# Nd-Fe-B

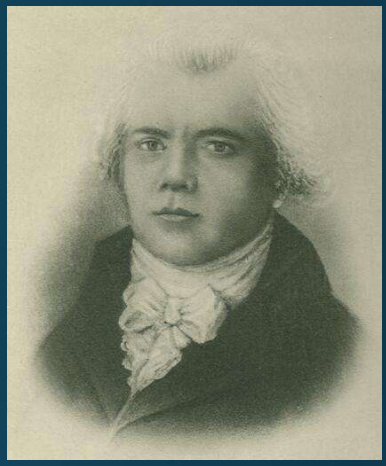
Paul McGuiness

- Where to start?
- Rare earths discovered in Europe
- Trouble in Africa
- How to make magnets without cobalt
- How to make Nd-Fe-B magnets
- Hydrogen Decrepitation
- Things we didn‘t talk about
- What have we learned?
- Some ideas for what remains to be done

600 BCE years ago lodestones, a natural magnetic material $Fe_3O_4$
1088, Shen Kuo described the magnetic needle compass
1600, William Gilbert concluded that the Earth was a magnet
1930s, Japanese researchers produced the first Alnico magnet
1940s, the first hard ferrites made in the Netherlands
1960s, Sm-Co magnets developed by theRaytheon Corporation
1980s, groups from the US and Japan discover Nd-Fe-B

But let's start in 1794

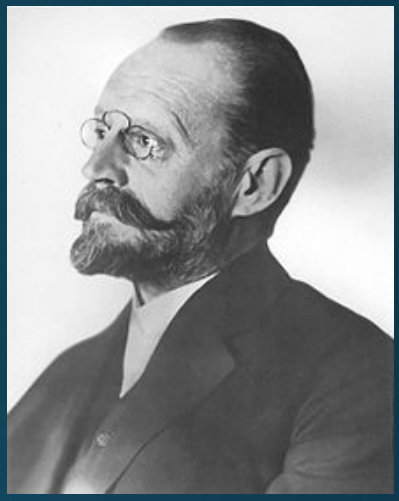
1793 he was give a lump of black material, like coal, by Karl Arrhenius, which was found in a pit near the town of Ytterby

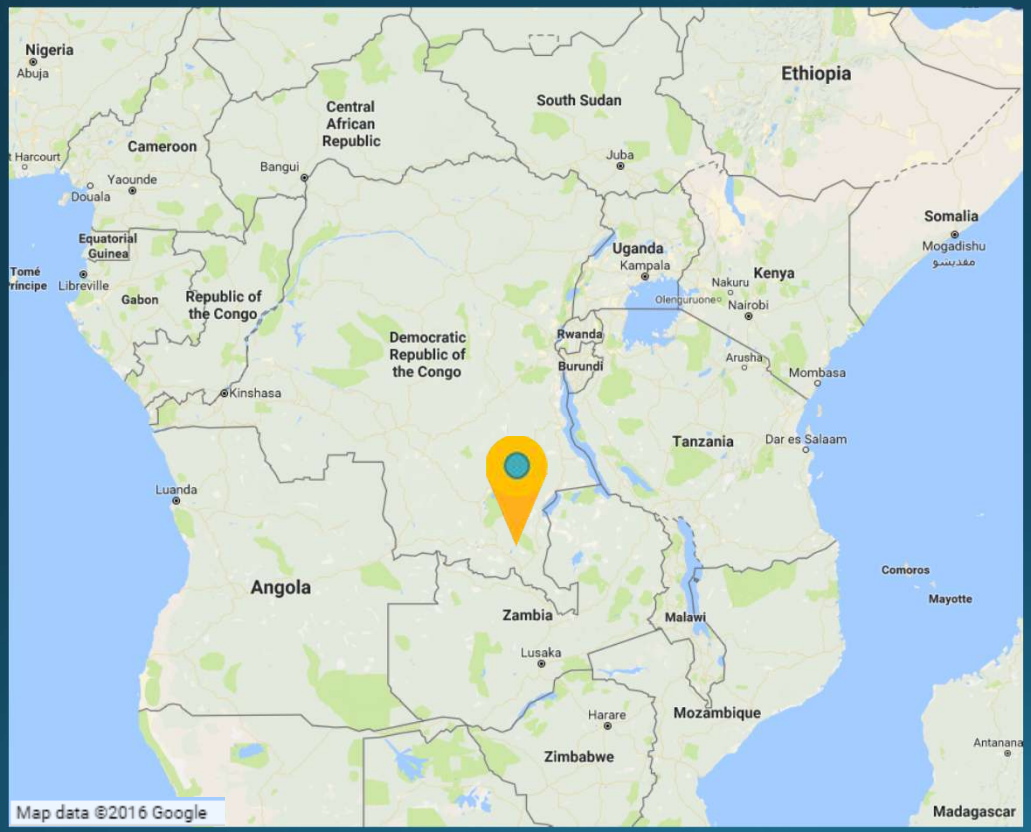
Johan Gadolin
(1760-1852)

*Rare earths discovered in Europe*

| | |
|---|---|
| 1794 | Yttrium |
| 1803 | Cerium |
| 1839 | Lanthanum |
| 1843 | Erbium |
| 1878 | Terbium |
| 1878 | Ytterbium |
| 1879 | Samarium |
| 1879 | Scandium |
| 1879 | Holmium |
| 1879 | Thulium |
| 1880 | Gadolinium |
| 1885 | Praseodymium |
| 1885 | Neodymium |
| 1886 | Dysprosium |
| 1896 | Europium |
| 1907 | Lutetium |



Carl Auer von Welsbach
(1858-1929)

