



# Dry Recycling Process of Rare Earth Elements from Alloy Magnets

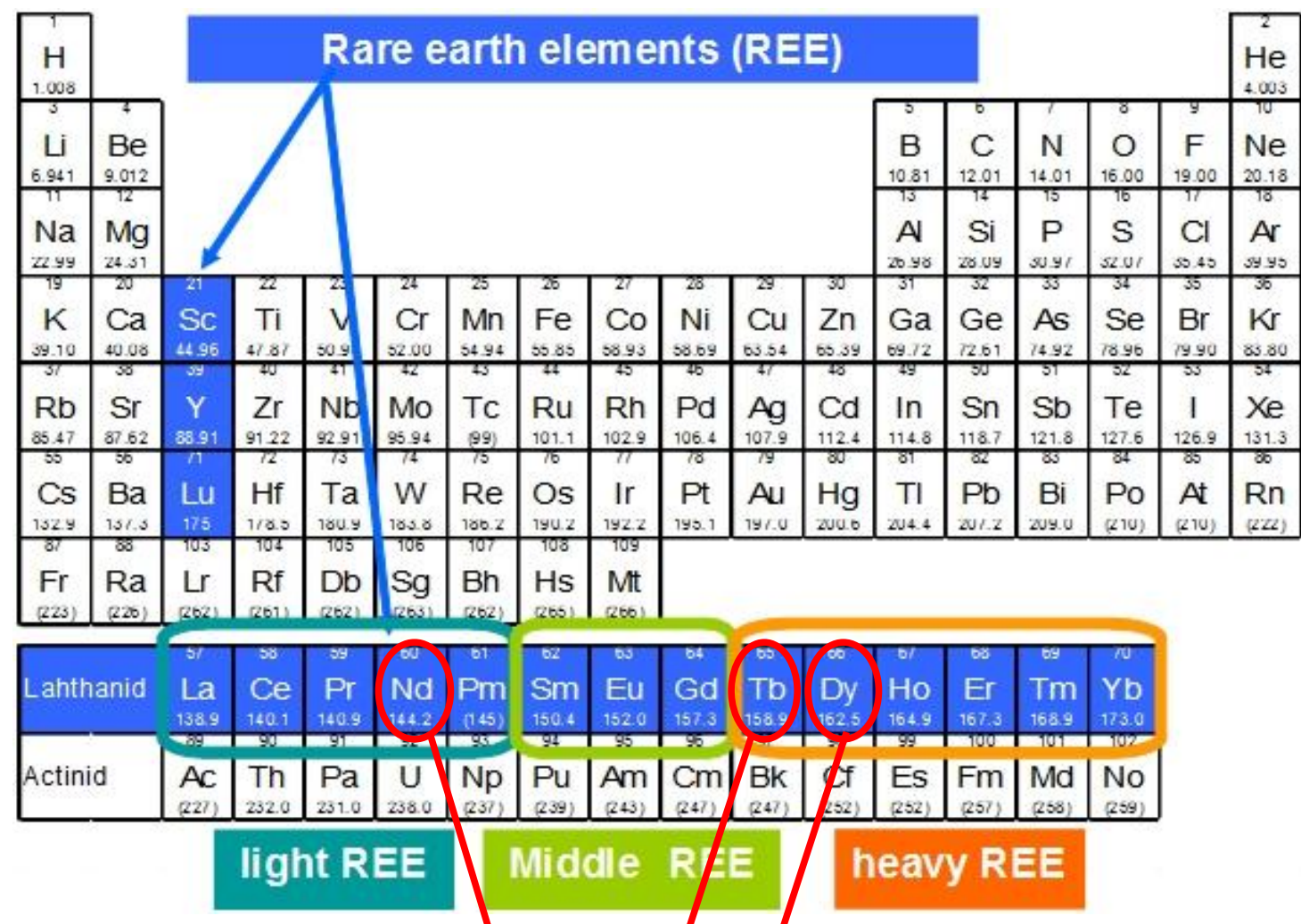


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## Introduction

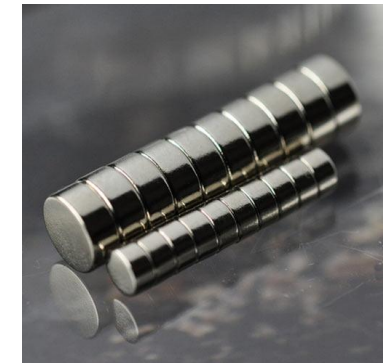
### Rare earth elements



Used for Nd-Fe-B alloy magnet

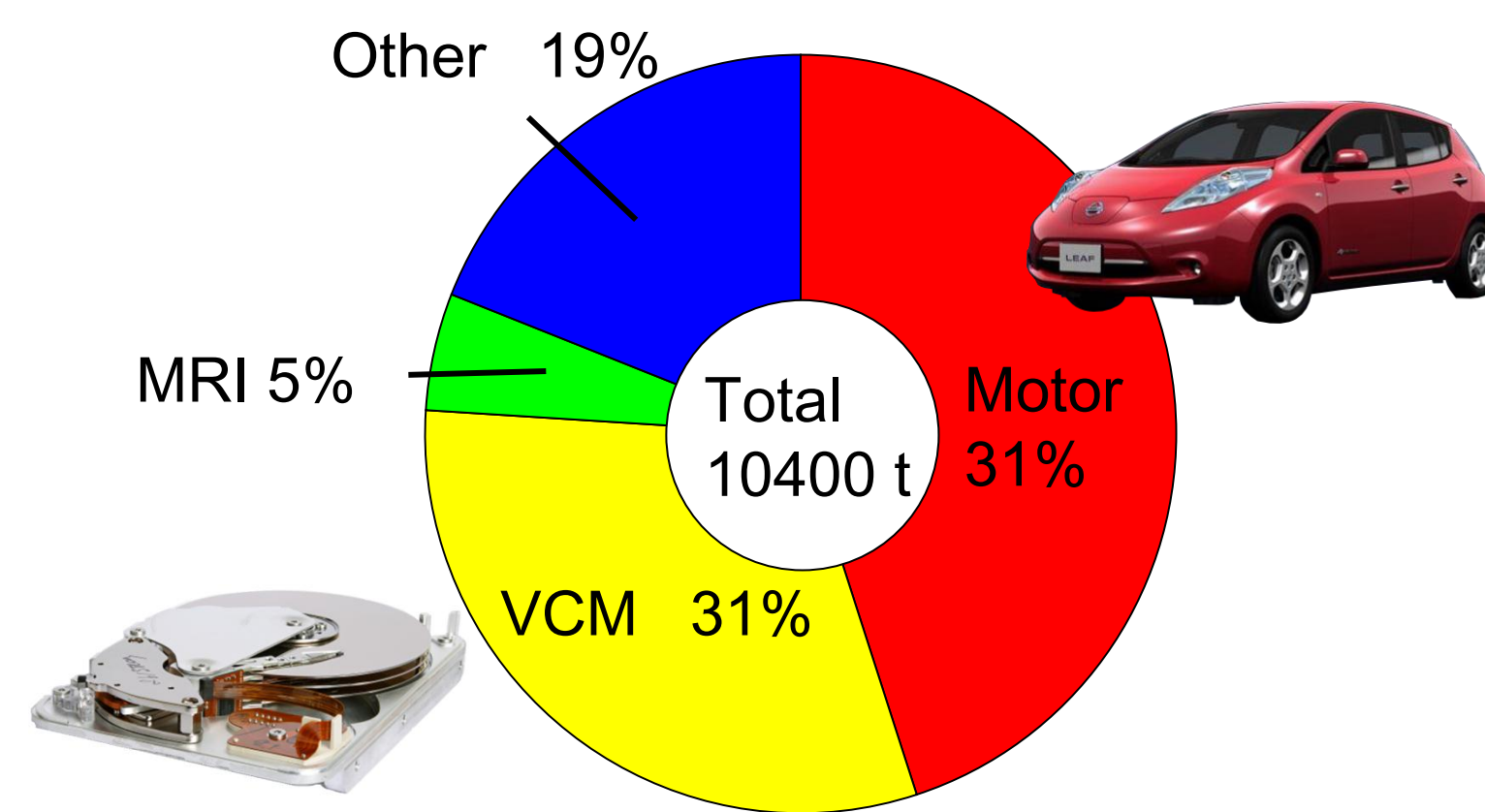
