Rare-Earth Permanent Magnets in Europe

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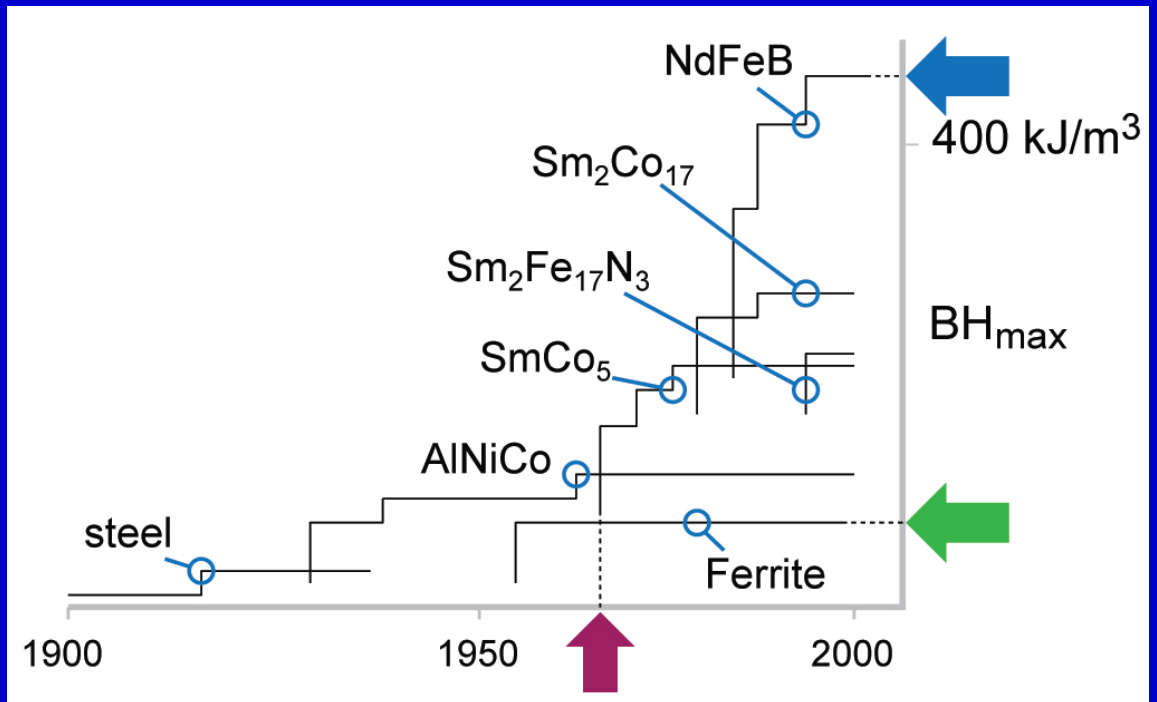
*China's Complete Control of Global High-Tech Magnet Industry

- Rare-earth minerals are used in:
  - rechargeable batteries (in camcorders), cell phones, PDAs, laptop computers and other portable devices..
  - wind turbines, drinking water filters, petrochemical catalysts, polishing powders, hydrogen storage, fluorescent lighting, flat panels, color televisions, glass, ceramics and automotive catalysts.
  - fiberoptics, dental and surgical lasers, MRI systems, as medical contrast agents, in medical isotopes and in positron emission tomography scintillation detectors.
  - magnetic refrigeration
  - rechargeable batteries used in hybrid vehicles
  - **permanent magnets**
  - military application

*by Richard McCormack, manufacturing / Technology news, September 2009, 16, No.16

