Functional Textiles: Nanotechnology Approaches

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What is Nanotechnology?

- Atom
- Virus
- DRAM (=1um)
- Visible Ray
- Hemoglobin
- Hair

NANO TECHNOLOGY AREA

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
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
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°C for 24 h
Nanopowders by a modified sol-gel method (Institute of Advanced Energy, Kyoto University, Japan)

Keep at 80°C for 1 week

Dry at 80°C for 24 h

Calcinations at 400°C for 4 h

Characterization

Results: The modified sol-gel process using a surfactant enabled to fabricate various metal oxides possessed high crystallinity with crystal size about **5-15 nm**, high surface area (44-80 m²/g) and average pore diameter about 3-6 nm.
Sol-Gel Technologies and Their Products

http://www.chemat.com/assets/images/Flowchart_72.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
Encapsulation

Fig. 1. The miniemulsion principle.

Ball Milling Machine for Nanoparticle Preparation

http://www.fritsch-heidolph.co.jp/page01.html
Milling Machine for Nanoparticle Preparation

1. Particles with an initial fineness of 1 to 20 μm

2. Particles can be ground down to a medium fineness of 40 to 200 nm

3. Grinding media size between 100 and 500 μm

Types of Media: polymers, ceramic, glass, steel or tungsten carbide

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
Contact angle approx.
95°

flat water droplet

Contact angle > 110°
almost round water droplet
Self-cleaning surfaces

http://www.wupperinst.org/FactorFour/best-practices/lotus-effect.html
2. UV-Protection Effect

ZnO Nanoparticles for UV Protection

3. Antimicrobial Effect

http://www.nano-silver.net/eng/index.php
NanoSilver for Anti-microbial Effects

![NanoSilver Image]

<table>
<thead>
<tr>
<th>Used organism</th>
<th>Staphylococcus aureus (ATCC 6538P)</th>
<th>Klebsiella pneumoniae (ATCC43652)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteriostatic Activity Value</td>
<td>5.3</td>
<td>4.6</td>
</tr>
<tr>
<td>Biostatic rate(%)</td>
<td>99.9</td>
<td>99.9</td>
</tr>
</tbody>
</table>

(KOTITI; Korea Textile Inspection & Testing Institute)

http://www.polychrom.com
4. Antistatic Effect
5. Wrinkle Resistance Effect
Clean, safe water passes through microstructured membranes.
7. Carbon Nanotube

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

<table>
<thead>
<tr>
<th>Fiber Type</th>
<th>Fiber Size Range, microns</th>
<th>Fiber Size Range, denier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrospun Nanofibers</td>
<td>0.04 – 2</td>
<td>0.00002 – 0.06</td>
</tr>
<tr>
<td>Meltblown Fibers</td>
<td>2 – 10</td>
<td>0.03 - 1</td>
</tr>
<tr>
<td>Spunbond Fibers</td>
<td>15 - 40</td>
<td>1.5 - 12</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Fiber Type</th>
<th>Fiber Size, microns</th>
<th>Fiber Surface Area per mass of fiber material, m²/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrospun Nanofiber</td>
<td>0.05</td>
<td>80</td>
</tr>
<tr>
<td>Electrospun Nanofiber</td>
<td>0.2</td>
<td>20</td>
</tr>
<tr>
<td>Small Meltblown Fiber</td>
<td>2.0</td>
<td>2</td>
</tr>
<tr>
<td>Spunbond Fiber</td>
<td>20</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Specific Surface area calculations based on fiber specific gravity = 1.
Polymeric Nanofibers and Nanofiber Webs: A New Class of Nonwovens

Timothy Grafe*, Kristine Graham Donaldson Co., Inc., PO Box 1199, Minneapolis, MN 55440
10. Counterfeit Nanofibers

11. Fragrance Release Textiles

11.1 Microcapsules

Phase Change Materials

Color change of M/C

pictures before and after exposure to the sunlight (ultraviolet)

Thermochromic Dyes in Microcapsules

http://www.polychrom.com
11.2 Cyclodextrins


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
<table>
<thead>
<tr>
<th>Product Applications</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Anti-microbial</td>
<td>Textile Fibers, Thermoplastics, Permanent Coating, Wood Preservation</td>
</tr>
<tr>
<td>Catalysts</td>
<td>Environmental Catalysts, Fuel Cells</td>
</tr>
<tr>
<td>Performance Coating</td>
<td>UV-Attenuating Coating, Abrasion-Resistant Coating, Charge Dissipating</td>
</tr>
<tr>
<td>Personal Care</td>
<td>Sunscreen Formulations, Foot Powder, Deodorant/Antiperspirant, Shaving Products, Oral Care</td>
</tr>
<tr>
<td>Polishing</td>
<td>Glass Polishing, Semi-conductor Polishing</td>
</tr>
</tbody>
</table>
An Example of Using TiO2 Microparticles Mixed With Concrete for Road Building
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
Vehicles

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

Technology radar

The Smart Schematic

- Electrical Conducting Component
- Optical Sensing Component
- Form-Fitting Component
- Static Dissipating Component
- Comfort Component

http://www.smartshirt.gatech.edu
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 zeolites, cubicles, nanoclay platelets, hexagons, chitosan, nanocoated metal/ceramic particles etc.
IR and Visible Light Camouflage
Military Suits

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

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 $\rightarrow$ 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

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What is Plasma?