### Nd-Fe-B magnets

- Nd-Fe-B magnet is the strongest permanent magnet in the world.
- Nd is an essential element for high performance alloy magnet.
- Addition of Dy or Tb improves heat resistance of magnet.



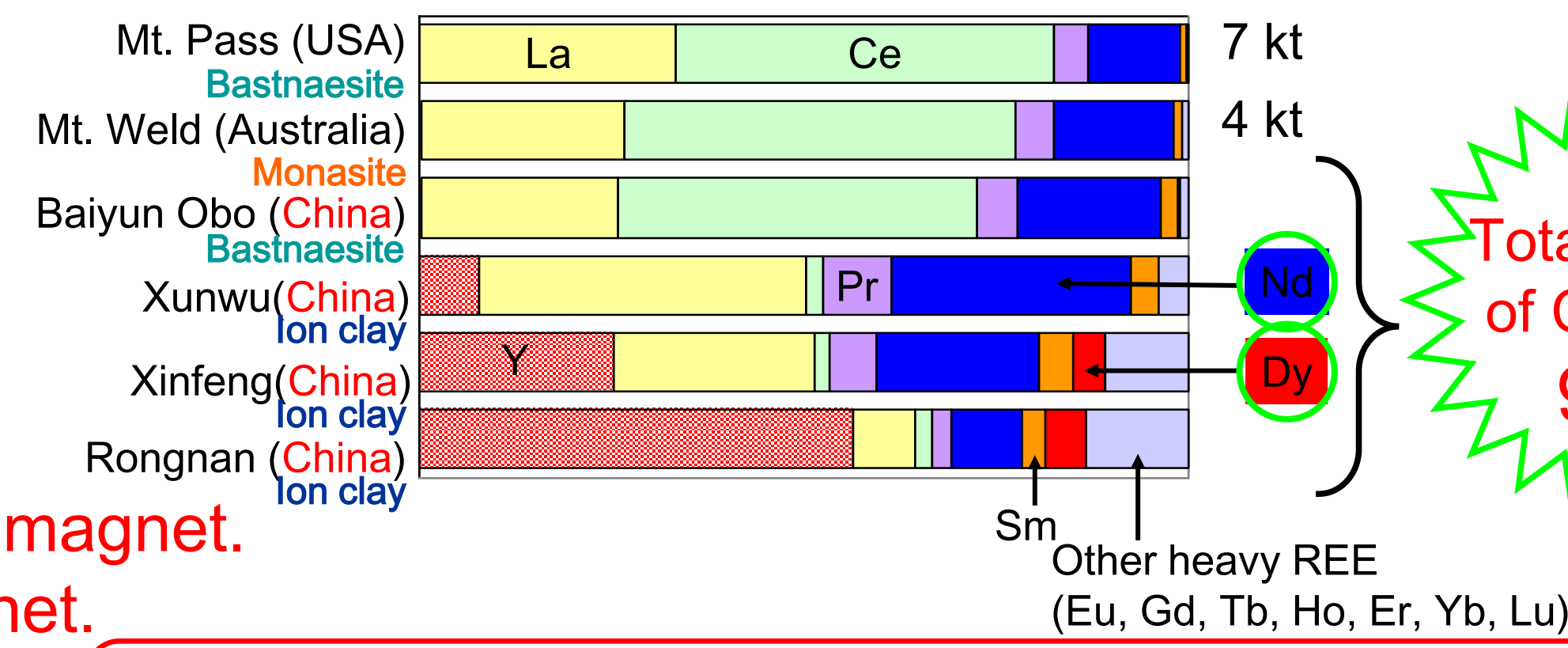
Nd and Dy are vital elements for strong magnets.

