THE STRUCTURE OF THE CRITICAL MATERIALS INSTITUTE AND WHAT DOES THE FUTURE BRING

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Critical Materials Institute
AN ENERGY INNOVATION HUB

CMI STRUCTURE

FOCUS AREAS – 4

THRUSTS – 11

PROJECTS – 35

TASKS – 125

PERSONNEL

Scientific ~80 Full-time Equivalent

~200 persons (bodies)

Support ~35 Full-time Equivalent

DIVERSIFYING SUPPLY
FOCUS AREA-1

- New Sources
  - 1.1.1 Advanced Beneficiation Techniques
  - 1.1.2 Recovery of REEs & Uranium from Phosphate Ore Proc.
  - 1.1.3 Improved Methods for Lithium Extraction

- Transformational Processes
  - 1.2.1 Enhanced Separation of Adjacent Rare Earth Elements
  - 1.2.2 Conversion to Metal, Alloys, and Materials
  - 1.2.3 Novel Separation Processes
  - 1.2.4 Computational Prescreening of Ligands

- New Uses for Co-Products
  - 1.3.1 New Uses for Co-Mined Abundant REEs

PROBLEM: SEPARATION SEQUENCE

First Remove Ce

oxidation process, cut problem in half

Mountain Pass, California (40% Ce)

R:	La→	Ce→	Pr→	Nd→	Sm→	Eu→	Gd→	Tb→	Dy→	Y	Ho→	Er→	Tm→	Yb→	Lu
%	25	--	4	19	1	0.5	1	0.1	0.1	<0.1	--	0.1	--	--	--

Bokan Mountain, Alaska (25% Ce)

R:	La→	Ce→	Pr→	Nd→	Sm→	Eu→	Gd→	Tb→	Dy→	Y	Ho→	Er→	Tm→	Yb→	Lu
%	10	--	3.1	12	3.1	0.2	3.5	0.8	4.2	27	8.8	2.4	--	--	--

Mountain Pass, California

To get to Eu, Tb and Dy need to remove ~99% other RE

Bokan Mountain, Alaska

To get to Eu, Tb and Dy and Y need to remove ~52% of the lighter REs, below Eu.

No simple solution to get the critical elements

DEVELOPING SUBSTITUTES FOCUS AREA-2

- Magnets
  - 2.1.1 Reduced RE Content High Performance Magnets
  - 2.1.2 Additive Manufacturing of Permanent Magnets
  - 2.1.3 Optimization of Grain Boundaries & Interfaces
  - 2.1.4 Thermo-Magnetic Processing of Rare Earth Metals

- Lighting
  - 2.2.1 Replacement of Eu^{3+}
  - 2.2.2 Replacement of Tb^{3+}
  - 2.2.3 Methods

- Materials Development Framework
  - 2.3.1 Quantitative Framework for Cost Efficient Materials Dev.
  - 2.3.2 Materials Design Simulator – Efficient Prototyping

SUBSTITUTION

NO SUCH LUCK

People have been looking

Eu – red color in TV; used for ~50 years – yet no substitute

Nd – permanent magnets; used for ~28 years – yet no substitute

Sm – permanent magnets; used for over 42 years – yet no substitute

Ce – 3-way catalytic converters (automotive exhaust), used for ~30 years – yet no substitute

Mixed REO FCC catalysts – used for ~47 years (Half-life of a new catalyst is ~5 years) – yet no substitute

IMPROVING REUSE AND RECYCLING FOCUS AREA-3

- Source Separation and Concentration
  - 3.1.1 Recovery & Reuse of RE Metals from Phosphor Dusts
  - 3.1.2 Value Recovery of REEs by Remanufacturing
  - 3.1.3 Cost Effective Recycling of RE Containing Magnets
  - 3.1.4 Beneficiation of Photovoltaic Functional Coatings

- Transformative Extraction and Materials Production
  - 3.2.1 Supercritical Fluid Beneficiation of Waste Streams
  - 3.2.2 Membrane Solvent Extraction for RE Separations
  - 3.2.3 Electro-Recycling of Rare Earth Metals
  - 3.2.4 Pyroprocessing Technologies to Recycle RE Metals
  - 3.2.5 Bioleaching for Recovery of Recycled REE

RECYCLING

Today

Europe and Japan much more active than USA

Recycling difficult: RE content quite small, generally less than a poor rare earth deposit (~2%). Exception: electric motors, wind turbines, batteries.