Research Funded by THTI
Converting Non Woven PP Fabric to Teflon-Like Oil/Water Repelling Media

Sigma Coated Oil and Water Repellant

Oil Wetting and Water Repellant (control)

Oil Water

http://www.emich.edu/public/coatings_research/smartcoatings/Abstracts/Sigma%20Technologies.pdf
Plasma Treatment on Degummed Silk Fibers

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

Plasma Treatment on Degummed Silk Fibers

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

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)

<table>
<thead>
<tr>
<th></th>
<th>Surface Energy dynes/cm</th>
<th>Water CONTACT ANGLE degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BEFORE</td>
<td>AFTER</td>
</tr>
<tr>
<td><strong>1. Hydrocarbons</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polypropylene</td>
<td>29</td>
<td>&gt;73</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>31</td>
<td>&gt;73</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>38</td>
<td>&gt;73</td>
</tr>
<tr>
<td>ABS</td>
<td>35</td>
<td>&gt;73</td>
</tr>
<tr>
<td>Polyamide</td>
<td>&lt;36</td>
<td>&gt;73</td>
</tr>
<tr>
<td>Polyethylene copolymer</td>
<td>&lt;36</td>
<td>&gt;73</td>
</tr>
<tr>
<td>Epoxy</td>
<td>41</td>
<td>&gt;73</td>
</tr>
<tr>
<td>Polyester</td>
<td>39</td>
<td>&gt;73</td>
</tr>
<tr>
<td>Rigid PVC</td>
<td>Note</td>
<td>&gt;73</td>
</tr>
<tr>
<td>Phenolic</td>
<td>Note</td>
<td>&gt;73</td>
</tr>
<tr>
<td><strong>2. Fluorocarbons</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polytetrafluorethylene</td>
<td>37</td>
<td>&gt;73</td>
</tr>
<tr>
<td>Polyethylene copolymer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluorinated ethylene</td>
<td>22</td>
<td>72</td>
</tr>
<tr>
<td>propylene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyvinylidene</td>
<td>25</td>
<td>&gt;73</td>
</tr>
<tr>
<td><strong>3. Elastomers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silicone</td>
<td>24</td>
<td>&gt;73</td>
</tr>
<tr>
<td>Natural rubber</td>
<td>24</td>
<td>&gt;73</td>
</tr>
<tr>
<td>Latex</td>
<td>Note</td>
<td>&gt;73</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>Note</td>
<td>&gt;73</td>
</tr>
</tbody>
</table>

Effects of Plasma Treatment on Some Fibers

### Effects of Plasma Treatment on Some Fibers

<table>
<thead>
<tr>
<th>Material</th>
<th>Value1</th>
<th>Value2</th>
<th>Note</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Styrene butadiene rubber</td>
<td>48</td>
<td>&gt;73</td>
<td>Note</td>
<td>Note</td>
</tr>
<tr>
<td><strong>4. Fluoroelastomers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluor carbon copolymer elastomer</td>
<td>&lt;36</td>
<td>&gt;73</td>
<td>87</td>
<td>51.1</td>
</tr>
<tr>
<td><strong>5. Engineering thermoplastics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pet</td>
<td>41</td>
<td>&gt;73</td>
<td>76.5</td>
<td>17.5</td>
</tr>
<tr>
<td>Poly carbonate</td>
<td>46</td>
<td>&gt;73</td>
<td>75</td>
<td>33</td>
</tr>
<tr>
<td>Polyamide</td>
<td>40</td>
<td>&gt;73</td>
<td>79</td>
<td>30</td>
</tr>
<tr>
<td>Poly aramid</td>
<td>Note</td>
<td>&gt;73</td>
<td>Note</td>
<td>Note</td>
</tr>
<tr>
<td>Polyarylether ketone</td>
<td>&lt;36</td>
<td>&gt;73</td>
<td>92.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Poly acetal</td>
<td>&lt;36</td>
<td>&gt;73</td>
<td>Note</td>
<td>Note</td>
</tr>
<tr>
<td>Poly phenylene oxide</td>
<td>47</td>
<td>&gt;73</td>
<td>75</td>
<td>38</td>
</tr>
<tr>
<td>Pbt</td>
<td>32</td>
<td>&gt;73</td>
<td>Note</td>
<td>Note</td>
</tr>
<tr>
<td>Poly sulfone</td>
<td>41</td>
<td>&gt;73</td>
<td>76.6</td>
<td>16.5</td>
</tr>
<tr>
<td>Poly ether sulfone</td>
<td>50</td>
<td>&gt;73</td>
<td>92</td>
<td>9</td>
</tr>
<tr>
<td>Poly arylsulfone</td>
<td>41</td>
<td>&gt;73</td>
<td>70</td>
<td>21</td>
</tr>
<tr>
<td>Poly phenylene sulfide</td>
<td>38</td>
<td>&gt;73</td>
<td>84.5</td>
<td>28.5</td>
</tr>
</tbody>
</table>

Q&A
References

- Technology Based Development: the case of nanotechnology Dr. N.M. Butt
- http://www.saferplane.com/stealthIV.pdf
- http://www.ascorchimici.it/coat_iii.htm
- http://www.science-forum.de
- http://www.textil.monforts.de/t3/mxl.455.0.html?&L=2