### Application of Nd-Fe-B magnet



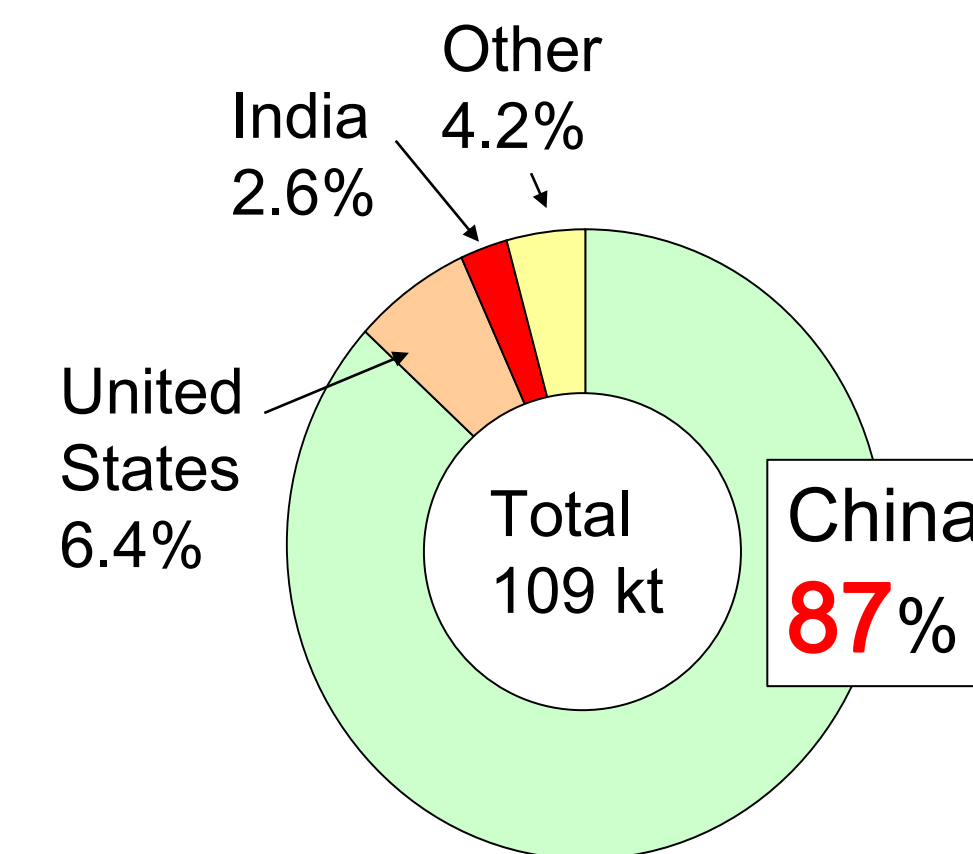
Demand for Nd-Fe-B sintered magnet by use in Japan (2008).

### The representative component of rare earth ore



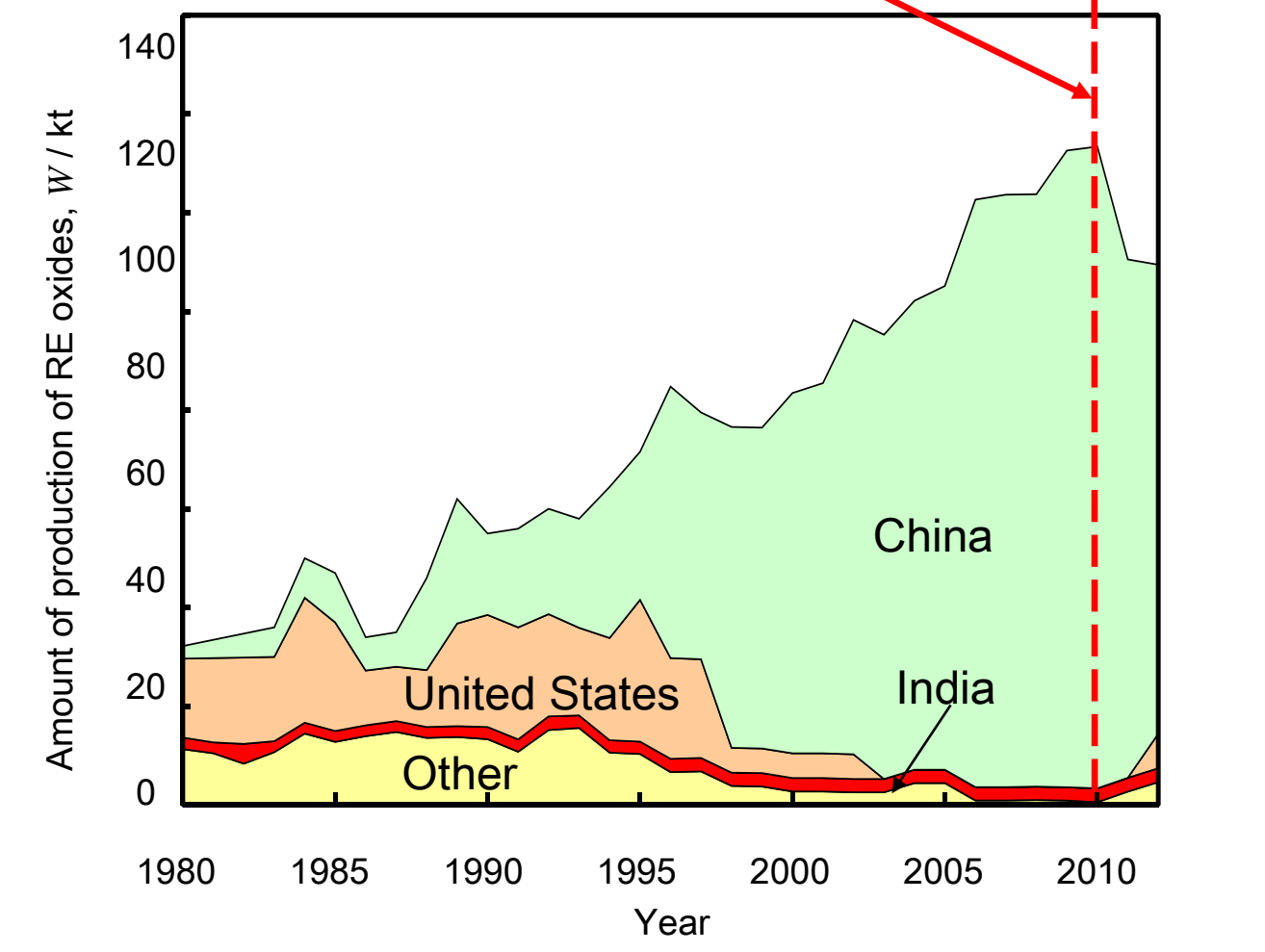
Ion clay which contains large amount of Dy and other heavy rare earth exist only in China.

### Production of rare earth ore



Supply of REE in 2012

In 2010, China accounts for 97% of world rare earth production.