Permanent magnets through the century



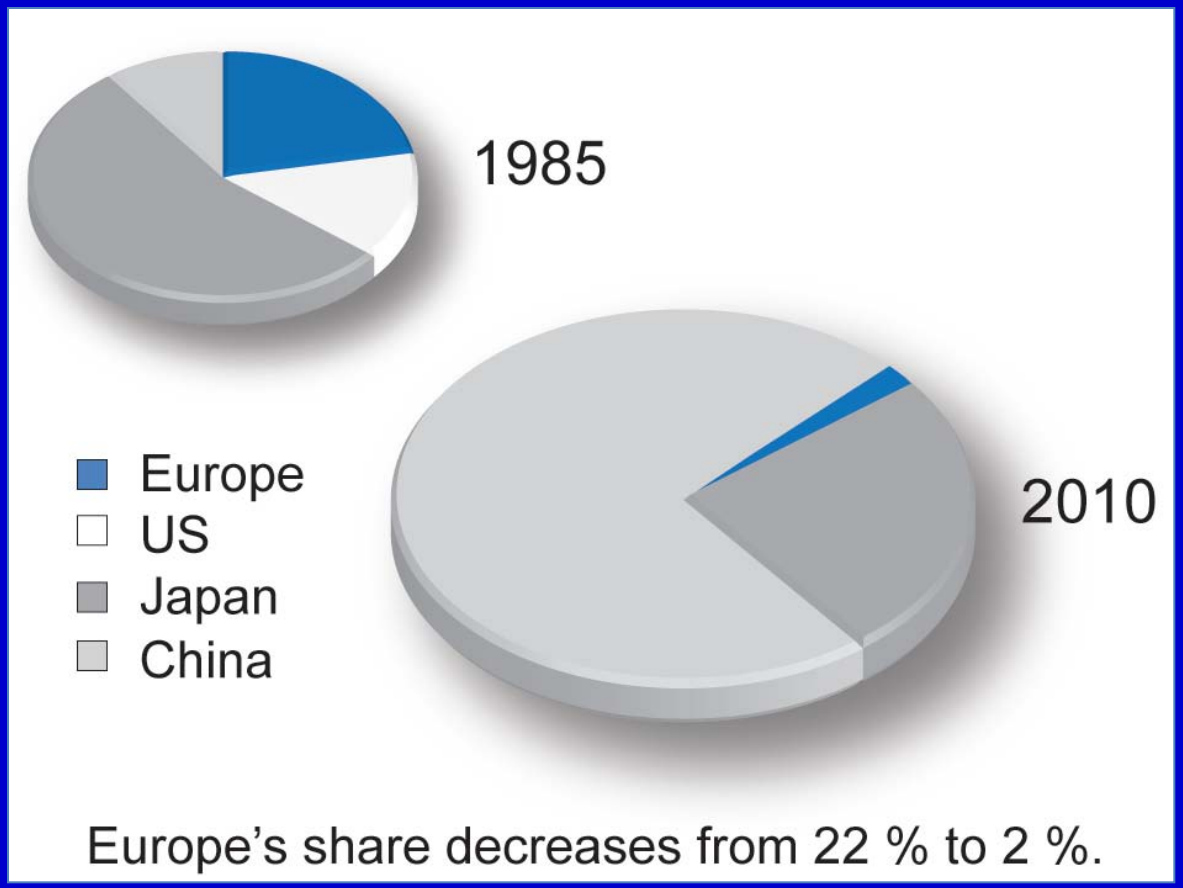
Improving magnetic properties in the past 100 years.

PM based on RE are increasingly important in **environmentally critical** technologies:

- for wind turbines
- hybrid and
- pure electric vehicles

(**HEVs and EVs**).

Europe's Share



The **Nd-Fe-B** permanent magnet industry is currently producing about 60,000 t/a, with a net value profit of about €400m.

By 2016, due primarily to the development of applications in the automotive industry, this is expected to double to 120,000 t/a and nearly €1 billion.

