Smelting Technologies for E-scrap in Japan

Workshop 2018 of the Asian Network for Prevention Illegal Transboundary Movement of Hazardous Wastes
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OUTLINE

• INTRODUCTION  - E waste -
  • Key-point on an E-waste Treatment business
• PROCESSES
  Pre-Treatments
  Hydrometallurgical Processes
  Smelting Processes
• SUMMARY
Trial of Precisely Recovery in WEEE treatment

- Outdoor unit
- Heat Exchanger
  - Aluminum
  - Copper

Additional Process for Compressor Disassembly
- Manual Dismantling
- Coil Cutting

- HDD
- HDD Magnet (NdFeB)
- Sell to Domestic Refinery

- Ta capacitor rich PCB
- Ta capacitor

- Focus to more good recovery of metals and plastics.
- Become to focus the critical metals recovery.
Examples of PCBs

Change of E-scrap treatment amount

- E-scrap Treatment amount in Japan
- E-scrap Treatment amount in Tohoku Area

Main Targets from PCBs are Au, Ag, Cu and Pd

However, Pb and other harmful heavy metals should be recovered.

And Halogens like Br has been still a problem during treatments.
The chemical composition of PCBs in engine computers

<table>
<thead>
<tr>
<th><strong>Element</strong></th>
<th><strong>Mass %</strong></th>
<th><strong>Element</strong></th>
<th><strong>Mass %</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>24.02</td>
<td>Ag</td>
<td>0.06</td>
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<tr>
<td>Ca</td>
<td>9.96</td>
<td>Sn</td>
<td>6.48</td>
</tr>
<tr>
<td>Mn</td>
<td>0.05</td>
<td>Sb</td>
<td>0.49</td>
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<tr>
<td>Fe</td>
<td>2.08</td>
<td>Ba</td>
<td>0.65</td>
</tr>
<tr>
<td>Ni</td>
<td>0.12</td>
<td>Sr</td>
<td>0.65</td>
</tr>
<tr>
<td>Cu</td>
<td>10.19</td>
<td>Ta</td>
<td>0.07</td>
</tr>
<tr>
<td>Zn</td>
<td>0.79</td>
<td>Br</td>
<td>8.79</td>
</tr>
<tr>
<td>Pb</td>
<td>4.20</td>
<td>O</td>
<td>31.33</td>
</tr>
<tr>
<td>Au</td>
<td>0.07</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Points of PCB Analytical data

• High content of Copper and some precious metals like Au, Ag and Pd
• Some of PCBs contain relatively high contents of Ta and other minor rare metals
• PCBs contain Pb
• Relatively high Br contents, especially PCB from car
• More than few % of SiO2 and Al2O3 are also contained in PCB
  → sometimes, it becomes a reason of difficulty of slag composition control
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Comparison between Urban Mine Development and Normal Mine Development

* Normal Mining

1. Exploration
2. FS for Mining
3. Mining
4. Mineral Dressing
5. Extraction

* Urban Mining

1. Material Flow Analysis
2. Planning for Collection
3. Collection
4. Pre-Treatment
5. Extraction
Acceptance and check of E-scrap and sampling

Value of precious metals is essential, then sampling and analysis of E-scrap are very important in this business.
Sampling

- unique state-of-the-art facilities
- dedicated to process all raw materials
- key drivers:
  - maximizing automations
  - adequate capacities in growing segments (e-scrap, auto catalysts...)
  - shortening the lead times
  - respecting environmental, health & safety standards
- substantial investments in last 10 years
- employment: 100 people
- secured area
- ± 8000 lots & 350,000 t/year
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A whole flow about the processing of E-scrap

- WEEE
  - Sorting
    - Dismantling
      - Reusable component
      - Required selective treatment
        - e.g. LCD, PCB
        - Harmful Substances
      - Recyclable material
        - e.g. Fe, Cu, Al, PS, PP, ABS, etc.
      - Difficult to process
        - e.g. Motor, Compressor, Components including minor metals
  - Processing
    - Materials (separated)
      - e.g. Fe, Cu, Al, PS, ABS
      - Material recycling
        - Recycled materials
        - Energy Recovery
        - Landfill
  - Residue
    - Normal metal recycle
    - Advanced metal recycle
    - Focusing Minor metals and Harmful components

- Energy Recovery
- Landfill
General Flow sheet of WEEE treatment focused on precious metal recovery
Parts separator

WEEE

Separation by Mechanical Power

Crusher

Photograph
By Prof. Owada
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Typical hydrometallurgical flowsheets for precious metals recovery from PCB

Yanhua Zhang, Shili Liu, Henghua Xie, Xianlai Zeng and Jinhui Li “Current status on leaching precious metals from waste printed circuit boards” Procedia Environmental Science 16(2012) 560-568 nd_03.html
Treatment concept for various scrap containing gold

S O L I D | Precious metals scrap 
IC tips 
Lead flame 
PCB 

Crushing, sorting 
Leaching by cyanogen solution or acid 
Cementation of Zn or 
Electrolysis 
Melt ingot 

Other metals high Ni, SUS 
others 

Precious metals, Au, Ag, Pd, Cu 

Electro-winning 
Oxidation and Reduction neutralization 

Precious metals, Au, Ag, Pd, Cu 
cyanogens solution (reuse) 
Waste water treatment 

