JOGMEC activities on the R/D of processing and metallurgical technologies for cobalt-rich ferromanganese crusts

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Nobuyuki Okamoto*1, Hiroshi Shibasaki*1, Mikio Kobayashi*1, Mayumi Ito*2, Yasuhiro Konishi*3 and Tasuya Ooki*4


Japan Oil, Gas and Metals National Corporation
OUTLINE

- JOGMEC Mission

- Processing & Metallurgical Technologies for Crusts
  - Processing
  - Metallurgy
  - Bio-leaching

- Other Topics (Polymetallic sulphides)

- Conclusion and Future Plan
JOGMEC’s Mission

JOGMEC is an organization under the jurisdiction of the Ministry of Economy, Trade and Industry (METI)

- Oil & Gas Upstream
- Stockpiling of Oil, LPG & Rare Metals
- Mine Pollution Control
- Mineral Resources
- Coal Mining
- Geothermal Resources

JOGMEC contributes to the stable supply of various mineral resources and energy to Japan
JOGMEC survey history on marine manganese deposits

More than 30 yrs. history in the high seas & EEZ

1987 NW pacific for crusts
- Stage 1 (Dredge sampling)
- Stage-2 (Coring sampling)

1985 South Pacific region (SOPAC)
- Manganese nodules: Cook, Kiribati, Tuvalu, Samoa, Niue
- Crusts: Marshall, FSM, Kiribati, Tuvalu

ISA license area for crusts

2014
Exploration areas for cobalt-rich ferromanganese crusts

Pacific Ocean Exploration Areas for Cobalt-rich Ferromanganese Crusts

- China Ocean Minerals Resources Research and Development Association (COMRA, China)
- Government of Republic of Korea
- United States of America (Wake Island) Exclusive Economic Zone
- United States of America (Federated States of Micronesia)
- Marshall Islands Exclusive Economic Zone
- Japan Exclusive Economic Zone
- Marcus-Wake Seamounts
- Magellan Seamounts Chain

Geological setting@ Japan’s license area for crusts

(Koppers et al. 2003)
R/D history of processing and metallurgy for CFC

<table>
<thead>
<tr>
<th>Preliminary study prior ISA contract</th>
<th>ISA contract</th>
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<td>2003-</td>
<td>2014-</td>
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<tr>
<td>Processing</td>
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<td>JIG Separation of crust and substrates</td>
<td>Smelting /Leaching</td>
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<tr>
<td>Smelting/Leaching method</td>
<td>JIG/Smelting/Leaching</td>
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<td>Bioleaching</td>
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</table>
RETAC JIG separation diagram

○ Light particles (Crust)
● Heavy particles (Substrate)

(based on Tsunekawa et al., 2012)
Proposed total process flow-sheet for CFC

Crusts (ore+substrate)

Crushing ➔ Classification (-4+1mm, -1+0.5mm, -0.5mm)

Distribution ratio: 0.73

JIG separation (1-4mm)

- Concentrate (go to smelting)
- Waste (disposal or bio-leaching)
- Middling

Distribution ratio: 0.11

JIG separation (0.5-1.0mm)

- Concentrate (go to smelting)
- Waste (disposal or bio-leaching)
- Middling

Distribution ratio: 0.16

JIG separation (-0.5mm)

- Concentrate (go to smelting)
- Waste (disposal or bio-leaching)
- Middling

Distribution ratio: 0.02

(Ito and Hiroyoshi, 2015)
RETAK JIG
Results of JIG separation test

Crust samples with substrates

Cursing

RETAK JIG

Before

After

Crust concentrate
Substrate rocks
Improved smelting and chlorine leaching process for CFC

- CaO, SiO₂
- O₂, SiO₂
- Sulfur
- Cokes

**Crust**

**Reduction smelting process**

- Crude metal

**Oxidation process A**

- Refined metal

**Sulfidation process**

- Matt

**Oxidation process B**

- Refined Matt

**Hydrometallurgical process**

- Residual alloy

- Slug - cleaning

(Shibasaki et al., 2015)
 Improved smelting and chlorine leaching process for CFC (cont.)

- HCl: Refined Matt → Chlorine leaching → Leachate → Leach residue
- Cl gas: Refined Matt

- Oxidation:
  - Solvent extraction (Fe extraction) → Reverse extracting → Hydrolysis → Fe₂O₃
  - Solvent extraction (Cu extraction) → Reverse extracting → Hydrolysis → E-Cu
  - Solvent extraction (Co extraction) → Reverse extracting → Hydrolysis → E-Co

- Ni electrowinning → E-Ni

(Shibasaki et al., 2015)
Reduction smelting test (Plasma torch furnace)

(Shibasaki et al., 2015)
Bio-hydrometallurgy study

- **Conventional processing** to recover value metals
  - Pyrometallurgical process:
    - smelting
  - Hydrometallurgical process:
    - high-temperature and high-pressure acid leaching
    - gas-reduction and ammoniacal leaching

- **Lab scale study**: Bio-hydrometallurgical process
  - "Bioleaching": the use of microbes to recover value metals at room temperature and atmospheric pressure
Commercial-scale copper bioleaching plants

Low-grade ores
Concentrates

Bioleaching

Tank bioleaching of concentrates

Heap bioleaching of low-grade ores

Solid

Liquid

Solvent extraction

Electrowinning
Bioleaching tests in a tank reactor

- Fe(III) – reducing bacterium
  *Shewanella algae* (ATCC 51181)

stirred tank reactor (volume: 1000 cm³)

30°C, pH 7 anaerobic conditions

crusts particles (< 75 mm)

<table>
<thead>
<tr>
<th>Initial operating conditions</th>
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<tbody>
<tr>
<td><strong>Cell concentration</strong></td>
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<tr>
<td>5 X 10⁷ cells / cm³</td>
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<tr>
<td><strong>Crust - liquid ratio</strong></td>
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<tr>
<td>5 g /L</td>
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<tr>
<td><strong>Leach solution</strong></td>
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<tr>
<td>5mM Fe (III)-citrate [electron acceptor]</td>
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<tr>
<td>100 mM formate [electron donor]</td>
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<tr>
<td>35 mM Na-citrate [complexing agent]</td>
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Bioleaching of Co, Ni and Mn from ferromanganese crusts in a batch reactor

![Graph showing bioleaching of Co, Ni, and Mn](image_url)

- **30°C**
- **pH 7**

**Bioleaching**

- **Ni**
- **Co**
- **Mn**

**S. algae**

**Control**

**Sterile**

**Fraction of metals leached (%)**

**Time (h)**

0 5 10 15 20 25
Bioleaching of Co, Ni and Mn from ferromanganese crusts in a batch reactor

![Graph showing bioleaching and chemical leaching of Ni, Co, and Mn at 30°C pH 7.]

- **Bioleaching**
  - S. algae + Na-citrate (35 mM)

- **Chemical Leaching**
  - Sterile + Na-citrate (35 mM)
Other minerals
SEM-MLA images of Okinawa-C sample

(Ooki, et al., 2015)
Grain size of each minerals is under 10µm (Ooki, et al., 2015)

Not easy to product Zn, Pb, or Cu concentrates respectively.
Basic studies of processing and metallurgical technologies was started in 2003.

High crust recovery rate of 96% from -4+1mm grain size of crust and substrate mix samples obtained with RETAC JIG.

Improved smelting and chorine leaching method with Pt recovery process were developed.

Lab-scale new test with bio-leaching technologies were also conducted. In the test by bioleaching process, a much higher leaching rate was obtained as compared with chemical leaching. But application point of this method is limited.

Scale-up tests and more efficient process are conducting during exploration contract.