Source:
Prof. Paul McGuiness, JSI, Slovenia

World market

*The total world market size for rare-earth magnetic materials was

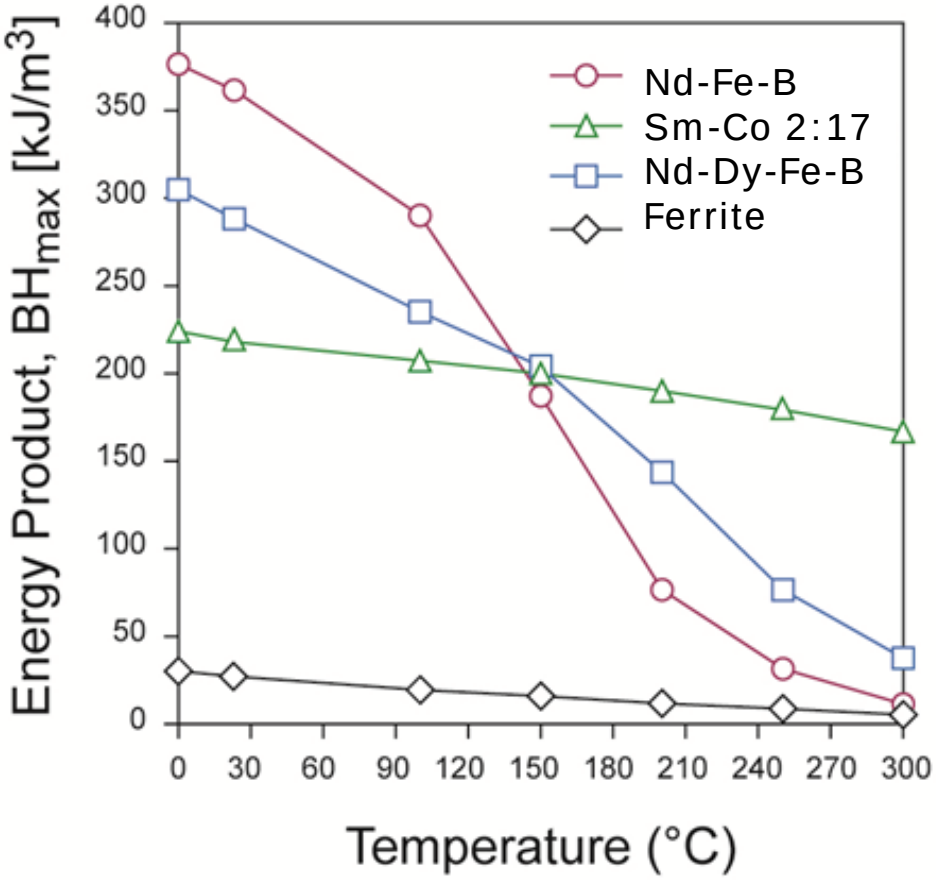
$9.1 billion in 2007 and is projected to grow to

$12 billion in 2011 and to

$21 billion by 2020

* by Dr. Peter Dent from Electron Energy Corp.

