

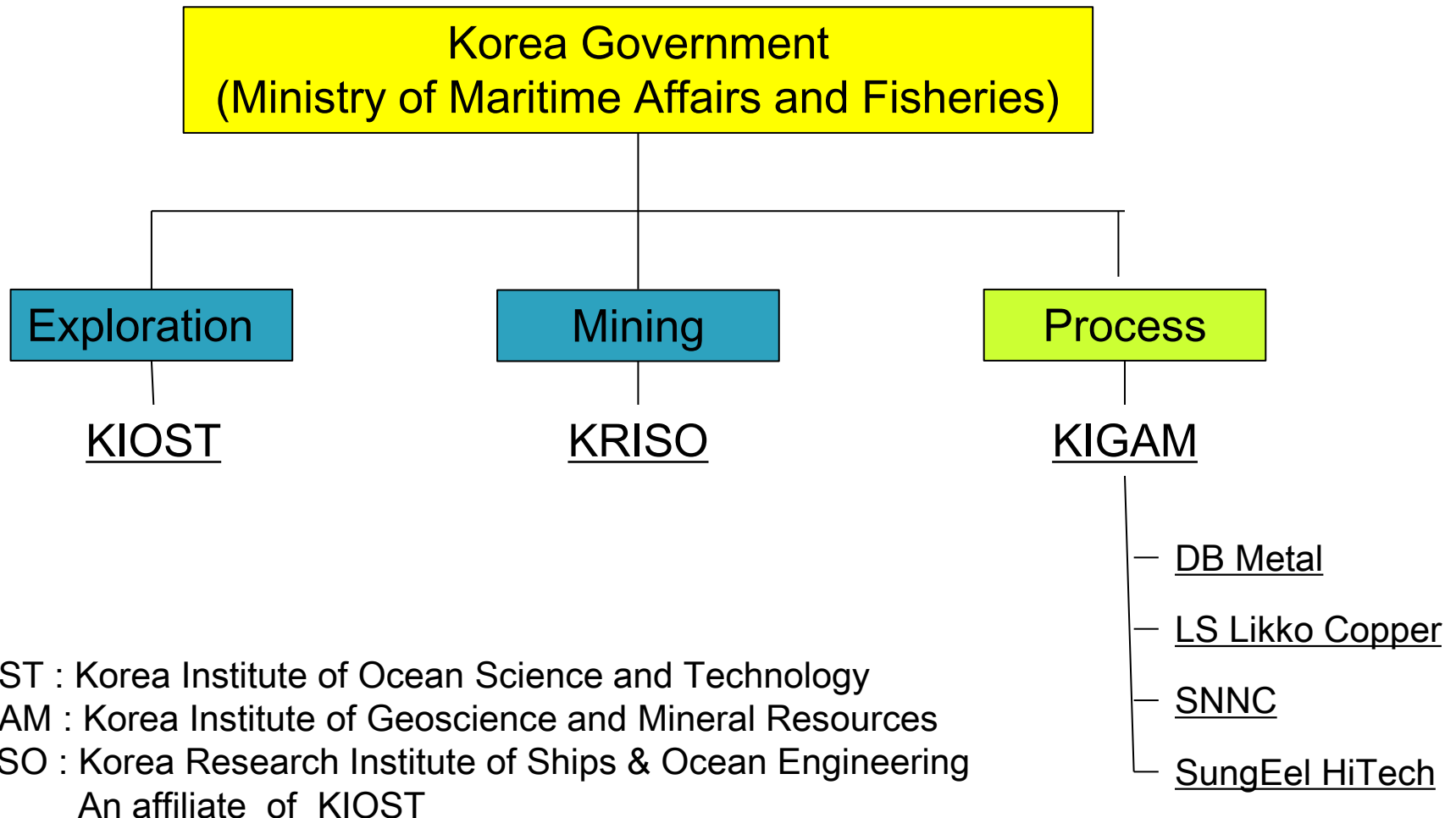
Status and Prospect of Polymetallic Nodules Process Development in Korea.

2018. 9.