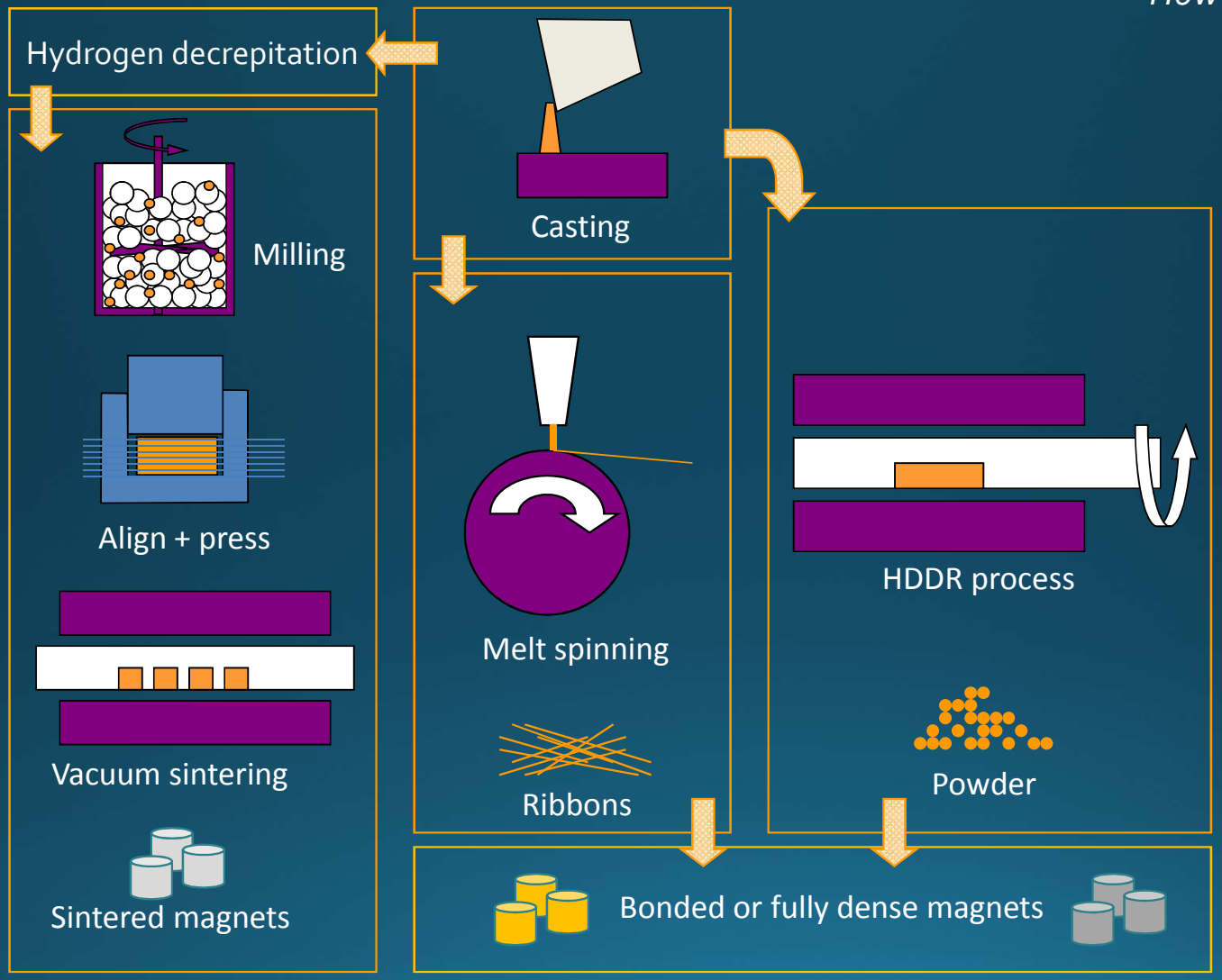


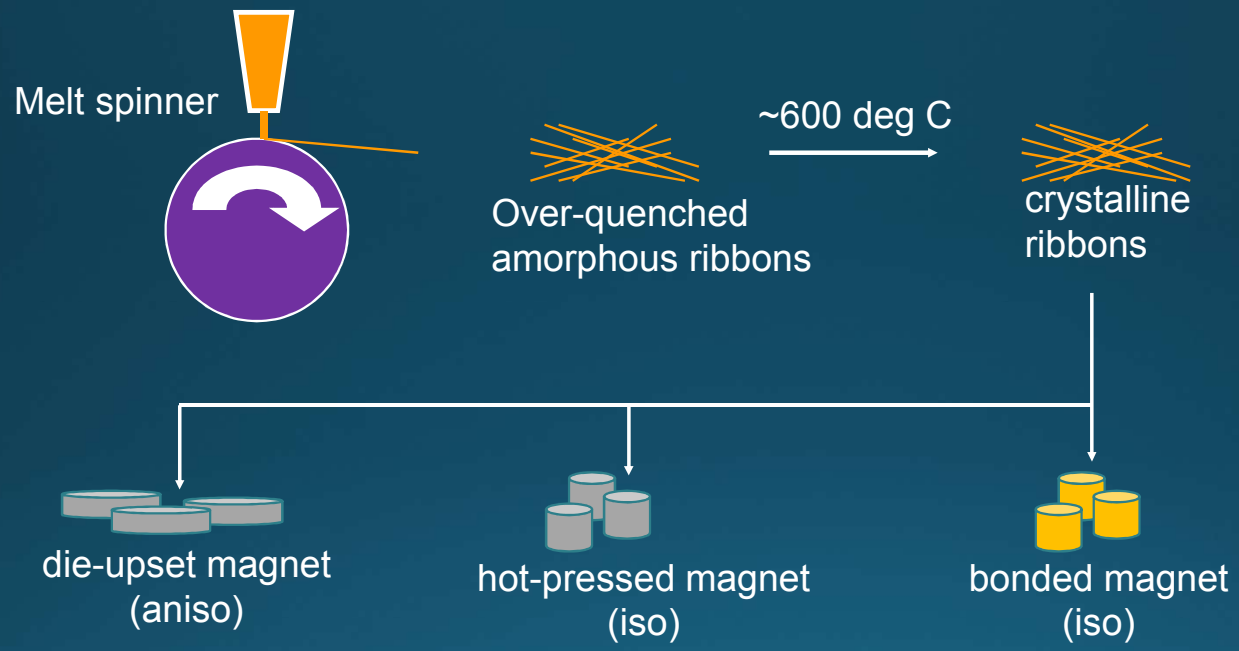

Mobutu Sese Seko
(1930-1997)

