Development of Improved Powder for Bonded Permanent Magnets

Anisotropic Magnets:

AMES LABORATORY

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Magnet Production Techniques

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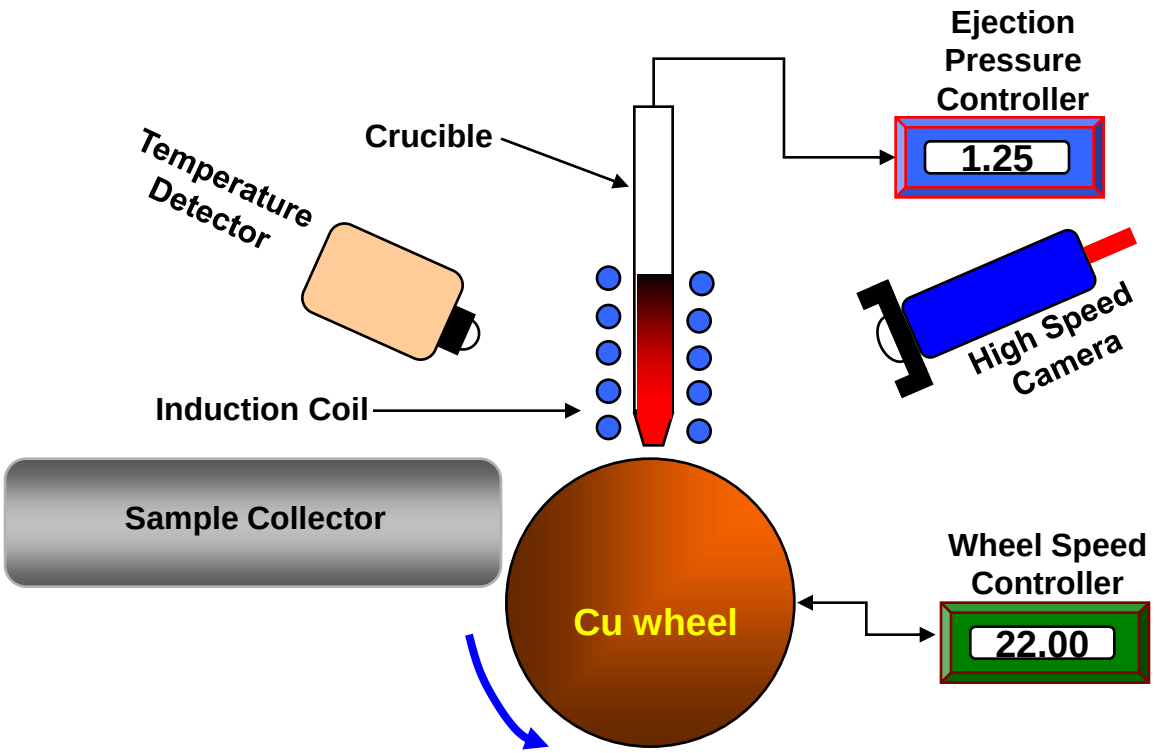
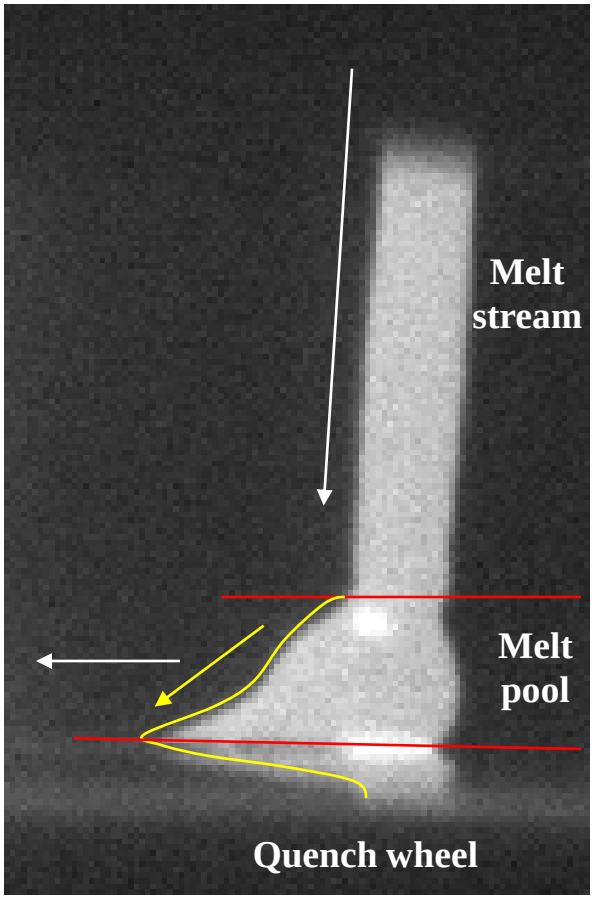
Melt Spinning Technique





