Nanomaterials

Lecture 16: Nanomagnetism
Magnetic Miniaturization

Capacity of magnetic hard disks:

- 1980’s: 30% growth per year
- early 1990’s: 60% growth per year
- late 1990’s: 130% growth per year
- disk capacity doubling every 9 months (twice the pace of Moore’s Law)

Economics of Magnetic Storage

Iron oxide coated aluminum

Limitations of Nanomagnetic Storage

(1) Superparamagnetic effect (SPE) \(\rightarrow\) at the nanoscale, the magnetization energy becomes comparable to ambient thermal energy \(\rightarrow\) bits become susceptible to random flipping

(2) Track width \(\rightarrow\) currently: 20,000 tracks/inch
\(\rightarrow\) at 150,000 tracks/inch, each track will be \(\sim\)170 nm wide
\(\rightarrow\) difficult for heads to follow (requires secondary actuator)

(3) Access speed \(\rightarrow\) at speeds greater than 10,000 revolutions/minute, hard disks emit noticeable audible noise

(4) Read head sensitivity \(\rightarrow\) improved by giant magnetoresistance
Superparamagnetic Effect (SPE)

\[ \Delta E = K_u V \]

- \( K_u \) is the magnetic anisotropy
- \( V \) is the bit volume

http://idefix.physik.uni-konstanz.de/albrecht/home.htm
Antiferromagnetically Coupled (AFC) Media Structure

http://www.hitachigst.com/hdd/research/storage/adt/afc1.html
Giant Magnetoresistance (GMR)

http://www.stoner.leeds.ac.uk/research/gmr.htm
http://www.stoner.leeds.ac.uk/research/gmr.htm
GMR Field Dependence

http://www.stoner.leeds.ac.uk/research/gmr.htm
GMR Spacer Thickness Dependence

http://www.stoner.leeds.ac.uk/research/gmr.htm
Using “Hard” Magnetic Materials

Materials like Fe/Pt or Co/Sm are more resistant to SPE but are also more difficult to magnetize → use a laser to soften materials during write steps

Lithographically Patterned Hard Disks

Alternative Memories: Optical Storage

Alternative Memories: E-Beam Arrays


Department of Materials Science and Engineering, Northwestern University
Alternative Memories: Millipede

Magnetic RAM

Semiconductor Spintronics

In addition to the SPIN FET, a number of other spin polarized semiconductor devices have been proposed:

(1) Spin polarized p-n junctions
(2) Spin polarized LEDs
(3) Photo-induced ferromagnetism
(4) Spin polarized BJTs

All of these technologies depend upon development in materials:

(1) Dilute Magnetic Semiconductors, (2) Ferromagnetic Contacts, (3) Spin Detection Strategies, etc.
Nanomagnetic Logic

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