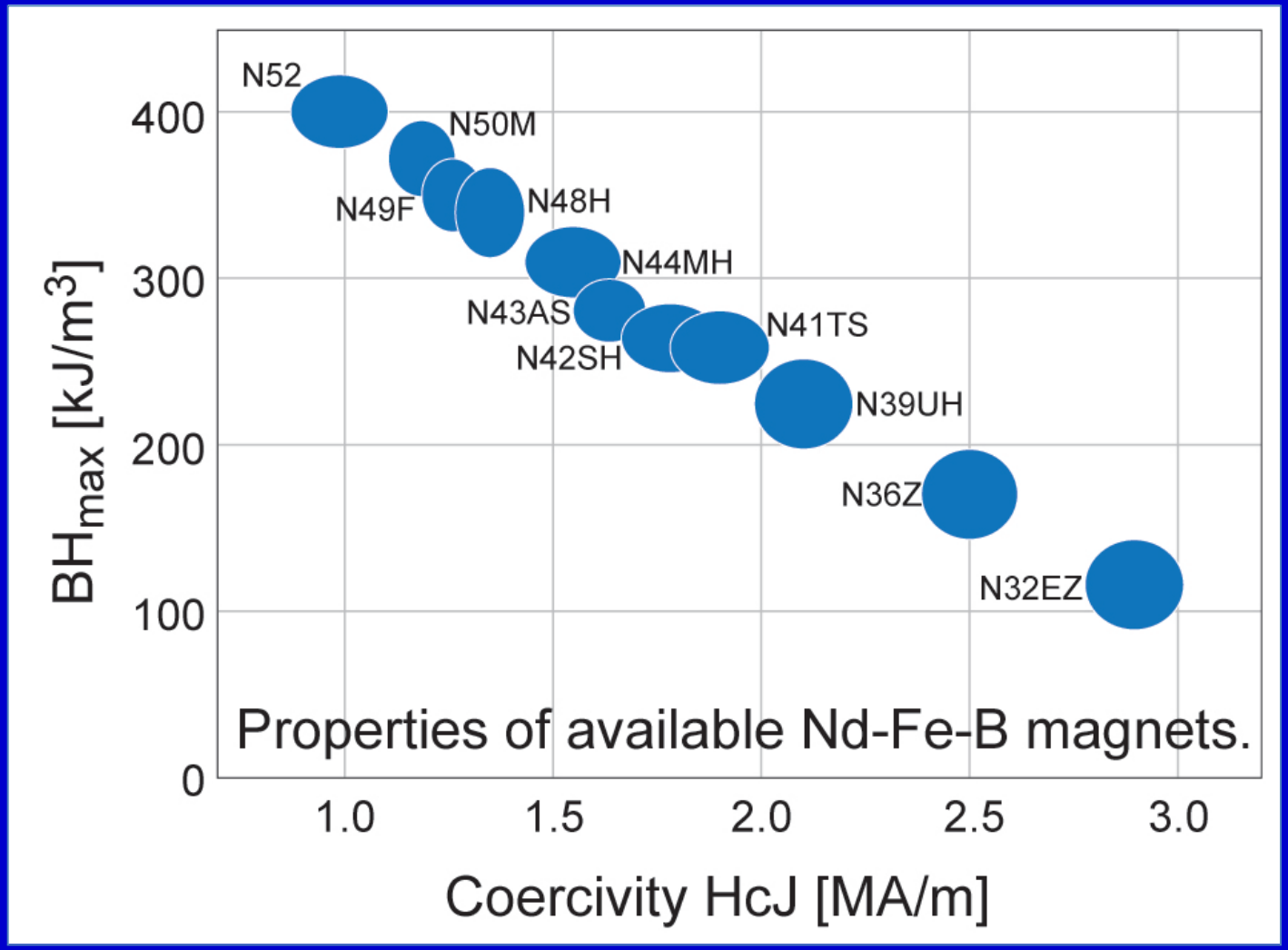
Temperature dependences of BH_{max}



Effect of temperature on magnetic properties for a variety of magnetic materials

Source:
Prof. Oliver Gutfleisch,
IFW Dresden, Germany

The state of the art in terms of magnetic properties



Nd-Fe-B and Sm-Co Permanent Magnets

The current situation

It would be wrong to say that there are no ideas as to how to replace the REs in permanent magnets and maintain the properties at a similar level,

but the fact that Nd-Fe-B remains the “king” of the magnets 25 years after it was first introduced clearly

points to the fact that RE replacement will not be any easy task.

Research and Industry of RE-PM in Europe

Europe has been responsible for some of the **major innovations and breakthroughs** since the discovery of Nd-Fe-B magnets in the 1980s.

- In terms of manufacturing RE-TM magnets Europe may now be a small player – since the early 90s we have lost **Philips** (UK), **Ugimag** (F), **Crucible** (UK), **Thyssen** (G) – but in terms of research interest Europe remains very active in the field.

