Rare Earth Materials

Important Industrial Applications and Uses

Date: February 24, 2011

To: Rare Earth Roundtable

Presented By: **TBD**

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Uses

CLEAN ENERGY TECHNOLOGIES AND *COMPONENTS*

		Solar Cells	Wind Turbines	Vehicles		Lighting
	MATERIAL	*PV films*	*Magnets*	*Magnets*	*Batteries*	*Phosphors*
Rare Earth Elements	Lanthanum				●	●
	Cerium				●	●
	Praseodymium		●	●	●	
	Neodymium		●	●	●	
	Samarium		●	●		
	Europium					●
	Terbium					●
	Dysprosium		●	●		
	Yttrium					●
	Indium	●				
	Gallium	●				
	Tellurium	●				
	Cobalt				●	
	Lithium				●	

Ref [1, p. 2]

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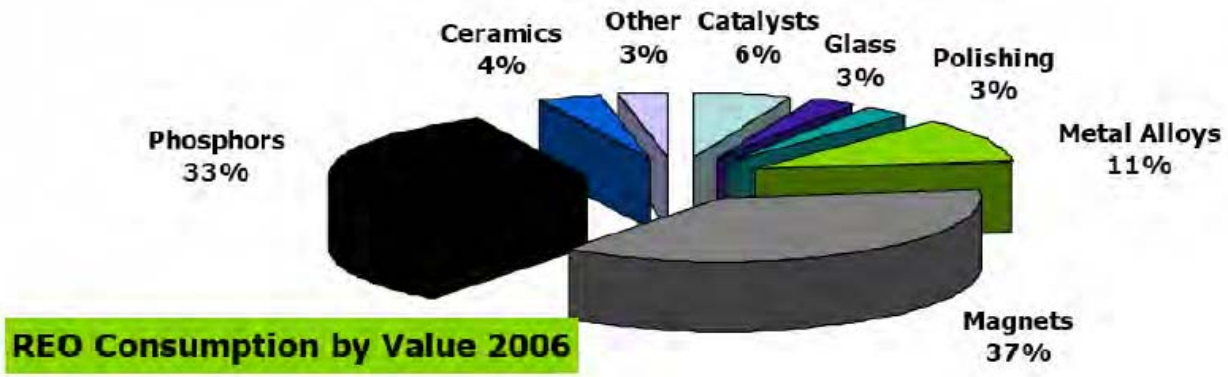
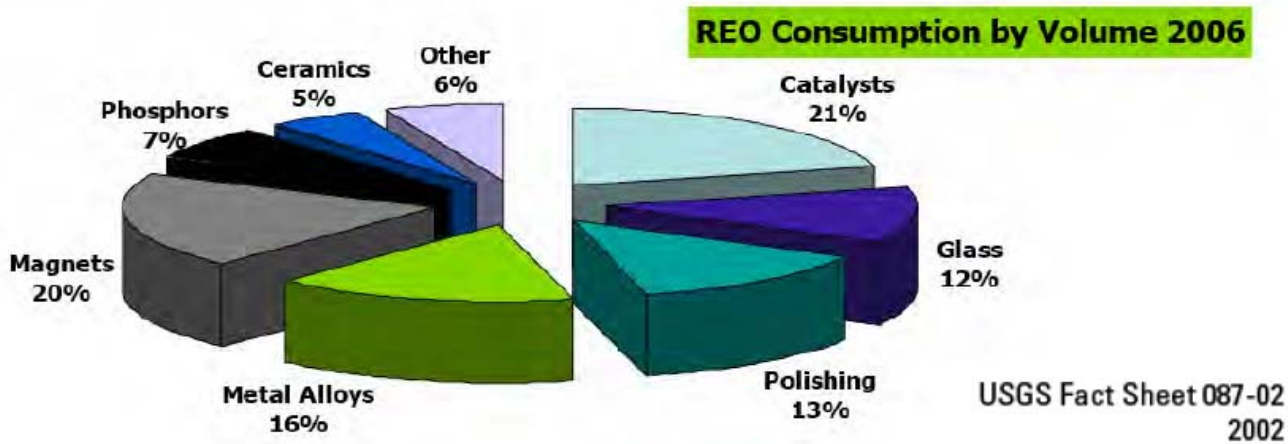
Rare Earth Uses by Value and Volume

Where else are rare earths used…





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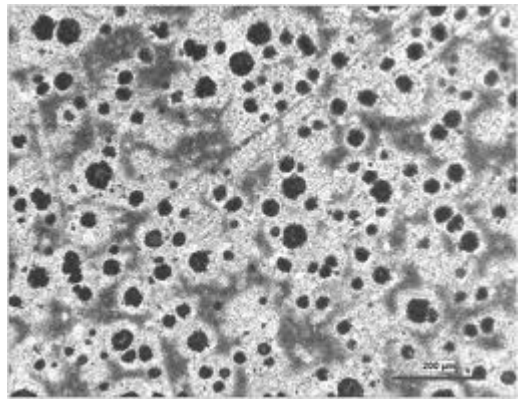
RE Uses as Alloying Elements

