

2018 2nd International Round Table on
Materials Criticality

Korea's Circular Economy for Rare Metal Waste

2018. 10. 9.

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Principal researcher
Korea Institute of Rare Metals
Korea Institute of Industrial Technology

Korea Institute for Rare Metals (KIRAM)

[Organization]

Korea Institute of Industrial Technology



Korea Institute for Rare Metals



Strategy
Planning
Team

Technical
Support
Team

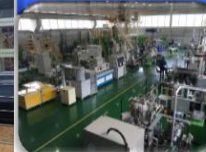
International
Cooperation
Team

[Facilities]



1,223 m²

P.P Lab.



- Rare metals test production support
- Prototype production support



IBITP 인천경제산업
정보테크노파크

1,561 m²

Research
Office



9F, 11F
5F

- Public Relations Office, Technical Support Office
- Corporate incubation office
- International Joint Office
- Meeting room & office

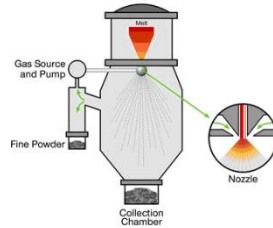
985 m²

Analysis Lab.



- Test / Analysis / Evaluation Support

R&D works in KIRAM



Powder manufacturing

- Rare metal processing- involving powder metallurgy technology
- Powder Preparation (GA, Plasma treatment)
- 3DP Feedstock

• Casting and Alloying Rare Metals

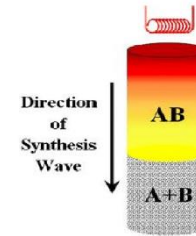
Casting/ Alloy design



Rare Metal

Synthesis

- Quantum Dot phosphor
- Tool Ceramics (SHS)
- Nano Materials for Semi Conductor



- Eco-friendly Pyrometallurgical process
- High Purity (Higher than 4N) refining technology
- Molten Salts Electrolysis

Smelting /Refining



Plastic working

- Rolling
- Drawing
- Extrusion
- Matched with SME



Support for SMEs

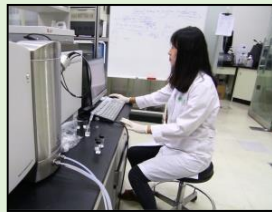
Enterprise supporting activities

Technical support

Incubation for SMEs

R&D

Instrument support (6,128, '17.)



Provide technical advice/ Prototype productions support



1. Technology Status-Liquid Metal Extraction (LME)
2. Technology Status-Integrated process for NdFeB permanent magnets
3. Eco molten salt electrolysis and SOM inert anode
4. Molten salt electro-refining and distillation of indium metal
5. Introduction of Self-Propagating high-temperature synthesis (SHS)
6. Synthesis of Cemented Carbide by SHS
7. Direct reduction of TiO_2 to Ti powder by SHS
8. Metallothermic reduction of refractory tantalum
9. Post process for clean metals and deformation
10. Technology Status-Spark Plasma Sintering (SPS) of electric materials



Brochure

Incubation program for SMEs

Rare Earth Extraction Behavior in Permanent Magnets Using Molten Mg

- Processing Diagram of Liquid Metal Extraction
- Rare Earth Extraction Experiment by High Frequency Induction Heating
- Diffusion Coefficient Diagram: Molten Mg and Nd-Fe-B Magnets

Rare Earth Separation Using Mg Vaporization

REE Separation Process in Mg-REE Alloy Using Mg Vaporization

Element	48 hrs
Mg	0.983 %
Nd	73.8 %
Dy	0.24 %
Fe	0.17 %
Ni	0.11 %
Total REE Purity	98.02%

* Pure Mg and pure REE can be recovered by Mg vaporization.

Fabrication of Multi-Function Mg Alloy Powder And Sintered Body

- Fabrication of Multi-Function Mg Alloy Using Abrasive
- SPS Sintering and Hot Extrusion Process
- SPS processing system - Sample fabricated by SPS
- Fabrication of sintered body using SPS sintering

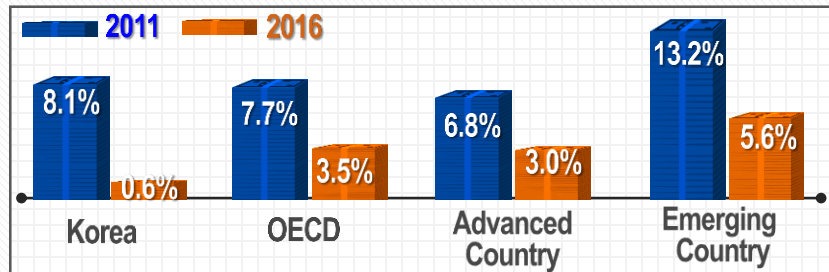
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- Expected effects
- Homogeneous Microstructure & Simple process
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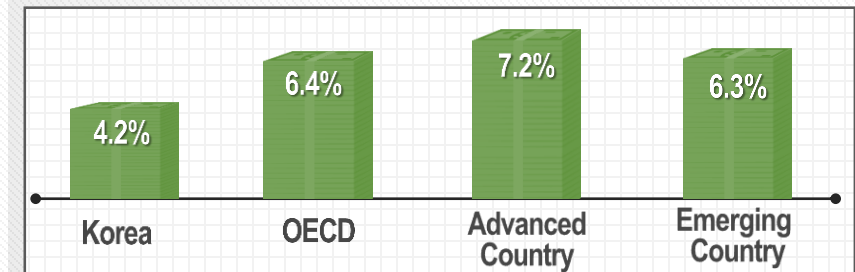
Promotion of new industries in Korea

- ▶ The Korean economy has entered a long-term low-growth phase due to the economic downturn of the major industries.

▶ Rate of increase in sales (Manufacturing Industry)



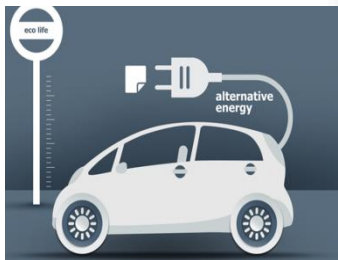
▶ Rate of operating profits (2015, %)



- ▶ Korea's new government has set a new industrial policy based on **4th industrial revolution**.

