High-tech recycling of critical metals: Opportunities and challenges
Umicore – a materials technology company

Ø 50% of metal needs from Recycling

14,400 people in ~ 80 industrial sites worldwide, turnover 2012 €: 12.5 Billion (2.4 B excl. metals)
Booming product sales & increasing functionality drive demand for (technology) metals

Drivers:
- growing population (Asia!)
- growing wealth
- technology development & product performance

... next wave: tablet computer:
- 2013 tablets will overpass laptops
- 2015 more tablets than laptops + PC
Confusion in public debate about metals
– ? critical metals – rare metals – rare earths - …?

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Precious Metals (PM)  Semi-conductors  Rare Earth Elements (REE)

Technology metals  EU critical metals

Technology metals: descriptive expression, comprising most precious and special metals
- crucial for technical functionality based on their often unique physical & chemical properties (conductivity; melting point; density; hardness; catalytic/optical/magnetic properties, …)
- mostly used in low concentrations and a complex substance mix (‘spice metals’)
- Key for “Hi-Tech” and “Clean-Tech”
Massive shift from geological resources to anthropogenic “deposits”

- **Electric & electronic equipment (EEE)**
  Over 40% of world mine production of copper, tin, antimony, indium, ruthenium & rare earths are annually used in EEE

- **Mobile phones & computer**
  account for 4% world mine production of gold and silver and for 20% of palladium & cobalt.

- **Cars**
  > 60% of PGM mine production goes into autocatalysts, increasing significance for electronics (“computer on wheels“) and light metals

- In the last 30 years we extracted > 80% of the REE, PGM, Ga, In, … that have ever been mined

- **Clean energy technologies & other high tech applications will further accelerate demand for technology metals**
  (precious metals, semiconductors, rare earths, refractory metals, …) ➔ without access to these metals no sustainable development
How to achieve clean solutions without dirty feet?

No foreseeable absolute scarcity of metals, but:

• Declining grades & increasing complexity of ores
• Need to mine from greater depths and/or in ecological sensitive areas (artic regions, oceans, rain forest etc.)

⇒ High **footprint of primary metals production**
  • Energy needs & related climate impact
  • Other burden on environment (land, water, biodiversity)

Market imbalances already today cause **temporary scarcity**, due to:

• Supply restrictions → political, trade, speculation; regional or company oligopolies, by-product challenges, …
• Limits of substitution
• Surges in demand

→ critical metals identification for the EU & others
Recycling & circular economy as key contributors

**Primary mining**
- ~ 5 g/t Au in ore
- Similar for PGMs

**Urban mining**
- 150 g/t Au, 40 g/t Pd & Ag, Cu, Sn, Sb, … in PC motherboards
- 300 g/t Au, 50 g/t Pd … in cell phones
- 2,000 g/t PGM in automotive catalysts

State-of-the-art recycling …
- improves access to raw material
- is for many technology metals far less energy intensive than mining

Focus circular economy
- metals can be recycled „eternally“ without losses of properties

reduce metal losses along all steps of lifecycle
• Reduce generation of residues
• Collect residues comprehensively & recycle these efficiently
• Improve metal yields by using high quality recycling processes

Based on: C.E.M. Meskes: Coated magnesium, designed for sustainability?, PhD thesis Delft University of Technology, 2008
Recycling of most technology metals still lags way behind …

End-of-Life recycling rates for metals in metallic applications

WEEE: precious metal recycling rates below 15%


New report (April 2013):
Metal Recycling: Opportunities, Limits, Infrastructure

Recycling needs a chain, not a single process
- system approach is crucial

Example recycling of WEEE
Recovery of technology metals from circuit boards

Collection 10,000’s
Dismantling 1000’s
Preprocessing 100’s
Global smelting & refining <10

Number of actors in Europe

Total efficiency is determined by weakest step in the chain
Make sure that relevant fractions reach most appropriate refining processes

Example: 30% x 90% x 60% x 95% = 15%
Challenge 1: relevant products/fractions don‘t reach suitable recycling processes

a) Low collection

⇒ ambitious targets & new business models are required

b) “Deviation” of collected goods
⇒ dubious exports ⇒ low quality ”recycling”

⇒ “Tracing & Tracking“, controls & enforcement, stakeholder responsibility, transparency
Technology metals need smart recycling
- traditional mass focussed recycling does not fit

- “Mono-substance” materials without hazards
- Trace elements remain part of alloys/glass

Recycling focus on mass & costs

- “Poly-substance” materials, incl. hazardous elements
- Complex components as part of complex products

Place focus on trace elements & value
Challenge 2: How to recover low concentrated technology metals from complex products?

