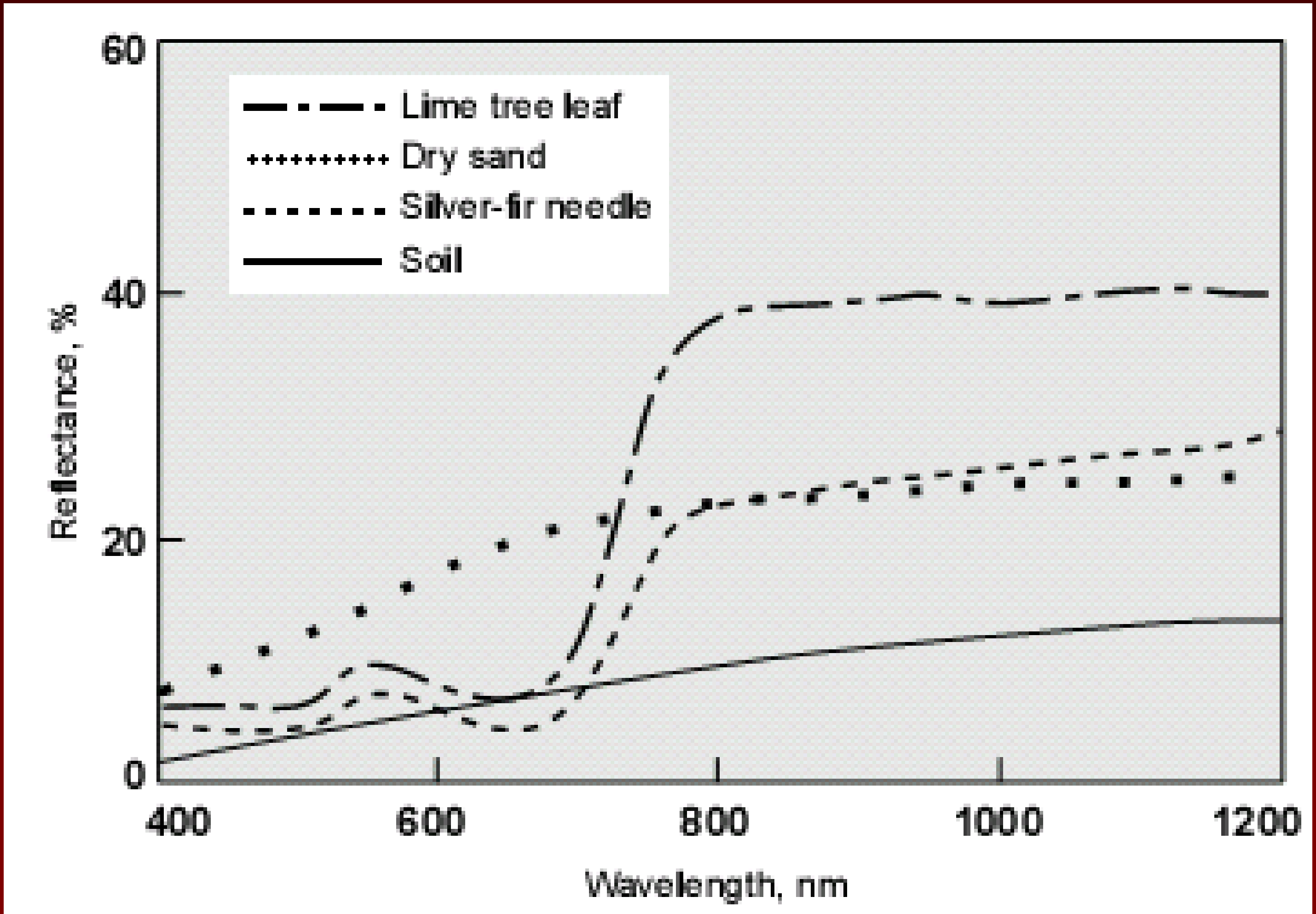




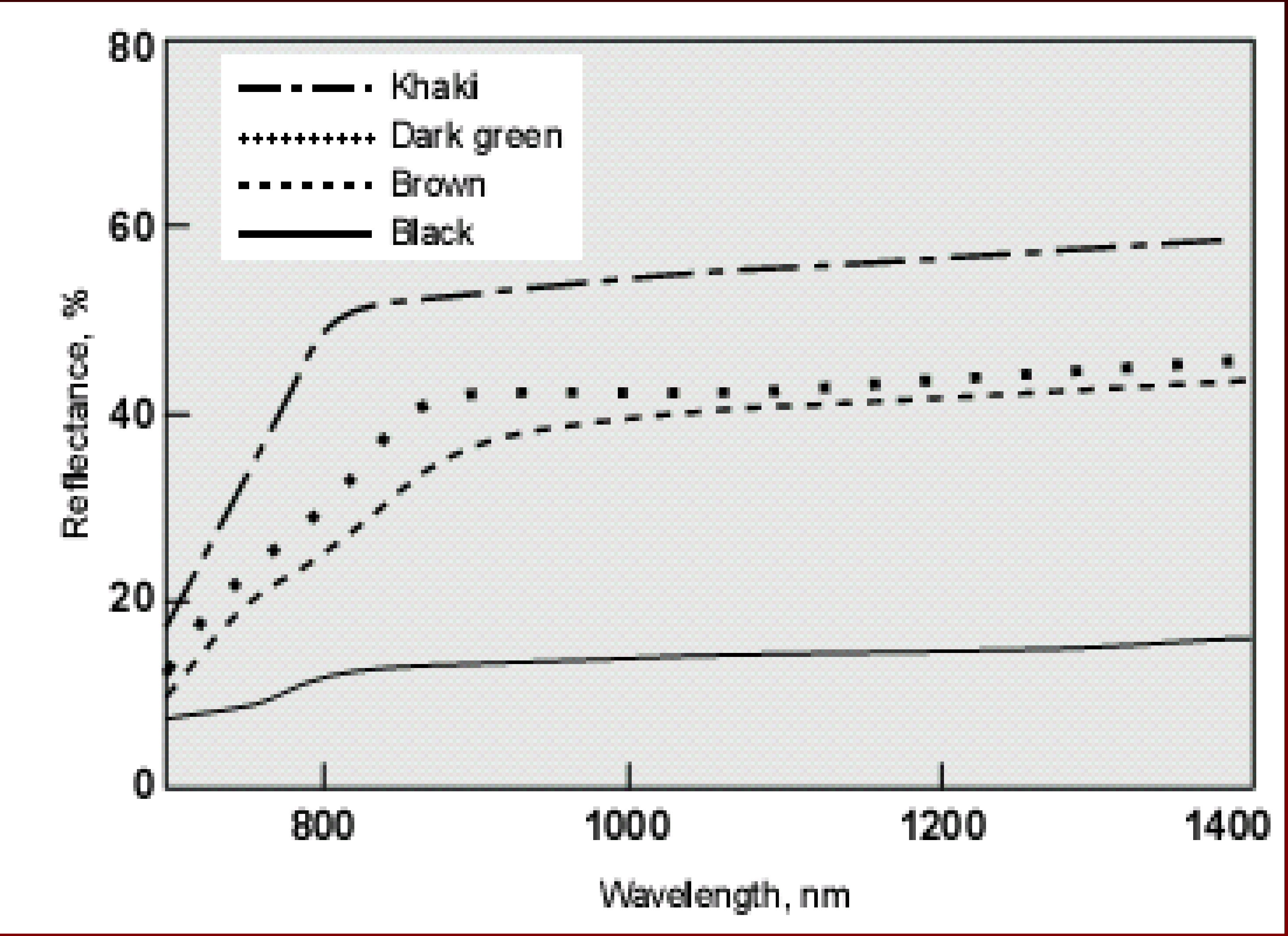
http://www.physics.ucla.edu/research/biophysics/pubs/pdf/ap_nanotube_fabric.pdf

