SYNTHESIS AND CHARACTERIZATION OF SILVER NANOPARTICLES

Lawrence Hall of Science, Spring 2013
Collaborative Lab Model

Due to the length and complexity of this lab, a collaborative model has been implemented, in which each discipline has a specific role. An advantage of this collaborative model is that it helps introduce students to interdisciplinary research.

**Chemistry Lab:** Synthesizes silver nanoparticles

**Biology Lab:** Tests anti-microbial properties of silver nanoparticles

**Engineering Lab:** Characterizes silver nanoparticles with a scanning electron microscope

**Students go to biology lab to explain synthesis process**

**Students go to chemistry class to explain results of yeast testing**

**Provides synthesized nanoparticles**

**Provides synthesized nanoparticles**
History of Silver

Silver has been used throughout history

- Greeks and Romans stored water in silver vessels
- 1800s: silver was used to treat ulcers
- 1880s: silver nitrate eye drops were given to newborns (now babies get antibiotic drops)
- 1920s: silver was used to manage wounds

Currently there are many products that use silver and silver nanoparticles
Uses of Silver and Silver Nanoparticles

**Silver nanoparticles**

- **Prophylactic environmental effect.** Silver NPs are added into antibacterial paints and disinfectants to ensure an aseptic environment for the patient.

- **Prophylactic antibacterial effect.** Silver NPs are added as a surface coating for neurosurgical shunts and venous catheters.

- **Prophylactic antibacterial effect.** Silver NPs are added to bone cement and other implants.

- **Infection protection.** Silver-NP-impregnated wound dressings prevent infection and enhance wound healing.

**Silver**

- **Cauterization.** Silver nitrate used to stop epistaxis.

- **Antibacterial effect.** First medical use: Crede’s 1% silver nitrate eyedrops were used to prevent mother-to-child transmission of gonococcal eye infection.

- **Inflammatory effect** (causes deliberate adhesion). Silver nitrate is used in pleurodysis.

- **Regenerative effect.** Silver sulfadiazine cream is used as a dressing for burns and ulcers. It also improves skin regeneration.

- **Cauterization.** Silver nitrate is used to stop the growth of post-traumatic granulomas, or ‘wild flesh’.

Chaloupka et al., *Trends in Biotechnology*, 2010
Other Uses for Silver Nanoparticles

- Washing machines
- Hair straighteners
- Athletic clothing
- Socks

http://cw-x.com/default.aspx
Collaborative Lab Model

Chemistry Lab: Synthesizes silver nanoparticles
Metallic nanoparticles can be synthesized through many methods. The two most popular methods for synthesizing silver nanoparticles (Ag NP) via chemical reduction are:

- Turkevich method (1951): Silver reduced by trisodium citrate
- Brust method (1994): Silver reduced by sodium borohydride

In this lab we’re going to use the Turkevich method, since the materials are less hazardous.
Turkevich Method for Ag NP Synthesis

- Boil 60mL of a 1mM silver nitrate solution, covered with a watch glass on a hot plate
  - Stir solution with a magnetic stir bar
- Once boiling, add 6mL of 10mM trisodium citrate dropwise, about 1 drop per second
- Replace watch glass
- Wait for solution to change to a light golden color
  - Carefully remove beaker from hot plate and let solution cool
Reason for Color Change During Synthesis

At the macroscale, silver always looks like silver.

But solutions of silver nanoparticles can have many colors!
Surface Plasmon Resonance

- In the silver nanoparticles, electrons oscillate collectively.
- These oscillations affect how light interacts with the nanoparticles.
- The specific oscillations depend on the particles’ size and shape, so particles of different sizes have different colors.
Solution color gives an approximate idea of the particle size.

The color we see is basically an integration of the absorption spectra.

Nanoparticle size can be monitored more accurately by taking absorption spectra.

Role of Citrate

Citrate ions
-- reduce gold ions
-- cap the resulting nanoparticles

Fig. 1. AuNP synthesis using the Turkevich method.

Collaborative Lab Model

Chemistry Lab:
Synthesizes silver nanoparticles

Biology Lab:
Tests anti-microbial properties of silver nanoparticles

Provide synthesized nanoparticles
Students go to biology lab to explain synthesis process

Students go to chemistry class to explain results of yeast testing
How Silver Ions Kill Bacteria

Silver ions cause destruction of the peptidoglycan bacterial cell wall and lysis of the cell membrane.

Silver ions may denature ribosomes, thereby inhibiting protein synthesis and causing degradation of the plasma membrane.

Silver ions bind to DNA bases. This causes DNA to condense and lose its ability to replicate, thereby preventing bacterial reproduction via binary fission.

