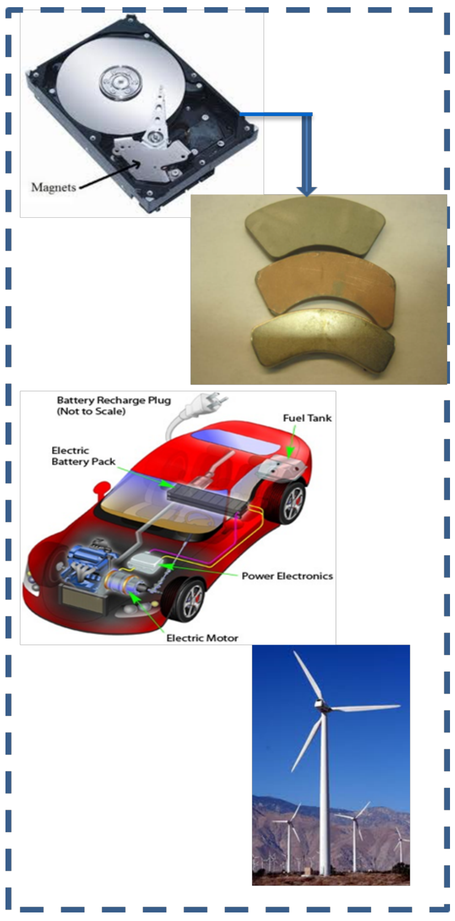
# Critical Materials Institute

*An Energy Innovation Hub*

# Recycling of NdFeB Magnets by Hydriding-Dehydriding (HDD) and Molten Salt Electrochemical Processes

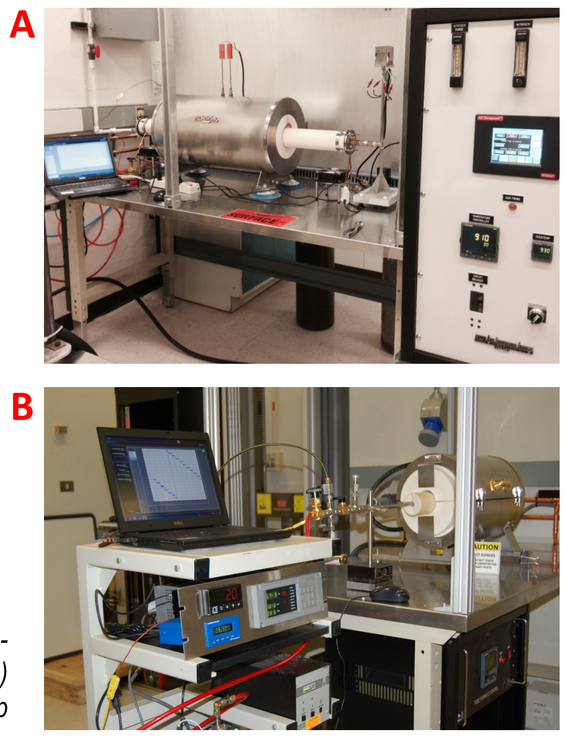
## Importance of Project:

- Seven major European research institutes (Fraunhofer, CEA, TNO, VTT, SINTEF, Tecnalia & SP) joined forces (titled “Value from Waste”) to recyclie rare earth materials. Rare earth permanent magnet materials (scraps, manufacturing wastes, swarfs) form a significant component of this research.
- More popular primary ore (*Bastanaesite*) contains only light rare earth elements, such as La, Ce, Pr and Nd, and a trace of heavy rare earth elements, such as Tb, Dy, Ho, Er, Tm and Yb.
- Clean energy sectors will require high performance neo magnets that contain more Dy than are currently being used.
- Primary Dy resources are becoming scarcer and as a result, recycling of waste magnets can be a value-added proposition.
- At the current rate of consumption, the Chinese Dy resource (ionic clays) will be exhausted in 15 to 25 years.
- Combined Nd and Dy market was worth over U.S. $ 4 billion in 2012 and is expected to grow to U.S. $8 billion by 2018.
- Recycling of waste Nd/Dy magnet materials has been estimated to be 88% energy efficient and 98% lower in human toxicity index (low environmental foot print).

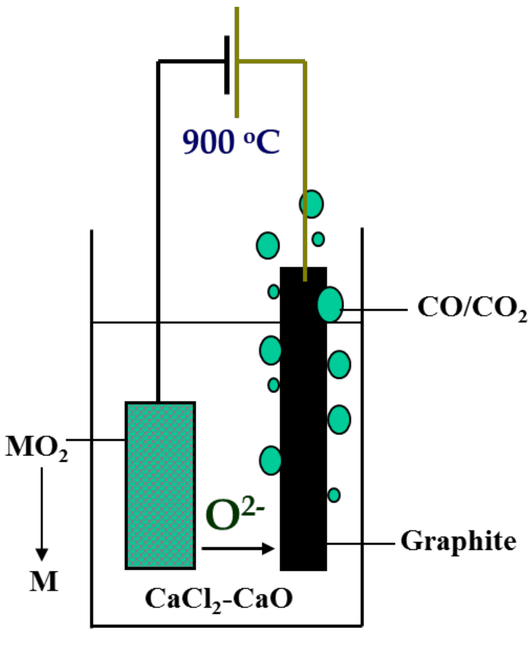



## Our Approach:

1. Chemical processing (hydriding-cum-dehydriding) of the manually recovered HDD NdFeB magnets and their re-fabrication in minimum possible unit operations.
2. Processing of the oxidized magnets by a novel molten salt electrochemical process (Electrodeoxidation technique).




*Hydriding(A)-cum-dehydriding(B) experimental set up*



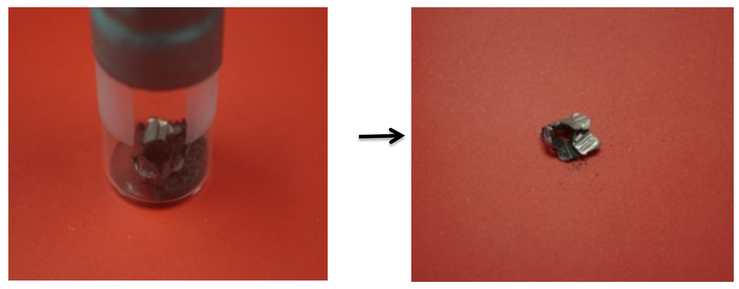

*Schematic diagram of the molten salt electrochemical apparatus*

## Opportunities:

- In a typical Nd-FeB magnet manufacturing facility, about 20–30% of the magnets are rejected as scrap, which is estimated to be typically ~1500–2500 tons/ year. To date,
  only very small quantities (~1%) have been recycled.
- During the journey from alloy to magnets ~ 50% of feed material becomes finished magnets.
- Limited number of non-Chinese magnet producers – less than 12.
- Market could double by the end of the current decade.
- Non-Chinese production (2009):12,000 T/year => 4080 T/yr Nd, Dy, Pr, Tb recovery potential.

## Accomplishments:

- Could remove the surface coating in just one step before further processing
- Identified process conditions to refabricate bonded and sintered magnets.
- Submitted two Invention Disclosure Records.



*After hydriding*

*State of the Nickel coating after Hydriding Step*

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