http://www.futuretechnologycenter.nl/downloads/nanobook.pdf

IR and Visible Light Camouflage Military Suits



S.M.Burkinshaw, G.Hallas and A.D.Towns, Infrared Camouflage, *Reviews of Progress in Textile Coloration,* 26(1996), pp. 47-53.



S.M.Burkinshaw, G.Hallas and A.D.Towns, Infrared Camouflage, *Reviews of Progress in Textile Coloration,* 26(1996), pp. 47-53.

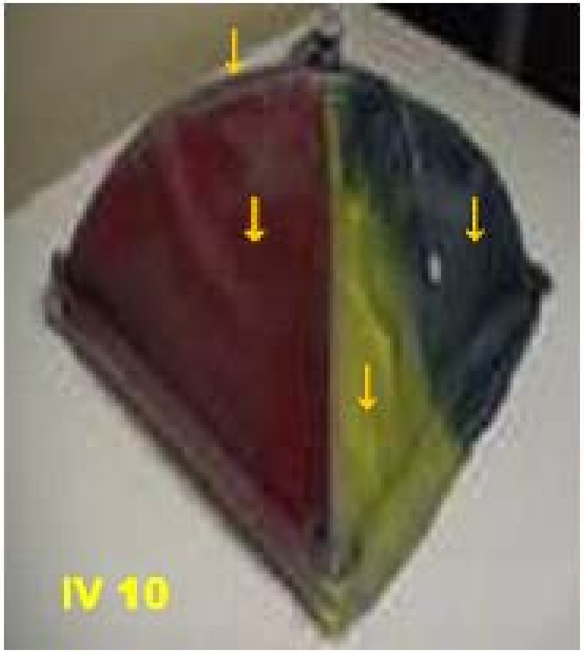
Shade	Dyes
Pale brown	CI Vat Brown 6 (Cibanone Brown F3B)
	CI Vat Brown 1 (Cibanone Brown FBR)
	CI Vat Orange 15 (Cibanone Golden Orange F3G)
Dark brown	CI Vat Brown 35 (Cibanone Yellow Brown FG)
	CI Vat Black 27 (Cibanone Olive F2R)
	CI Vat Red 24 (Cibanone Red F4B)
Pale green	CI Vat Green 28 (Cibanone Green F6G)
	CI Vat Black 27 (Cibanone Olive F2R)
	CI Vat Orange 15 (Cibanone Golden Orange F3G)
Dark green	CI Vat Green 28 (Cibanone Green F6G)
	CI Vat Black 27 (Cibanone Olive F2R)
	Cibanone Brilliant Green F4G
Grey	CI Vat Black 30 (Cibanone Grey F2GR)
	CI Vat Brown 35 or CI Vat Orange 15
	CI Vat Black 27 (Cibanone Olive F2R)

Source: *Dyes for Infrared Camouflage*, Ciba Ltd, Basle, Switzerland.

Camouflage Dyestuffs Recommended by Ciba

IR Camouflage Suit without Stealth Hat (Left) and with Stealth Hat (Right)

http://www.saferplane.com/stealthIV.pdf



IR Stealth Hat (Left) Camouflage Suit (Middle) and Multicolour Tent (Right)

http://www.saferplane.com/stealthIV.pdf

Daytime Visibility Stealth of Personnel

http://www.saferplane.com/stealthIV.pdf

Problems from Nanomaterials?

Poor ventilation → Inhalation (lung cancer?) need nanofilter

Digestion/penetration thru skin (Skin cancer?)