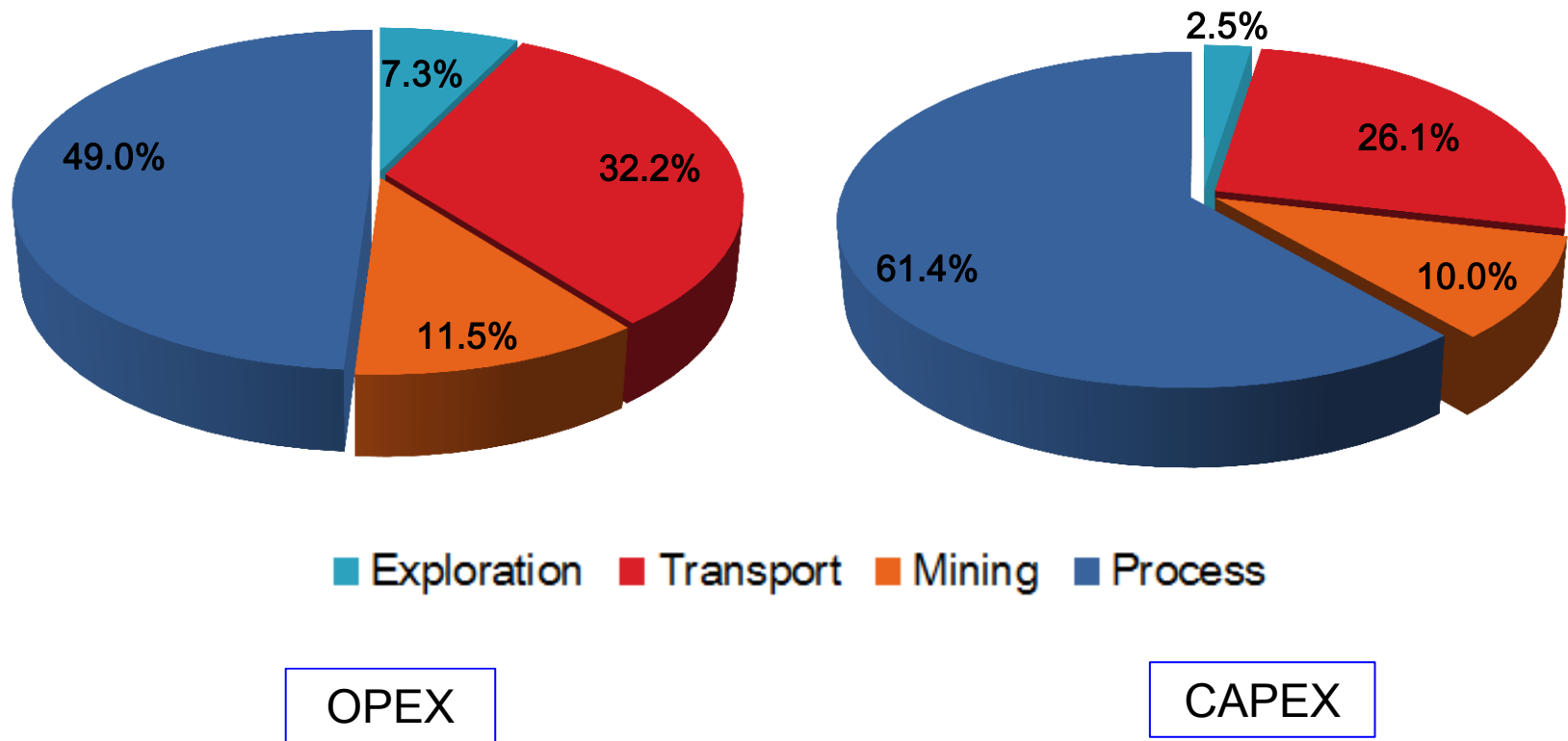
Korea Institute of Geoscience and Mineral Resources

KIGAM

Research System for developing Ocean Minerals in Korea



Costs for Nodules Development

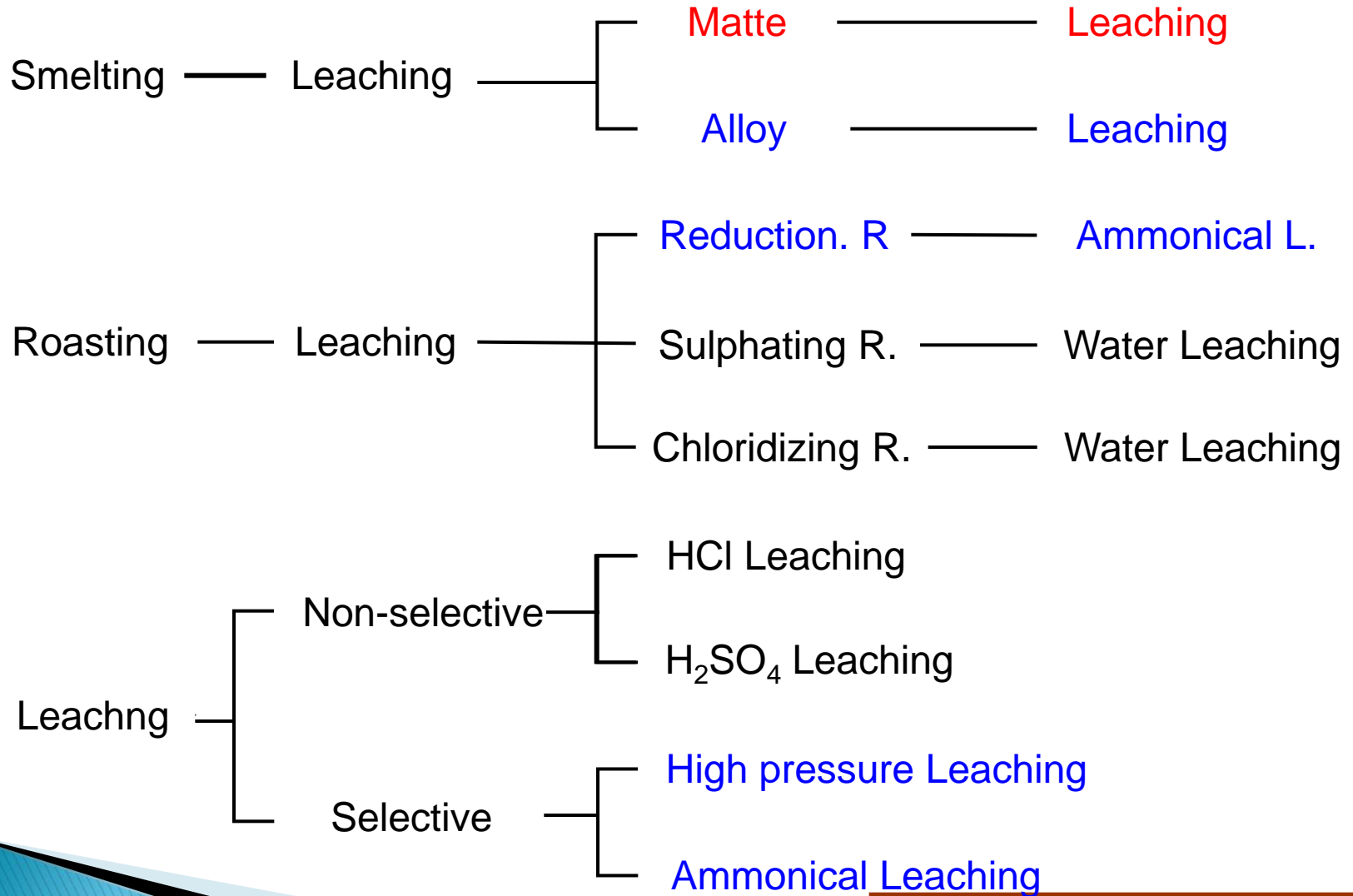


Source : KIOST report (2017)

