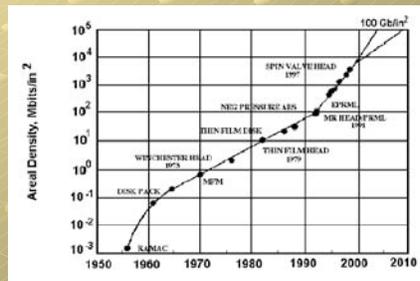# The Fe-Pt system for perpendicular magnetic recording.

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May 11, 2004

Magnetic Recording

- Growth rate 40%/year
- Continuous donwscaling
- Price per megabyte
  - $200 in 1980
  - $0.02 in 2004
- Today:
  - 70 Gbit/in^2 in market
 - 150 Gbit/in^2 in lab
- Need for high density

The Goal: 1Tbit/in^2

- Industry's goal:
  - Keep on improving areal density with minimum changes in technology
- Possible in theory
- Problems:
  - Signal to Noise Ratio (SNR)
  - Superparamagnetic Limit

Challenges

- Signal to Noise Ratio
  - Inherent to polycrystalline media
  - Reduction of recording bit needs to be accompanied by reduction in particles size (grains)
  - Reduction in grain size
    = reduction in volume
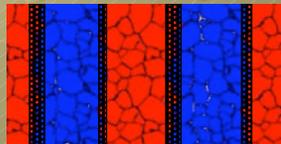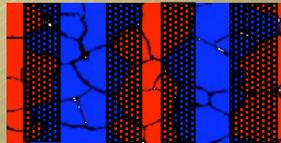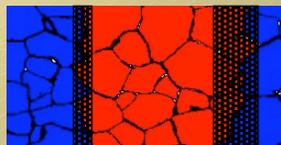
Challenges

- Superparamagnetic Limit
  - Thermally activated
  - Energy barrier: $\mathbf{K_uV}$ ("Magnetic Hardness")
  - Reduction in $\mathbf{V}$ needs increase in $\mathbf{K_u}$
  - ~10 nm on today's media

$$P = f \cdot e^{\left(\frac{K_uV}{kT}\right)}$$

Why FePt?

Magnetically significant parameters for different alloy systems

Material	K_u [erg/cm^3]	M_s [emu/cm^3]	T_c [K]	D_p [nm]
Co	4.6 x 10^6	1400	1393	7.5
CoPt	1.7 x 10^7	530	833	4.9
FePt	7 x 10^7	1150	750	3
Nd2Fe14B	4.5 x 10^7	1281	859	3.5

- FePt: large K_u
- T_c can allow for Heat Assisted Magnetic Recording
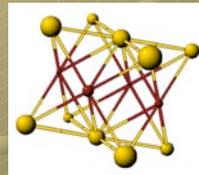- Small superparamagnetic particle size (D_p)
- Corrosion Resistant

Fe-Pt

- Phases
  - α_1, L1$_2$ Fe3Pt
  - α_3, L1$_2$ FePt3
  - α_2, L1$_0$ FePt
    - Face Centered Tetragonal
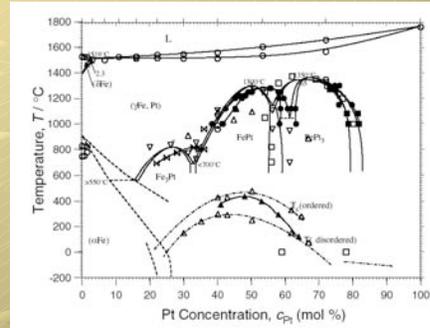
- L1$_0$ FePt
  - Layered structure
  - Uniaxial anisotropy

FePt

- (BH)$_{MAX}$ product
  - α_2, L1$_0$ FePt: 24kJ/m^3
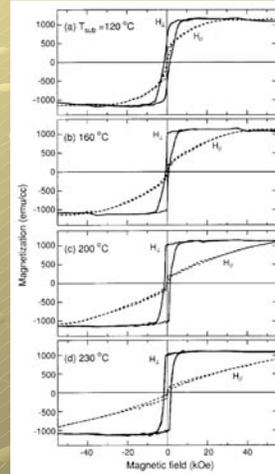 - α_1, L1$_2$ Fe3Pt: 160 kJ/m^3
    - Difficult to achieve ordering

- Ordering parameter S

$$S = 2(\gamma_\alpha - \chi_{Fe}) = 2(\gamma_\beta - \chi_{Pt})$$

  - γ_α : Fraction of Fe atoms in α sites
  - χ_{Fe}: Concentration of Fe
  - γ_β : Fraction of Fe atoms in β sites
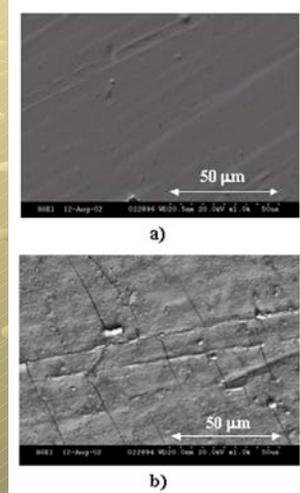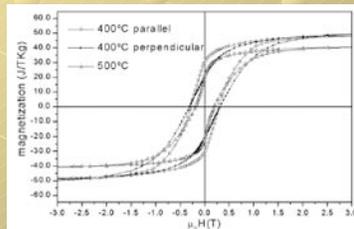 - χ_{Pt}: Concentration of Pt