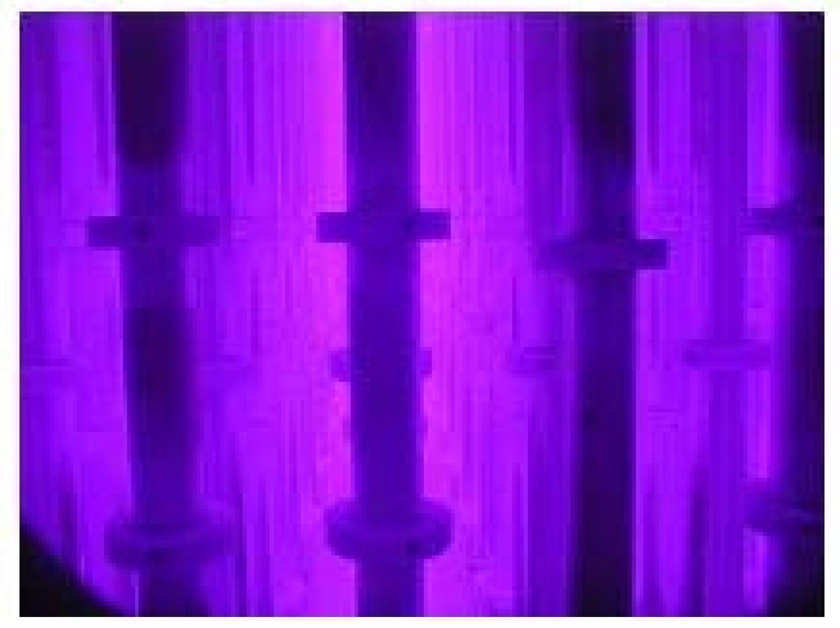
Surface Area too much (high affinity?)

Unknown properties of the materials?????? etc.