Road Map for Process Development in Korea

process	period	contents
Basic study	1994 ~ 2002	<ul style="list-style-type: none">- Basic research on processing methods- Selection of favorite process (smelting-wet method)
Development of unit operations (Lab scale)	2003 ~ 2006	<ul style="list-style-type: none">- Process development of unit operations (Reduction, Smelting, Leaching, Separation, Recovery)- Si-Mn product
Technology improvement (scale up tests)	2007 ~ 2011	<ul style="list-style-type: none">- Technological improvement of unit operations- Integrated process system- Scale up tests (50kg)
Applied technology for commercialization (Pilot tests)	2012 ~ 2015	<ul style="list-style-type: none">- Pilot tests (2ton/day-pyro, 200kg/day-hydro)- Recovery of rare earth metals- Conceptual design for commercial plant

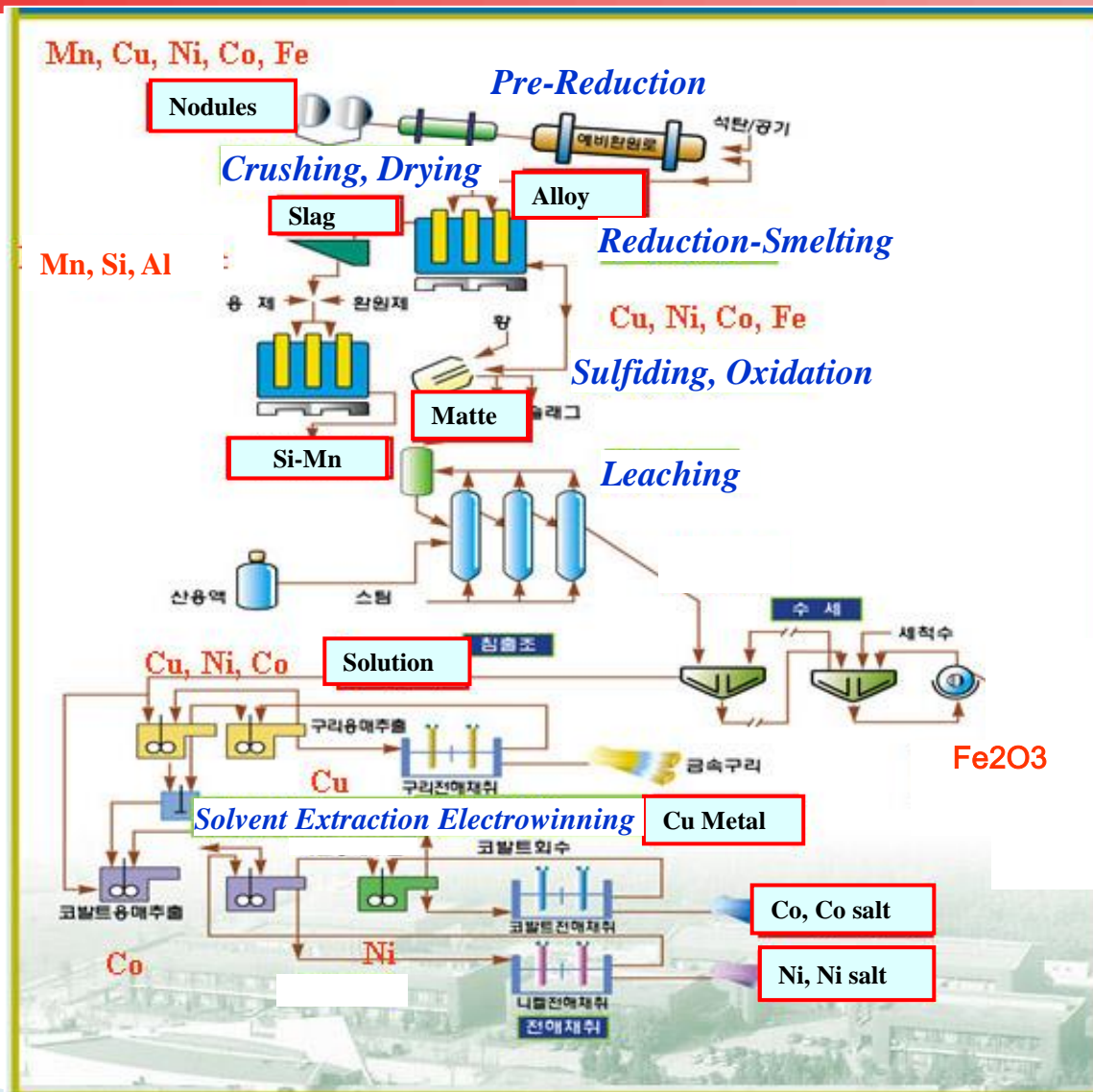
Methods of Nodules Processing



Smelting-Leaching Process

- Technical side (best known)
- Smaller environmental impact
- Easy to prepare Mn alloy
- Great flexibility for raw materials (metal wastes, scraps, manganese crust)
- Low burden for hydrometallurgical process (1/10)
- High energy required

Smelting-Leaching Process



Rotary Kiln for Reduction Roasting



Reduction Smelting (Alloy preparation)



DC Arc Furnace (Batch type, 50kg/Ch.)

