Criticality assessment and R&D for circulation of critical materials

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National Institute of Advanced Industrial Science and Technology (AIST)

- Public research institute
- 2,300 full time researchers
- R&D areas:
  - Energy and Environment
  - Electronics and Manufacturing
  - Materials and Chemistry
  - Life Science and Biotechnology
  - Information Technology and Human Factors
  - Geological Survey
  - Metrology Standards
AIST’s R&D in Urban mining / Minor metal recycling
— SURE research base and consortium —

Presentation topics

- Overview of criticality assessment in Japan
- Introduction of AIST’s R&D in urban mining
Agenda

1. Criticality assessment
2. Criticality and recycling
3. Challenges in minor metal recycling
4. AIST’s R&D in urban mining
5. Summary
1. Criticality assessment

- A wide variety of metals are being used in industry today
- Japan imports most of material resources including minor metals
- Criticality assessment has been important in Japan
1. Criticality assessment

Governmental actions in Japan

- Economic security committee in MITI (1980s)
  ⇒ Determined to stockpile several type minor metals
- The Basic Energy Plan of Japan (METI, 2010)
  ⇒ Set targets for self-sufficiency ratio for metals
- Resource securement strategy (METI and MOFA, 2012)
  ⇒ Determined 30 type minerals to watch carefully

<table>
<thead>
<tr>
<th>Antimony</th>
<th>Cobalt</th>
<th>Gallium</th>
<th>Graphite</th>
<th>Chromium</th>
<th>Germanium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indium</td>
<td>Silicon</td>
<td>Zirconium</td>
<td>Strontium</td>
<td>Tungsten</td>
<td>Tantalum</td>
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<tr>
<td>Niobium</td>
<td>Manganese</td>
<td>Nickel</td>
<td>Vanadium</td>
<td>PGMs</td>
<td>Fluorine</td>
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<tr>
<td>Magnesium</td>
<td>Molybdenum</td>
<td>Copper</td>
<td>Lithium</td>
<td>REEs</td>
<td>Rhenium</td>
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<tr>
<td>Iron</td>
<td>Aluminum</td>
<td>Lead</td>
<td>Zinc</td>
<td>Tin</td>
<td></td>
</tr>
</tbody>
</table>
## 1. Criticality assessment

### Factors of criticality

#### Supply side

<table>
<thead>
<tr>
<th>Indicators for evaluating supply risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country concentration</td>
</tr>
<tr>
<td>Country risk</td>
</tr>
<tr>
<td>Depletion time</td>
</tr>
<tr>
<td>By-product dependency</td>
</tr>
<tr>
<td>Substitutability</td>
</tr>
<tr>
<td>Import dependence</td>
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<tr>
<td>Price volatility</td>
</tr>
</tbody>
</table>

#### Demand side

<table>
<thead>
<tr>
<th>Indicators for evaluating vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of products affected</td>
</tr>
<tr>
<td>Spread of utilization</td>
</tr>
<tr>
<td>Strategic importance</td>
</tr>
<tr>
<td>Value of the utilized material</td>
</tr>
<tr>
<td>Substitutability</td>
</tr>
<tr>
<td>Demand share</td>
</tr>
<tr>
<td>Import dependence</td>
</tr>
</tbody>
</table>

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1. Criticality assessment

Assessment cases

European Commission
EC (2010)

Critical metals:
14 out of 41 metals

EC (2013)

Critical metals:
27 out of 54 metals

Yale Univ. (US)

“Criticality space” proposed by Yale univ.
(Graedel et al., PNAS, 2015, 112(14), 4257-4262)
1. Criticality assessment

Assessment cases in Japan (NEDO, 2009)

Assessment criteria and rating rules

<table>
<thead>
<tr>
<th>Category</th>
<th>Criteria</th>
<th>Rating rules</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Supply risk</td>
<td>Depletion time</td>
<td>&gt;150 yrs</td>
</tr>
<tr>
<td></td>
<td>Concentration of reserves</td>
<td>&lt;70%</td>
</tr>
<tr>
<td></td>
<td>Concentration of ore production</td>
<td>&lt;70%</td>
</tr>
<tr>
<td></td>
<td>Concentration of import trading partners</td>
<td>&lt;70%</td>
</tr>
<tr>
<td>Price risk</td>
<td>Price change</td>
<td>&lt;125%</td>
</tr>
<tr>
<td></td>
<td>Price variation</td>
<td>&lt;125%</td>
</tr>
<tr>
<td>Demand risk</td>
<td>Global demand growth</td>
<td>&lt;125%</td>
</tr>
<tr>
<td></td>
<td>Domestic demand growth</td>
<td>&lt;125%</td>
</tr>
<tr>
<td></td>
<td>Domestic demand growth for specific uses</td>
<td>&lt;125%</td>
</tr>
<tr>
<td>Recycling restriction</td>
<td>Stockpiles</td>
<td>Prepared</td>
</tr>
<tr>
<td></td>
<td>Recyclability</td>
<td>Implemented</td>
</tr>
<tr>
<td>Potential risk</td>
<td>Possibility of usage restrictions</td>
<td>Safe</td>
</tr>
</tbody>
</table>

High criticality minor metals (14 metals): In, Eu, Tb, Dy, Li, Nd, W, Y, Ce, La, Nb, Sb, Pt, Bi

- The assessment has been updated
- Base metals were added to the assessment
1. Criticality assessment