*How to make magnets without cobalt*


Masato Sagawa

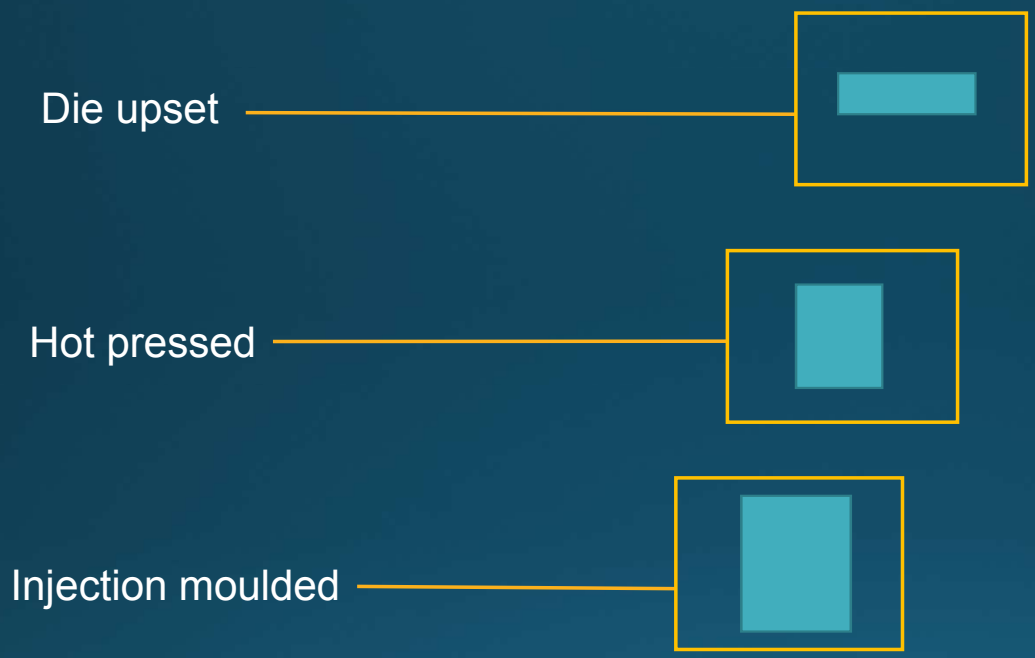
*How to make Nd-Fe-B magnets*

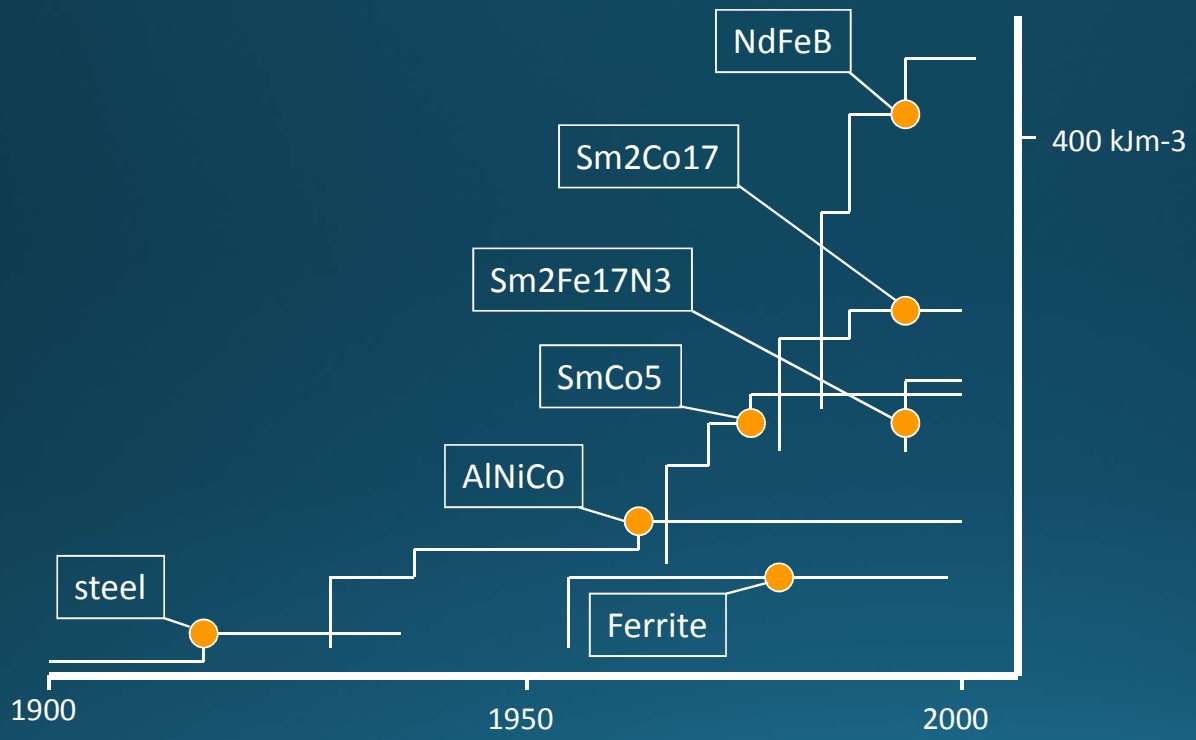


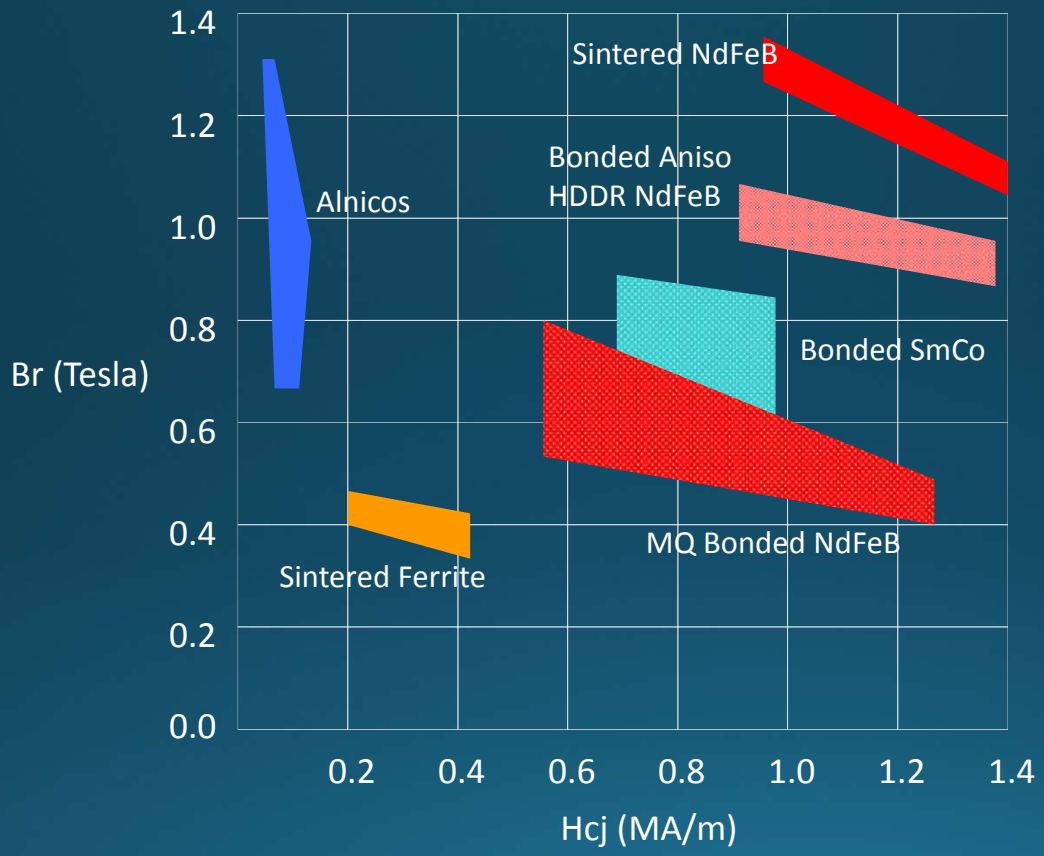

Melt spinner
Over-quenched
amorphous ribbons
~600 deg C
crystalline
ribbons
die-upset magnet
(aniso)
hot-pressed magnet
(iso)
bonded magnet
(iso)


melt-spinning

as-spun ribbons


Die upset
Hot pressed
Injection moulded


NdFeB
Sm2Co17
Sm2Fe17N3
SmCo5
AlNiCo
steel
Ferrite