FePt MBE Deposition

- Molecular Beam Epitaxy
  - Achieve (001) growth:
    - MgO or Al_2O_3 + Pt buffer layer
  - Monoatomic layer deposition
  - Heated substrate
  - Long deposition time

FePt Electrodeposition

- Electrodeposition
  - Simultaneous: Fe + Pt
  - Excellent surface finish*
  - H_c: 10% of normal value
  - K_u: almost non-existing

FePt Magnetron Sputtering

- **Magnetron Sputtering**
  - Monoatomic layer deposition
  - Low substrate temperatures
  - Requires post-deposition ordering

FePt High Pressure Sputtering

- High Pressure Sputtering
  - Ar pressure controls incident atom energy
  - Ar inclusions promote ordering
  - Ar inclusions increase **c**
  - Ar atoms pin domain wall motion and increase H_c

Magnetic properties and structural parameter of $L1_0$ ordered [Fe(1ML)/Pt(1ML)] films Ts=300°C.

P_{Ar} [Torr]	S	Ku [erg/cm3]	Hc [Oe]	c [nm]
(bulk)		7×10^7		3.712
1.3	0.3	5.6×10^6	400	3.744
5.1	0.6	1.9×10^7	400	3.727
9	0.5	1.9×10^7	1400	3.722

FePt Co-sputtering

- Fe & Pt co-sputtering

  - Further simplified process
  - $K_u \sim 1 \times 10^7$ erg/cm^3

  - Not ordered
  - Requires heated substrate

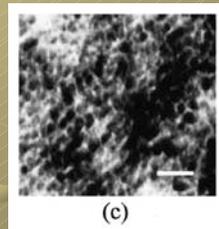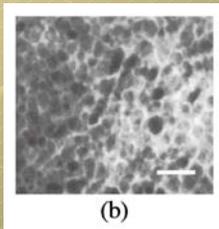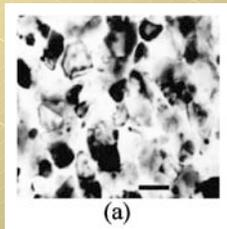# FePt + dopant co-sputtering

- Dopant: Usually Cu, C, Al
- Agglomeration at grain boundaries
  - Prevents grain growth
  - Inhibits exchange between grains
- Can make ordering more difficult

(a)   (b)   (c)

Post-deposition processing

- From Phase diagram:
  - FePt is FCT at room temperature
  - Transformation temperature is ~1300 °C
  - BUT:
    - slow cooling can lead to large grain size
  - SO:
    - Deposition has to occur at low temperatures
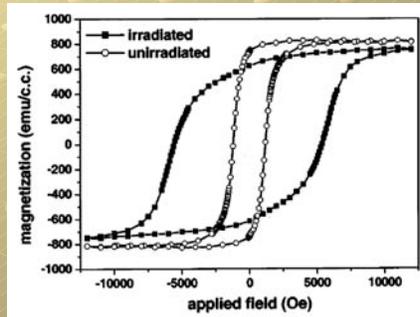   - Low-temperature post-processing is required

FePt annealing

- Possible at ~350 °C
  - Long time required
    - Large grains
- Faster at ~550 °C
  - 5-600 s required
    - Small grains ~8-10nm

- Most effective in Multilayer Films

- Can get bad results
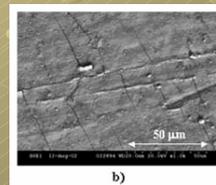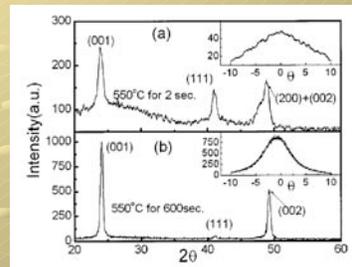
FePt Ion Irradiation

- Increased diffusivity
  - Excess point defects introduced
  - Local heating

- Effective ordering at only ~230 °C

- Magnetic patterning possible

Summary

- Deposition
  - MBE:
    - Excellent results
    - High temperature
  - Electrodeposition
    - Simple
    - Bad results
  - Sputtering
    - Good results
    - Low temperature
    - Requires post-processing

- Post-processing
  - Annealing
    - Good Results
    - High temperature
  - Ion Irradiation
    - Good results
    - Low temperature