Five new industries

EV/Self-driving Vehicle



IoT Home appliances



Renewable energy



Semiconductor/Display

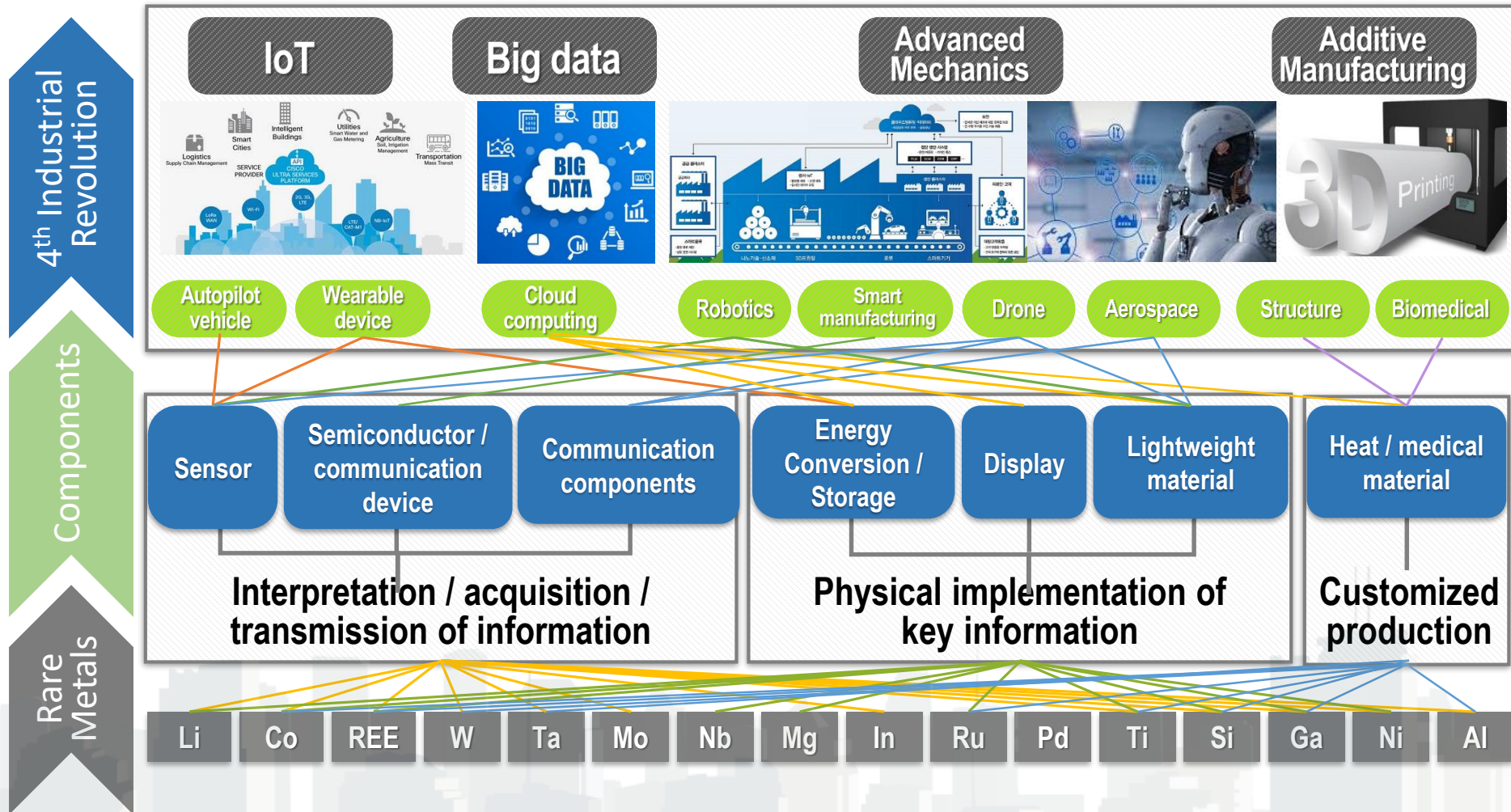


Bio/Health care



Rare metals as core materials for 4th industrial revolution

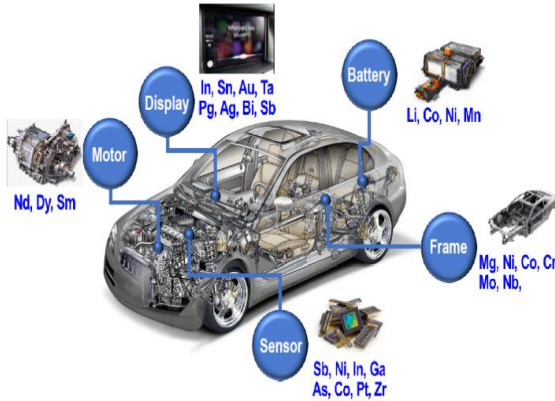
- ▶ Rare metals is the key materials for implementing the main functions of the high-tech equipment components supporting the concept of 4th industrial revolution.



Rare metals for new industries

EV/Self-driving Vehicle

- Secondary cell
: Li, Co, Ni, Mn
- Light weight metals
: Mg
- Motor : Rare earth