LIQ UID 
Waste water from plating plants 
Waste of acid and alkaline solutions 

Treatment process

Normal grade Scrap 
Low grade scrap 

Crushing, sorting 
Leaching by cyanogen solution 

Electro-winning 

Waste water treatment 
Crude Au, Ag 

Processes are ready for grade of scrap 
Crude Au, Ag, Pd and Cu will be treated in non–ferrous refinery to get high purity metals 

Roasting 
Residue containing Au, Ag, Pd and Cu 

PCB
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Pyrometallurgical Processes

• Copper smelting
• Flash smelting - PS converter: most popular
• Mitsubishi continuous smelting, Noranda process
• TSL Furnaces
  - Umicore, Dowa smelting,

Pre-Treatment Processes:
• Rotary Kiln Furnace
  - Mitsubishi Materials, Mitsui Kinzoku, JX Metals
• Reverberatory furnace
  - Mitsubishi Materials, JX Metals
• Cupola Furnace
  - Aurubis, Montanwerke Brixlegg, (JX Metals)
Raw materials:
Powder like resources into flush smelter
Lamb type resources into converter

Precious metals like gold, silver and PGM are recovery after electrorefining of copper
Mitsubishi Continuous Process

High Efficiency
Very compact smelter
Easy to fix \( \text{SO}_2 \) to \( \text{H}_2\text{SO}_4 \)

Since 1975

http://www.ptsmelting.com/smelter.htm
Mitsubishi Continuous Copper Smelting
Shredder dust/ PCBs treatment process in Onahama Smelter

Onahama Smelter is essentially copper smelter, however, Shredder dust is treated in a reverberatory furnace. Their dioxins emission is less 0.1ng TEQ/m³

Key Point: Halogens in flue gas are not put into a main acid plant but put into plaster (CaSO₄) plant.
Top Submerged Lance Furnace (TSL furnace)

Fuel: Oil and pulverized carbon

Raw Materials:
E-scrap (Printed Circuit boards)
Sludge containing precious metals and copper

Product:
Black copper or matte
Slag

It is necessary one more process (furnace) after TSL furnace treatment
Precious Metals Operations: Smelter

- unique Isa smelt, submerged lance combustion technology, injecting oxygen enriched air & fuel in a molten bath
- separating precious metals in a copper bullion from mostly all other metals concentrated in a lead slag
- operating at 1,000 mt/day at an availability >92%
- highly flexible technology for PM recycling:
  - variability of physical aspect (lumps, fines, wet, dry, shredded material...)
  - variability of feed mix (e.g. volume e-scrap vs. total volume)
  - ratio PM / PGMs & impurities in the feed mix
Waste Electronic Instruments

Decomposing & Separating

Precious Metal Scraps

Incinerating

Precious Metal Ash

Saganoseki Smelter & Refinery

Precious Metals (Au, Pt, Pd, Rh, Ru)

HMC Factory New Refinery

Precious Metals (Au, Ag, Pt, Pd, Rh, Ru, Ir)

Recovery Process of Precious Metals
Incineration of Precious Metal Scrap

Before Incineration

After Incineration
HMCⅢ Plant (Copper Electrolysis)
Precious Metals Products

Gold

Silver

Platinum

Palladium

Rhodium

Ruthenium
Key points of PCB Treatments in metallurgical Processes

• What kinds of resources are target to recover?
  Simple process can be applied, if target metals to recycle are Cu, Ag, Au and Pd.

• How much PCB can be treated?
  This means how much PCB can be collected

• Hydrometallurgical process is fine if the amount is small and high grade of precious metals

• Pyrometallurgical process is suitable if treatment amount is large. On the other hand,

• How to treat Brominated Flame Retardant
Brominated Flame Retardants (BFRs)

Majority (38%) of global production of bromine (Mehran et al., 2003)

Tetrabromobisphenol A (TBBPA)
59% of global production of BFRs in 2001 (Sarah, 2005)

Reactive FR (90%):
- epoxy resins, polycarbonate resins
  (20-25 wt % bromine)
  (Alaee et al., 2003)
- printed circuit boards (PCB)
- printed wire boards (PWB)

Additive FR (10%):
- acrylonitrile -butadiene styrene resins (ABS), high -impact polystyrene
  (6-18 wt % bromine)
  (Alaee et al. 2003, Maag et al., 2010)
- PC and TV set housing,
- PC monitors, another electronics,
- paper, textiles

Waste of Electronic and Electric Equipment (WEEE)
TG curves of each Pd compounds with Brominated flame retardants
E-scraps, especially PCB recycling, is vital to maintain a supply chain of non-ferrous metals, including precious metal and minor rare metals. Non-ferrous smelters play an important role of it.

PCB recycling requires the treatment of resin with brominated flame retardants from an environmental point of view. Insufficient research exist in this field, even of very basic studies on the physical properties of metallic bromides and the decomposition behaviours of brominated flame retardants in recycling facilities.

A new system is necessary to progress the recycling of PCBs to prevent illegal trade of E-waste and a change of Basel related law in Japan was one of actions. It supports to achieve an international resource circulation of E-waste to keep a fine environment.
Base Metals and Minor Metals recovered from Primary and Secondary Resources in Non-Ferrous Industry

Copper Smelting

Zinc Smelting

Lead Smelting

More than 20 metals can be recovered except RE, W, Mo, Mn, Cr, Nb, Ta and Li