Gas Atomization

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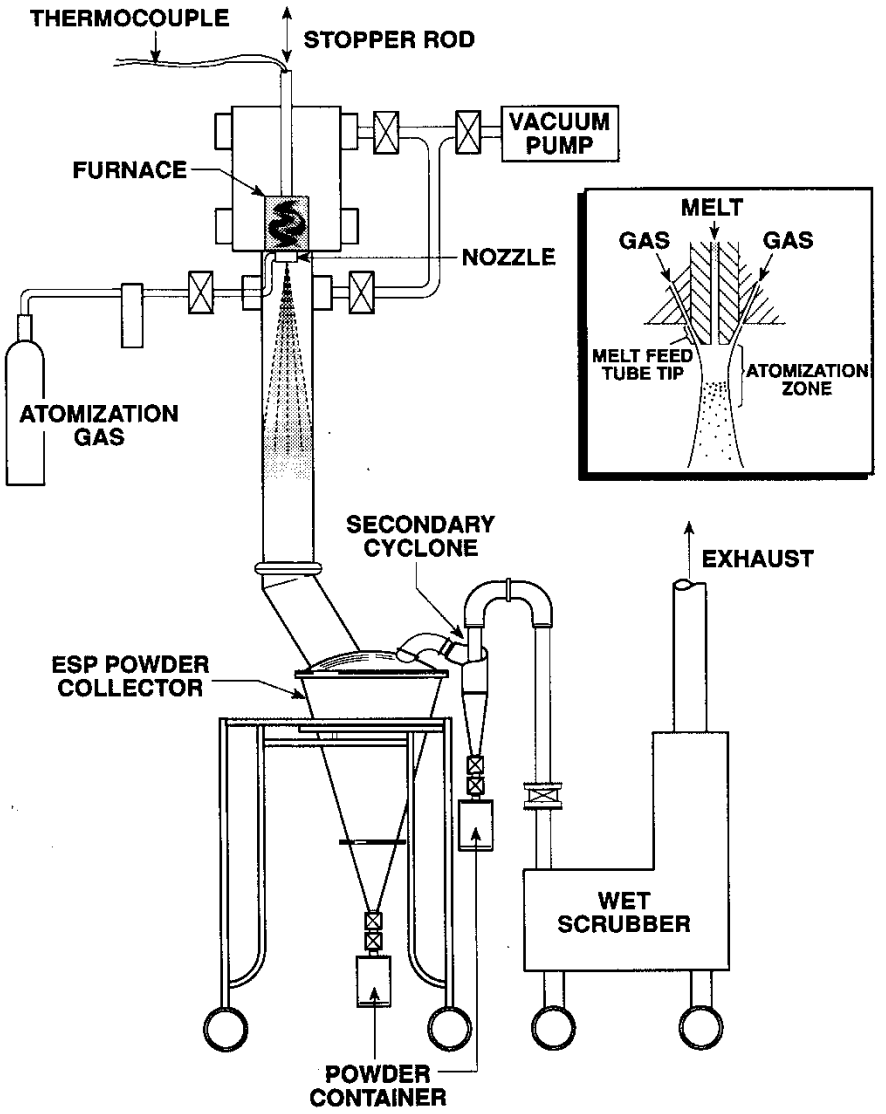
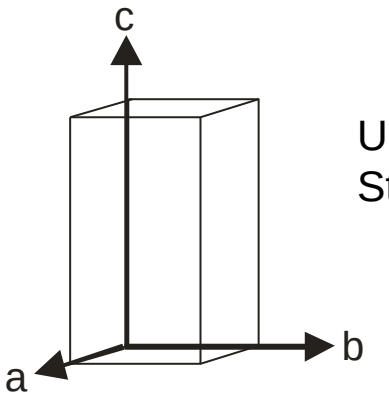
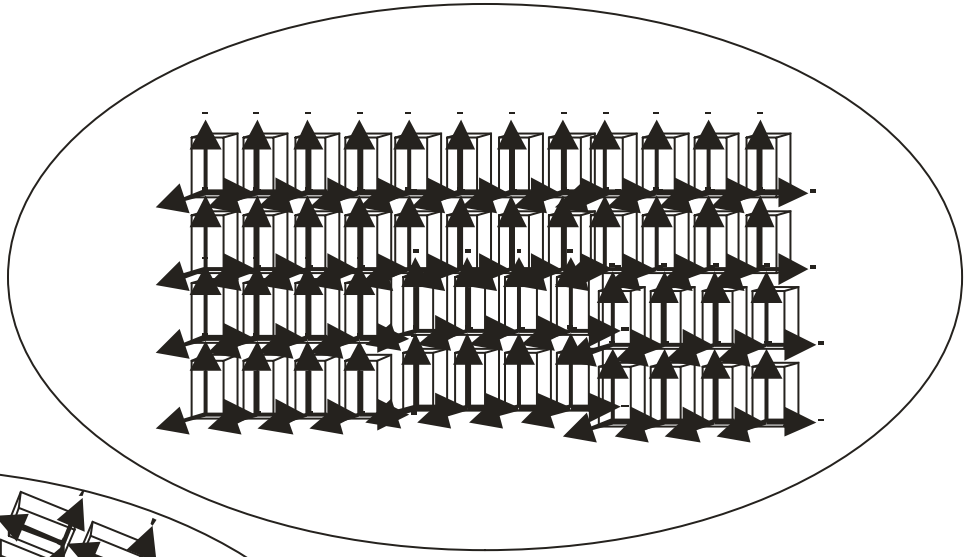