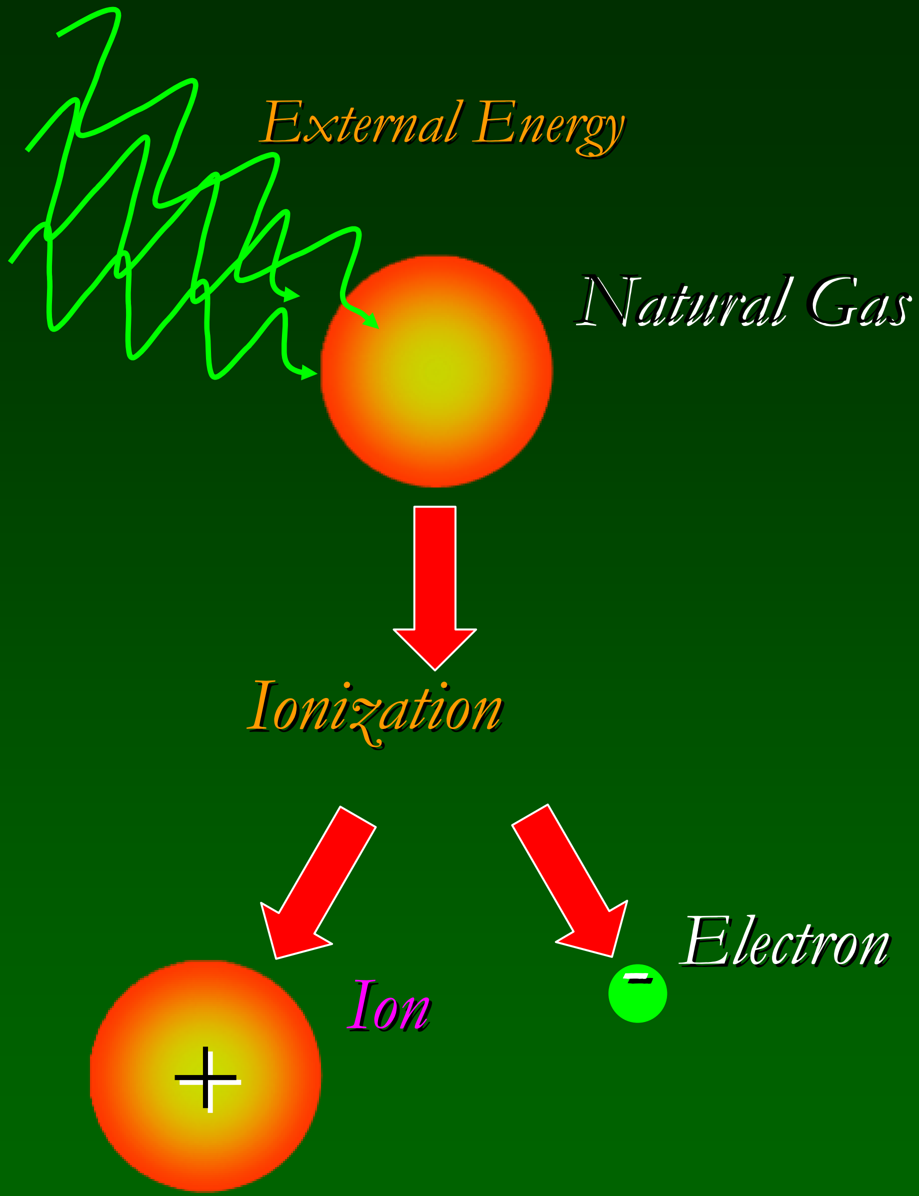
Plasma Treatment

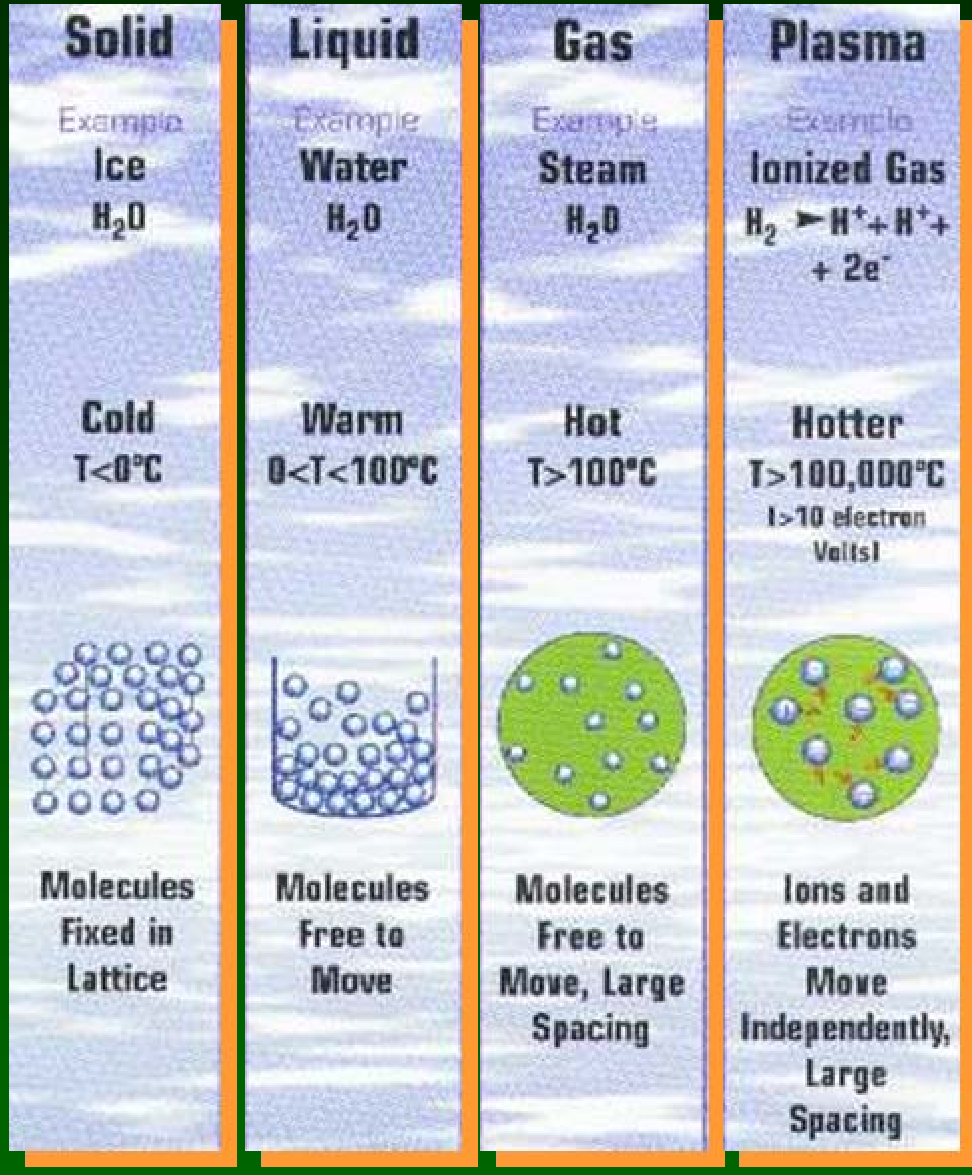
Assistant Prof. Dr. Somprasong Parsarpatet
Assistant Prof. Dr. Apichart Sonthisombat
Rajamangala University of Technology Thanyaburi

What is Plasma?



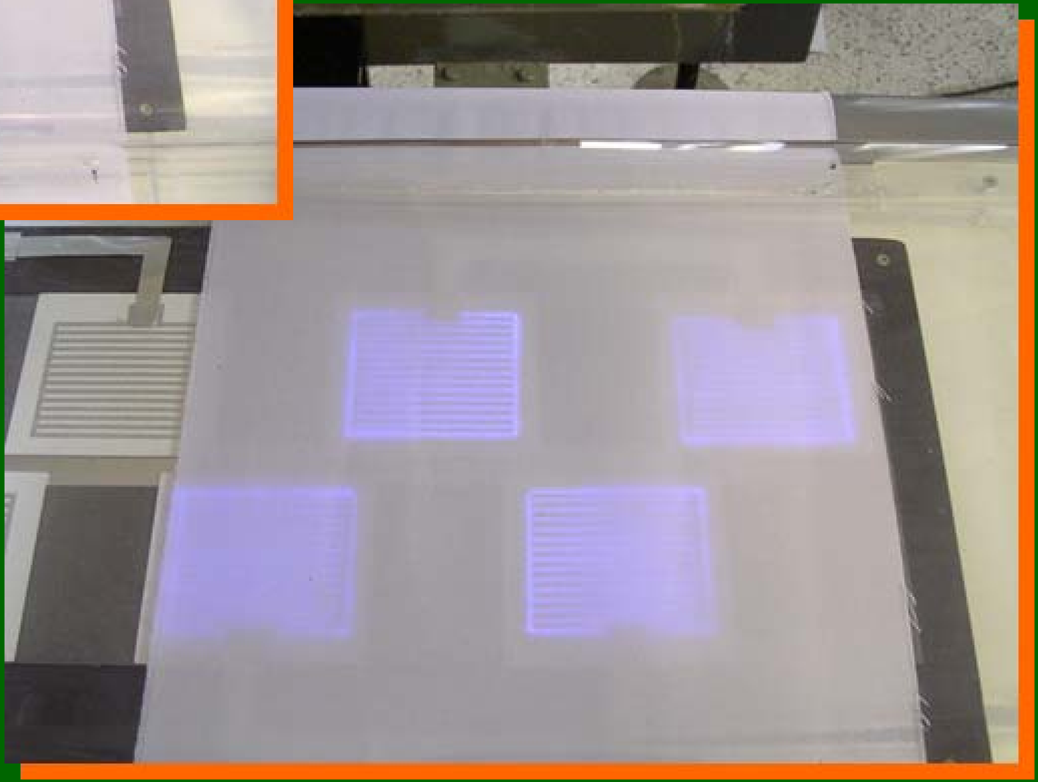
http://acms.lodestar.be/europlasma/bestanden/Plasma%20technology%20%20what%20is%20plasma.pdf