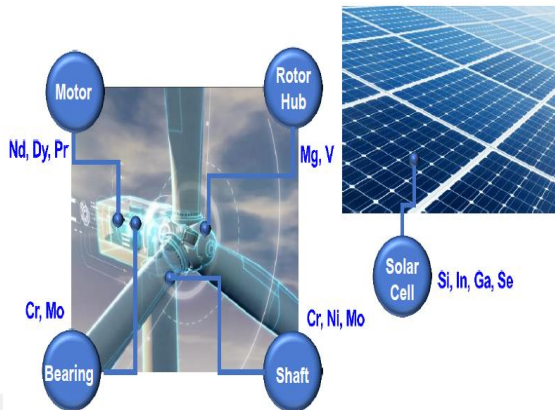
IoT Home appliances

- Sensor
: Sn, Ta, V
- Metal parts : Ni, Cr
- Motor : Rare earth



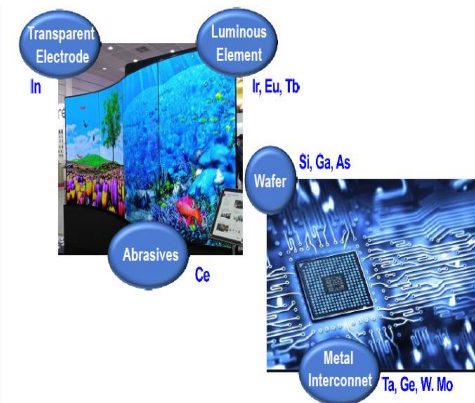
Renewable energy

- ESS
: Li, Co, Ni, Mn
- Solar cell : Si, In, Ga, Se
- Wind power
: Ni, Cr, Mo, rare earth



Semiconductor/Display

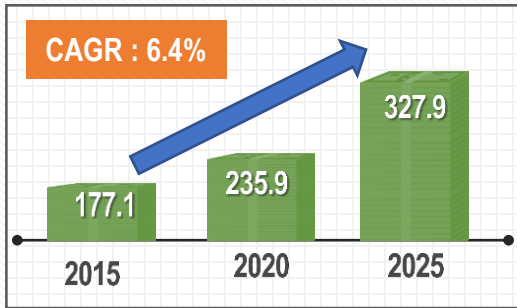
- Semiconductor
: Si, W, Mo, Ga, As
- Display
: Rare earth, Si, In, Ti, W, Ni etc.



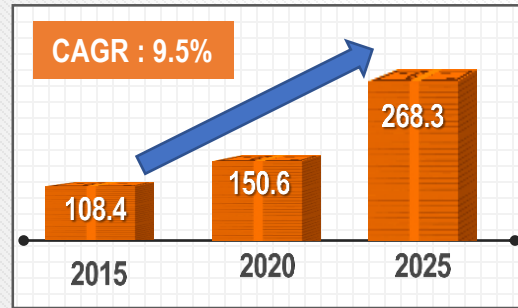
Global Demand-supply trend of Rare Metals

- ▶ Increasing demand for electric vehicles and the development of new industries such as renewable energy cause a sharp increase of demand in rare metals.

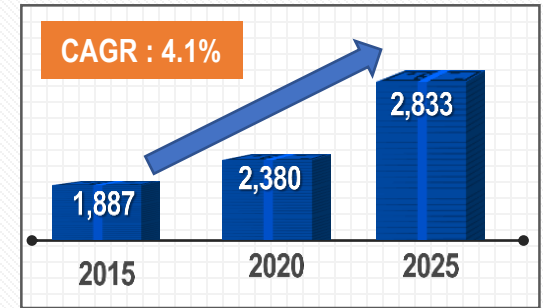
▶ Forecast of Li demand (kton)



▶ Forecast of Co demand (kton)



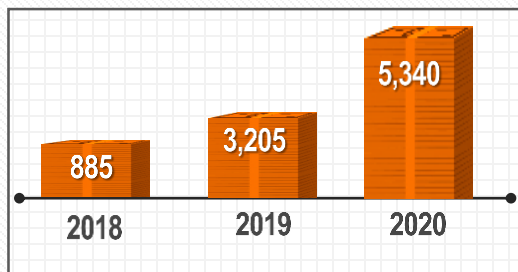
▶ Forecast of Ni demand (kton)



*Roskill (Global industry, markets and outlook)

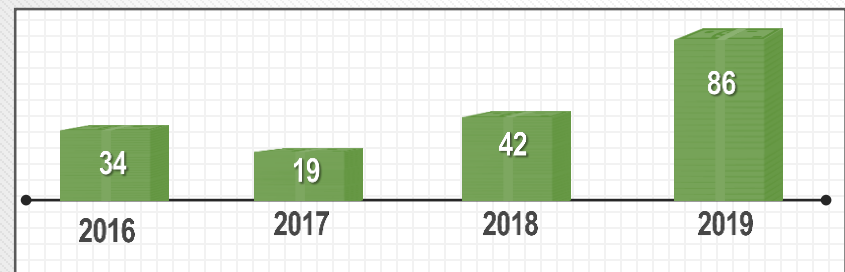
- ▶ Increasing demand for electric vehicles results in the lack of supply in rare metals such as Co, Ni, and Mn, which are used as electrode materials.

▶ Forecast of Co supply shortage (ton)



*Wood Mackenzie (2017)

▶ Forecast of Ni supply shortage (kton)

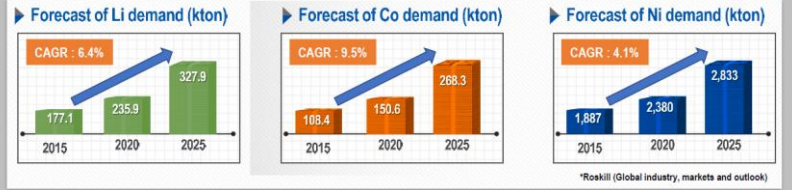


*Macquarie Research (2017.2)