Bacterial cell wall

DNA plasmid

Chaloupka et al., Trends in Biotechnology, 2010
Silver Ions vs Silver Nanoparticles

- The antimicrobial properties of silver nanoparticles (Ag NPs) are less understood

- Possible bactericidal mechanisms for Ag NPs include
  - Cell uptake followed by disruption of both ATP production and DNA replication
  - Cell membrane damage
  - Generation of reactive oxygen species
How Silver Nanoparticles Kill Bacteria

Yeast Fermentation

- The anti-microbial properties of the silver nanoparticles (Ag NP) can be tested by measuring how Ag NPs affect yeast respiration.

- Yeast fermentation:
  \[ C_6H_{12}O_6 \rightarrow 2CO_2 \text{ (gas)} + 2 \text{ alcohol molecules} \]

- If Ag NPs kill yeast, there will be fewer yeast undergoing respiration, so the CO₂ production will be lower.

- The CO₂ produced can be measured in yeast fermentation tubes by tracking gas bubble height.
Yeast Fermentation

- Draw horizontal lines on fermentation tubes, (makes it easier to record bubble height data)

- Measure appropriate chemicals into beakers and stir to mix
  - control: water and yeast/molasses solution
  - test: silver nanoparticles and yeast/molasses solution

- Pour mixtures from beakers into fermentation tubes, taking care to not get bubbles in the vertical portions

- Transfer fermentation tubes to a water bath (set to 50 °C)

- Monitor fermentation and record data
Sample Fermentation Data

<table>
<thead>
<tr>
<th>Sample</th>
<th>Silver nanoparticles</th>
<th>Water</th>
<th>Yeast/molasses solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>20 mL</td>
<td>20 mL</td>
</tr>
<tr>
<td>5ml silver NPs</td>
<td>5 mL</td>
<td>5 mL</td>
<td>20 mL</td>
</tr>
<tr>
<td>10ml silver NPs</td>
<td>10 mL</td>
<td>10 mL</td>
<td>20 mL</td>
</tr>
</tbody>
</table>

Sample data collection table

<table>
<thead>
<tr>
<th>Line</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>start</td>
<td>1:41:30 PM</td>
</tr>
<tr>
<td>0</td>
<td>1:43:45 PM</td>
</tr>
<tr>
<td>1</td>
<td>1:45:35 PM</td>
</tr>
<tr>
<td>2</td>
<td>1:48:05 PM</td>
</tr>
<tr>
<td>3</td>
<td>1:52:25 PM</td>
</tr>
<tr>
<td>4</td>
<td>1:54:55 PM</td>
</tr>
<tr>
<td>5</td>
<td>1:58:06 PM</td>
</tr>
<tr>
<td>6</td>
<td>1:59:15 PM</td>
</tr>
</tbody>
</table>
Collaborative Lab Model

Chemistry Lab:
Synthesizes silver nanoparticles

Biology Lab:
Tests anti-microbial properties of silver nanoparticles

Engineering Lab:
Characterizes silver nanoparticles with a scanning electron microscope

Provides synthesized nanoparticles

Students go to biology lab to explain synthesis process

Students go to chemistry class to explain results of yeast testing

Provides synthesized nanoparticles

Students go to biology lab to explain synthesis process
Use a Hitachi SEM (a TM3000) to characterize a filter paper soaked in silver nanoparticle solution.

http://science.howstuffworks.com/scanning-electron-microscope2.htm
Considering Impacts of Technology

Values shape what technologies are developed and adopted.

Technologies affect social relationships.

Technologies work because they’re part of systems.

http://nisenet.org/catalog/tools_guides/nano_society_training_materials
Silver nanoparticles could affect individuals

Overdose of macro silver causes Argyria
Safety of nano silver still unknown

Silver nanoparticles could also affect whole societies and ecosystems

Silver nanoparticles can inhibit many bacteria, including “good bacteria”
Silver nanoparticles can prevent photosynthesis in algae
Nano Around the World

- Available from http://www.nisenet.org/catalog/programs/nano_around_world

- Participants reflect on the potential uses of nanotechnology as they trade technology cards

- Fun way to reflect on the impacts of many technologies, not just nanotechnology
References

- To find more products that use nano silver, search this inventory of nanotechnology-based consumer products: [http://www.nanotechproject.org/inventories/consumer/](http://www.nanotechproject.org/inventories/consumer/)
- “Antimicrobial Effects of Silver Nanoparticles”. Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems. [https://nano-cemms.illinois.edu/media/content/teaching_mats/online/antimicrobial_silver/docs/guide.pdf](https://nano-cemms.illinois.edu/media/content/teaching_mats/online/antimicrobial_silver/docs/guide.pdf)