Future

Design processes for direct recovery of the metallic materials from magnets, battery and metallic alloying agents.

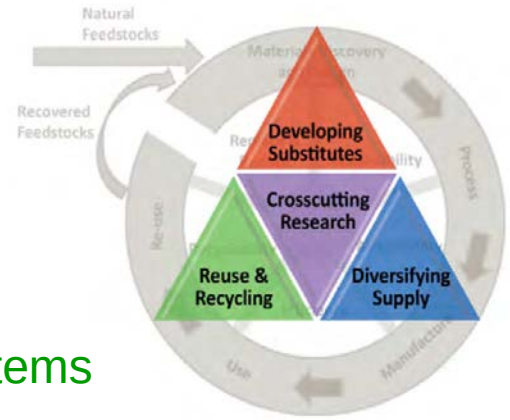
Better recovery techniques for rare earth phosphors from CFL (compact fluorescent lamps), long tubes, color TVs and monitors, color display units

Recovery of rare earths from cracking catalysts, especially the heavy lanthanides Tb and Dy

Develop value-based lifecycle models

CROSSCUTTING RESEARCH FOCUS AREA-4

- Enabling Science
  - 4.1.1 Temperature Dependent and Multi-Scale Phenomena
  - 4.1.2 Crystal Electric Field Splitting for Magnetic Anisotropy
  - 4.1.3 Fundamental Properties & Phase Diagrams
  - 4.1.4 Rapid Assessment Methodologies



- Environmental Sustainability
  - 4.2.1 Treatment Using Sorption and Microfiltration Systems
  - 4.2.2 RE Effects on Biological Wastewater Treatment Systems
  - 4.3.1 Criticality & Sustainability Assessment

- Supply Chain, Economic Analysis and Policy
  - 4.3.2 Economic Analysis of Global Materials Supply Chains
  - 4.3.3 National Technology Roadmap for Critical Materials

CANNOT MINE WAY OUT OF Dy PROBLEM

Estimated Production (mined) in 2014 (mtons)

Company	Total REO	Dy_2O_3
Molycorp	20,000	10
Lynas	10,000	11
Nolan's Bore	10,000	30
Dubbo	2,500	53
Steenkampakraad	5,000	34
China	110,000	661
TOTAL	160,000	800
DEMAND FOR Dy		1000 (200 short fall)

ALSO TRUE FOR Nd, Eu, Tb and Y

WILL THE CHINESE CUT THE PRICE OF *MINED-EXTRACTED* RARE EARTHS?

NOT LIKELY

WILL THE CHINESE RAISE THE PRICE OF RARE EARTHS AT THE *MINING-EXTRACTION LEVEL?*

NO

WHAT ABOUT INTERMEDIATE AND END USE PRODUCTS?

Intermediate Use Products

metals and alloys, magnets, phosphors, hard drives, catalysts, chemicals

End Use Products

electric motors, computers, TVs and other optical displays, CFL and long tube fluorescent lamps, wind turbines, speakers, cell phones, i-pods©, sensors, NiMH batteries, polishing compounds

MAY SEE SOME PRICE CUTS IN 2018-2025

Chinese want to maintain their markets

Price wars?

A PREDICTED RARE EARTH SCENARIO

American manufacturers - this is what CMI is all about

produce magnets, electric motors, speakers, high end electronics, better CFLs, LED lamps, computers

Competition

American vs. other nations' products

Price Wars?

American manufacturers

must remain viable for our military and energy securities

SHOULD WE BE CONCERNED – YES

Military Security

Energy Security

Employment in companies producing
high tech products
This is seriously lacking today

THANK YOU FOR YOUR ATTENTION

ANY QUESTIONS?

WILL THE CHINESE CUT THE PRICE OF *MINED-EXTRACTED* RARE EARTHS?

NOT LIKELY – BECAUSE

Chinese economy is growing so fast they will need all of Chinese rare earths by 2015 at the latest

Chinese do not want to use their vast, but finite, resources to supply the rest of the world (ROW) high tech products

Why reduce the price – they can sell at a high price and increase their profit.

WILL THE CHINESE RAISE THE PRICEOF RARE EARTHS AT THE *MINING-EXTRACTION LEVEL?*

NO

minor increases, however, may come

WHY "NO"?

Large price increases will adversely affect their end use products – magnets, phosphors, electric motors, optical displays (TVs), lighting, wind turbines, etc.