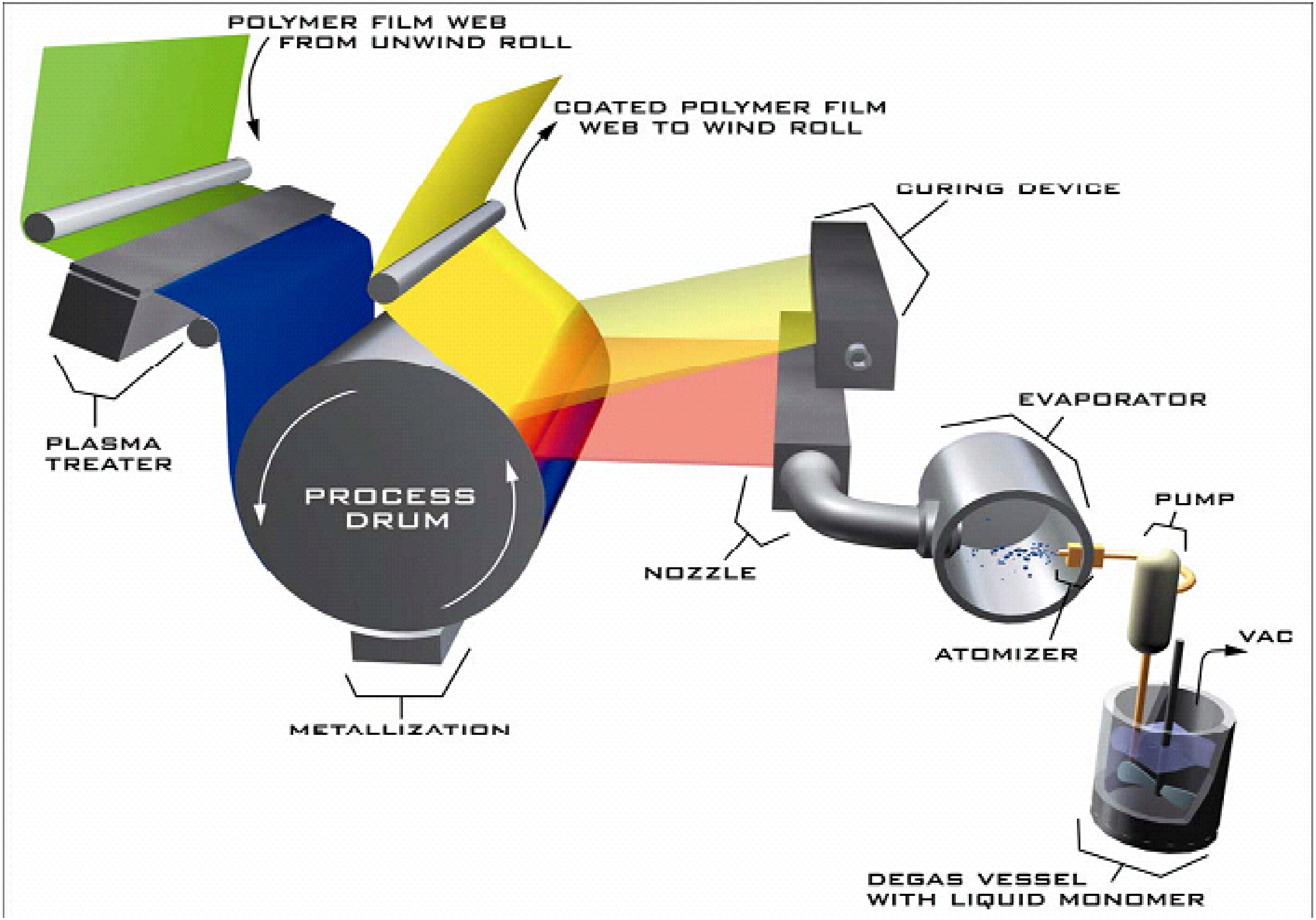


http://www.fnrf.science.cmu.ac.th

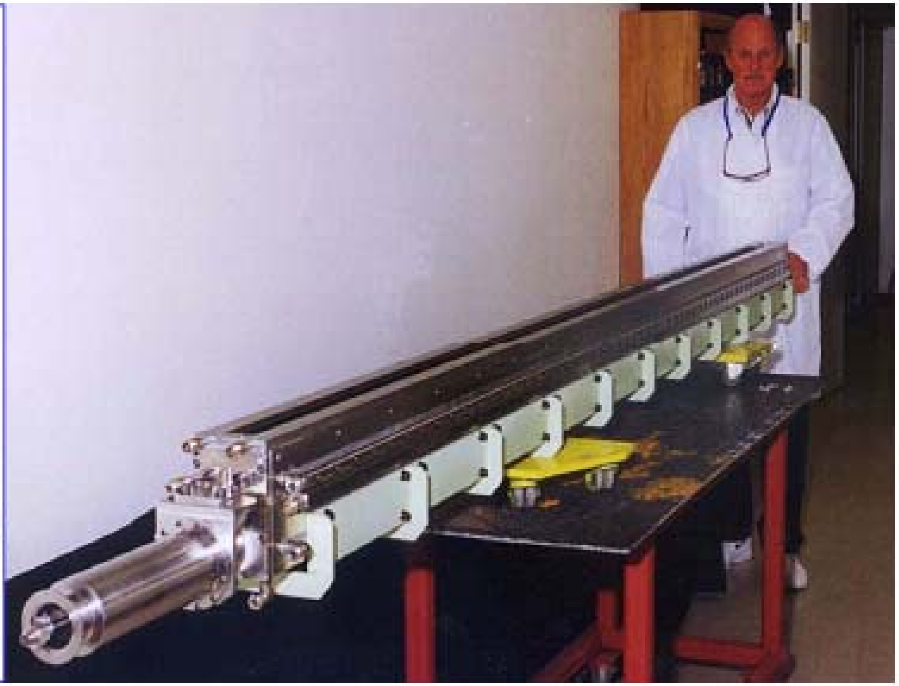
Research Funded by THTI



Research Funded by THTI

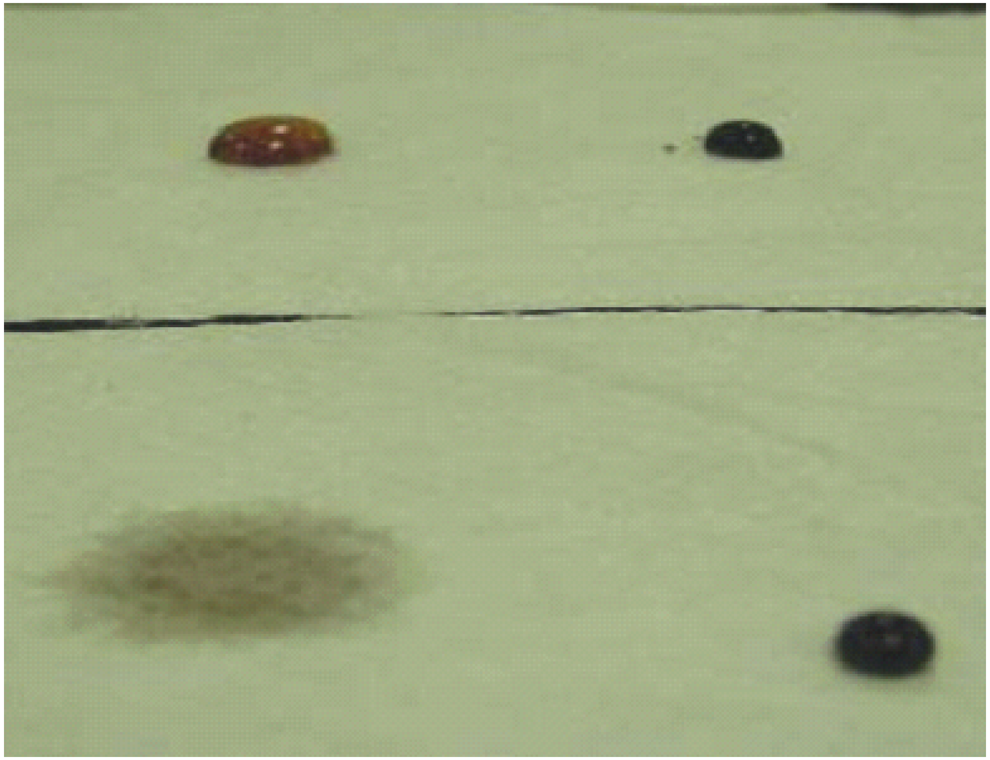


http://www.emich.edu/public/coatings_research/smartcoatings/Abstracts/Sigma%20Technologies.pdf



