Metal Scavenging:
using low-value phosphorus materials to make metal refining more sustainable

http://www.magpie-polymers.com

Steven van Zutphen
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<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic Number</th>
<th>Mass Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon</td>
<td>14</td>
<td>28.0855</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>15</td>
<td>30.973761</td>
</tr>
<tr>
<td>Sulfur</td>
<td>16</td>
<td>32.065</td>
</tr>
<tr>
<td>Selenium</td>
<td>34</td>
<td>78.96</td>
</tr>
</tbody>
</table>
Selective capture precious metals

Filtration of industrial effluents

Recover value from waste
SMALL EFFICIENCY INCREASES IMPACTS BOTTOM-LINE

Market Value: 28,000€/kg
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Market Value: 28 000€/kg

- Raw materials: 26 600€
- Processing cost: 520€
- Inefficiencies: 480€ (50% more efficient)
- Profit: 400€ (60% higher)
EFFICIENT RECYCLING KEY FOR SUSTAINABILITY

Sources:
- Sustainable Development Report 2009, p56, Anglo Platinum
- Sustainability Reporting and the Platinum Group Metals, G.M. Mud 2012,
  Nature Biotech 1999, p541
- PGM recycling at Hereaus, 2012
Manufacturing of high-value chemicals

Innovation driven by economics

Real and measurable impact on health, safety and environment
Founded in **2011**

450 m² facilities **1h** from Paris

**10** people, **10** products, **10** countries

Based on **innovation** from 2007
Discovery of something existing but unknown

Invention of something new

Innovation by combining things in a novel way
Typical ion-exchangers

- Use acids (sulphonate or carboxylic) for **cation** exchange
- Use amines (tertiary and quaternary) for **anion** exchange
- Use sulfur (thiol, thiouronium) for **chelating** functional groups

Magpie uses phosphorus

- **Unique coordination properties** of phosphines, phosphine oxide and phosphonates
- No need for **PCl** or **PLi** type species in production
- Use **PH** bonds for our chemistry
Process development example:
- Surface treatment industry
- Use our knowledge in solution chemistry

Product development example:
- Silver refining industry
- Exploit stability of our materials
POP, complex multistep process

- Layer **decorative** or **functional** gold/nickel/copper onto ABS plastic

- Key-step involves **Pd(0)** catalyst reducing a thin layer of metal on the surface

- Catalyst applied in **Pd/Sn colloid** form and reduced in-situ
PROBLEM FACED

Surface treatment bath

Concentration:
Pd: 50–60 mg/L
Sn: 2 g/L

Pd recovery on spent electrolyte

Rinsing baths

Concentration:
Pd: 4 mg/L
Sn: 800 mg/L

Rinsing water

Pd recovery on rinsing water
MAGPIE SOLUTION

Colloid is destablized while retaining palladium in Pd(II) form

Avoid co-precipitation of palladium and tin together

Scavange the palladium onto phosphine-oxide resin MPS-1207

Leave most tin in waste water to be removed at the water treatment station (hydroxide precipitation)

Step1:

<table>
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<tr>
<th>Palladium Loading</th>
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<tbody>
<tr>
<td>1% volume added, 15 min</td>
</tr>
<tr>
<td>25.7 g/L of MPS-1207</td>
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</tbody>
</table>
INDUSTRIAL SOLUTION

Automated system:

- Carries out the two step process with minimum intervention
- Recovers palladium on columns that can be changed when saturated
SILVER MARKET DEMANDS INCREASED PURITY

- 50/50 industrial / non-industrial uses of silver
- Electronics grade requires highest purity
- up to 30% higher in price
- 0.01% of impurity or 100 mg/kg
SILVER REFINING PROCESS: FROM WASTE TO VALUE

Step 1: obtain 80-90% pure silver
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Step 2: obtain 99.9-99.99% pure silver
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“THE REASONABLE MAN ADAPTS HIMSELF TO THE WORLD; THE UNREASONABLE ONE PERSISTS IN TRYING TO ADAPT THE WORLD TO HIMSELF. THEREFORE ALL PROGRESS DEPENDS ON THE UNREASONABLE MAN.”

GEORGE BERNARD SHAW