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Recent aspects :Rare earth resources and metal production for rare earth iron base permanent magnet

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ABSTRACT

This paper presents the recent availavility of the rare earth metals and alloy for the rare earth iron base permanent magnets.
The rare earth production capacity is enough to fulfil demand of permanent magnets.

1. INTRODUCTION

In the modern era, the rare earths play a unique role in science and industry owing to the many attractive characteristics of the rare earths.
Tremendous efforts have been directed towards basic and applied research, technology development and commercial utilization of the rare earths.
The most exciting among them is the development of the rare earth permanent magnets.
First of all, I would like briefly to explain the rare earth elements.
The rare earth metals comprise the elements with atomic number 57 through 71 (La, Ce, Pr, Nd, (Pm) Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb).
They are found in the Periodic table in group 3 Period 6 and have another name of lanthanides.
It is important to point out that as a class the rare earths should not be considered as rare.
Rare earths are abundant on the contrary to the name.
In the earth crust, cerium is more abundant than both copper and nickel; neodymium are more abundant than lead; samarium, dysprosium are more abundant than tin.

2. ORES OF RARE EARTHS

Most of the commercially available rare earths are extracted from three minerals:
bastnasite (a flurocarbonate),
monazite (a phosphate),
ion adsorbed concentrates (an oxide)
(as shown in Table 1).
Ion adsorbed concentrates are recently discovered in southern China which is very important

Table 1 Contents of individual rare earth in raw materials

(Western world market taking in account some improtations of ore from China)

(metric tonns REO in 1990, estimated)

RAW MATERIALS	REO	La	Ce	Pr	Nd	Sm	Dy	others
BASTNASITE								
USA	16.000	5.120	7.840	704	2.160	80	16	80
CHINA	9.895	2.265	4.925	591	1.920	98	10	41
MONAZITE								
AUSTRALIA	8.000	1.840	3.720	408	1.472	184	80	296
CHINA	1.260	290	538	52	214	38	13	115
INDIA	1.800	423	846	97	342	50	18	24
ION-ABSORBING								
CHINA	2.920	871	210	208	881	185	52	513
TOTAL	39.830	10.809	18.079	2.060	6.989	635	189	1.069

material for rare earth magnets, because of containing richer Nd, Sm, Dy in comparing with other minerals.

3. THE RARE EARTH RESOURCES IN THE WORLD

As shown in Figure 1, the world reserves of rare earths is estimated more than 80 million tons. This world reserves are almost 2,000 times of the world annual consumption, the richest deposit of rare earths is in China where share 51 %, next richer is 15 % in USA, 6 % in Australia, 2.7 % in India and rest of the reserves is located in numerous countries like Canada, Russia, Brazil, Malaysia, Indonesia, Africa, Egypt, etc.

4. THE PRESENT CUNSUMPTION TONNAGE PER COUNTRY

As shown in Figure 2, the present world consumption is estimated as total 35,500 tons, where biggest consumption is 28 % in USA, next 20 % in Europe, 16% in Japan, 16 % in China, 9 % in Russia and others.

5. DOLLAR PER APPLICATION

The total amount is estimated as 340 million dollar, the biggest application in dollar is 41 % for phosphors, next 18 % for glass, 16 % for magnets, 13% for metallurgy. 9% for catalysis and others.

6. PRODUCTION OF RARE EARTH METALS AND ALLOYS

The primary extraction of rare earth metals can be accomplished in two ways: thermochemical and electrochemical.

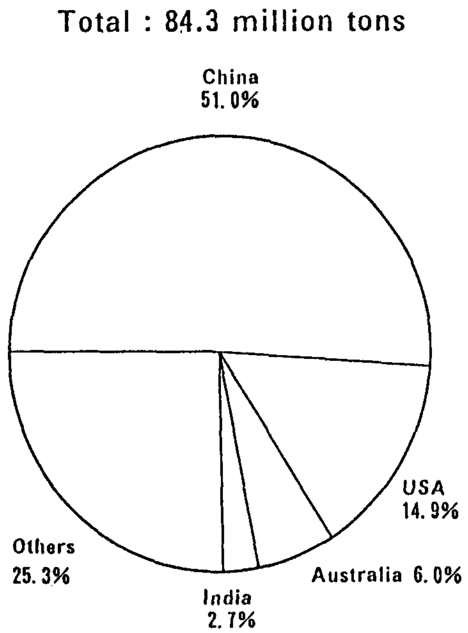

Figure 1
World reserves of rare earths(1990)

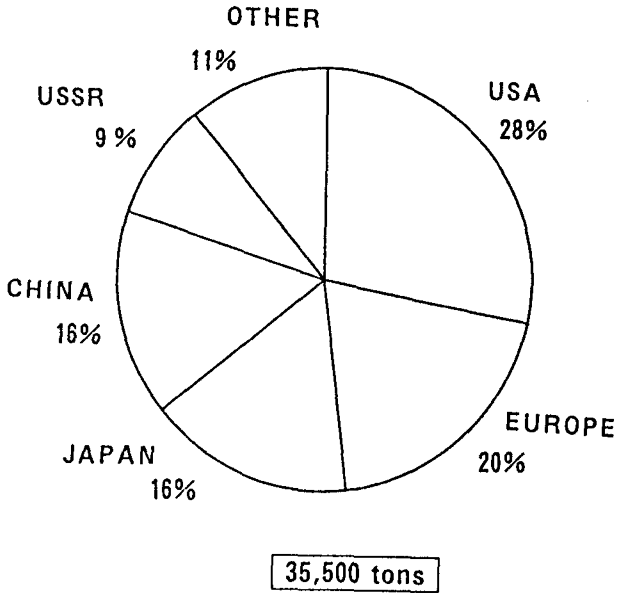

Figure 2 Consumption tonnage(1990)