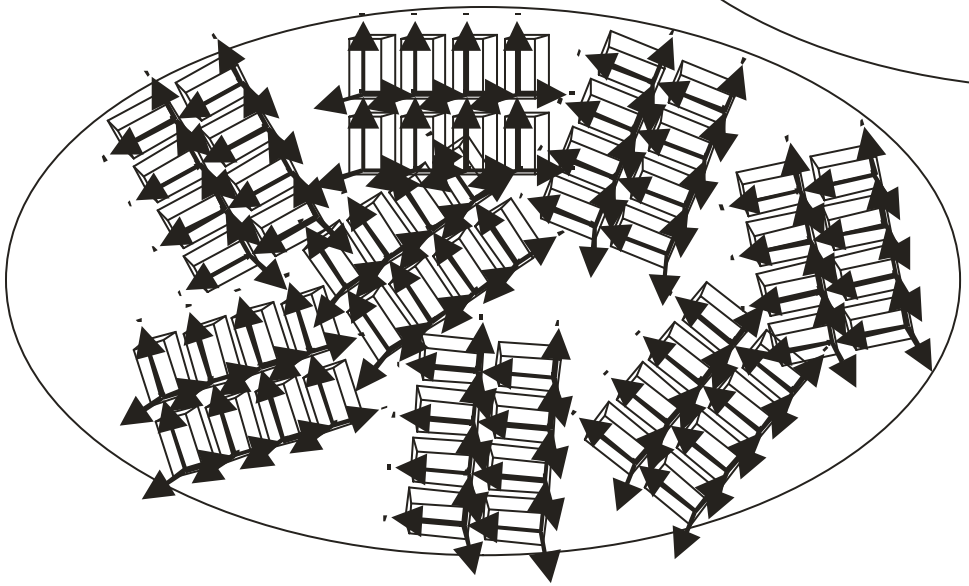
Powder Particle Structure



Uniaxial Crystal Structure



Single grain particle



Polygrained particle

Anisotropic Magnets: Benefits

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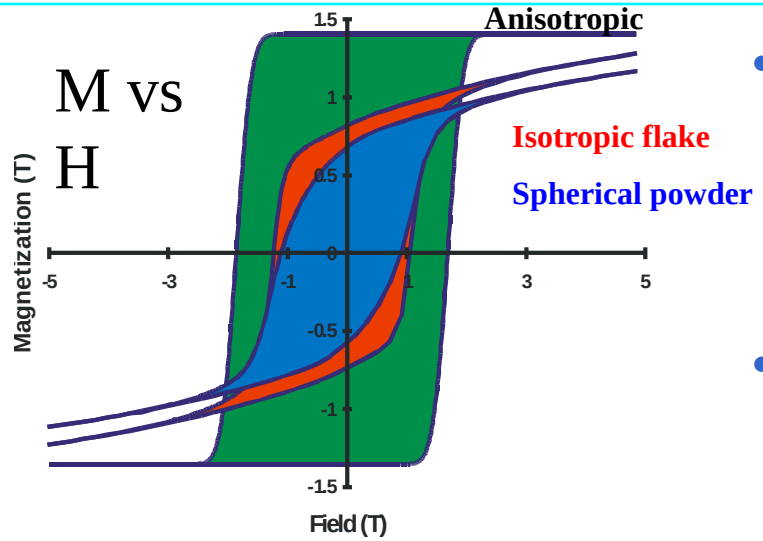

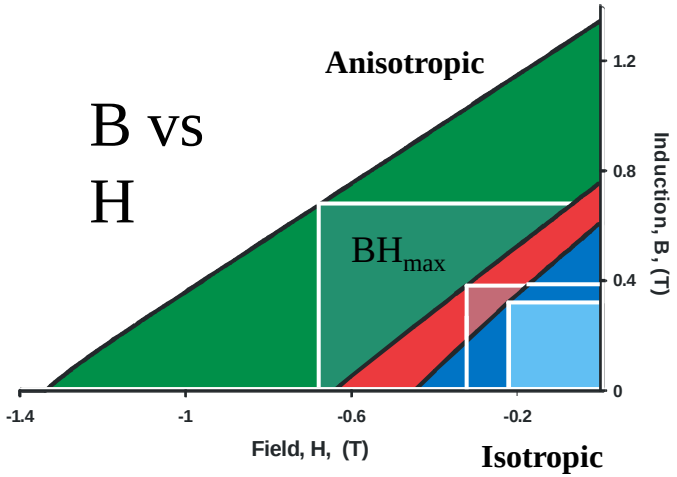

- **Anisotropic magnets**
  - 2 times the remnant magnetization (Br) of same type isotropic magnets
  - 4 times the energy product (BH_{max}) of same type isotropic magnets
- **Sintered Magnets**
  - Highest energy product
  - Highest Remnant
- **Anisotropic bonded magnets**
  - Potential for 70% BHmax of sintered magnet
  - Superior mechanical properties
  - Superior corrosion resistance
  - Superior ease of manufacture
    - net shape molding

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Anisotropic Magnets: Benefits and Drawbacks

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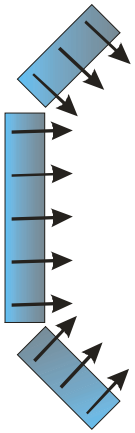
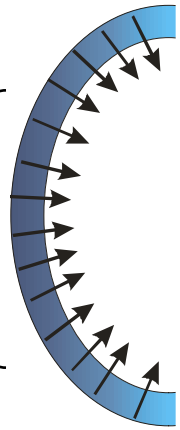
anisotropic sintered PM