Price instability of Rare metals

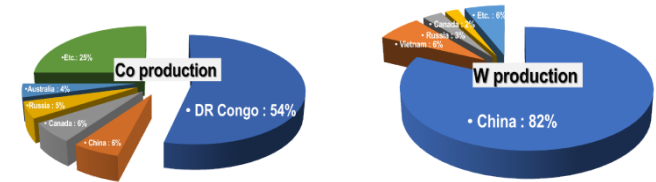
Growth in rare metal demand

Demand increase of rare metals for new industries



Instability of rare metal supply

Biased distribution of rare metals



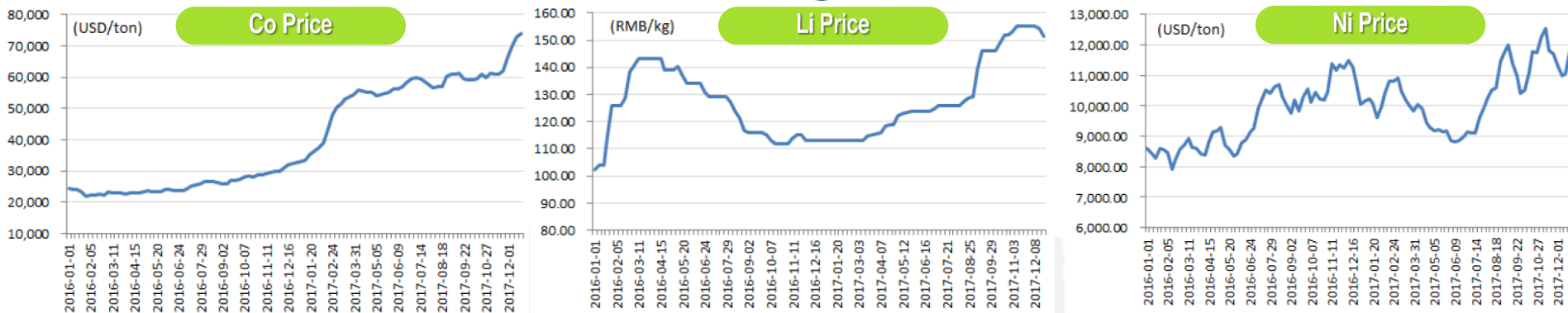
*U.S. Geological Survey Mineral Commodity Summaries (2017)

Conflict Minerals



- DR Congo, Sudan, Rwanda..... 10 countries
- Sn (Tin), Ta (Tantalum), W (Tungsten), Au (Gold)
- Supply problem of conflict minerals

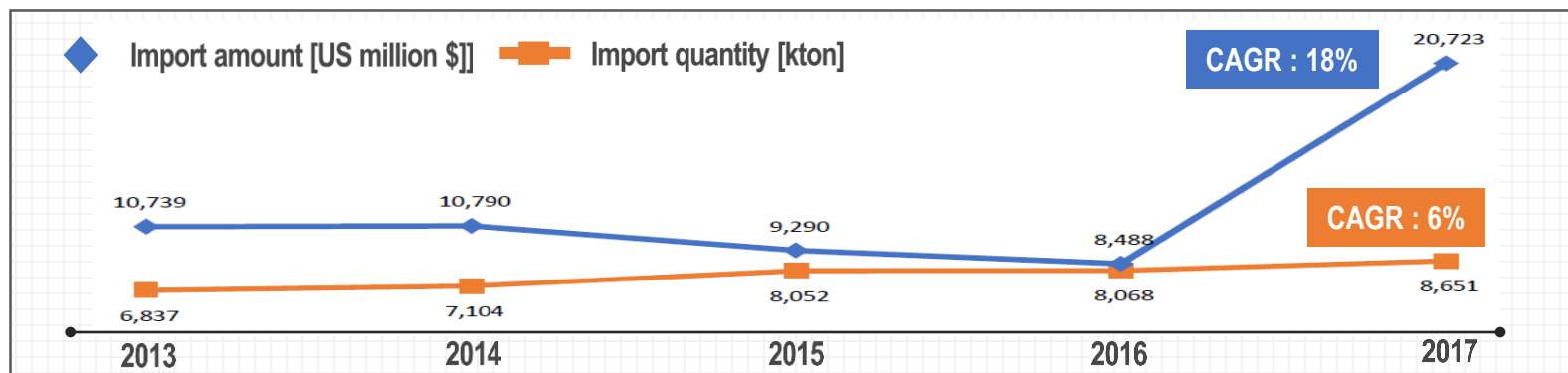
Price increase



*KOMIS (Korea Resources Corporation)

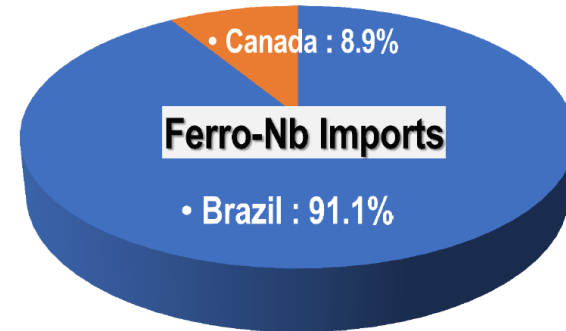
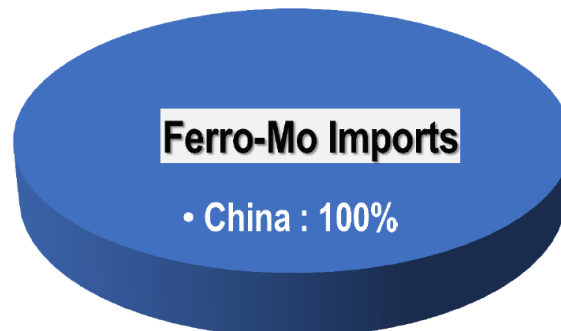
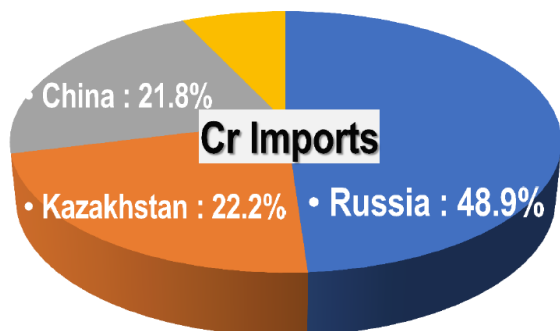
Trend of supply and demand of rare metals in Korea

- ▶ With the upbringing and development of new industries, imports of rare metals in Korea are steadily increased.



*Korea Trade Statistics Promotion Insitute

- ▶ Korea is a global metal consuming country, but depends on imports for 99.6% of the required minerals.
- ▶ The dependence of rare metals on specific countries is very high.