Thermochemical extraction involves the metallothermic reduction of compound containing the rare earth elements.
The compounds are oxide, fluoride or chloride and the reactive metal have been employed as reductant.
Electrochemical extraction involves the electrolytic reduction of a rare earth compound which has been dissoved in a molten salt solution.
The electrolytes are multicompound melts of either chlorides or flourides.
Chloride method has many troublesome problem.
Flouride method has many advantage in comparing to chloride method.
Large scal industrial production has been employed flouride method.

6.1 Nd and Nd-Fe alloy production by oxide-flouride electrolysis

The electrolyte comprises rare earth oxide in disolved in NdF_3-LiF-BaF_2.
The feed material is rare earth oxide.
There are two kind style of metal deposition, that is, pure Nd metal and Nd-Fe eutectic alloy.
Nd metal deposition method use nonconsumable cathod of Mo, W .etc.
Nd-Fe alloy deposition method use consumable cathod of iron.

6.2 Nd metal electrowinning method

As shown Table 2 , this operation condition is a little different from Nd-Fe alloy method , because of its higher melting point.

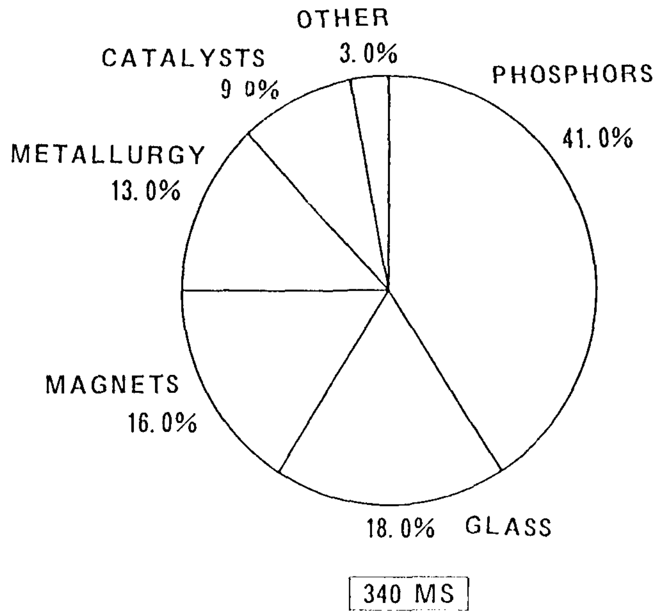

Figure 3 Dollars per application(1990)

6.3 Nd-Fe electrowinning method

As shown Table 2, this process is more easy large scale production, but disadvantage of this method is unstable on Fe content in deposit metal.

6.4. The preparing of magnet alloy

By using a high frecuency vaccum furnace that is most popular way, Nd-Fe-B alloy ingot is made with strict control of composition and stable high quality through melting in crucible and casting in the mold. We have the excellent ingot for making permanent magnets.
Typical composition of Nd-Dy-Fe-B alloy is following :
Nd 30.0%, Dy 3.0%, Fe bal. B 1.2%, Si<1.0%, Mg<0.01%, Ca<0.01%, Al, 0.015% C <200ppm, O <300ppm, Cl <50ppm.

7. AVAILAVILITY OF RARE EARTH TO PERMANENT MAGNETS

Japanese current production of Nd-Fe-B magnets in weight is estimated as 1,750 t/y including bond-magnets.
Nd_2O_3 consumption of for magnets may be almost 1,030 t/y in Japan and world cosumption may be 1,500 t/y. As shown Table 3 the potential availavility quantity of Nd_2O_3 is 6,989t/y.
But real availavility quantity is much less since it depends on the existing separation capacity at a given time , real availavility may be 4,000 t/y.
This fugure is too enough to fulfil present world consumption of 1,500t.

Table 2 Some operation condition in the electrolysis

	FOR PURE METAL PROCESS(SEC)	FOR ALLOY PROCESS(SANTOKU)
BATH TEMPERATURE	1,050 - 1,100 C	850 - 1,000 C
VOLTAGE	10 - 15 V	10 - 15 V
CURRENT	8 - 10 KA	20 KA
CE	60 %	65 %
FEED MATERIAL	Nd_2O^3	Nd_2O^3
BATH	$LiF-BaF_2-NdF_3$	$LiF-BaF_2-NdF_3$

COMPOSITIONAL ANALYSIS OF DEPOSIT METAL

Nd	balance	balance
Pr	1.7 %	1.5 %
Fe	1.6 %	17.0 %
Al	0.01%	0.01%
Si	0.01%	–
Mo	0.10%	–
C	0.04%	0.025%

Table 3 Ava i lavility for rare earth magnets estimated (1993)

	Potential Availability	Real Availability	present consumption
Neodymium Oxide	6,989 t/y	4,000 t/y	1,600 t/y
Neo-Pr Oxide	9,049 t/y	5,200 t/y	–
Samarium Oxide	635 t/y	600 t/y	300 t/y
Dysprosium Oxide	189 t/y	180 t/y	80 t/y

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