- **Ductile iron (alter the carbon morphology),**
- **Superalloys (increase operating temperatures),**
- **Magnesium alloys (enhance creep resistance),**
- **Aluminum alloys (improve tensile strength and corrosion resistance),**
- **Oxygen-free, high-conductivity copper (improve oxidation resistance), and**
- **Dispersion-strengthened materials (improve high-temperature properties).**



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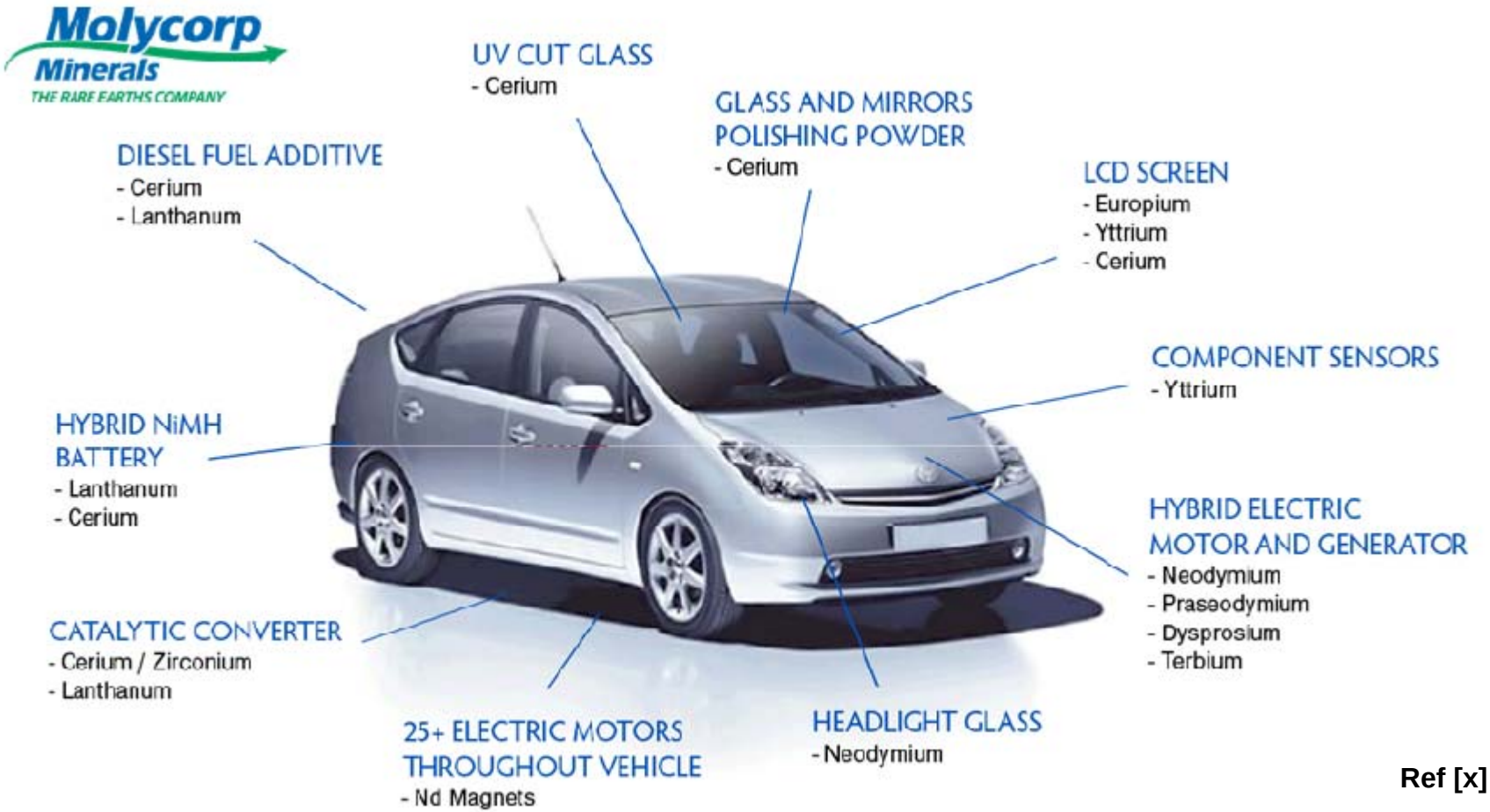
Automotive - Toyota Prius