- At the recent International Workshop on Rare-Earth Magnets and their Applications in August 2010 (**the most important forum for permanent-magnets research**), and which was held in Slovenia, **more than one-quarter** of the attendees and speakers were **from European countries.**

http://nano.ijs.si/repm10.htm

Existing European factories producing RE – based PM

- VAC, Germany - still running, also acquired Neorem, Finland
- Arnold, CH - still running (SmCo only)
- Magnetfabrik Schramberg - still facility for Neo and SmCo sintered
- Sura MAgnets, Sweden (poly bonded in particular anisotropic Sm_2Co_{17})
- Aichi Steel - a plant in Czech Republic
- Kolektor Magnet Technology GmbH, Germany, poly bonded RE
- Kolektor Magma Ljubljana, polybond Neo
- KFH, Slovenia, rotors of polymerbonded and sintered Neo
- Magneti Ljubljana, Slovenia
- Magnetfabrik Bonn, Germany
- Max Baerman, Germany

- …..and few other small companies

US and Japan Actions

Major projects in the US and Japan to develop RE-free magnets

AGENCY	PROJECT	INSTITUTION	VALUE	SUBJECT
ARPA-E (US)	High Energy Permanent Magnets for Hybrid Vehicles and Alternative Energy	Univ of Delaware	$4.5m	Magnets based on Fe-, Co- or Mn-rich materials.
US DoE	Transformational Permanent Magnet Materials	GE	$5m	80 MGOe and 80% less rare-earth mineral content
Japan Gov	New generation magnets based on FeN	Tohoku Univ	Not disclosed (Large project)	Gas-phase-modified TM materials
Japan Gov	Permanent Magnets based on FeNi	Tohoku Univ	Not disclosed	FeNi phases with the L10 structure

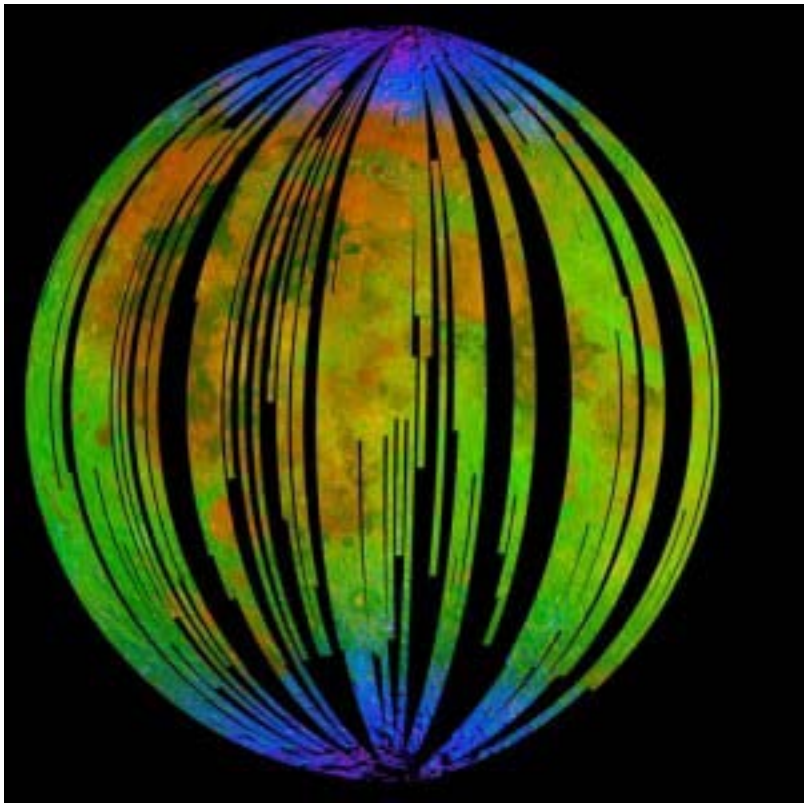
European Actions

Raw Materials Initiative (2008), identify neodymium in its role in high-performance magnets, as being vital for hybrid cars as part of the EU's attempt to reduce the problem of future energy supply.

In June 2010 the European Commission published a list of 14 critical metals or groups of metals – with specific reference to the rare earths – that are important for Europe's economy.

According to Antonio Tajani, the Industry and Entrepreneurship Commissioner, action by Europe in terms of these critical materials must include more efficient recycling.

The next frontier? Lunar mining of rare earth elements?