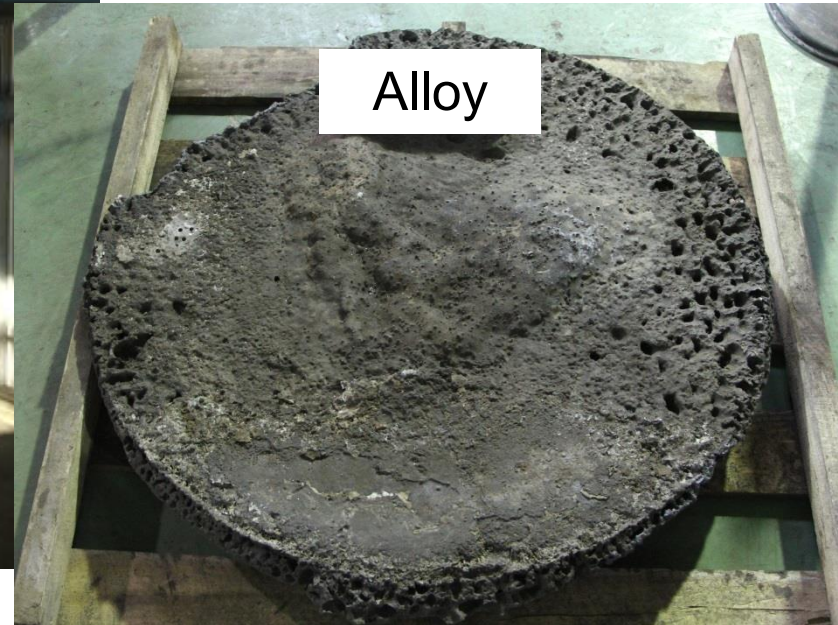
Composition of alloy

element	Ni	Co	Cu	Fe	Mn
Content (%)	16.94	2.45	13.20	67.02	0.39

Alloy weight : 10-15% of nodules

Reduction Smelting (Continuous type)

- Joint research with [Dongbu Metal](#)



DC Arc Furnace (Continuous type)

Preparation of Si-Mn from Slag

- Joint research with [Dongbu Metal](#)



Slag from Smelting process



Si-Mn

Preparation of Matte

- Matte : easy to crush and to leach
- Add sulfur source to alloy
- Sulfur source :
 - elemental sulfur,
 - pyrite,
 - waste gypsum



Induction Furnace

Leaching of Matte



Leaching Solution



Residue(Fe₂O₃)



Batch type autoclave (15 Liter)

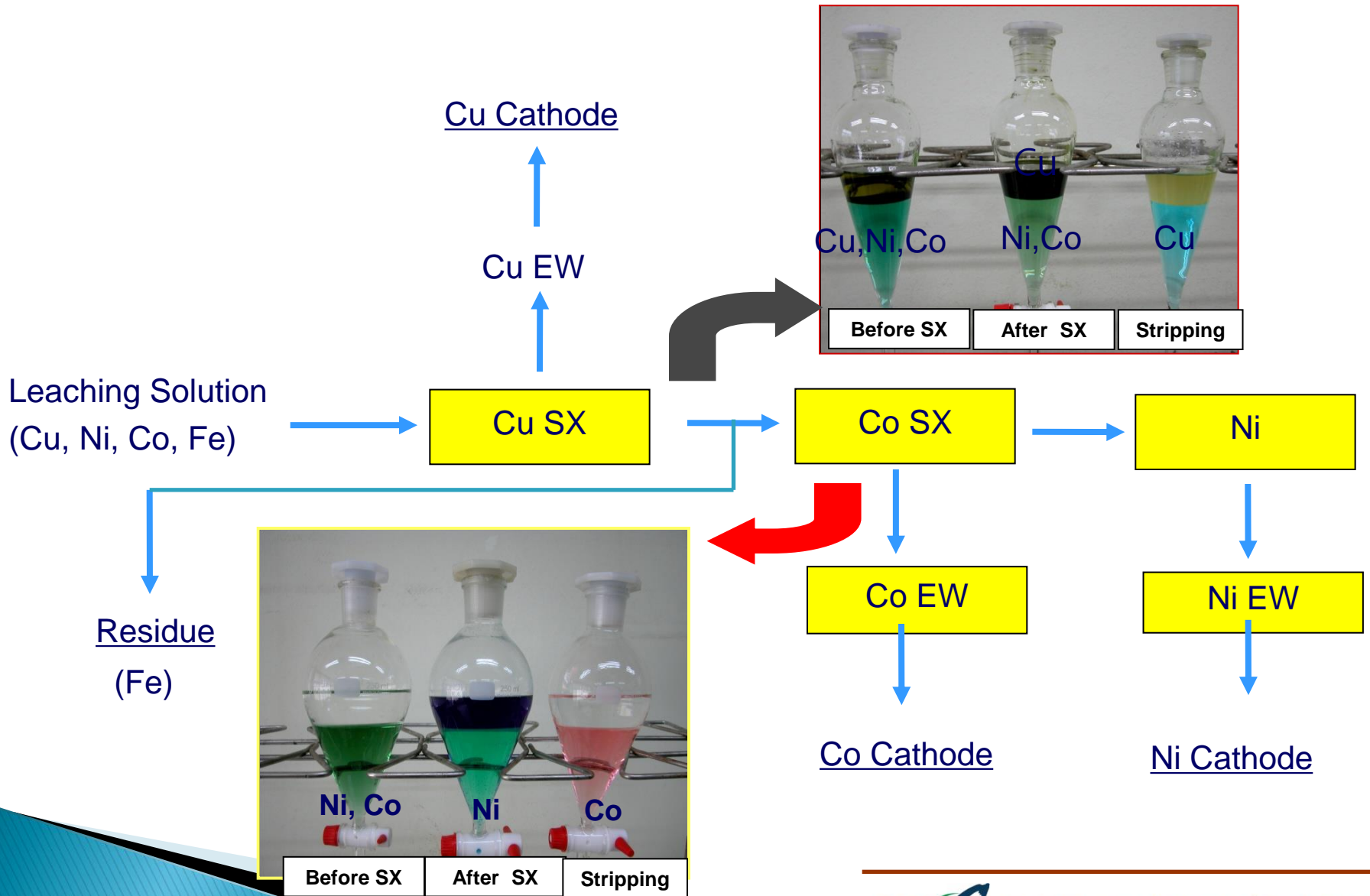
Autoclave for leaching matte (Continuous)

- Joint research with LS-Nikko Copper Inc.