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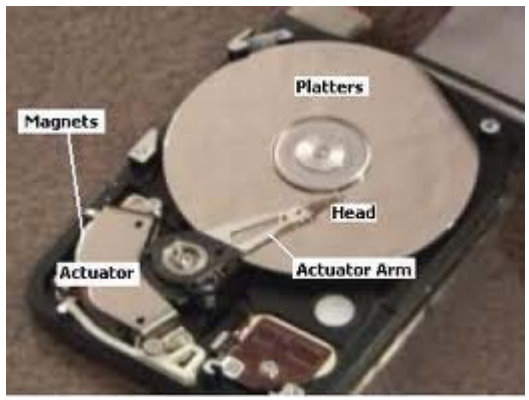
Magnets - $Nd_2Fe_{14}B$

- **Ultra strong small permanent magnets enabled by discovery of $Nd_2Fe_{14}B$ compound during search for low-cost replacement for samarium-cobalt magnets. Revolutionary advances in small electronics and actuators.**
- **Beijing San Huan New Materials High-Tech Inc. and China National Non-Ferrous Metals Import & Export Corporation acquired control former GM Magnequench operations, moved to China in 2002.**
- **Hitachi Metals (Japan) acquired ownership of Sumitomo magnet operations.**



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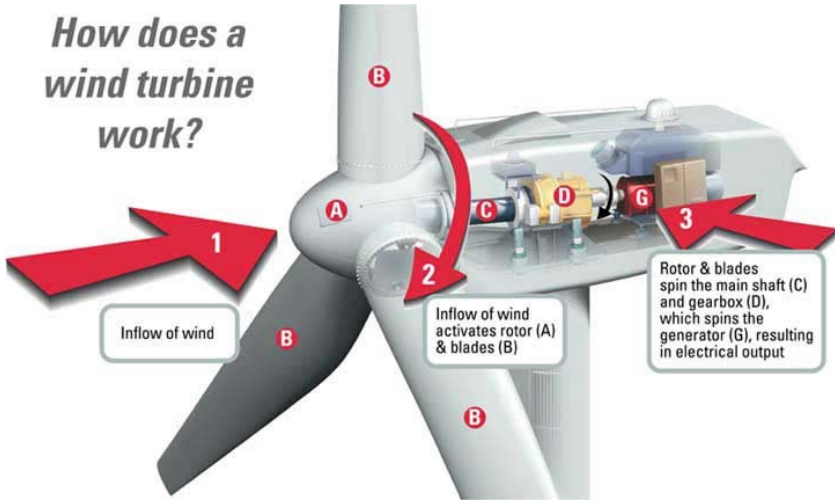
Rare Earth Content in NdFeB Motors and Generators

- **Wind turbines: 400 kg-600 kg rare earth metals in generator magnets. Neodymium and dysprosium content is 31% and 5.5% of magnet weight, respectively.**



- **Electric Drive Vehicles: Material intensity for neodymium and dysprosium is calculated from the estimated weight of total NdFeB magnet material per vehicle motor. The weight for rare earth magnets is about 2 kg per vehicle. Neodymium and dysprosium content is 31% and 5.5% of magnet weight.**

Ref [x]

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Lighting

- **Phosphors represent a significant portion of the cost of a compact fluorescent light (CFL) bulb. Phosphors accounted for 7% of all REE usage by volume and 32% of the total value in 2008.**

- **Emerging lighting technologies (LEDs and organic OLEDs) have dramatically lowered REE content, some still use cerium and europium phosphors to convert blue LEDs to useful white light.**

NiMH Batteries

Element	Molar % in AB5	Weight % in AB5	kg per battery high	kg per battery low
La	5.7%	11.2%	0.73	0.49
Ce	8.0%	15.9%	1.03	0.69
Pr	0.8%	1.6%	0.10	0.07
Nd	2.3%	4.7%	0.31	0.20
Ni	59.2%	49.2%	3.20	2.13
Co	12.2%	10.2%	0.66	0.44
Mn	6.8%	5.3%	0.34	0.23
Al	5.2%	2.0%	0.13	0.09
Total			**6.5**	**4.33**

GM Ovonics NiMH battery for EV1; superseeded by Li-ion battery for Volt

Ref [6, p. 129]

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Material Content in Li-Ion Batteries (EVs and PHEVs)

Application	Material	High/ Low	Material content (kg)	Battery Chemistry Designation	Cathode	Anode
PHEV 40	*Lithium*	Low	1.35	LMO-G	$LiMn_2O_4$	Graphite
		High	5.07	LMO-TiO	$LiMn_2O_4$	$Li_4Ti_5O_{12}$
	Cobalt	Low	0	LMO (both)	$LiMn_2O_4$	Either
		High	3.77	NCA-G	$LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$	Graphite
EV 100	*Lithium*	Low	3.38	LMO-G	$LiMn_2O_4$	Graphite
		High	12.68	LMO-TiO	$LiMn_2O_4$	$Li_4Ti_5O_{12}$
	Cobalt	Low	0	LMO (both)	$LiMn_2O_4$	Either
		High	9.41	NCA-G	$LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$	Graphite

Ref [6, p. 134]

Eliminates rare earth materials but raises new concerns about sources for lithium, predominantly Chile and Bolivia.