Benefits	Drawbacks
Maximum magnetic flux	Fixed/single direction of magnetization
Established fabrication and assembly processes	Metallic conductor (high eddy current loses)
Well known motor designs	Brittle (limited shapes)
	Spark cut (depends on low-cost labor)

high temperature anisotropic bonded PM



Reduced cost/robust/high temperature operation	B_r reduced by fill factor, f
Directed anisotropy and magnetization	BH_{max} reduce by f^2
Electrically insulated (low eddy current loses)	High risk particulate material/bonding process
Insert molded (net shape)	New motor designs needed

Magnet properties

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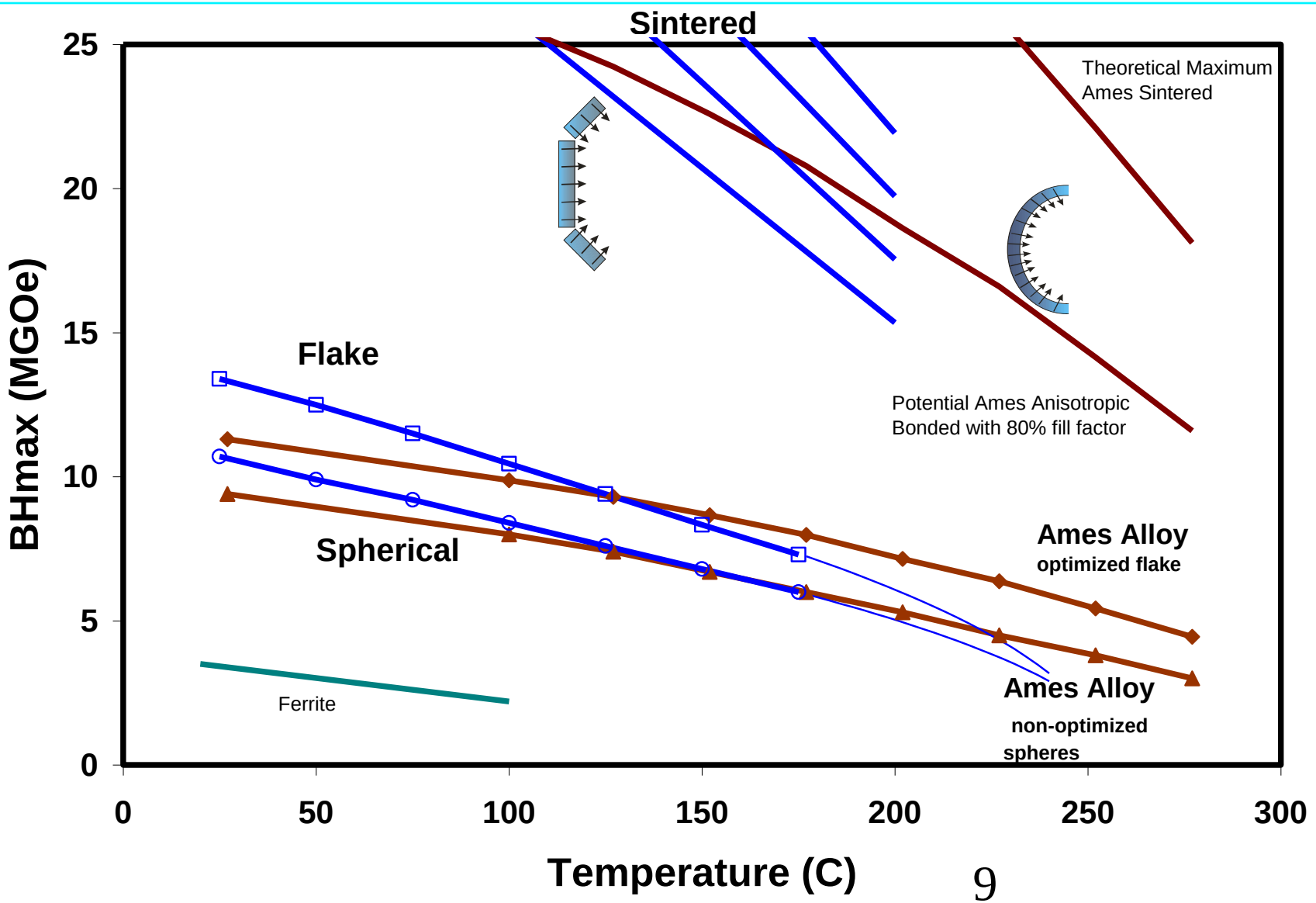