400 kJm-3
1900
1950
2000


1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Br (Tesla)
Sintered NdFeB
Bonded Aniso
HDDR NdFeB
Alnicos
Bonded SmCo
MQ Bonded NdFeB
Sintered Ferrite
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Hcj (MA/m)

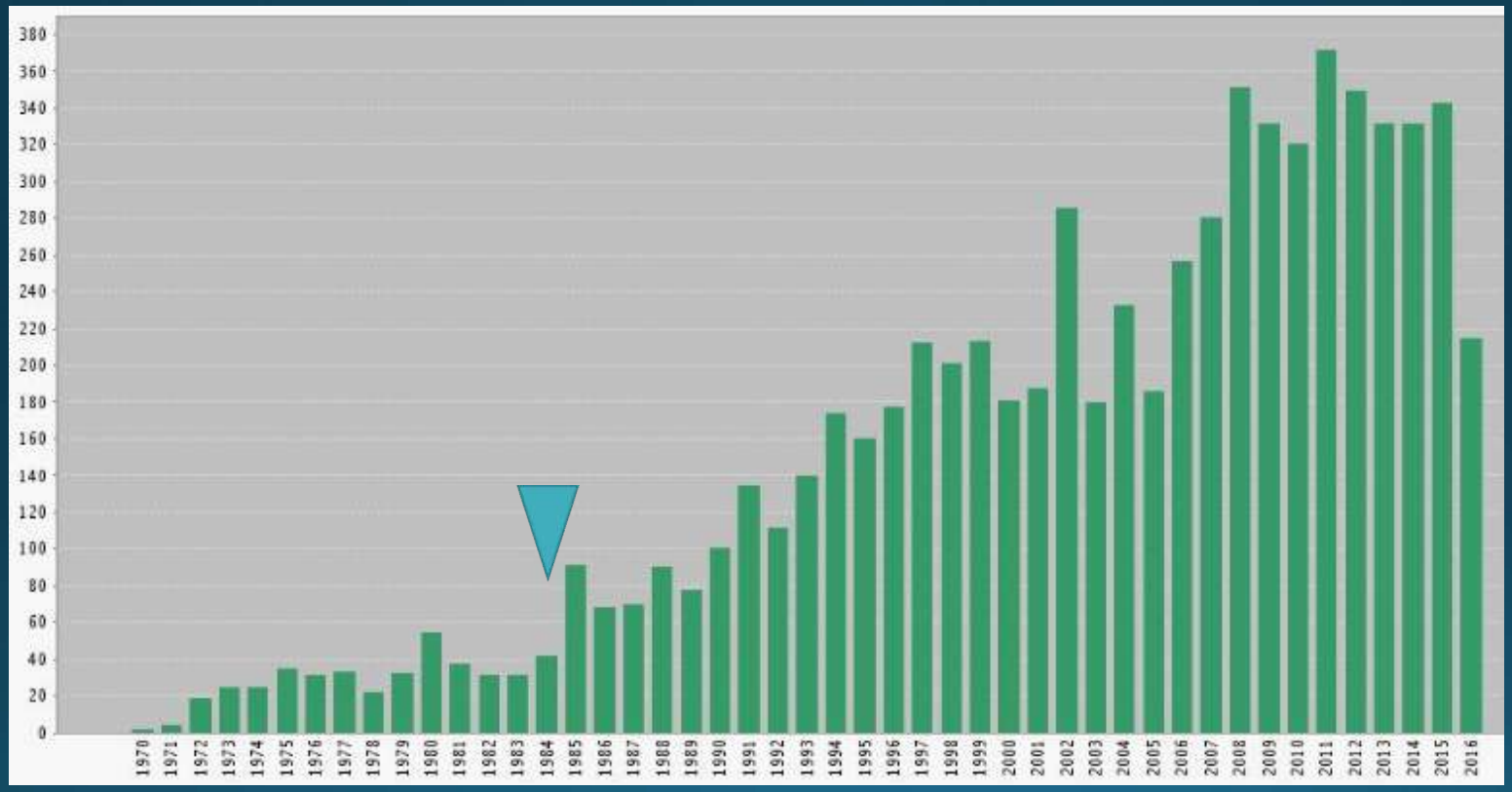
CONSTITUTION, STRUCTURE AND MAGNETIC-PROPERTIES OF SOME RARE-EARTH-COBALT-ALUMINUM ALLOYS
By: EVANS, J; HARRIS, IR
JOURNAL OF MATERIALS SCIENCE Volume: 17 Issue: 1 Pages: 17-30 Published: 1982

