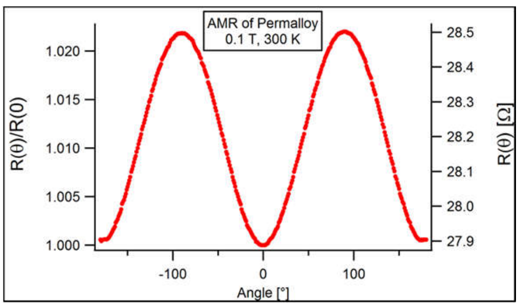
MAGNETORESISTANCE

Anisotropic Magnetoresistance

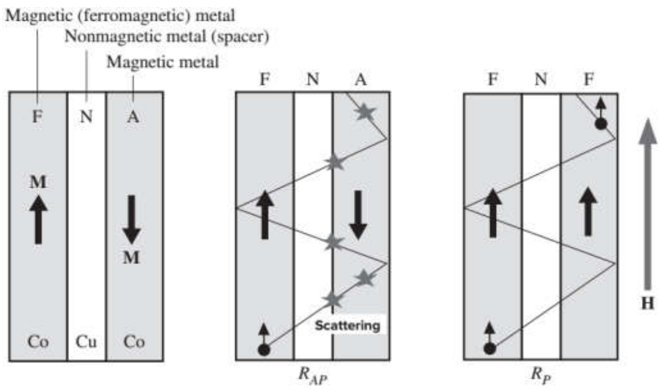
- The change in the resistivity due to the applied magnetic field is *anisotropic* (depends on the direction) and is called **anisotropic magnetoresistance (AMR).**



2

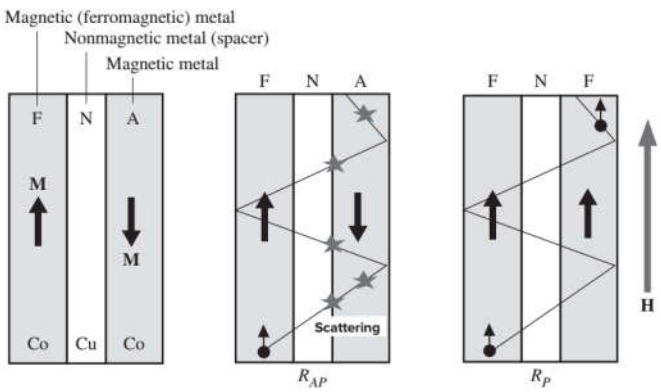
Giant Magnetoresistance

- **GMR:** Certain special multilayer structures exhibit substantial changes in the resistance (>10%) when a magnetic field is applied
- Widely used in the read heads of hard disk drives, and also in various sensors.
- In the absence of an external field, magnetizations are *antiparallel.*
- In the presence of an external field, magnetizations are *parallel.*



Giant Magnetoresistance

- $R_P < R_{AP}$
- The difference in R_P and R_{AP} in this simple trilayer is roughly 10% or less.
- Angular dependence: $\frac{\Delta R}{R_P} = \left(\frac{\Delta R}{R_P}\right)_{max} \frac{1 - \cos\theta}{2}$



Giant Magnetoresistance

- Multilayered structures: A series of alternating magnetic and nonmagnetic layers can change the resistance >100% at low temperature and 60–80% at room temperature.

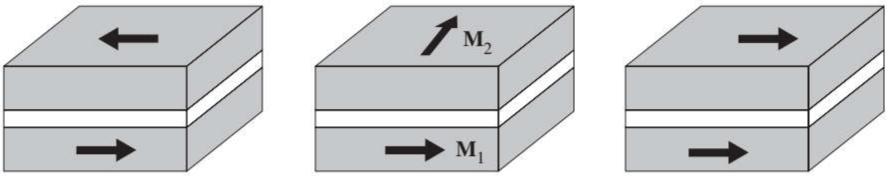
- GMR effect in trilayers and multilayers