http://www.emich.edu/public/coatings_research/smartcoatings/Abstracts/Sigma%20Technologies.pdf

Converting Non Woven PP Fabric to Teflon-Like Oil/Water Repelling Media

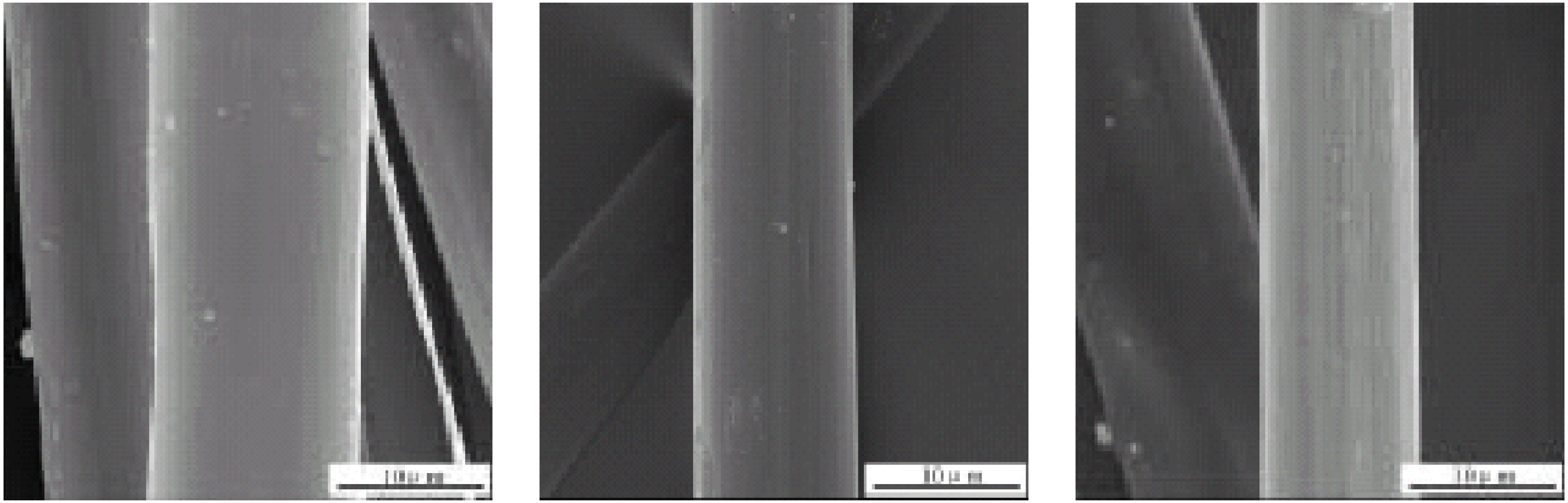


Oil Water

Sigma Coated Oil and Water Repellant

Oil Wetting and Water Repellant (control)

http://www.emich.edu/public/coatings_research/smartcoatings/Abstracts/Sigma%20Technologies.pdf

