Textile Functionalization and its Effects on the Release of Silver Nanoparticles into Artificial Sweat

Heike Romanowski
Content

1. Background Functionalization of Textiles

2. Experimental Setup

3. Results

4. Conclusion
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## Nano Textiles – Application Examples

<table>
<thead>
<tr>
<th>Properties of nano textiles</th>
<th>Nanomaterial</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV protection</td>
<td>TiO$_2$</td>
</tr>
<tr>
<td></td>
<td>ZnO</td>
</tr>
<tr>
<td>Thermally conductive/insulating</td>
<td>CNT</td>
</tr>
<tr>
<td>Moisture-absorbing</td>
<td>TiO$_2$</td>
</tr>
<tr>
<td>Antibacterial</td>
<td>Ag</td>
</tr>
<tr>
<td></td>
<td>TiO$_2$</td>
</tr>
<tr>
<td></td>
<td>ZnO</td>
</tr>
<tr>
<td>Self-cleaning/dirt and water repellent</td>
<td>CNT</td>
</tr>
<tr>
<td></td>
<td>SiO$_2$</td>
</tr>
<tr>
<td></td>
<td>TiO$_2$</td>
</tr>
</tbody>
</table>
Risks (Nano)-silver

**Risks:**
- Silver ions can damage living cells
- Resistance to silver and antibiotics in microorganisms

**Recommendation:**
Avoid (Nano)-silver in food and everyday products
Motivation

Better understanding of:
- Consumer Ag exposure
- Ag release from textile
- Influence of the functionalization

Different functionalization techniques

<table>
<thead>
<tr>
<th>composites</th>
<th>coating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particles embedded within textile fiber</td>
<td>Particles on fiber surface</td>
</tr>
</tbody>
</table>
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Experimental Setup: 10 different Textiles

4 commercially available
• Towel
• Socks
• Sports shirt
• Pillow

6 laboratory-prepared
• 2 Ag composites
• 3 Ag coatings
• 1 untreated
Experimental Setup

Characterization of Textiles

Visualization of NPs on textile surface
- environmental scanning electron microscopy (ESEM) with energy dispersive X-ray spectroscopy (EDX)
- time-of-flight secondary ion mass spectrometry (ToF-SIMS)

Quantification of total Ag Content
- Digested in microwave oven / ICP-MS
Experimental Setup

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Visualization of NPs on textile surface
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Migration

Textile covered with artificial sweat (pH 5.5 and pH 8) for 24h/48h
- Release of total Ag into sweat → Artificial sweat analyzed with ICP-MS
- Release of particulate Ag into sweat → Artificial sweat analyzed with spICP-MS (single particle mode)
Content

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## Characterization of Textiles: Visualization of NPs on textile surface

<table>
<thead>
<tr>
<th></th>
<th>Visualization of NPs on textile surface</th>
<th>Quantification of total Ag Content (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Towel</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Socks</td>
<td>✔ (a few particles)</td>
<td></td>
</tr>
<tr>
<td>Sport shirts</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>Pillow</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>T-L-1 (composite)</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>T-L-2 (composite)</td>
<td>Not analyzed</td>
<td></td>
</tr>
<tr>
<td>T-L-3 (coating)</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>T-L-4 (coating)</td>
<td>Not analyzed</td>
<td></td>
</tr>
<tr>
<td>T-L-5 (coating)</td>
<td>✔</td>
<td></td>
</tr>
</tbody>
</table>
Characterization: Larger numbers of Ag particles on commercial textiles compare to lab-prepared nano-composite

ESEM images with EDX-spectra of a pillow (T-C-1), a sports shirt (T-C-4) and a lab-prepared nano-composite textile (T-L-1).

Characterization: Difference between Ag-NP and AgCl coated textiles

ToF-SIMS images of lab coated textiles with large aggregates for nano-Ag (T-L-3) and a very thin film for AgCl (T-L-5)

### Characterization of Textiles: Quantification of total Ag Content

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<tr>
<td>Towel</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Socks</td>
<td>✓ (a few particles)</td>
<td>Below LOD</td>
</tr>
<tr>
<td>Sport shirts</td>
<td>✓</td>
<td>14.2</td>
</tr>
<tr>
<td>Pillow</td>
<td>✓</td>
<td>23.5</td>
</tr>
<tr>
<td><strong>T-L-1 (composite)</strong></td>
<td>✓</td>
<td><strong>128.0</strong></td>
</tr>
<tr>
<td><strong>T-L-2 (composite)</strong></td>
<td>Not analyzed</td>
<td>132.8</td>
</tr>
<tr>
<td>T-L-3 (coating)</td>
<td>✓</td>
<td>12.4</td>
</tr>
<tr>
<td>T-L-4 (coating)</td>
<td>Not analyzed</td>
<td>14.9</td>
</tr>
<tr>
<td>T-L-5 (coating)</td>
<td>✓</td>
<td>26.6</td>
</tr>
</tbody>
</table>
Migration into sweat: Comparison Ag release from coating vs composites

Migration into sweat:
No significant pH-related influence

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Conclusion

• Ag functionalized textiles release Ag
• Predominantly release of ions
• But also particulate Ag was identified
• Functionalization type influences released amount
  → Higher release for coated textiles vs nanocomposites
Thank you for your attention!

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