Sample	Structure and Layer Thicknesses	$\Delta R/R_P$ (%)	Temp. (K)
CoFe/CAgCu/CoFe	Trilayer	4–7	300
NiFe/Cu/Co	Trilayer, 10/2.5/2.2 nm (spin valve)	4.6	300
Co90Fe10/Cu/Co90Fe10	Trilayer, 4/2.5/0.8 nm (spin valve)	7	300
[Co/Cu]100	100 layers of Co/Cu 1 nm / 1 nm	80	300
[Co/Cu]60	60 layers Co/Cu 0.8 nm / 0.83 nm	115	4.2

5

Spin Valve

$$\frac{\Delta R}{R_P} = \left(\frac{\Delta R}{R_P}\right)_{max} \frac{1 - \cos\theta}{2}$$



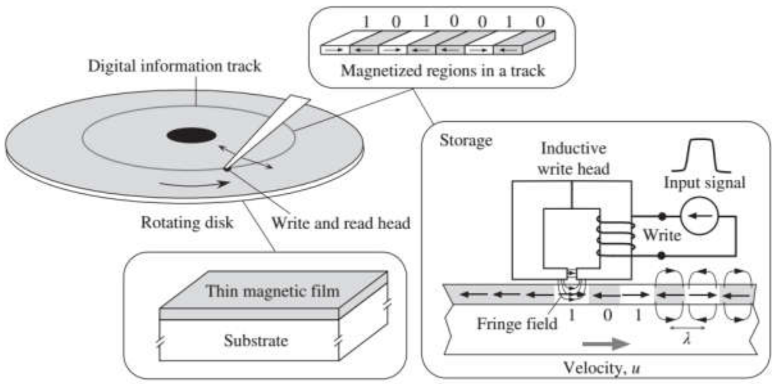
$\theta = 180°$ Maximum resistance | $\theta = 90°$ | $\theta = 0°$ Minimum resistance

6

MAGNETIC RECORDING MATERIALS

Longitudinal Magnetic Recording

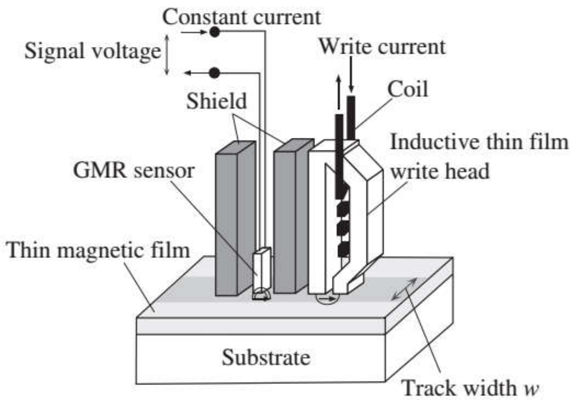
- **Magnetic materials in magnetic recording:** (1) magnetic heads to write (record), (2) read sensors, (3) storage of information either permanently or until the next write requirement.
- **Example:** Recording of digital data on a magnetic disk in a hard disk drive → Electrical signal is stored as a spatial magnetic pattern in the magnetic film in circular tracks.



8

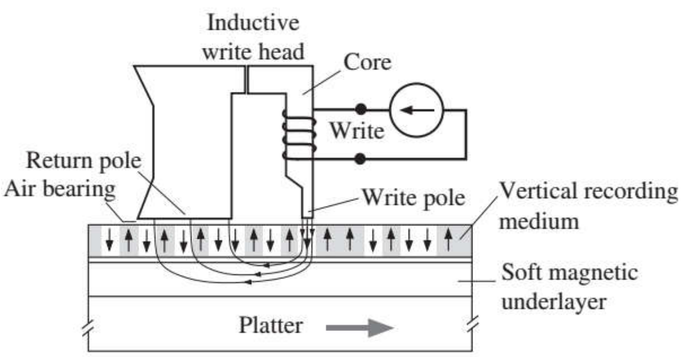
Write and Read Heads

- Both the write and the read heads are in a single compact assembly that moves radially across the rotating disk
- The read-write head is on an air bearing and the head to thin magnetic film separation is roughly 10 nm or less.