Change in amount of production of REE

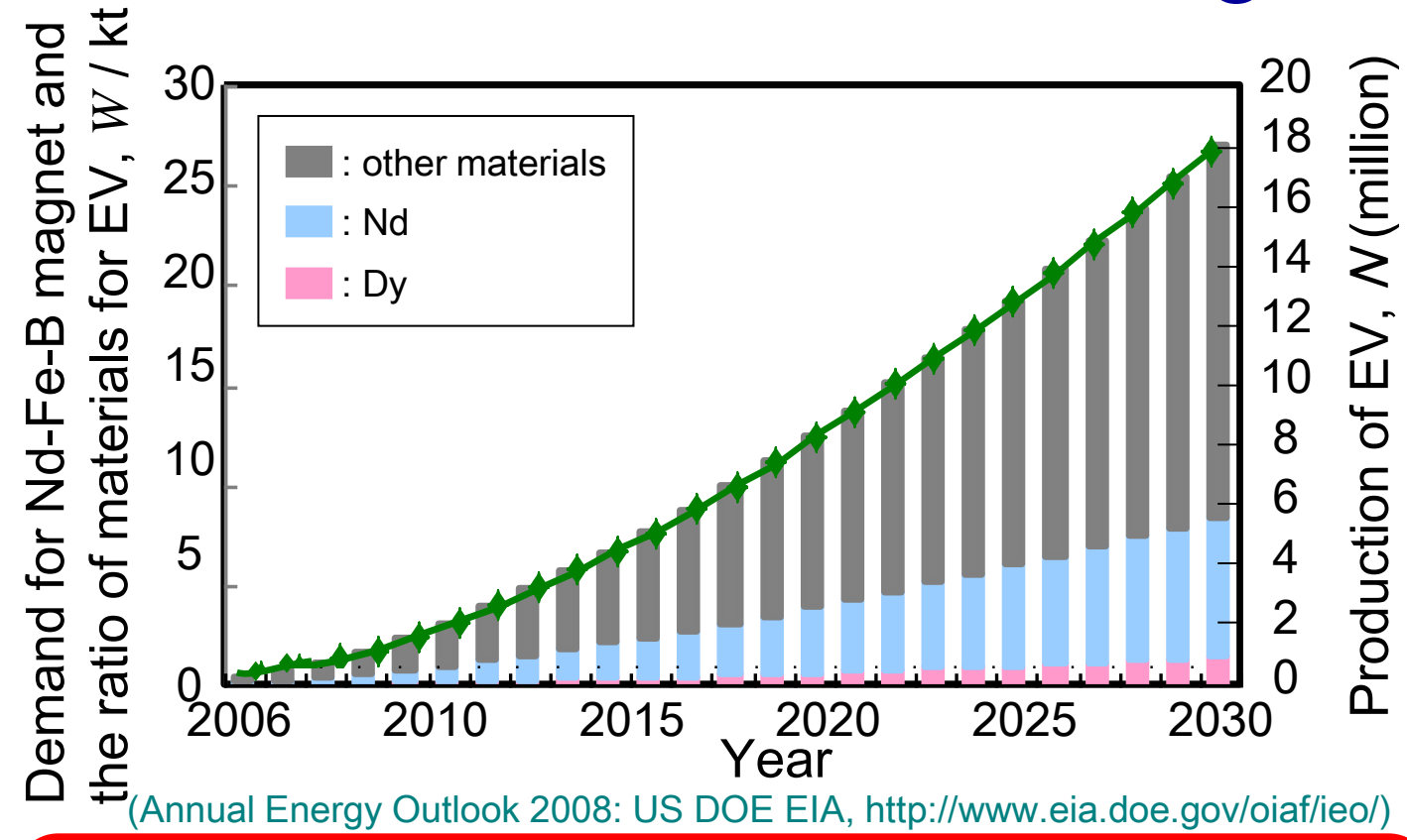
Almost all rare earth are produced in China.

But...

Serious environmental pollution occurs.