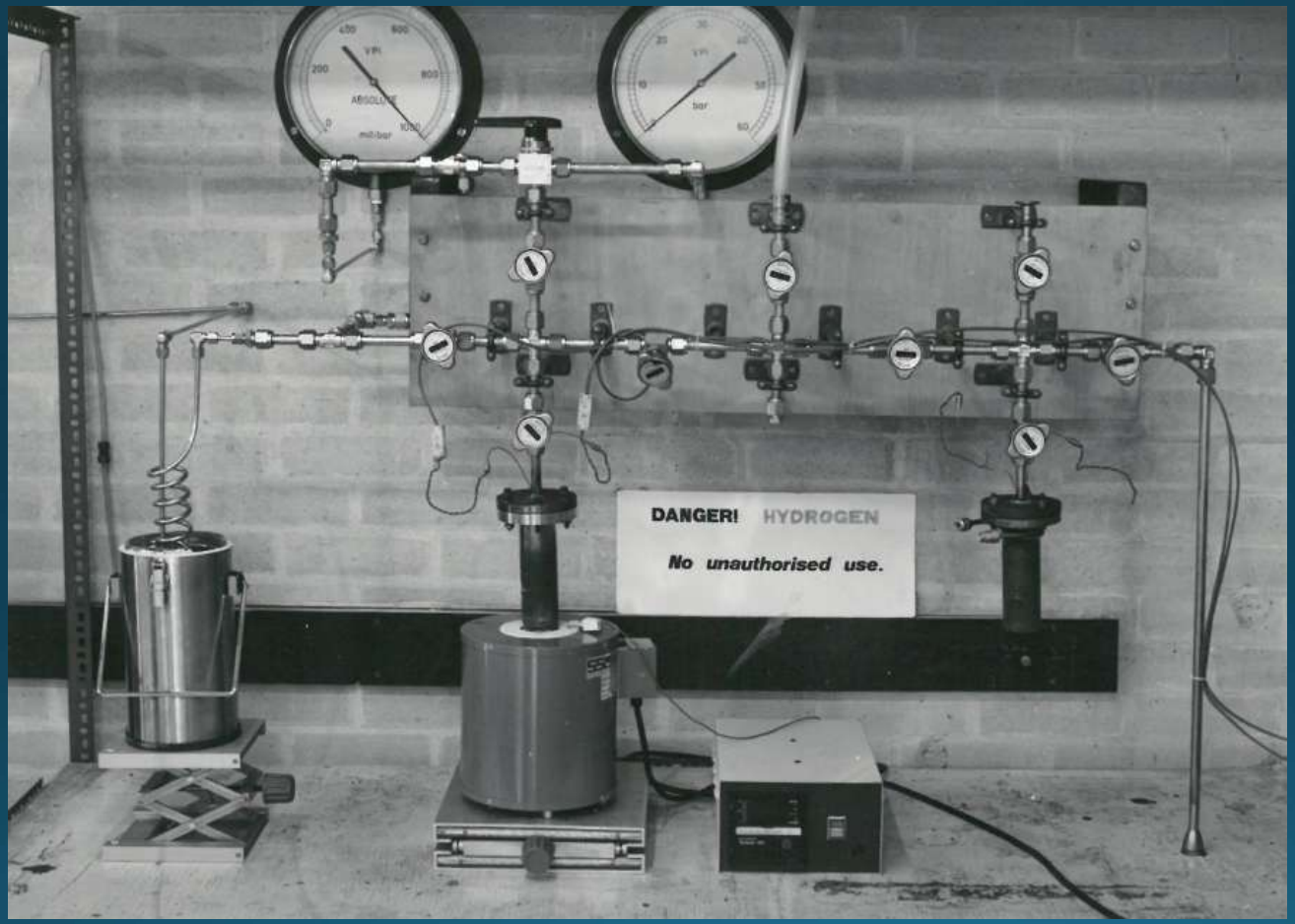
A PROPOSED METHOD OF HYDROGEN ISOTOPE-SEPARATION USING PALLADIUM ALLOY MEMBRANES
By: EVANS, J; HARRIS, IR; ROSS, DK
JOURNAL OF THE LESS-COMMON METALS Vol.: 89 Issue: 2 Pgs: 407-414 Published: 1983

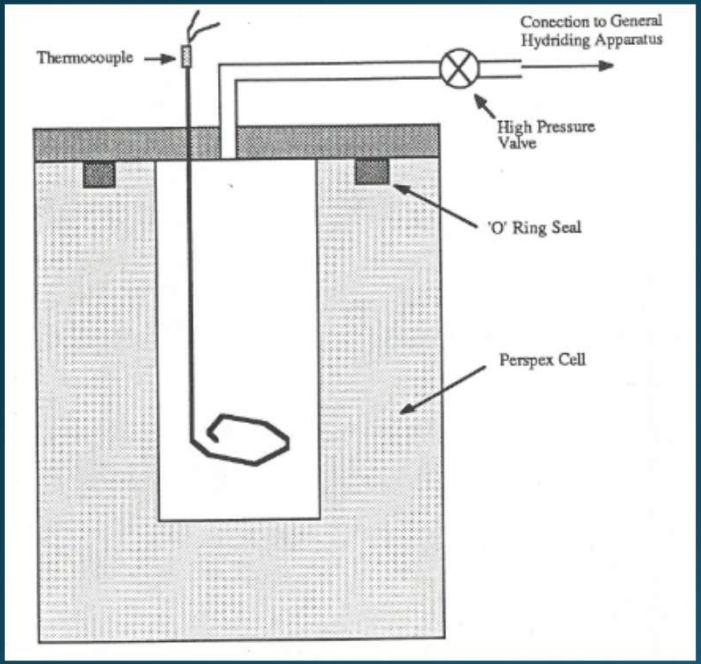
EFFECT OF QUENCHING ON THE MAGNETIC-BEHAVIOR OF SOME NI-RICH NIAL ALLOYS
By: KILNER, JA; HARRIS, IR
JOURNAL OF MATERIALS SCIENCE Volume: 16 Issue: 12 Pages: 3398-3404 Published: 1981

Rex Harris
(Univ Bham)

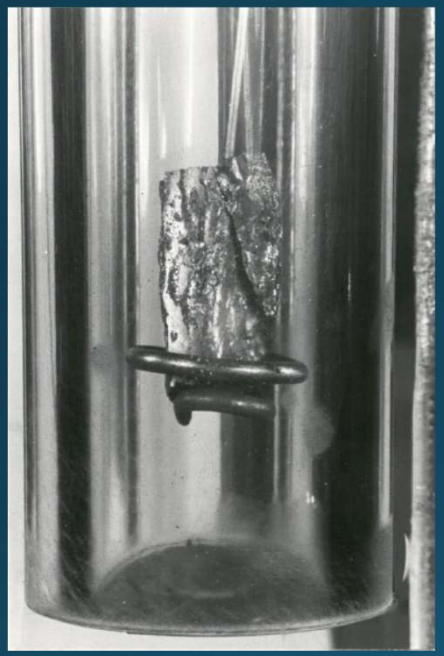
IR Harris 1972-2016




DANGER! HYDROGEN
No unauthorised use.