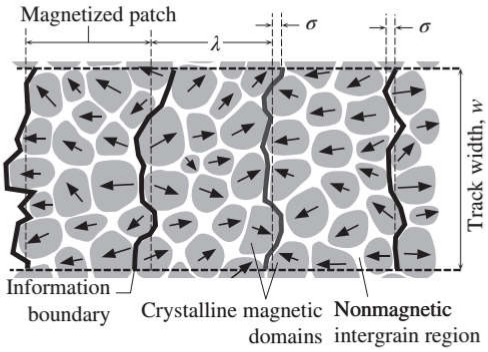
Perpendicular Magnetic Recording

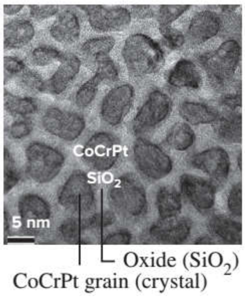
- Induced **M** is either up or down.
- The write operation is distinctly different than that in longitudinal storage.
- There is an inductive write head with a narrow "write pole" that brings the magnetic flux onto the film.



Information Boundary

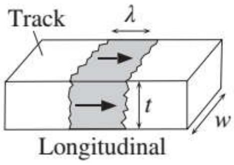
- The magnetic thin film has small crystalline grains and a region between the grains that is nonmagnetic



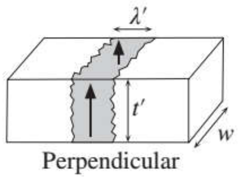


Bit Length

- How small can we make the magnetized region for one bit?
- λw should be as small as possible to increase the storage capacity.
- $\mathrm{SNR}_{\mathrm{grain}} \approx 20 \log \sqrt{N} = 10 \log N$
- A 20 dB SNR implies that a bit-volume should be 100 grains.

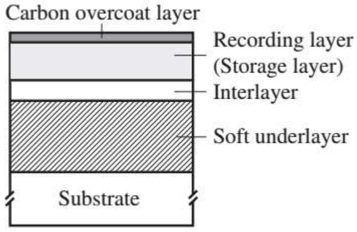


- In perpendicular recording, we can reduce λw and increase t, keeping the bit volume the same.



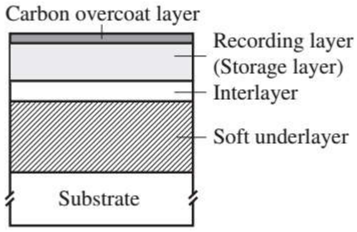
Materials for Magnetic Storage

- **Magnetic thin film:** Typical film thicknesses are less than 30 nm. The film is not a single phase homogenous magnetic medium → roughly 10 nm grains separated by an oxide nonmagnetic amorphous region.
- The film must be able to retain the spatial magnetization pattern → high remanent magnetization.
- However, H_c cannot be too high because, otherwise, the inductive head will not be able to change the magnetization **M** of a magnetic grain; we need a semihard magnetic medium.
- **Example:** $CoCrPt\text{-}SiO_2$



Materials for Magnetic Storage

- **Soft underlayer:** Should be sufficiently soft to be easily magnetized → magnetic field lines restricted to this layer.
- **Interlayer:** Separates storage thin film and the SUL.
- **Top overcoat layer:** Usually carbon → protects the magnetic thin film's surface.
- **Thin film inductive recording head:** must be able to produce a strong magnetizing field. The thin film coil is normally Cu and the oxide insulation maybe SiO_2 or $Al2O_3$. The magnetic core is a soft medium that can be easily magnetized



Bit Patterned Recording Medium

- A recording medium in which a bit is a well-defined nanostructure, and these nanostructures are patterned to form a *periodic array* of "isolated magnetic islands."
- Clearly, we no longer have a granular medium → an *N*-fold increase in storage capacity, breaking through the limits of multigrain media.
- Further, we can develop write and read techniques that involve synchronization with the periodicity in the bit-pattern; obviously such new techniques would require a more demanding technology for the inductive write head.