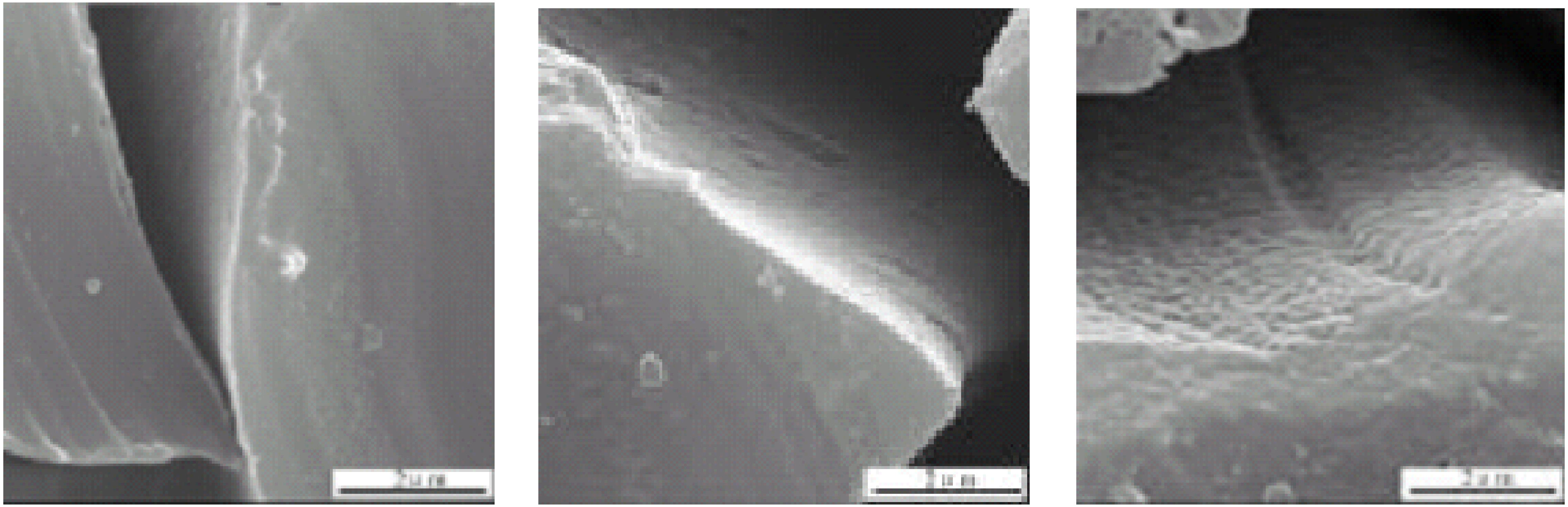


(a) (b) (c)

Plasma Treatment on Degummed Silk Fibers

a) Untreated b) Oxygen Plasma Treated for 1 min. c) Oxygen Plasma Treated for 5 min.

http://www.zju.edu.cn/jzus/2004/0408/040805.pdf

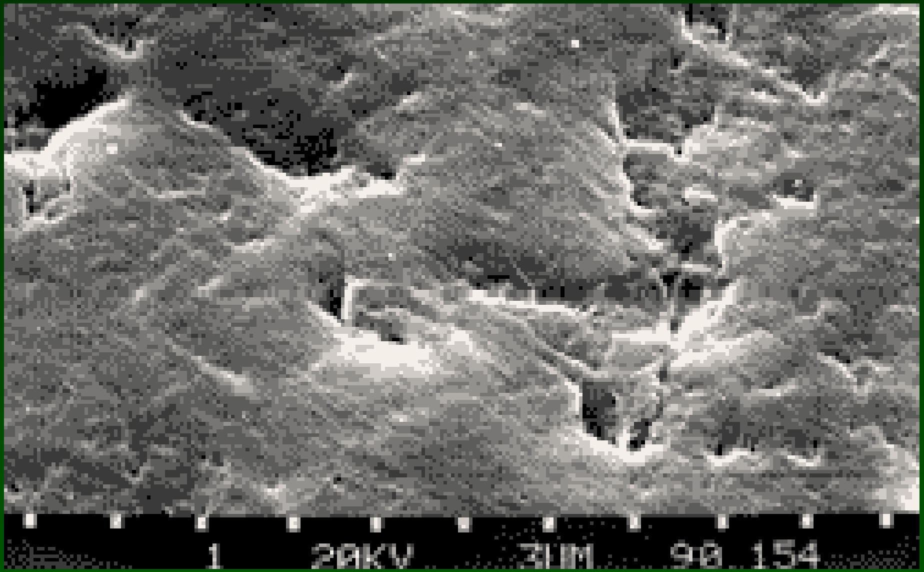


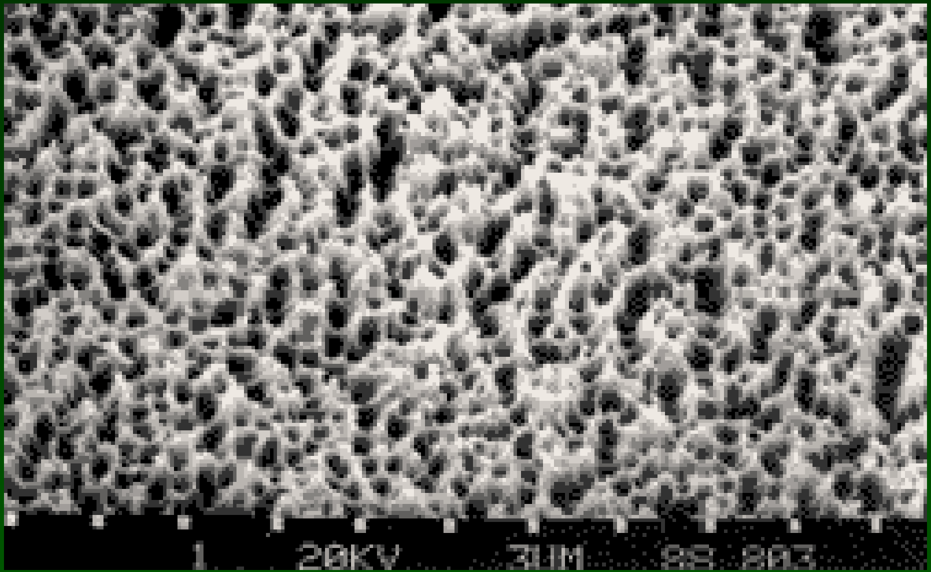
(a) (b) (c)

Plasma Treatment on Degummed Silk Fibers

a) Untreated b) Oxygen Plasma Treated for 5 min. c) Oxygen Plasma Treated for 15 min.