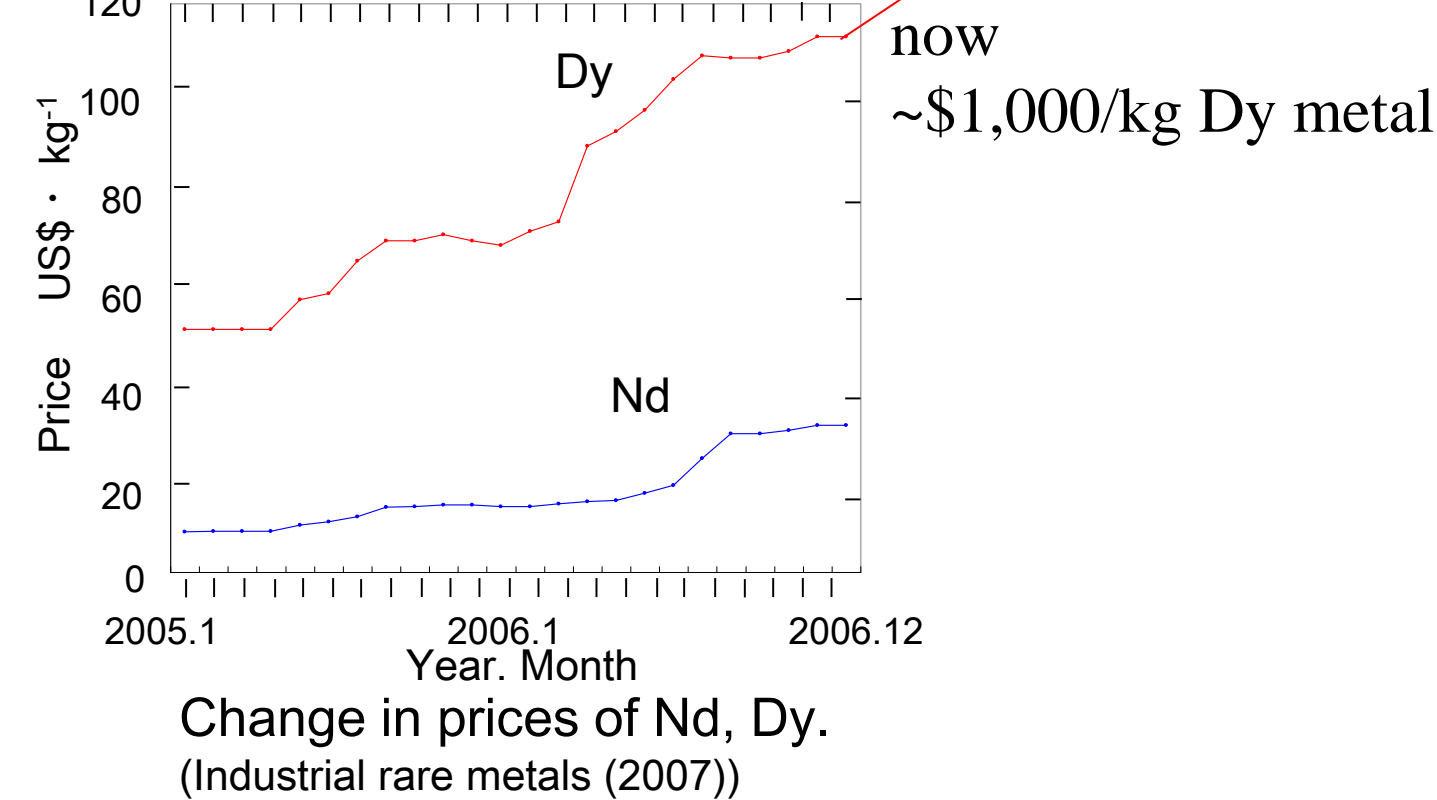


### Demand for Nd-Fe-B magnet



Large amount of scraps will be generated in the future.