Thermocouple
Conection to General
Hydriding Apparatus
High Pressure
Valve
'O' Ring Seal
Perspex Cell

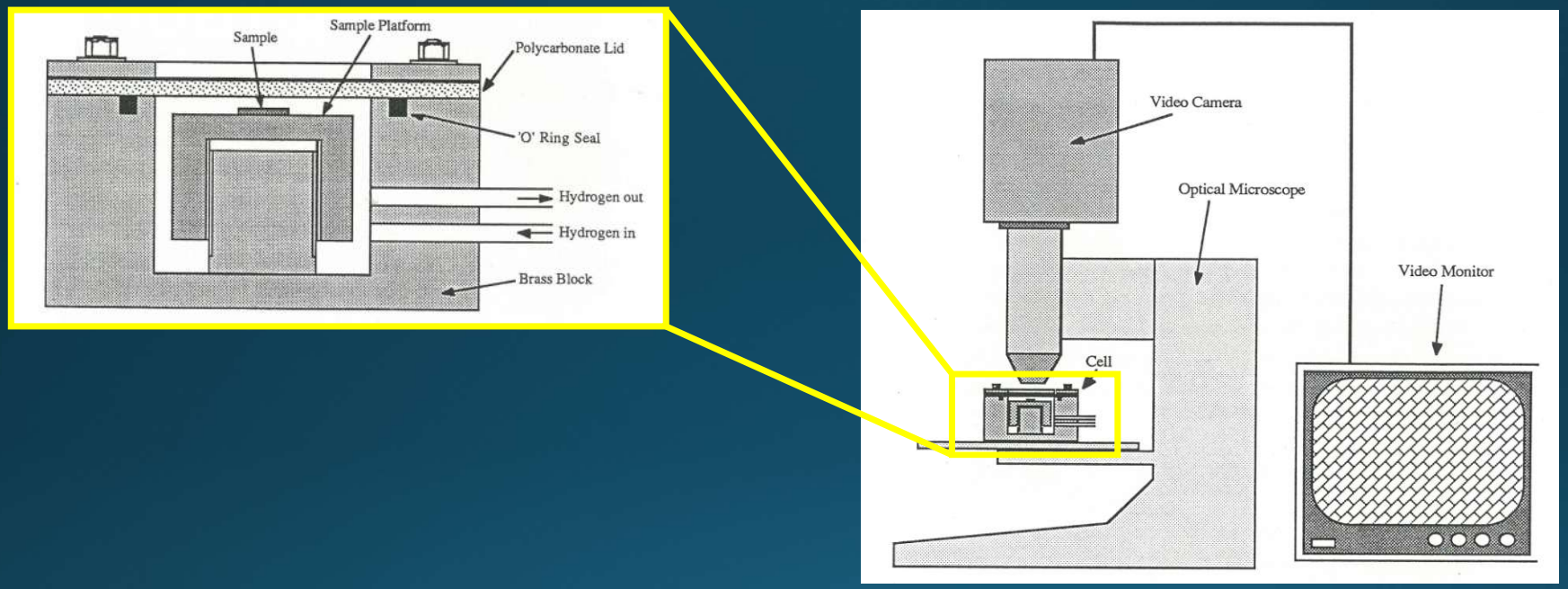
0 secs



300 secs

900 secs

1200 secs

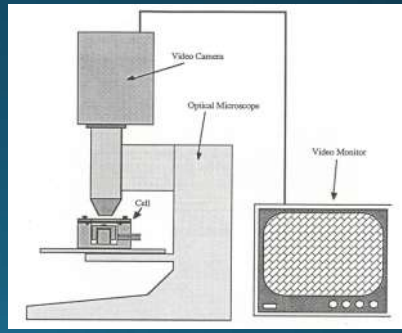

Sample
Sample Platform
Polycarbonate Lid
'O' Ring Seal
Hydrogen out
Hydrogen in
Brass Block
Video Camera
Optical Microscope
Video Monitor
Cell