The American Ceramic Society, November 16, 2010

This image of the moon is from NASA's Moon Mineralogy Mapper illustrates the extent to which different materials are mapped across the side of the moon that faces Earth. (Credit: NASA.)

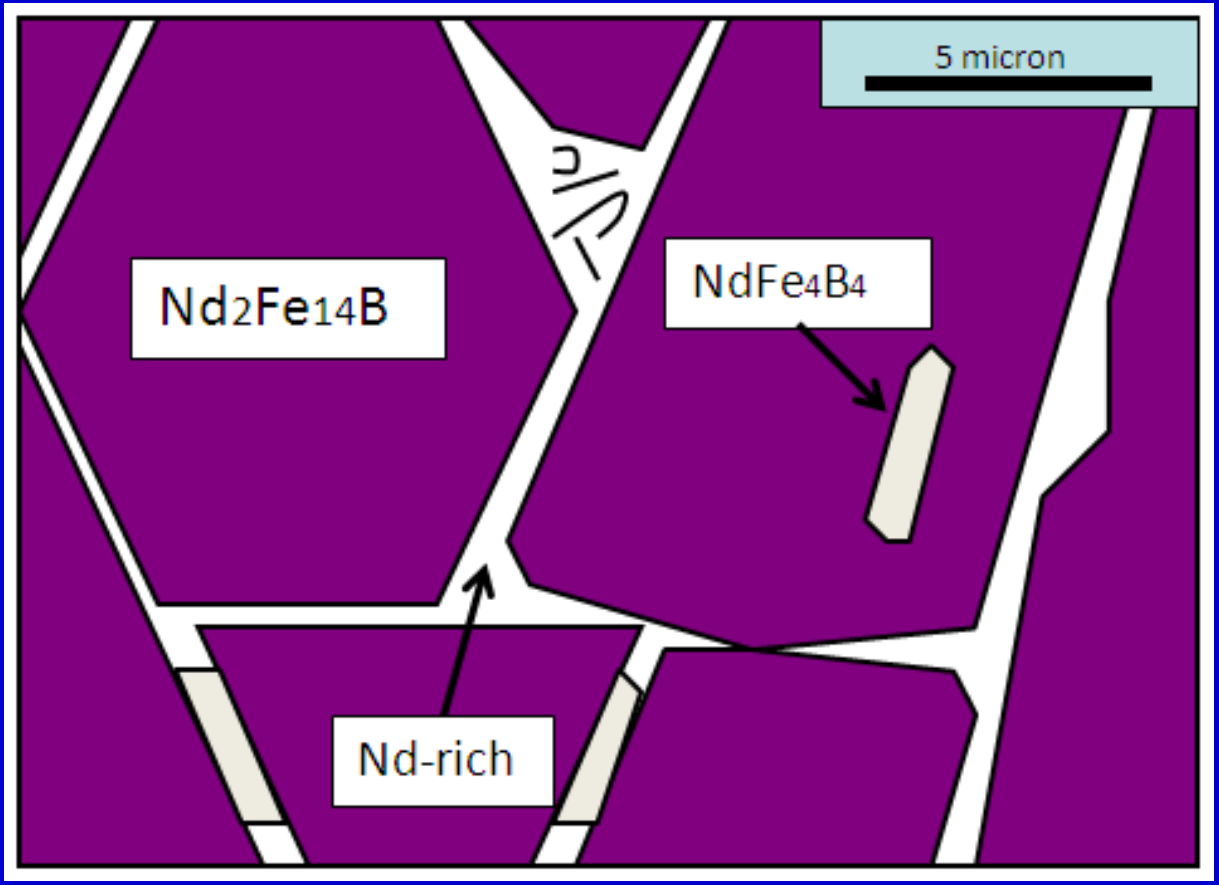
Lunar mining may be in our not-so-distant future, as evidence of rare earth elements is clear, and China tightens its exports, increasing demand worldwide.
“We know there are local concentrations of REE on the moon,” Carle Pieters, a planetary scientist in the Department of Geological Sciences at Brown University, and principal investigator for NASA’s Moon Mineralogy Mapper, told Space.com. “We have not sampled these REE concentrations directly, but can readily detect them along a mixing line with many of the samples we do have.”