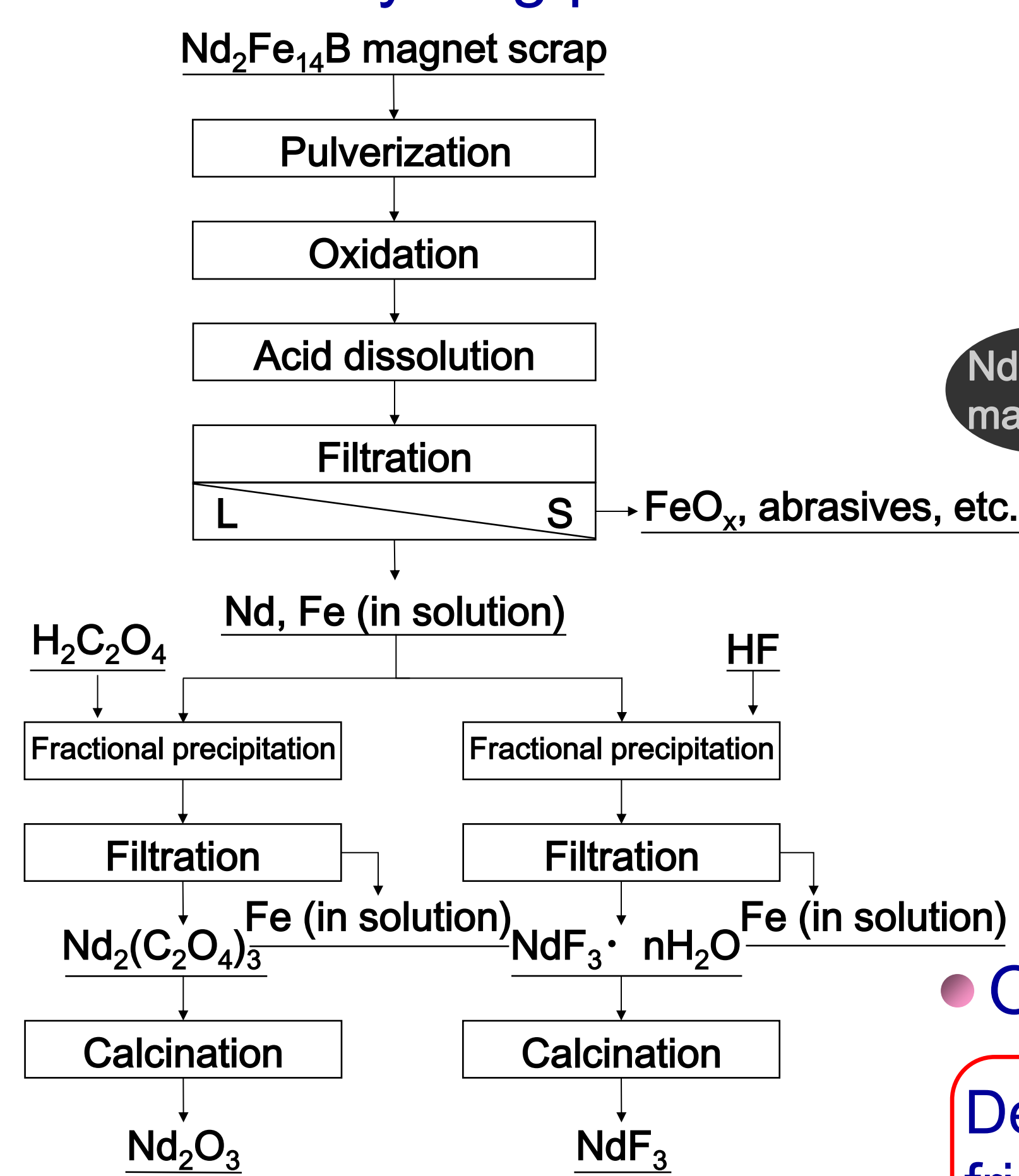
### Price chart of Nd and Dy



Price of Nd and Dy is increasing

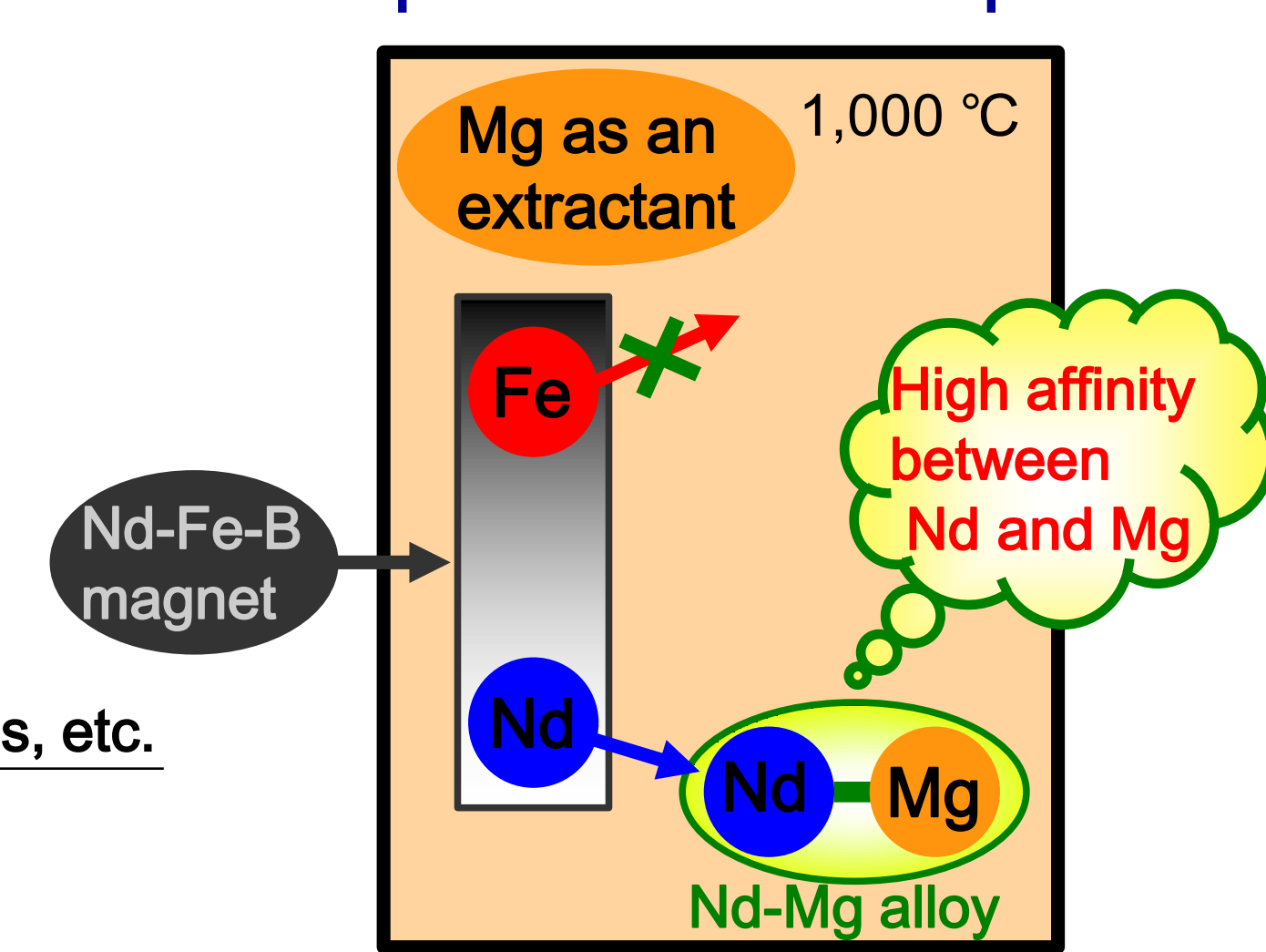
Recycling of Nd from scraps is important.

### Current recycling process



Discarding large amount of highly toxic waste solutions

### Concept of our new process



Extract only Nd and Dy from Nd-Fe-B alloy magnet by using molten Mg.

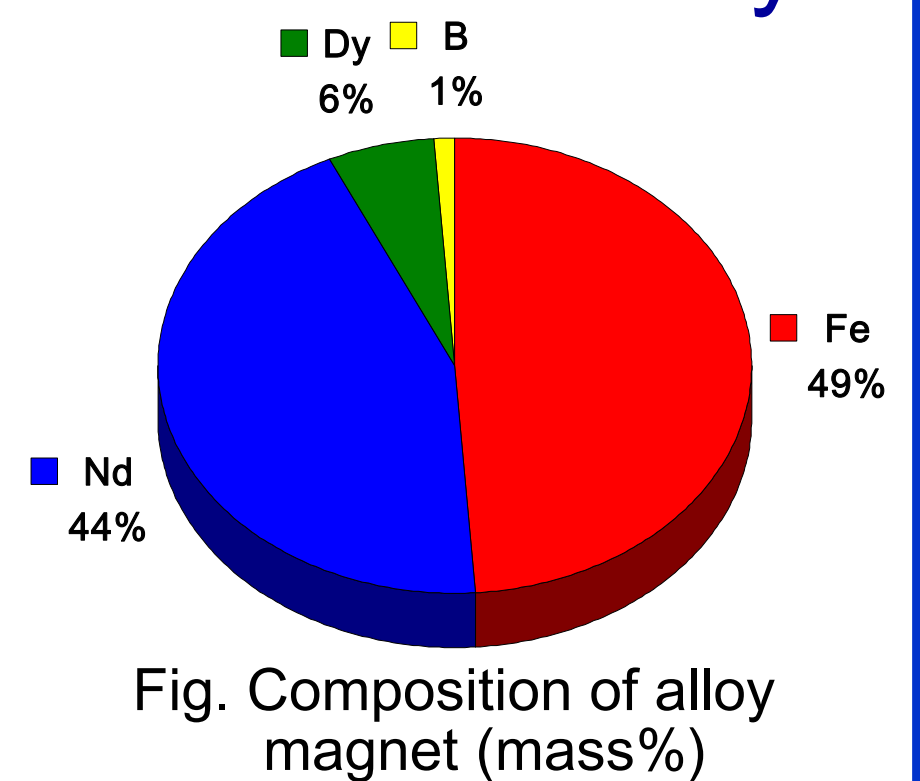
### Objectives

Development of environmentally friendly dry recycling process for rare earth.

Stable supply of rare earth.