Wind Turbines

NdFeB magnets are a critical component for some models of the new generation wind-powered turbines. Two tons of rare earth magnets are required in the permanent magnet generator that goes on top of the turbine. "If the permanent magnet is two tons, then 28 percent of that, or 560 lbs. is neodymium.

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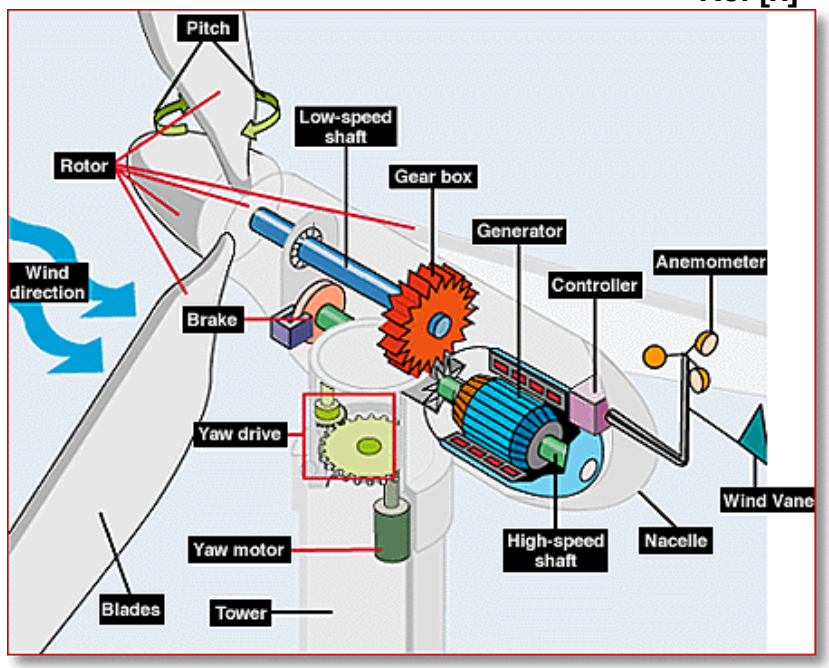

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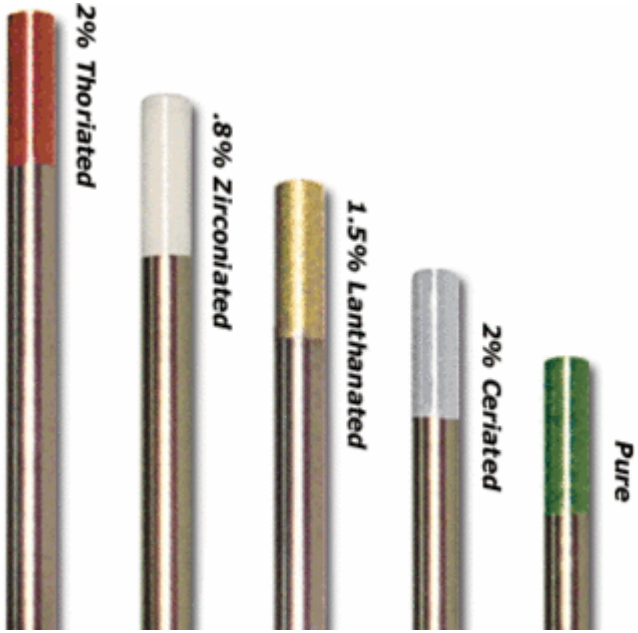
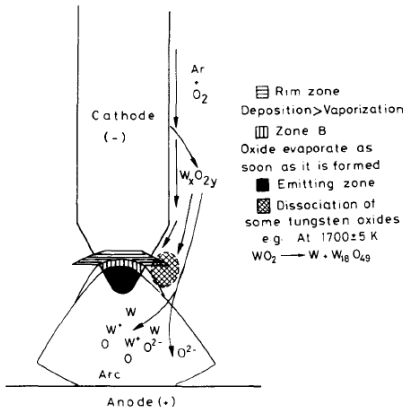
Welding Electrodes



Welding electrodes used for automatic gas tungsten arc welding and resistance spot welding often contain 0.5-2.0% rare earth oxides (Y_2O_3, La_2O_3 , ThO_2, or CeO_2 proprietary additions).

The rare earth oxide additions enable a stable arc to be established at a lower temperature, reducing deformation of the electrode, extending its useful life, and reducing contamination of the weld.



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