Strategy of Korea for stable supply of rare metals

▶ Overseas Resource Development

- Korea Resources Corporation
- Rare metals to be developed
: 25 countries, 14 metals

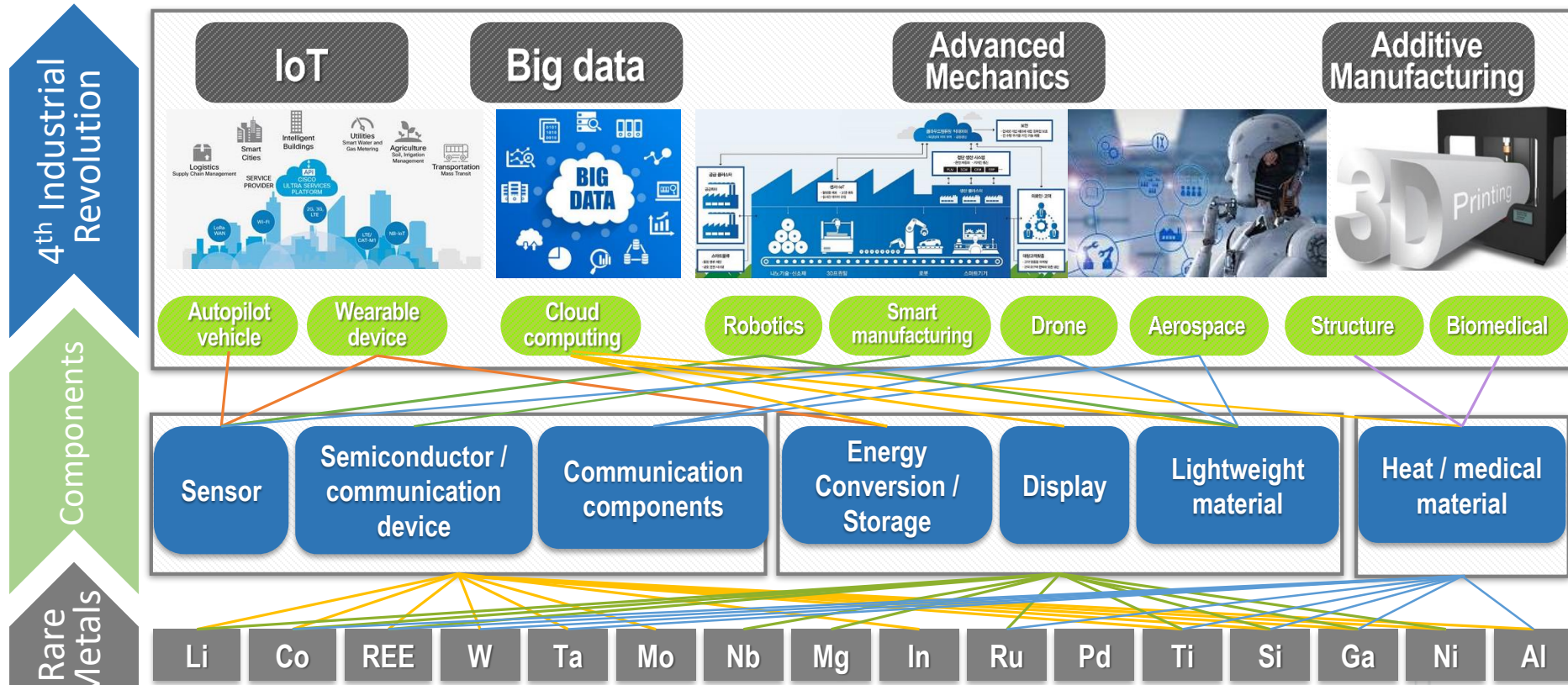
▶ Rare metal stockpiling policy

- Government-led stockpiling of major rare metals
- Korea Resources Corporation
- Rare metals to be stockpiled : 15 metals

▶ Recycling of waste metals (Urban mining)

- Industrial complex activity in recycling of waste metals
- Industrial permission by government (recycling business) : positive → partial negative
- Import tax of solid waste off
- Establishment of urban mining network
- Technology development support :
 - R&D fund
 - Support of information for enterprise
 - Quality certification for good recycled(GR)

Establishment of circular economy for rare metals supporting 4th industrial revolution



Urban Mining



Supply of recycled Rare metals



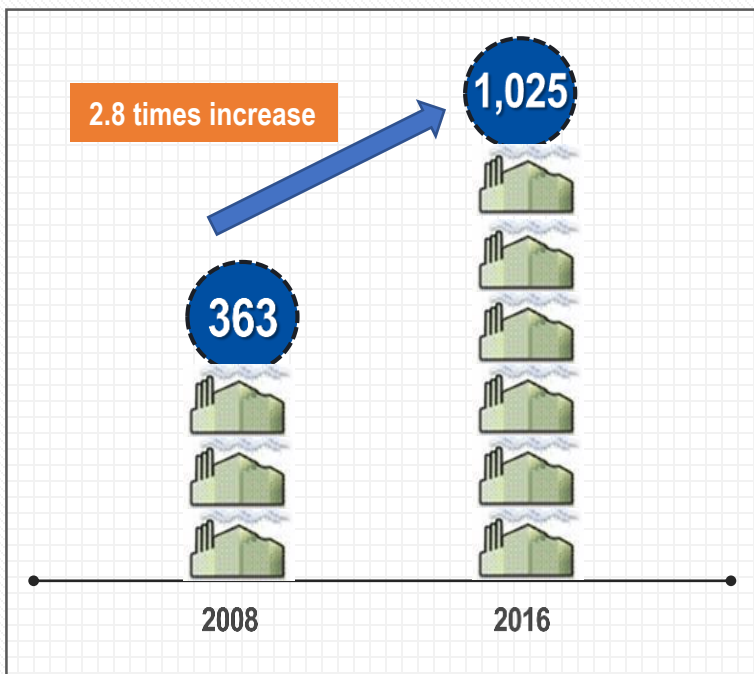
Current status of urban mining industry in Korea

► Enterprises: 1,026 (2016)