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Anisotropic Bonded Barriers

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- Requires high coercivity single grain particles
  - 1-3 μm size
  - Smooth particle surface
- Consolidation and alignment
  - Net shape
    - Modification of existing technology
  - Injection molded
    - Requires technology to align during molding
- Variation
  - Metal matrix magnet

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Anisotropic Sintered Magnet Processing

Ames Alloy Barriers

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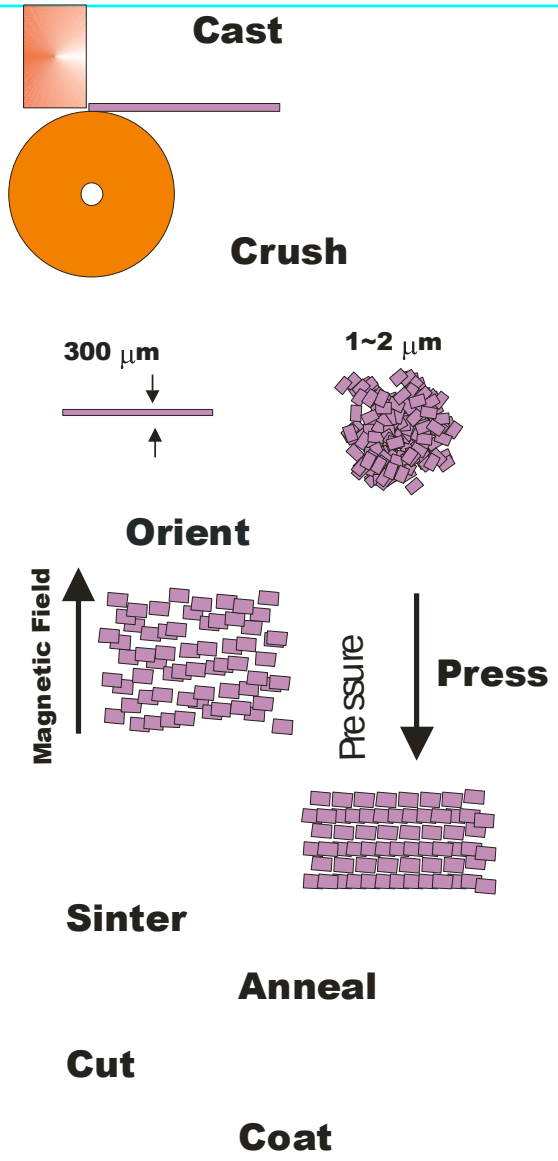

- Ingot or strip cast
- Crush to 1 ~2 μm
- Orient in a magnetic field
- Press
- **Liquid Phase Assisted Sinter** (high T)
  - Results in high density material
  - Standard Nd2Fe14B alloys contain low melting Nd-Fe eutectic (685 C), inherent liquid phase sintering aid
  - Ames alloy lowest liquid ~ 1050 C
    - Requires added liquid phase compatible with alloy
    - Opportunity to enhance corrosion resistance
    - Opportunity to enhance mechanical strength
- **Post Sintering Anneal** (low T)
  - Required to provide smooth grain boundaries
    - Necessary to develop coercivity
    - Dependent on liquid phase properties
- Cut to shape
- Corrosion Coating

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