http://www.zju.edu.cn/jzus/2004/0408/040805.pdf



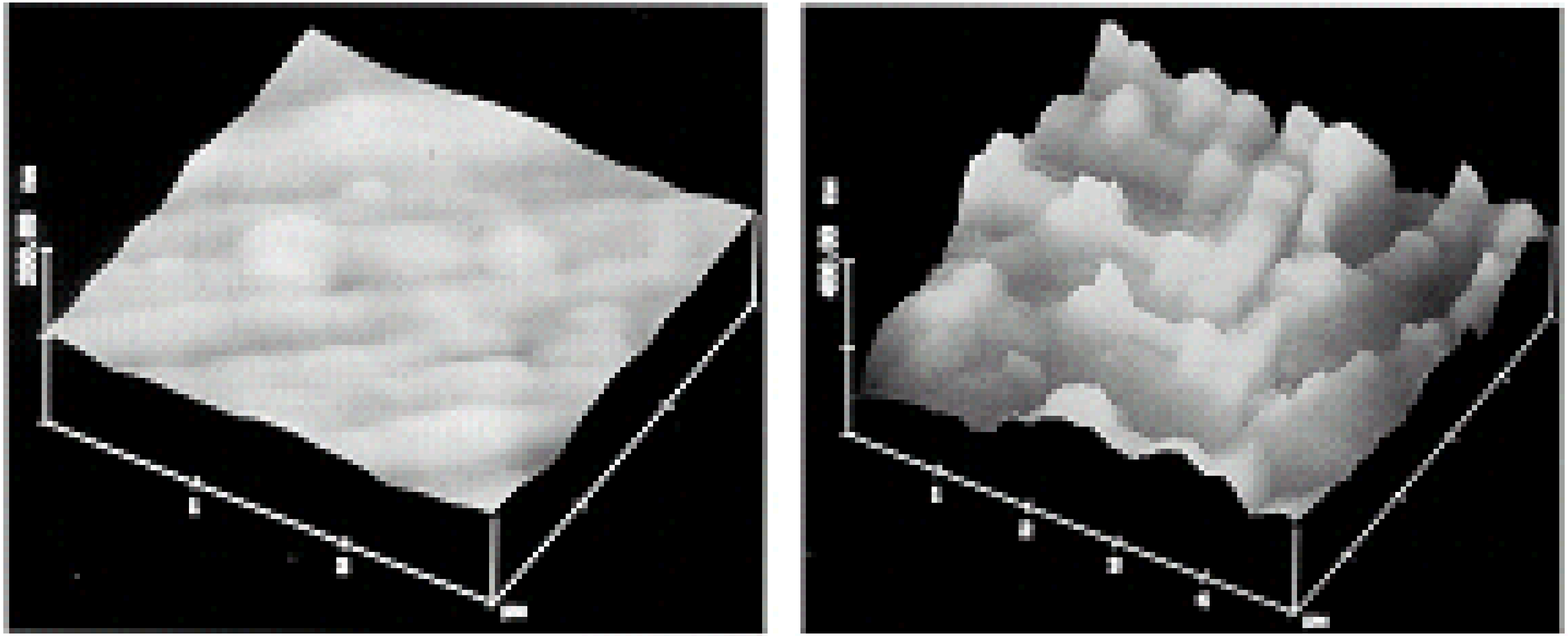


Plasma Treatment on PTFE

Untreated (Left)

Plasma Treatment (Right)

http://www.plasmabeam.de/31-1-etching.html



Effects of Plasma Treatment on Surface of Nonwoven

Untreated (Left) Plasma Treated (Right)

P.Bellini, F.Bonetti, E.Franzetti, G.Rosace, and S.Vago, *Reference Books of Textile Technologies: Finishing*, Italian Textile Machinery (ACIMIT), Milan, 3rd Edition, 2002, pp.160-161.

	Surface Energy dynes/cm		Water CONTACT ANGLE degrees	
	BEFORE	***AFTER***	***BEFORE***	***AFTER***
1. Hydrocarbons				
Polypropylene	29	>73	87	22
Polyethylene	31	>73	87	42
Polystyrene	38	>73	72.5	15
ABS	35	>73	82	26
Polyamide, Polyethylen copolymer	<36	>73	63	17
Epoxy	<36	>73	59.0	12.5
Polyester	41	>73	71	18
Rigid PVC	39	>73	90	35
Phenolic	Note	>73	59	36.5
2. Fluorcarbons				
Polytetrafluorethylene/ Polyethylene copolymer	37	>73	92	53
Fluorinated ethylene propylene	22	72	96	68
Polyvinylidene	25	>73	78.5	36
3. Elastomers				
Silicone	24	>73	96	53
Natural rubber	24	>73	Note	Note
Latex	Note	>73	Note	Note
Polyurethane	Note	>73	Note	Note

Effects of Plasma Treatment on Some Fibers

http://www.astp.com/PDFs/PS_biomed.pdf

Styrene butadiene rubber	48	>73	Note	Note
4. Fluoroelastomers				
Fluor carbon copolymer elastomer	<36	>73	87	51.1
5. Engineering thermoplastics				
Pet	41	>73	76.5	17.5
Poly carbonate	46	>73	75	33
Polyamide	40	>73	79	30
Poly aramid	Note	>73	Note	Note
Polyaryel ether ketone	<36	>73	92.5	3.5
Poly acetal	<36	>73	Note	Note
Poly phenylene oxide	47	>73	75	38
Pbt	32	>73	Note	Note
Poly sulfone	41	>73	76.6	16.5
Poly ether sulfone	50	>73	92	9
Poly arylsulfone	41	>73	70	21
Poly phenylene sulfide	38	>73	84.5	28.5

Effects of Plasma Treatment on Some Fibers

http://www.astp.com/PDFs/PS_biomed.pdf

Q&A

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Technology Based Development: the case of nano-technology Dr.N.M.Butt

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