Product manufacturing ↔ manual/mechanical preprocessing ↔ metallurgical recovery preprocessing

Technical-organisational improvement needs along entire chain:
- Inappropriate product design
- Insufficient alignment within recycling chain (system & interface management)
- Insufficient use of recognised high-quality recycling installations
- Laws of nature (thermodynamics) prohibit recovery of all metals in some complex “inappropriate” material mixes (“composition conflict”)

Design determines connections
Various Grades/Qualities of Recyclates
Multi-metal recycling with modern technology

High tech & economies of scale

- Recovery of ~20 metals with innovative metallurgy from WEEE, catalysts, batteries, smelter by-products, ...
  - Au, Ag, Pt, Pd, Rh, Ru, Ir, Cu, Pb, Ni, Sn, Bi, Se, Te, Sb, As, In (via versatile multi feed process)
  - Co, REE (via specialised process for battery materials)
- Value of precious metals enables co-recovery of specialty metals ('paying metals')
- High energy efficiency by smart mix of materials and sophisticated technology
- High metal yields, minimal emissions & final waste

Umicore's integrated smelter-refinery in Hoboken/Antwerp
Treatment of 350 000 t/a, global customer base

ISO 14001 & 9001, OHSAS 18001
How to become viable & effective?
- matching product properties & process capabilities

**Product: Sufficient (extractable) value**
- Composition (what is in?)
- Concentration (how much of it?)
- Material prices

**Process: Performance & costs**
- Technological efficiency for value recovery (range, yields, energy, …)
- Process robustness & flexibility
- Environmental & social compliance
- Available volumes → Economies of scale
- Factor costs (labour, energy, capital)
- Process chain organisation / interface management

Depending on:
- Product & technology development
- Market development

Process quality
- Legal, societal & other frame conditions
Concluding – Overall recycling success factors

Prerequisites:

1. Technical recyclability as basic requirement
2. Accessibility of relevant components → product design
3. Economic viability intrinsically or externally created
4. Completeness of collection business models, legislation, infrastructure
5. Keep within recycling chain → transparency of flows
6. Technical-organisational setup of chain → recycling quality
7. Sufficient recycling capacity

Complex products require a systemic optimisation & interdisciplinary approaches (product development, process engineering, metallurgy, ecology, social & economic sciences)
Focus circular economy
- innovation and improvements still needed at every step

- Consider recycling in product design
- Develop business models to close the loop
- Recycle production scrap
- Improve range & yields of recovered metals
- Improve efficiency of energy & water use
- Avoid dissipation
- Minimise residue streams at all steps & recycle these effectively
- Take a holistic system approach
- Improve collection
- Increase transparency of flows
- Ensure quality recycling
- Go beyond mass recycling (more focus on technology metals)
- Develop innovative technologies to cope with technical recycling challenges

Mining & Recycling are complementary systems!
It’s all linked
- ensure appropriate policy support

Recycling contributes to resource efficiency, access to critical RM and innovation
- Create appropriate legal framework; focus on high quality recycling
- Ensure stringent enforcement of legislation
- Support R&D funding & implementation of innovative recycling solutions

Recycle more & better
⇒ don’t waste metals
⇒ don’t waste time, let’s move with the frontrunners
Thanks for your attention!

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For more information:

Activities addressing recycling innovation

**European Innovation Partnership (EIP) on Raw Materials**

**ERA-MIN roadmap**
Coordination of RM related research funding between EU Member States
www.era-min-eu.org/documents-page/era-min-documents

**UNEP Resource Panel**
www.unep.org/resourcepanel

with new report "Metal Recycling - Opportunities, Limits, Infrastructure"
www.unep.org/resourcepanel/Publications/MetalRecycling/tabid/106143/Default.aspx
Example cars – evolution of mobility

1900s
- Mobility

1950s
- Style
  + steel alloys & decoration

2000s
- Intelligence
  + electronics
  + aux. electric motors
  + lightweighting

1920s
- Power

1980s
- Clean air
  + catalyst

> 2010
- Low carbon
  + NiMH/Li-Ion battery
  + FC stacks
  + e-drives

Metals*

Fe Pb Cu Cr
Al Zn Pt Pd
Rh Ce La Au
Ag Sb Sn Ge
In Ga Nd Pr
Sm Tb Dy Mg
Li Co Ni Ru

*list only indicative
The mechanical pre-processing challenge
- materials separation for final metallurgical recovery

Avoid dissipation of trace elements
Gold losses of up to 75% if PC-motherboards are not removed prior to shredding
100% gold losses in a car shredder

“versatile” integrated smelter processes for Cu, PM & some special metals

Dedicated processes for certain components & special metals