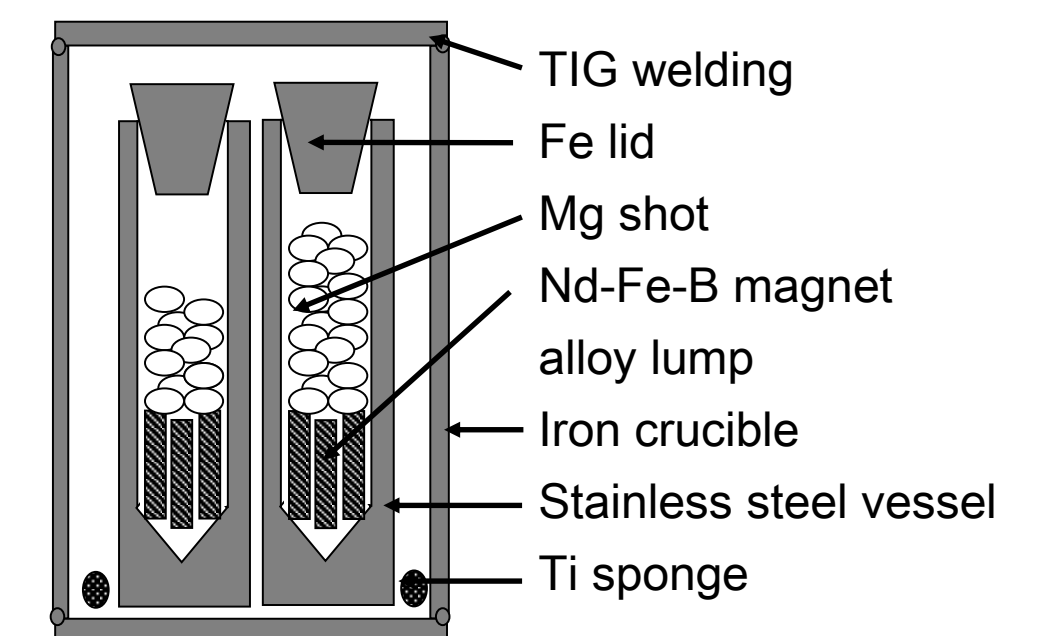
## Experimental

### Alloy magnet used in this study



### Experimental procedure

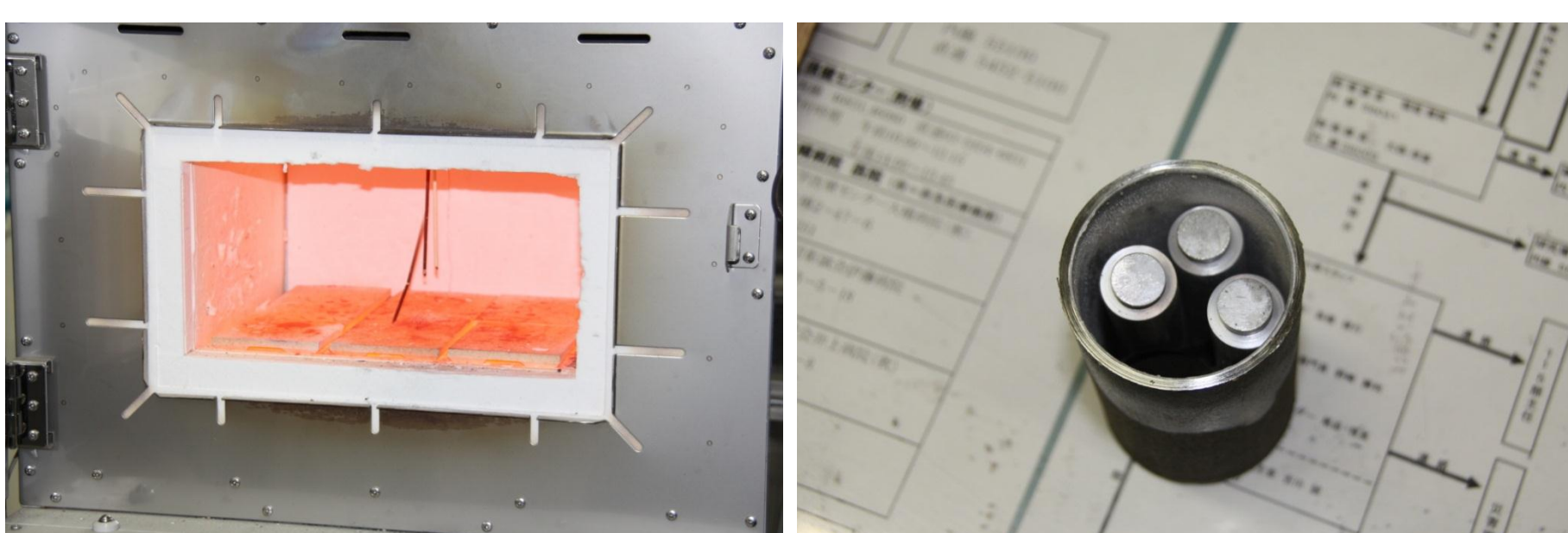
#### 1. Experimental setup



Weight ratio of alloy magnet lump and Mg shot

	Mg shot	Magnet alloy lump
A	1	1.5
B	1	2.0
C	1	2.5

### 2. Nd extraction at elevated temperature.



Nd-Fe-B magnet alloys were reacted with Molten Mg at 1000°C for 24 hours.