*Pretreatment related : 76%

*Smelting related : 24%

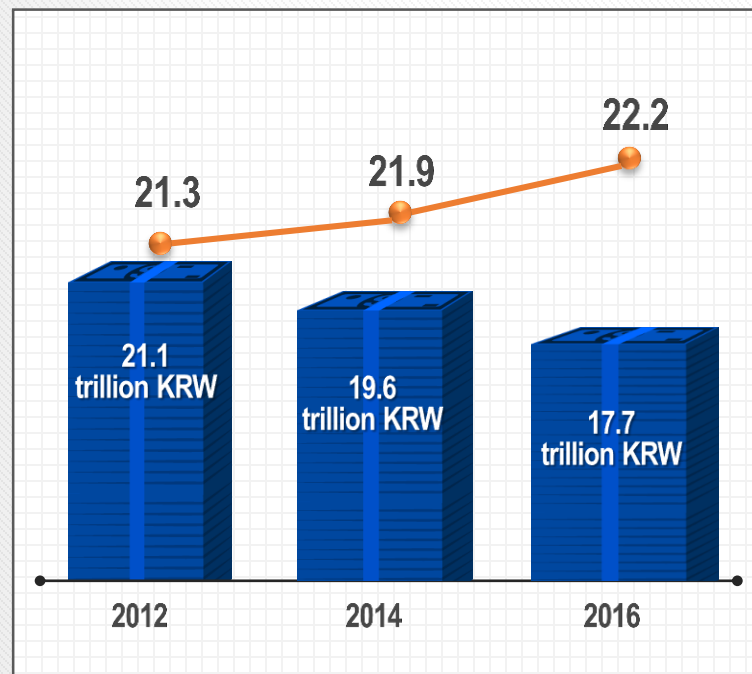
Growth of no. of enterprises



► Market size : 17.7 trillion KRW (2016)

*Urban mining replace more than 22% of domestic Metal resource demand (79.7 trillion KRW, 2016)

Urban mining industrial production rate to domestic metal demand [%]



Limitation of urban mining industry in Korea

Small business size

- ▶ The urban mining industry in Korea is mainly composed of **small scale enterprises**, which is **insufficient in industrial competitiveness**.

Year	Sales amount [US million \$]						Less than 10 employees
	Below 5	5 ~ 10	10 ~ 50	50 ~ 100	100 ~150	Over 150	
2016	70.4%	10.3%	14.3%	1.9%	0.7%	2.4%	77

Low recycling rate of rare metals

- ▶ Rare metals are contained in small quantities in waste products, so if sufficient raw materials containing rare metals, it is difficult to secure economic efficiency of the recycling business.
- ▶ **Since the recovery rate of waste resources in Korea is very low, most rare metals contained in small quantities are mostly landfilled or exported.**

Strategy of urban mining industry development

Establishment of sustainable urban mining industry ecosystem

Target Metals

As-Is

Ferrous or general non-ferrous or precious metals

- Ferrous or general non-ferrous metals : abundant waste resource
- Precious metals : high economic profit
- Recycling rate > 30%



R&D

As-Is

Development of rare metal recovery technology

- Improvement of efficiency for rare metal recovery
- Common required technology for metal recycling
- General nonferrous metal (Al, Cu etc.)



Industry infrastructure

As-Is

Expansion of urban mining industry

- Supporting an unspecified urban mining related companies
- Supporting companies centered on the metropolitan area



To-Be

Rare Metals for new industries

- Selection of strategic metals for new industries
- Securing policy formulation for selected metals
- Recycling rate > 30%

To-Be

Development of technology for circular resources

- Value-up materialization technology by using process by-product
- Recycling technology of high-tech products
- Rare metals