Continuous type autoclave (40 Liter)

Separation of Cu, Ni and Co from Leach liquor



Mixer-settler for solvent Extraction



mixer-settler



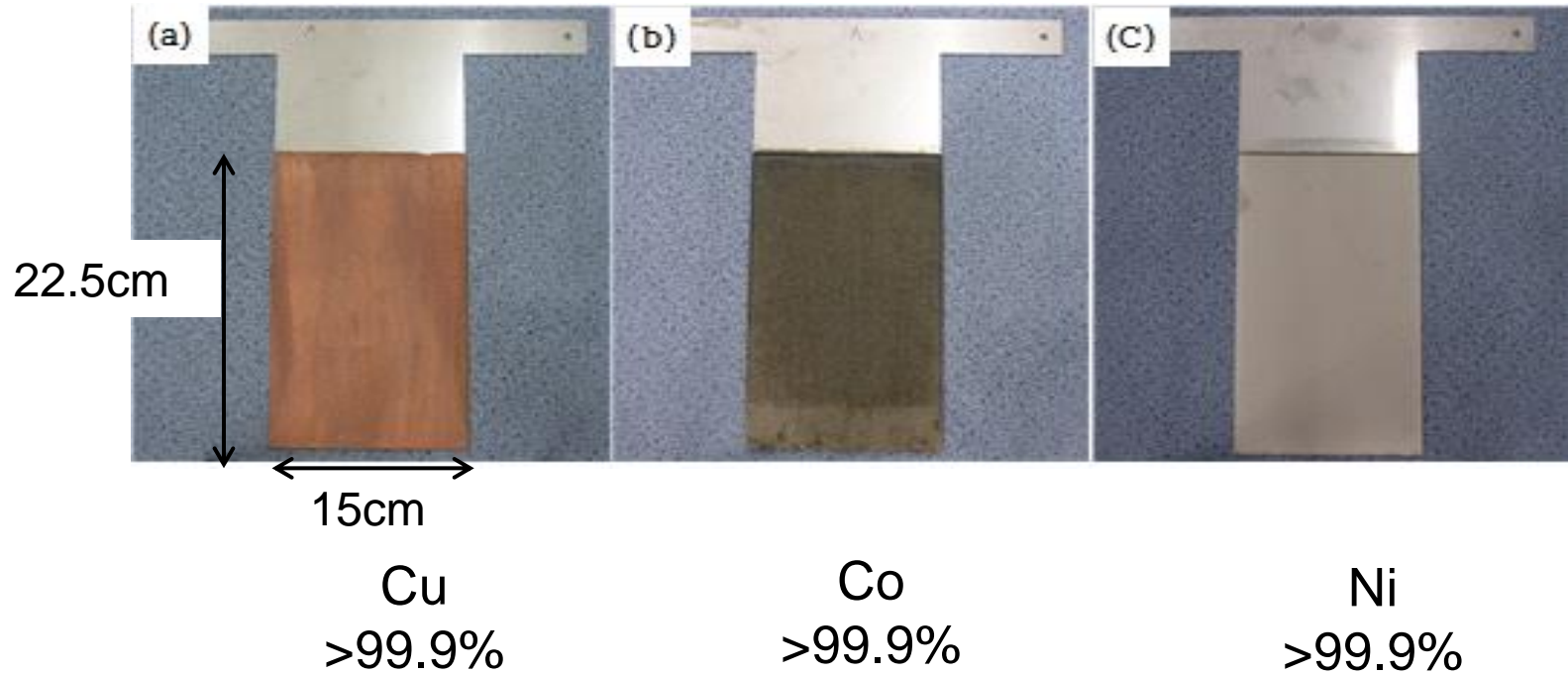
View of mixer-settler

Electro-winning to produce metals



View of electro-winning system