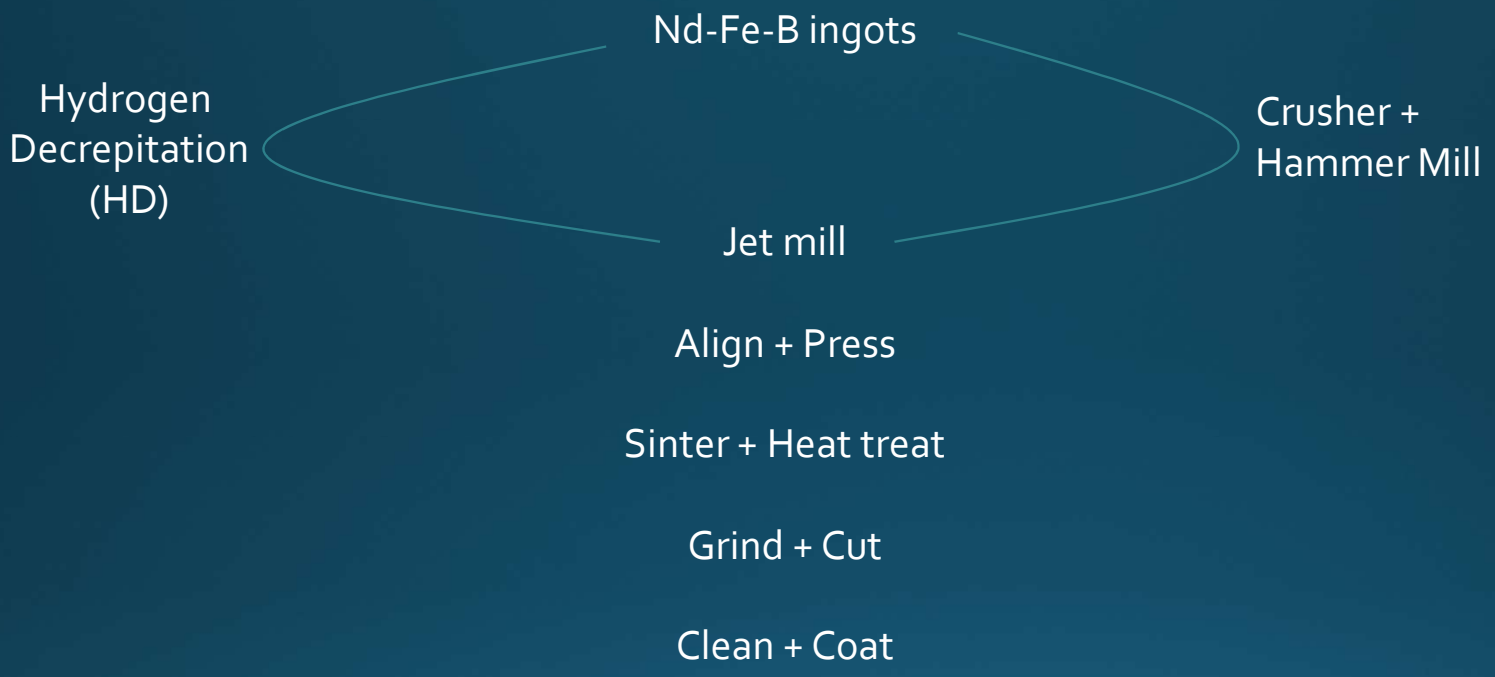

3600 s


4500 s


3900 s


4800 s


Video Camera
Optical Microscope
Video Monitor
Cell


Nd-Fe-B ingots
Hydrogen Decrepitation (HD)
Crusher + Hammer Mill
Jet mill
Align + Press
Sinter + Heat treat
Grind + Cut
Clean + Coat

*The CEAM project*

Mike Coey
(Trinity College Dublin)

Dominique Givord
(CNRS)

Rex Harris
(Univ Bham)

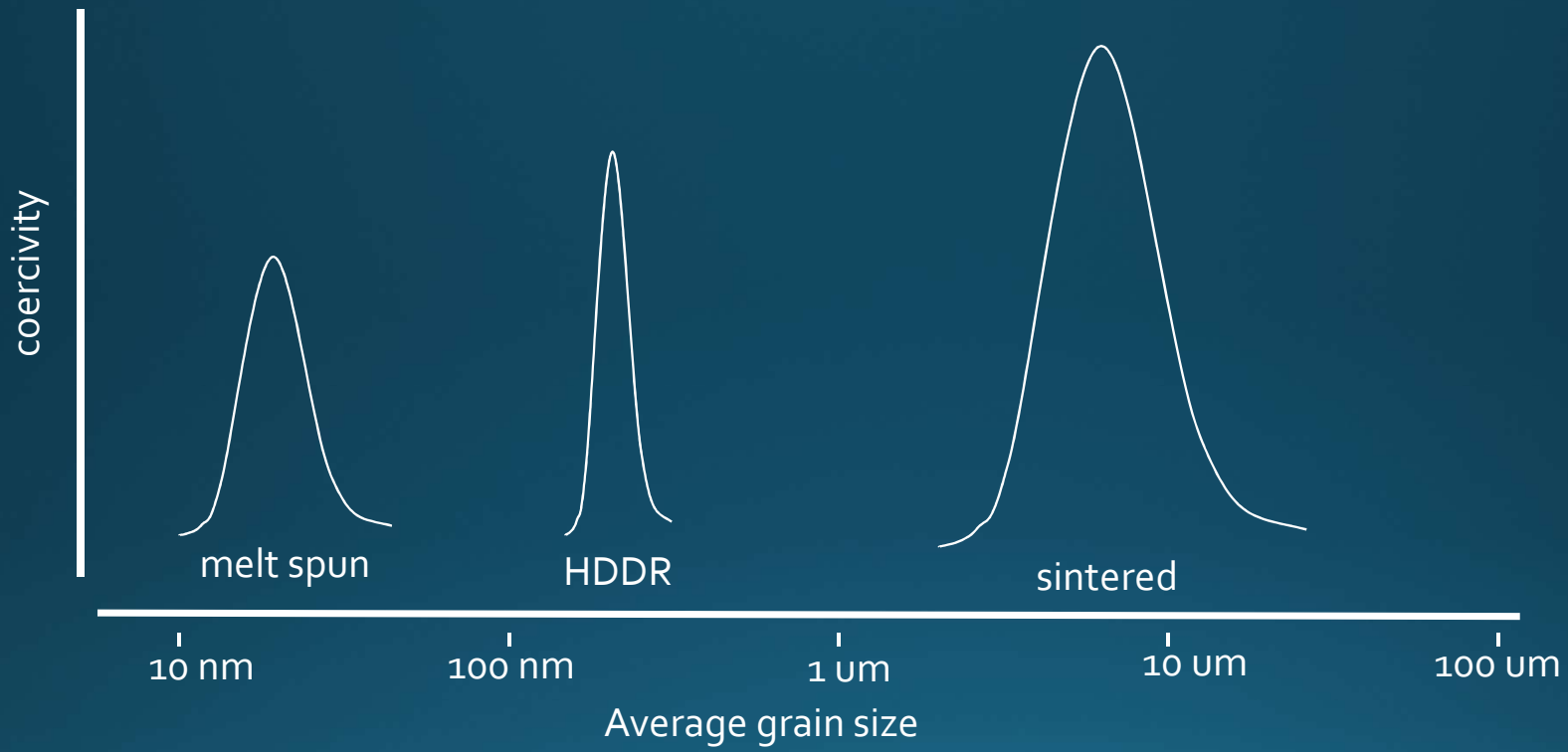
Rolf Hanitsch
(TU Berlin)

58 laboratories and more than 120 scientists and engineers in a sustained thirty month effort. It spanned every aspect of new iron-based high performance magnets from theoretical modelling of their intrinsic magnetic properties to the design and construction of novel electrical devices and machines. Besides adding a new European dimension to advanced magnetic technology, CEAM also ensured that a whole new generation of young researchers and technicians have been trained in applied magnetism.