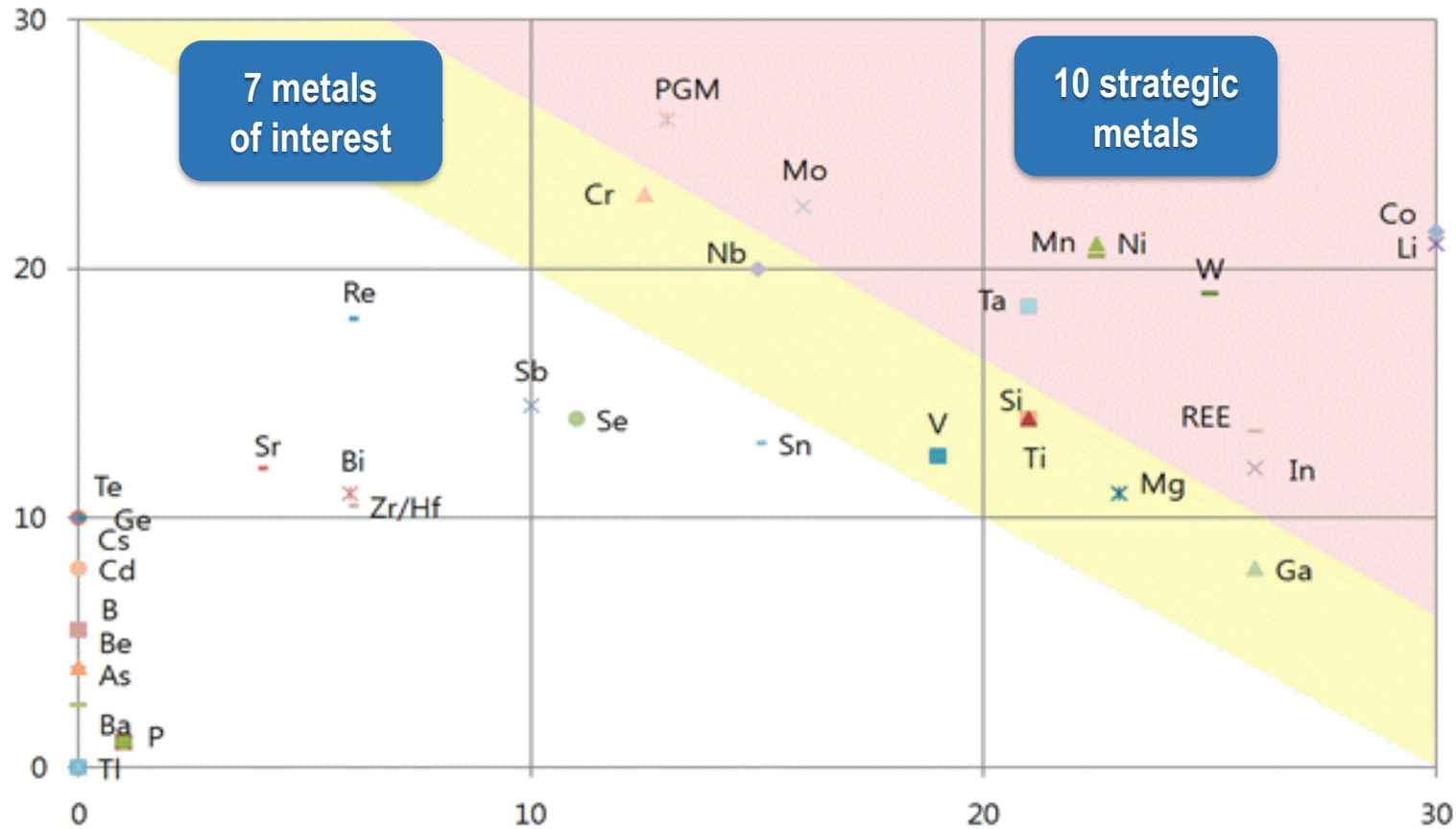
To-Be

Urban mining industry linked with local main industry

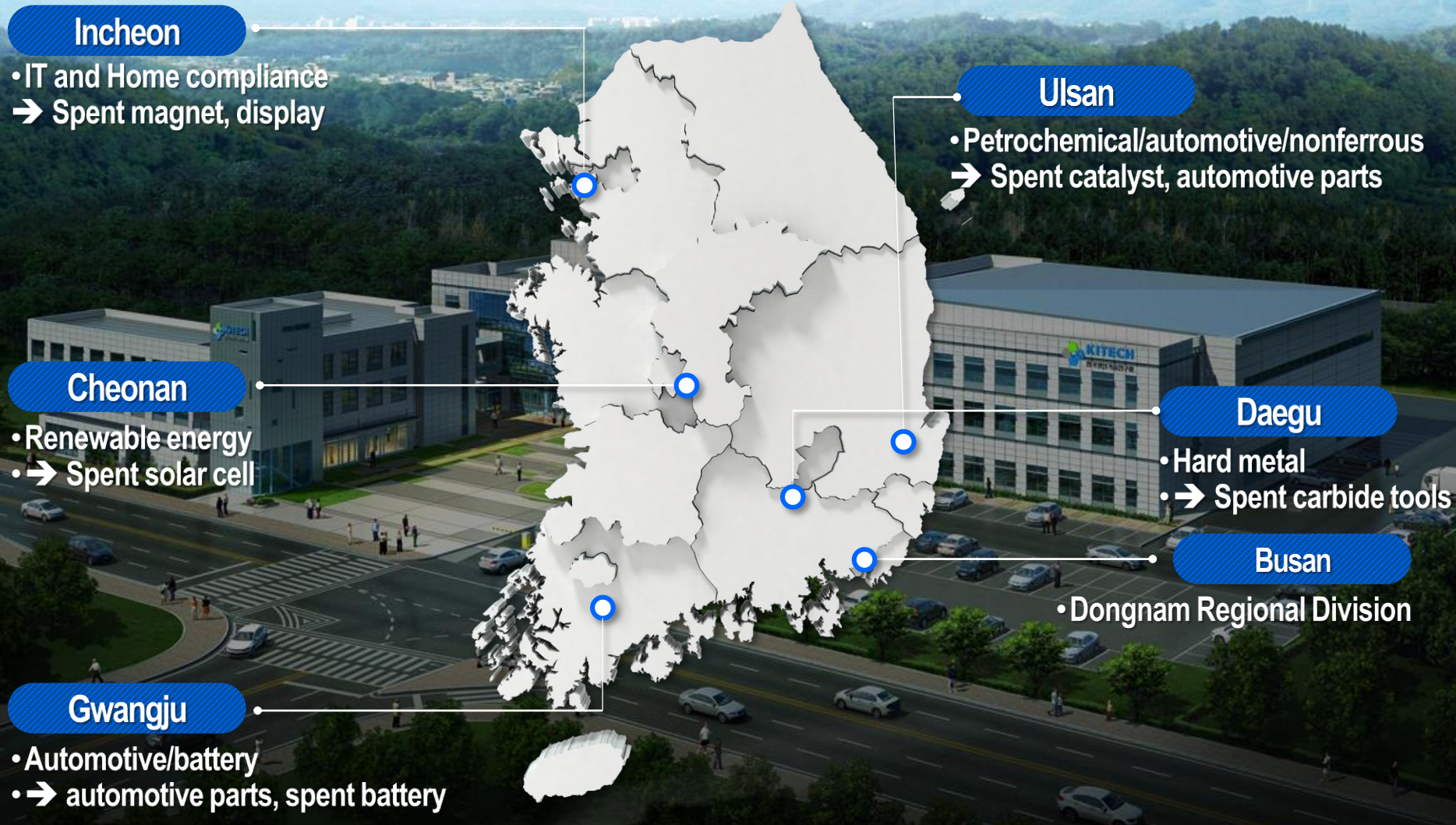
- Supporting local base companies
- Supporting companies related with local main industry

Strategic rare metals for future industry

► Strategic metal selection : **strategic importance & market importance**



Local base Urban mining industry (example)



Korea Institute for Rare Metals (KIRAM)

[Organization]

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Korea Institute for Rare Metals



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[Facilities]



1,223 m²

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1,561 m²

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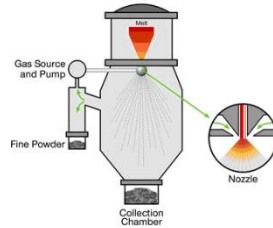
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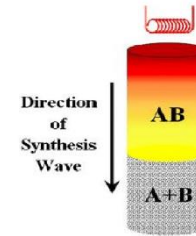
Casting/ Alloy design



Rare Metal

Synthesis

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- Tool Ceramics (SHS)
- Nano Materials for Semi Conductor



- Eco-friendly Pyrometallurgical process
- High Purity (Higher than 4N) refining technology
- Molten Salts Electrolysis