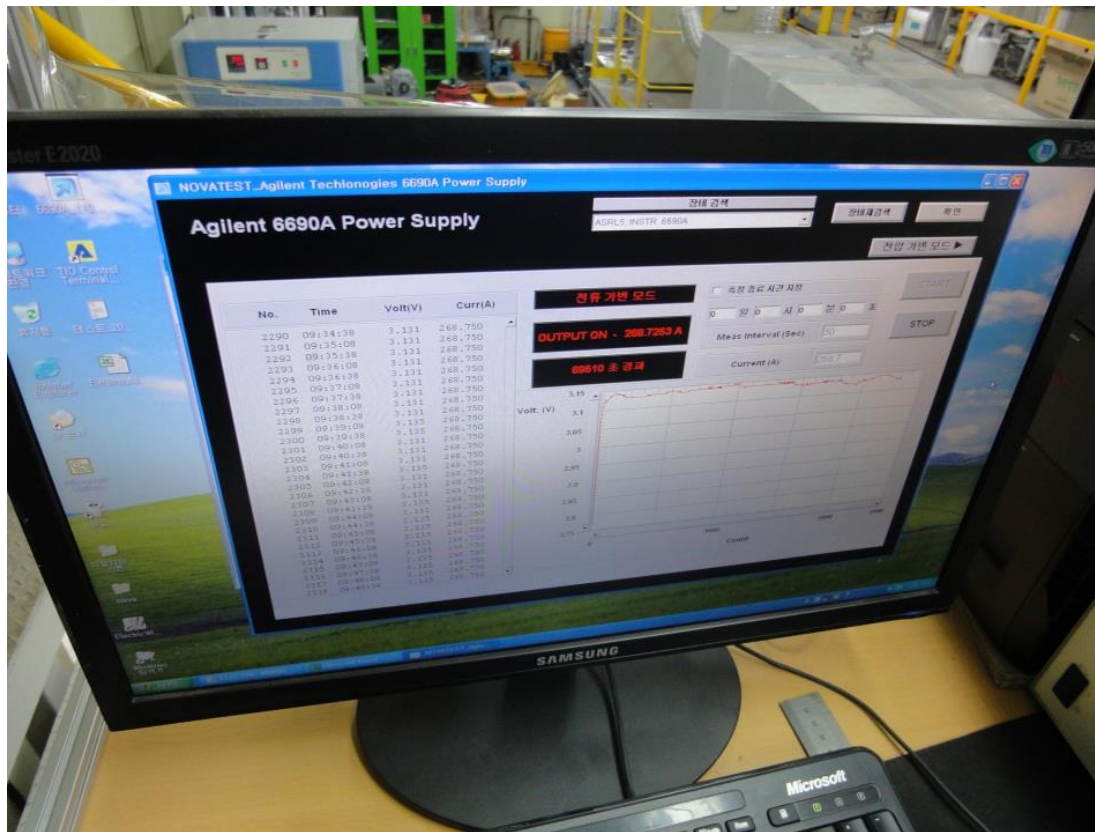
Cu, Co and Ni product



Control Panel for Pilot Plant of SX-EW system

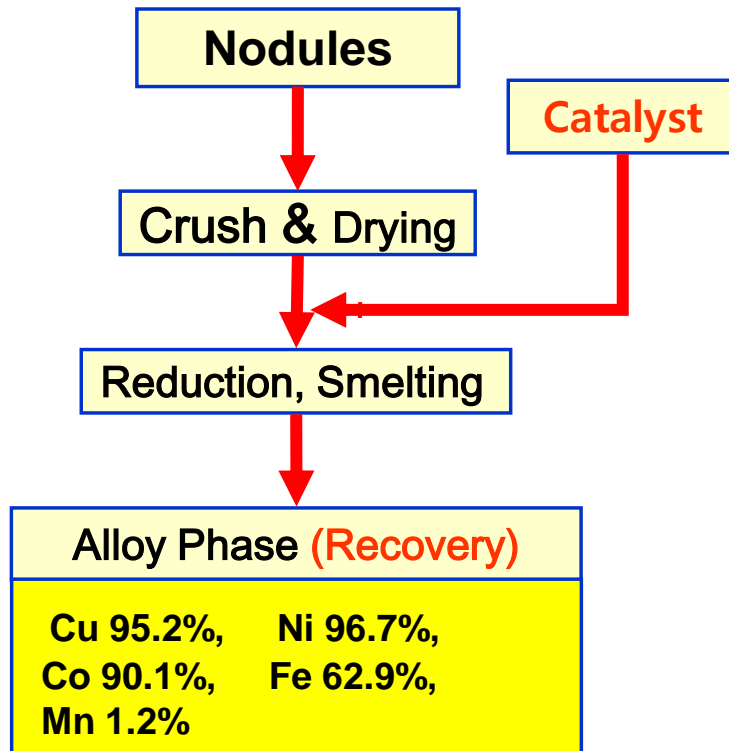


Data Analysis of SX-EW system



Treatment of Wastes with Mn nodules

Spent battery, catalyst, metal scrap, plating sludge, etc.