Assessment cases in Japan
Criticality in 2012 (Hatayama et al. (AIST), 2015)

- Referred to (NEDO, 2009), and updated criteria, rating rules, and data
High criticality materials (in Japan) include:

- Minor metals: In, Nb, Ta, W…
- REEs: Nd, Dy, Eu, Sm…
- Precious metals: Pt, Ag, Rh…
- Base metals: Sn, Zn…

Criticality’s degrees change over time as:

- Supply-side structures change
- Demand-side structures (e.g. domestic industry structures) change

Continuous updates of the assessments are needed
2. Criticality and recycling

Measures to mitigate the criticality

Japanese government’s strategy pillars

- Securing overseas resources
- Deep-sea bottom resource development
- Stockpiling
- Recycling
- Development of alternative materials

Under which conditions, is recycling effective?
For what type metals, is recycling effective?
2. Criticality and recycling

Recycling is effective for the metals whose:

✗ “Criticality” is high    AND
✗ “Potential of recycling” is high (= Urban mine is abundant)

Recycling is effective for the metals where:

- “Criticality” is high AND
- “Potential of recycling” is high

Other measures to mitigate the criticality are needed.
2. Criticality and recycling

"Potential of recycling" assessment

Assessments of “potential of recycling” are our ongoing work

Products are exported

In-process wastes

Under assessment

(Hatayama et al. (AIST), 2015)
2. Criticality and recycling

“Potential of recycling” changes over time

2025
Increased demands for EVs (Criticality ↑)
Waste-EVs not available (Potential ↓)

2035~
Waste-EVs increase (Potential ↑)

“Criticality” and “potential of recycling” change depending on product/material flows. → Strategies for effective recycling are necessary
3. Challenges in minor metal recycling

Recycling in Japan

- Recycling laws in Japan (enacted since 1990s) have increased recycling of Fe, Al, Cu, Plastics, etc.
- But recycling of minor metals is still rare and a challenge.

Recycling Laws in Japan
3. Challenges in minor metal recycling

Barriers for minor metal recycling

- Small amount of metals
- Low concentration (in products)

⇒ Economically difficult

Challenges

- Collection of waste products ⇒ Legislation, Business
- Economic recycling processes ⇒ R&D, Business
- Recycling strategies ⇒ R&D, Policy, Business

R&D challenges

Product disassembly, Minor metal physical separation, Metallurgy, Product design for resources (Eco-design), Information sharing scheme, Recycling process optimization, etc.
4. AIST’s R&D in urban mining

SURE research topics

- Automation dismantling and sorting
- Development of selective grinding
- Waste product database
- Development of physical separator
- Logistics analysis
- Development of pyrometallurgy
- Material flow analysis
- Development of hydrometallurgy
- Product design
- Materials development for recycling

38 AIST researchers
4. AIST’s R&D in urban mining

① Physical separation
Tantalum (Ta) separation in Printed-Circuit-Boards

[Diagram of process involving physical separation, size separation, magnetic and shape separations, and gravity separation, with various components and labels for different materials and stages of processing.]
4. AIST’s R&D in urban mining

① Physical separation

Tantalum (Ta) separation in Printed-Circuit-Boards

Succeeded to obtain the concentration product of tantalum capacitors of 70-97% (purity)
4. AIST’s R&D in urban mining

① Physical separation
Tantalum (Ta) separation equipment
4. AIST’s R&D in urban mining

① Physical separation
Tantalum (Ta) separation equipment

Separators for other metals/products have been developed.
E.g. Nd-Dy magnets separator
4. AIST’s R&D in urban mining

② Product sorting
Automatic sorting system for mobile phones

![Diagram showing the process of product sorting using ARENNA Sorter, highlighting mobile phones with many tantalum capacitors being separated from those with a few tantalum capacitors.](image-url)
3. Hydro-metallurgy

Extractants for palladium (Pd) and rhodium (Rh)

**Palladium extractant, TDGA**

- Extraction % ($E\%$) of Pd(II) and Pt(IV) as a function of extraction time
- Conventional extractant: Di-n-hexyl sulfide (DHS)
- New extractant: Thioglycolamide (TDGA)

**Rhodium extractant, BisAA**

- Extraction % ($E\%$) of Rh(III) as a function of HCl concentration
- The highest $E\%$ of Rh from highly concentrated HCl solution (>1 M)
  - Rh extraction from 0.5-3.0 M HCl
  - Rh stripping using 10 M HCl or NaOH solution

**Patents and Papers**

- Narita et al.: Extractants for palladium and process for separation and recovery of palladium

(Narita et al. (AIST))
4. AIST’s R&D in urban mining

④ Product-flow / Material-flow analysis

Waste-product amount forecasts

Waste product flow analysis

Geographical distribution

“Potential of recycling” assessment

Optimizations of logistics, recycling facility allocation, etc.

(Komoto, et al.(AIST), 2015)
4. AIST’s R&D in urban mining

SURE consortium: Collaboration with industry
Summary

1. Criticality assessment
   - Criticality assessment has been undertaken in Japan. The assessments need to be updated continuously.

2. Criticality and recycling
   - “Potential of recycling” should be assessed, which is necessary for effective recycling.

3. Challenges in minor metal recycling
   - The economical difficulty is the largest barrier today. R&D is necessary to enable minor metal recycling.

4. AIST’s R&D in urban mining
   - AIST promotes R&D
Your visits to us are very welcome

AIST branches

Thank you for your attention

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