Smelting /Refining



Plastic working

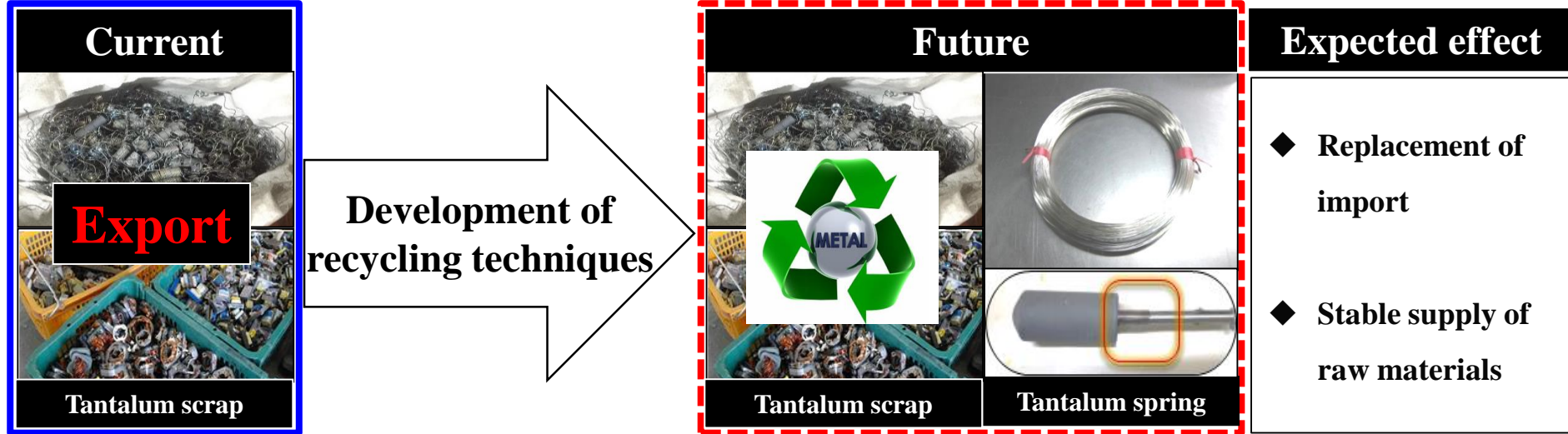
- Rolling
- Drawing
- Extrusion
- Matched with SME



Thank you for your attention!

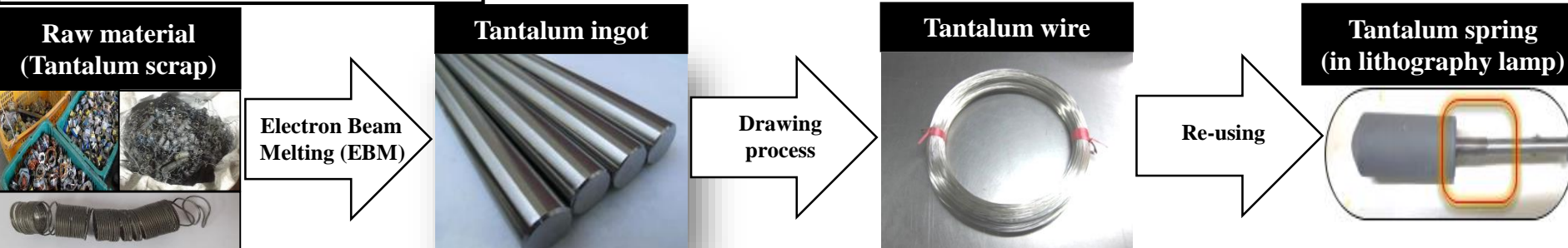
Fabrication of Ta wire by using Ta scraps

Purpose of Research



- If our study is commercialized, export of scrap will be reduced
- In addition, it can be reached on replacement of import and stable supply of raw materials

Summary of Research



- Tantalum metal is utilized in spring-type electrode material of lithographic lamps in the semiconductor processing
- We manufactured 4N5 grade tantalum wire from tantalum electrode scrap by EBM and drawing process

Manufacturing of TaC powder by using Ta scraps

Purpose of Research

Raw material
(Ta metal scrap)



(Almost 40 tone/year at 2016)

TaC powder



Cemented
carbide



Cutting tool



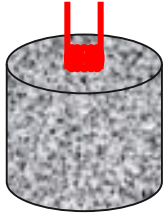
Machine
industry



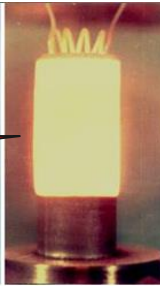
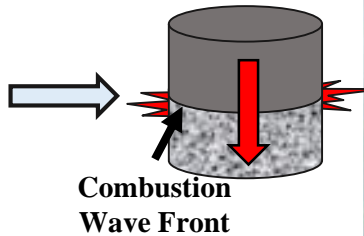
: Main research focus

Summary of Research

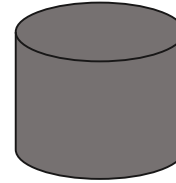
Ignitor



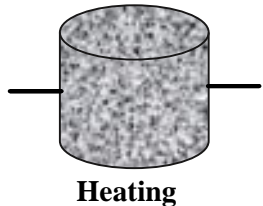
Layer by Layer
combustion



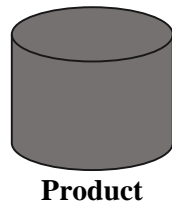
Product



- Self propagating mode
- Combustion is initiated in a point, propagate rapidly through the reaction mixture



Heating



Product

- Simultaneous combustion mode
- When the entire mixture has been heated to the ignition temperature (T_{ig}), reaction take place simultaneously

Support for SMEs

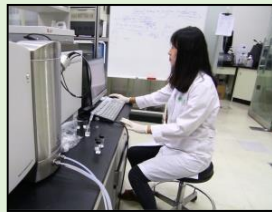
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- Fabrication of magnet powder having fine grain
- Fabrication of magnet powder having ferromagnetic and non-magnetic phases

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