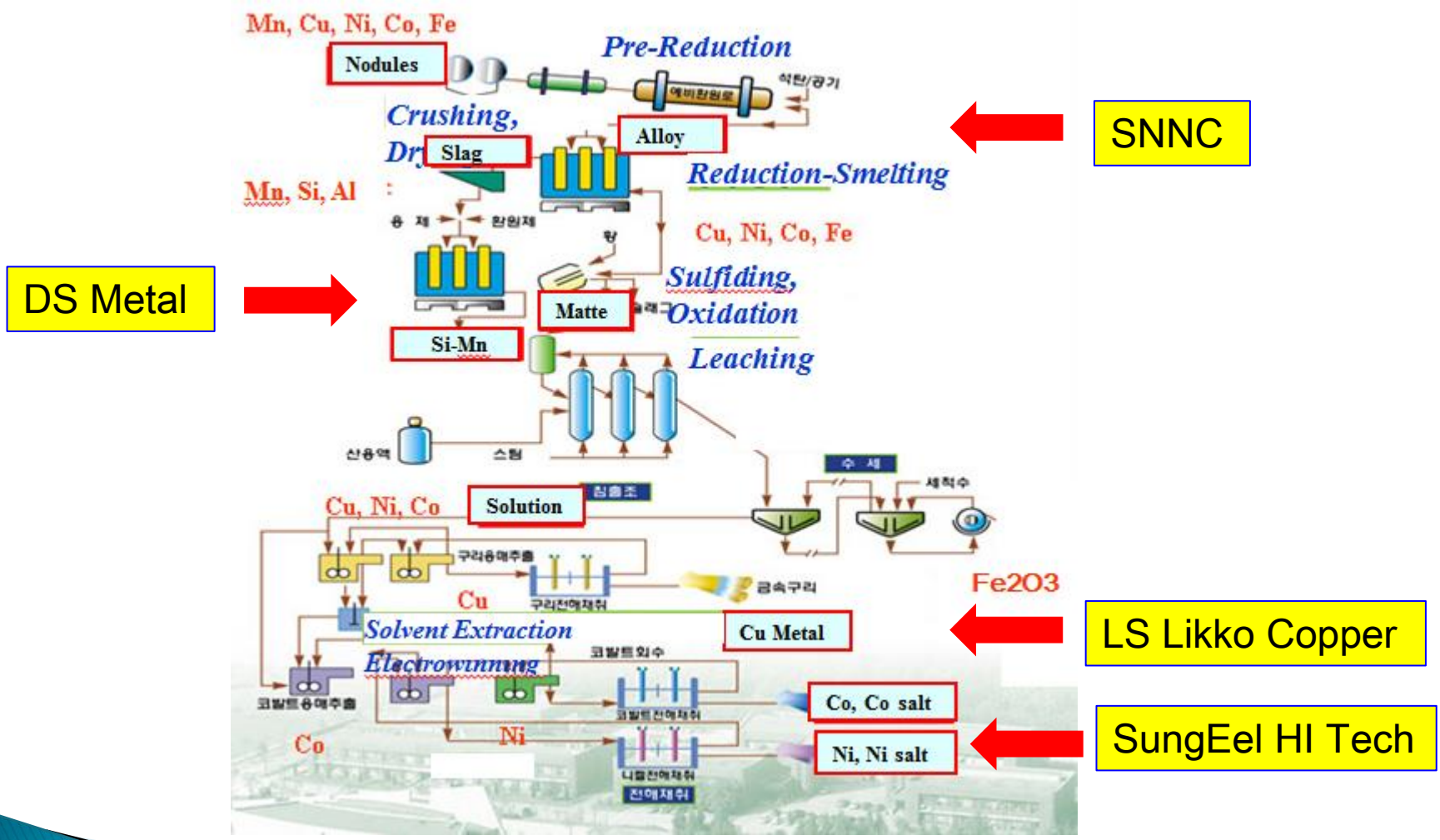


Roasted spent CMB (Cobalt manganese Bromide) Catalyst :
Co : 16.1%, Mn : 27.9%

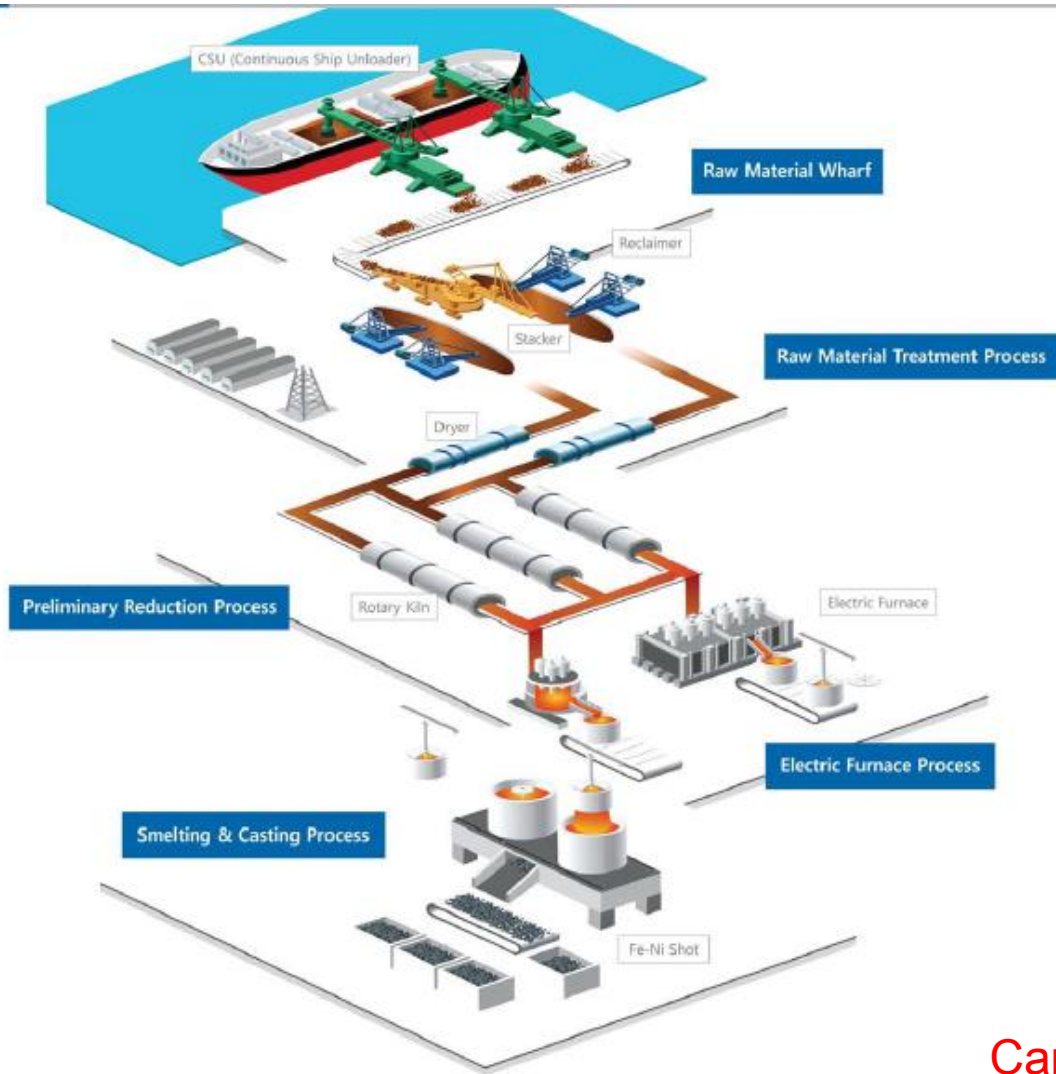
Achievements

- Development of economical and environmentally friendly process
- Process development of high recovery of valuable metals (Cu, Ni, Co, Mn, Mo)
- Efficient treatments and utilization of process wastes
- Basic study to recover REE
- Pilot tests (Pro : 2 ton/day, Hyro : 200kg/day)
- Conceptual engineering design