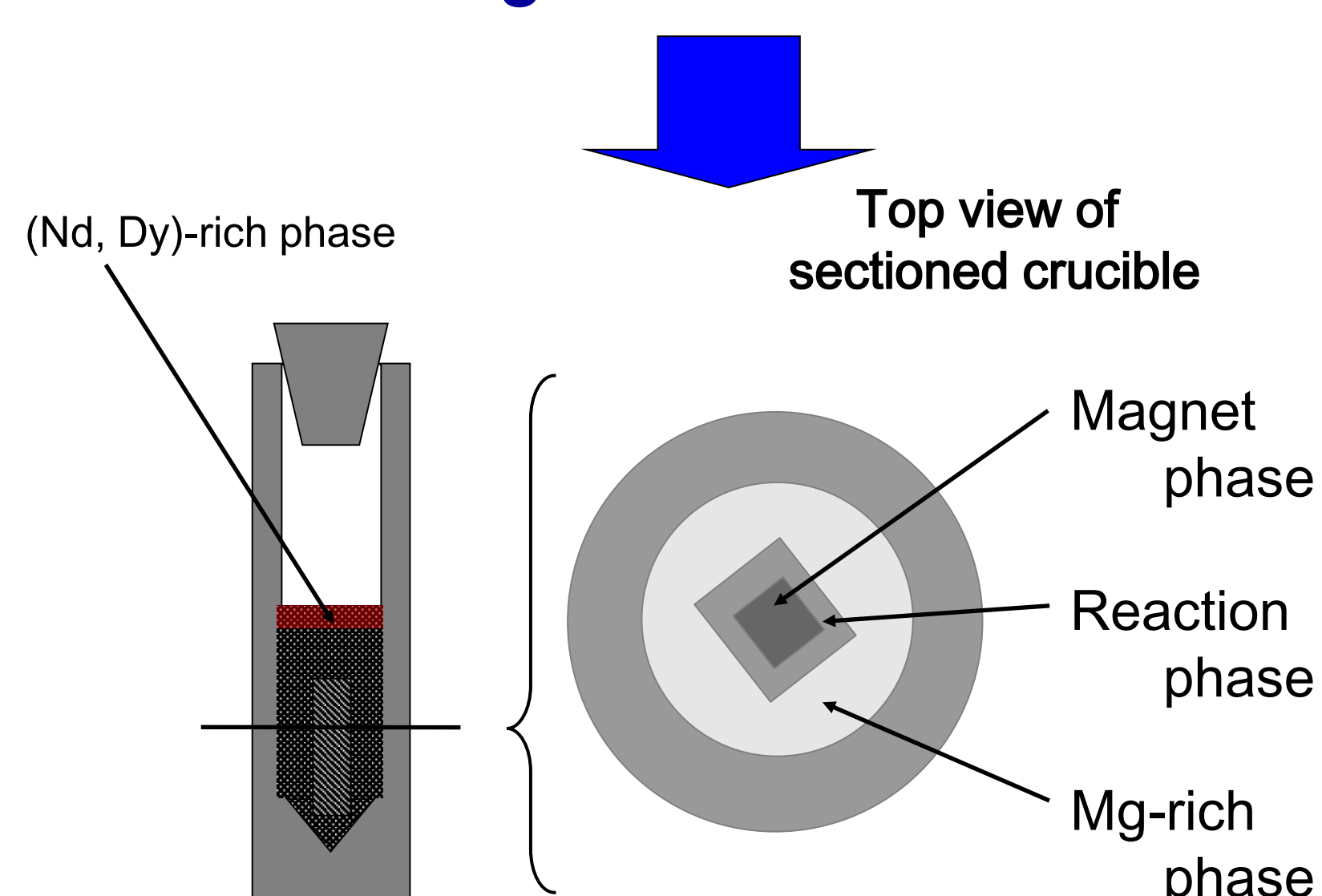
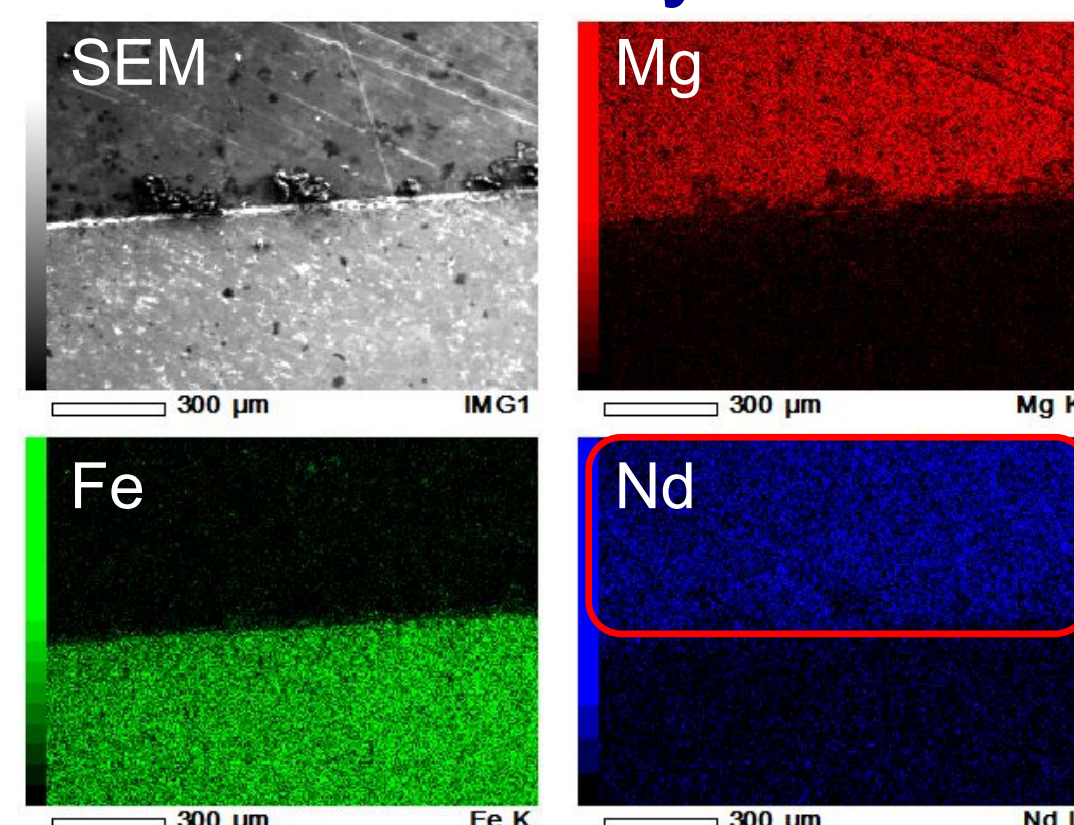


Fig. Samples obtained after the extraction experiment.

## Results

### SEM-EDS analysis of sample



### ICP-AES analysis of sample

Result in magnet alloy phase			
Composition, C <sub>i</sub> (mass%)			
	Mg	Fe	Nd
A	0.82	96.1	3.07
B	1.11	93.7	5.19
C	0.64	92.6	6.75
Result in Mg phase			
Composition, C <sub>i</sub> (mass%)			
	Mg	Fe	Nd
A	62.65	0.87	35.79
B	62.38	0.00	36.97
C	53.35	0.35	45.41

Extraction rate of Nd (On assumption that Mg is not flowing outside as gaseous phase)

Sample	A	B	C
Extracted Nd ratio (%)	93.2	88.5	85.0

\*1 The value was determined from the composition of magnet alloy after extraction.

Over 90 % of Nd was extracted from Nd-Fe-B alloy magnet.

Most of Nd was extracted from alloy phase to Mg phase. On the other hand, Fe was not extracted into molten Mg.

Nd can be extracted and separated directly from magnet alloy

## Conclusion

- Nd was extracted directly from Nd-Fe-B magnet by dry recycling process.
- Not any highly toxic waste solution was generated by this dry process.



Keigo Nishimura is expert of Taiko, martial arts.