New magnets without RE & equivalent properties to existing?

Before we think of “Lunar mining” there are ideas and reasonable believes that we can progressively remove Rare Earth’s from RE-Permanent Magnets by:

1. substituting RE at the grain boundaries and
2. substituting the main magnetic hard phase with the new one

Microstructure of Nd-Fe-B Permanent Magnets



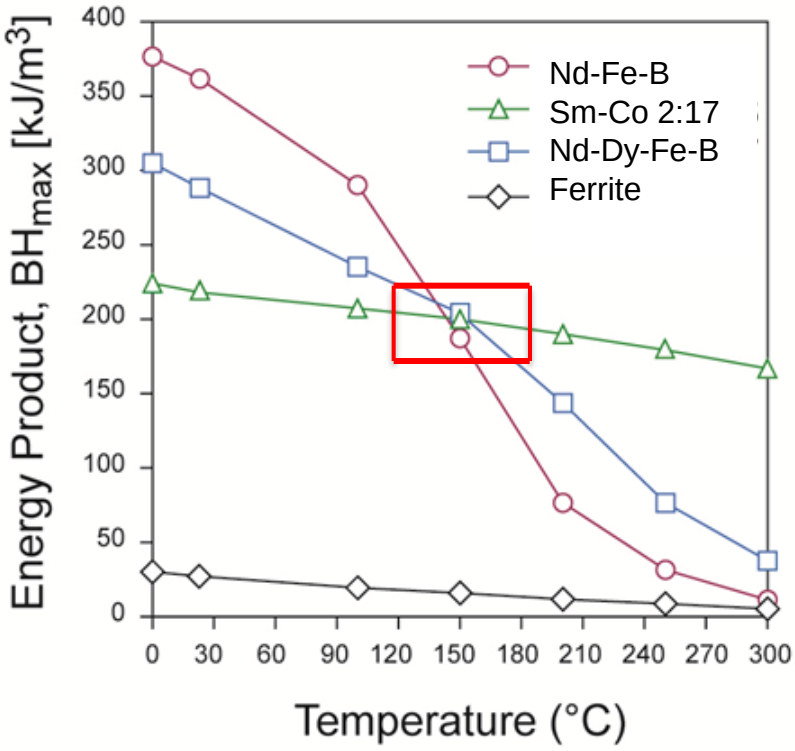
Total amount of Rare-Earth is 32 – 34 wt.%

RE-rich phase at grain boundaries (7-8 wt.%)

The main goal of future focused research

The main goal of **2000+kA/m** coercivity values is

a vital requirement for magnets to be used in EVs, HEVs and large wind turbines.



Effect of temperature on magnetic properties for a variety of magnetic materials

The strongest R/D Groups in Europe active in the field

Leibniz Institute for Solid State and Materials Research, Dresden, DE

Institut Néel, Grenoble, FR

Trinity College, Dublin, IE

St. Pölten University of Applied Sciences, AT

Vienna University of Technology, AT

Jožef Stefan Institute, Ljubljana, SI

Vacuumschmeltze, GmbH, DE

KOLEKTOR Worldwide, SI

SIEMENS, GmbH, DE

Future Benefits of Concerted Action

- **Eliminating the dependence on REs** will reverse the distortion of the market.

- Existing and new European companies will achieve success based **on high-tech processing** rather than with access to raw materials.

- The change in market conditions and the re-impacting of EU-based companies will see **key European-trained scientists** now working in China and the Far East attracted back to Europe – **a reversal of the brain drain** – where they can rapidly establish development and production facilities that will employ people in primarily knowledge-based jobs.

- Europe can get back its **20+% share of this €1 billion** market if we act quickly – all it needs is **an independence from REs**, that a breakthrough in technology will allow.

Concerted Action US-Europe-Japan?

Thank you for your attention!