Collaboration works with Industry



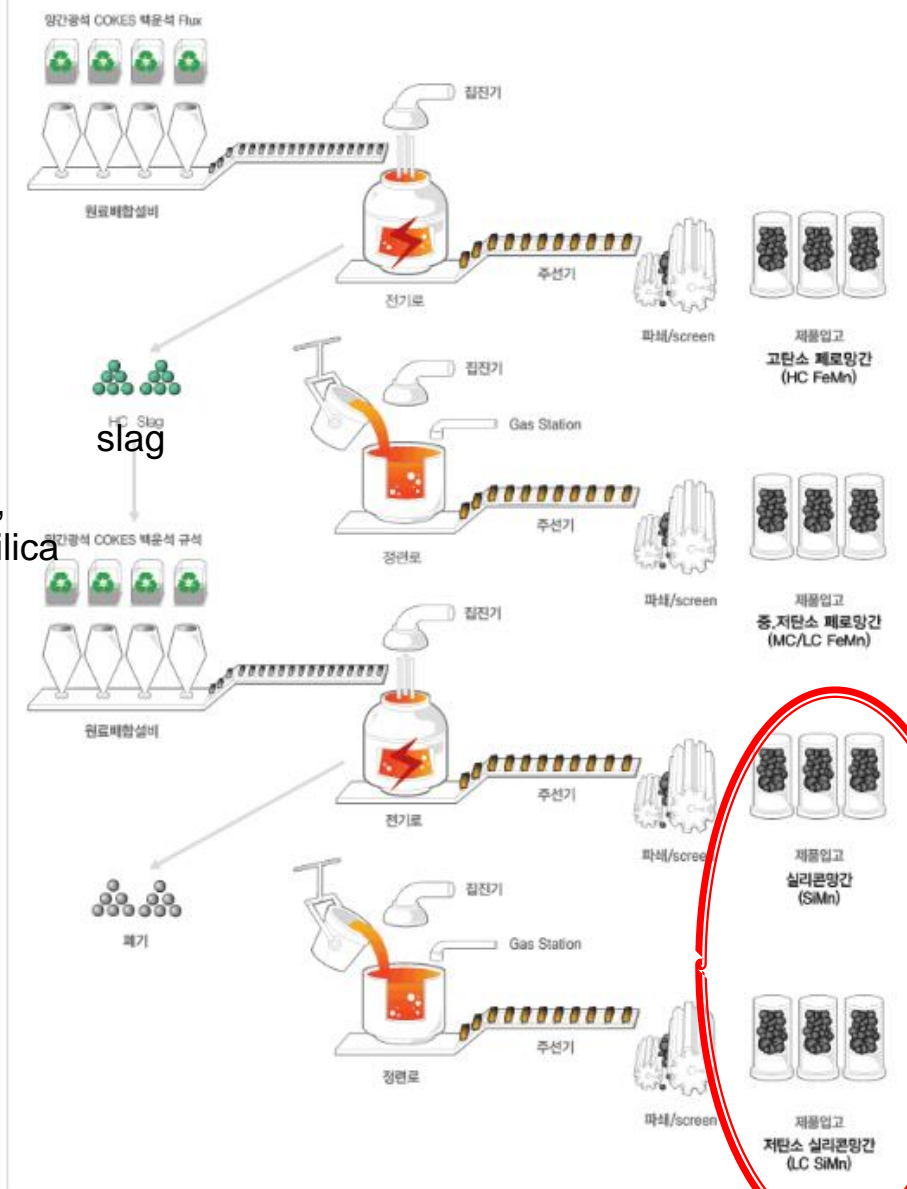
Manufacturing Process of Fe-Ni (SNNC)



Capacity : 3.6 million ton Ore

Manufacturing Process of Si-Mn (DB metal)

Ore, cokes, dolomite, silica



LS-Nikko Copper

SMELTING & REFINING 제련&정련

세계가 인정하는 독보적인
기술력을 보유하고 있습니다.

제련 사다리인 불광산에서 채굴한 광석을 여러 공정을 거쳐

SMELTING 제련

LS-Nikko 동제련의 온산제련하는 자동화 공법과 이차비치 연속공법의 2개 공법을 채택하고 있으며, 세계 최고 수준의 운영기술력을 보유하고 있습니다. 그중 특히 연료의 불을 사용하지 않고 산소를 이용해 동정광을 용해시키는 자동화 공법은 제품의 질을 높이고 단가를 낮추어 전 세계 동제련 산업의 50%를 점하고 있는 기술입니다. 공정과정에서 발생하는 이산화탄소를 최상으로 쉽게 기공할 수 있어 친환경적인 동시에 사업분야의 확장이 용이해지는 장점이 있습니다.

REFINING 정련

제련공정에서 자동화 공법과 이차비치 연속공법으로 만들어진 순도 99.5%의 정제8종 (Anode)은 정제공정으로 옮겨진 뒤 전기분해 과정을 거쳐 99.99% 이상의 고순도 전기용으로 다시 태어납니다. LS-Nikko 동제련의 전기용은 런던금속거래소(LME)의 'Good Delivery'와 상해선물거래소(SHF)의 최고등급인 'Grade A'로 분류되어 국제적으로 그 품질의 우수성을 인정받고 있습니다.

CHEMICAL 화학

LS-Nikko 동제련은 정밀화학 분야에서의 운영경험과 기술을 바탕으로 고품질의 핵심 원료를 생산 및 공급하고 있습니다. 특히 1989년 하연사립 전기 및 사립 다각화의 일환으로 문을 연 PSA 공장에서는 동제련 과정에서 발생하는 아황산가스 등을 이용하여 LSGD 전도제용 촉진을 생산하고 있으며, 이는 온산공정이 세계에서 유일합니다.

PRECIOUS & RARE 희귀금속

LS-Nikko 동제련은 동 공정에 함유된 미량의 희소금속들을 추출하여 제품화하고 있습니다. 정제전의 마지막 공정에서 정제된 가공을 거둬서 생산된 순도 99.99% 이상의 금, 은, 백금, 팔라듐 등은 장신구, 고급 예술품 산업용 소재 등으로 활용되고 있습니다.

1,250°C



LS-Nikko Copper is the global leader with the world-best metal producing technology. Since Janghang refinery's launch in 1936, LS-Nikko Copper has contributed in Korea's industrial development and taken lead in "resources-rich Korea" through strengthening metal recycling and overseas resources development projects.

Cu product capacity : 600Kt



FLASH SMELTING PROCESS
MITSUBISHI CONTINUOUS SMELTING PROCESS

SungEel HiTech

- Recycling of Li ion battery
- Products : Co, NI, Mn, Cu, Li



Solvent extraction system

Thank for your attention