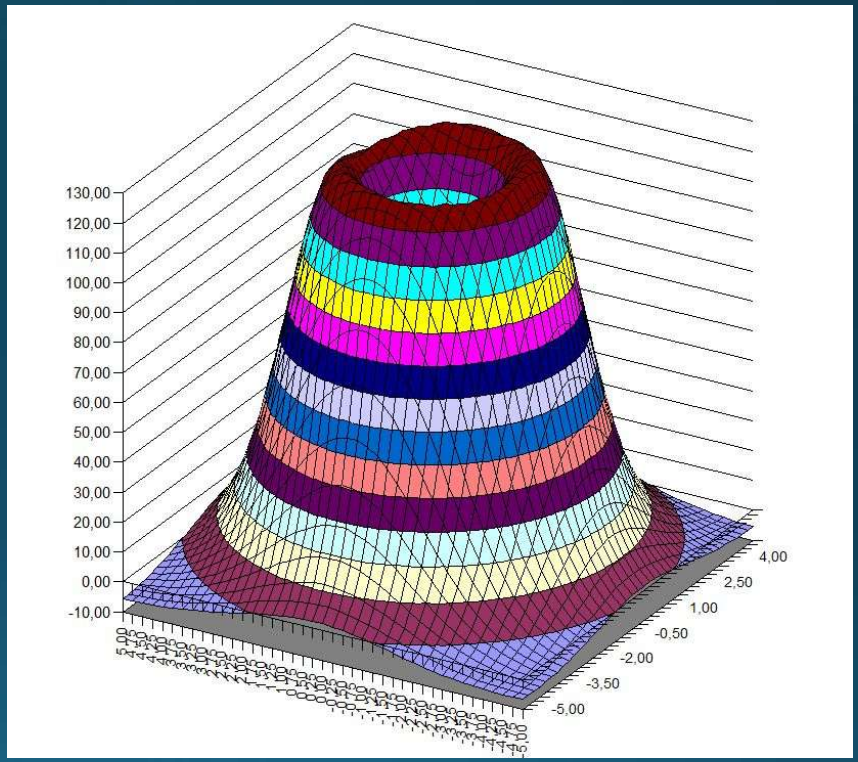
## *Things we didn't talk about*

- Microscopy, scanning, transmission, etc.
- Micro-analyses, EDX, WDX, Auger, etc.
- Modeling, ab-initio calculations, etc.
- Corrosion, coatings, etc.
- Applications
- Producing alloys, casting, etc.

*Some ideas for what remains to be done*

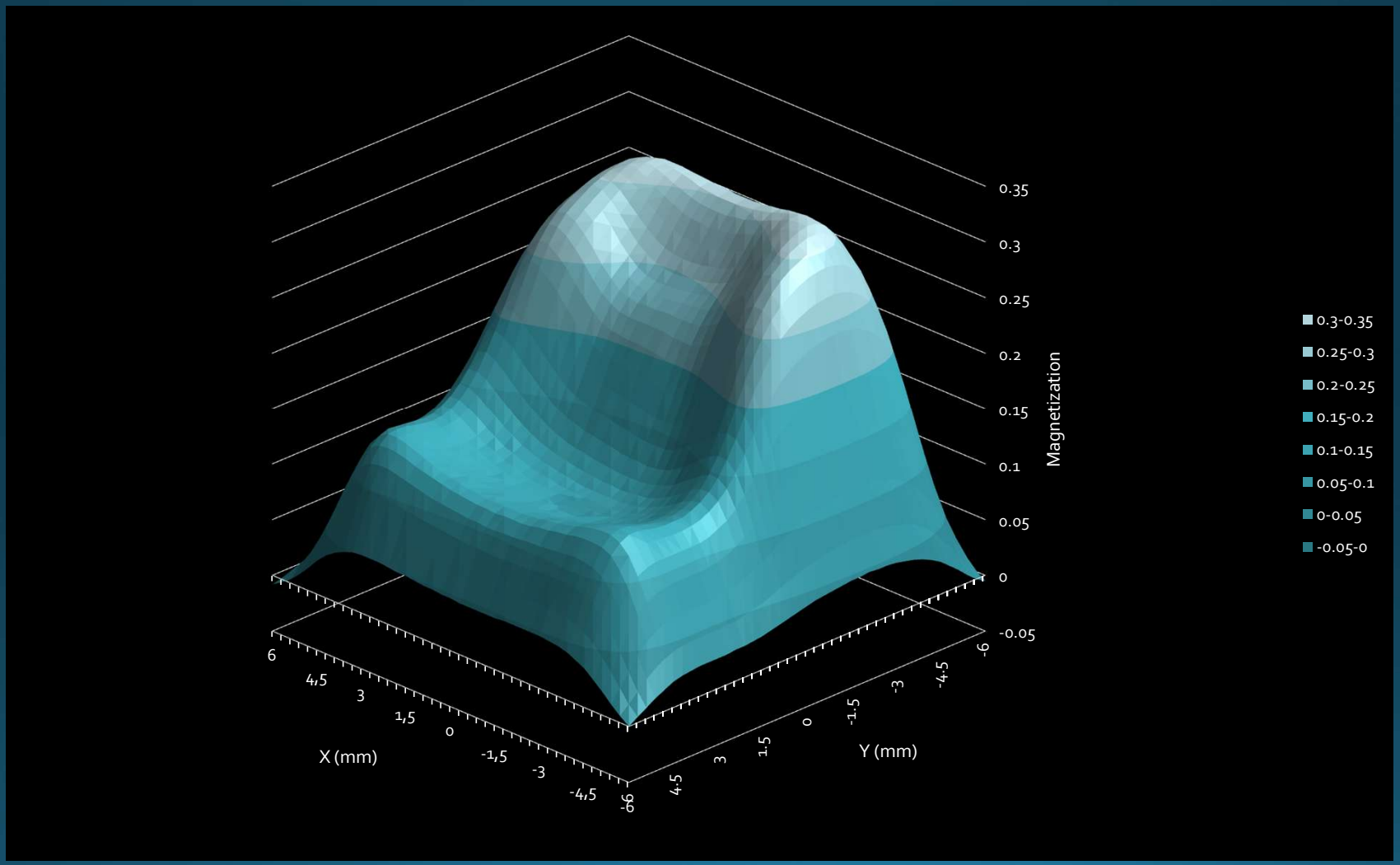


Half GBDP sample:



*Some ideas for what remains to be done*

# Stage 2 demagnetization



- Don't get too focused – look around you for ideas
- For industry to accept new ways, they have to be straightforward to implement
- Looking for new permanent-magnet materials is very blue sky
- 30 years of research means properties are close to peaking