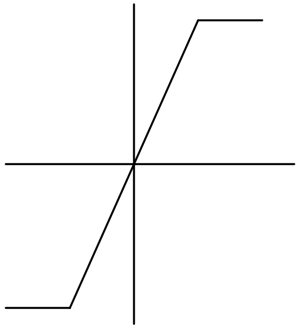
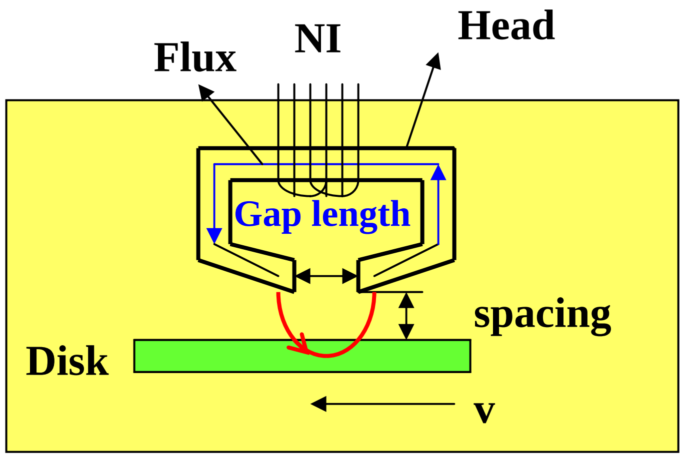
3.3 Magnetic Recording Materials

Head:

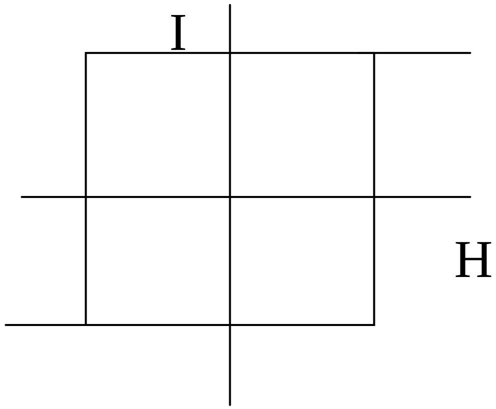
Soft magnetic materials
- High permeability
- Low coercivity
- High magnetization



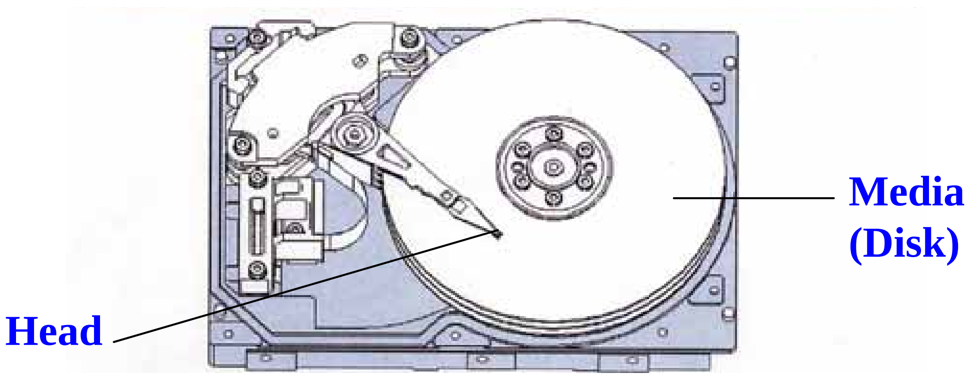


Media (Disk):

Hard magnetic materials
- High coercivity
- High magnetization
- Rectangular hysteresis



HDD



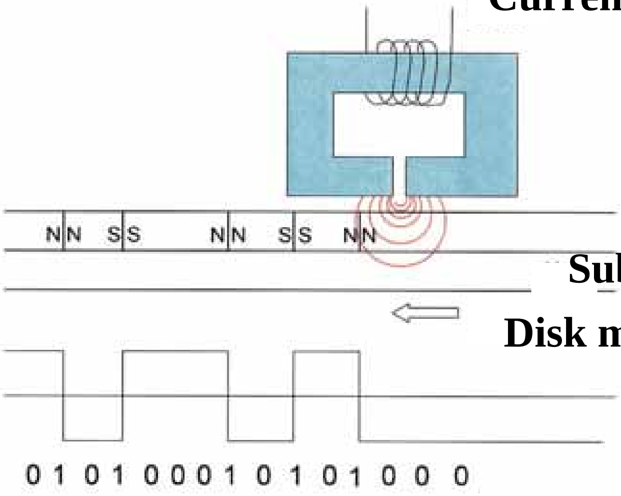
Spindle motor: NeFeB magnet
Actuator: NdFeB magnet

Recording Principle (digital)

Writing

Current I

Frequency f



Disk media

Substrate

Disk moving direction

Current I

Relative velocity : *v*

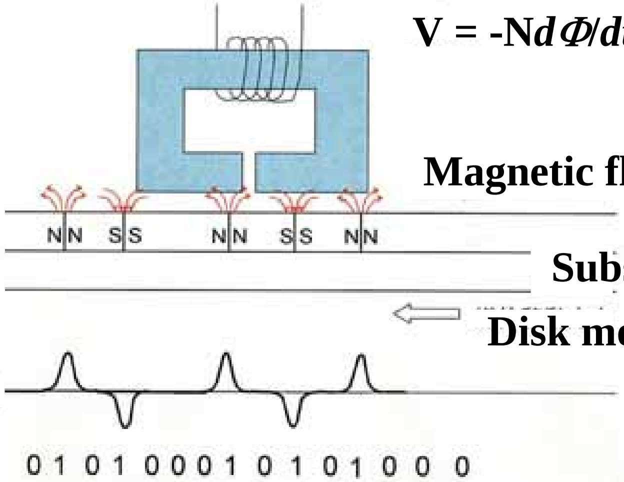
Recording wave length

$\lambda = 2\pi/k = 2\pi(v/f)$

Reading

Induced voltage

V = -N$d\Phi/dt$



Magnetic flux

Disk media

Substrate

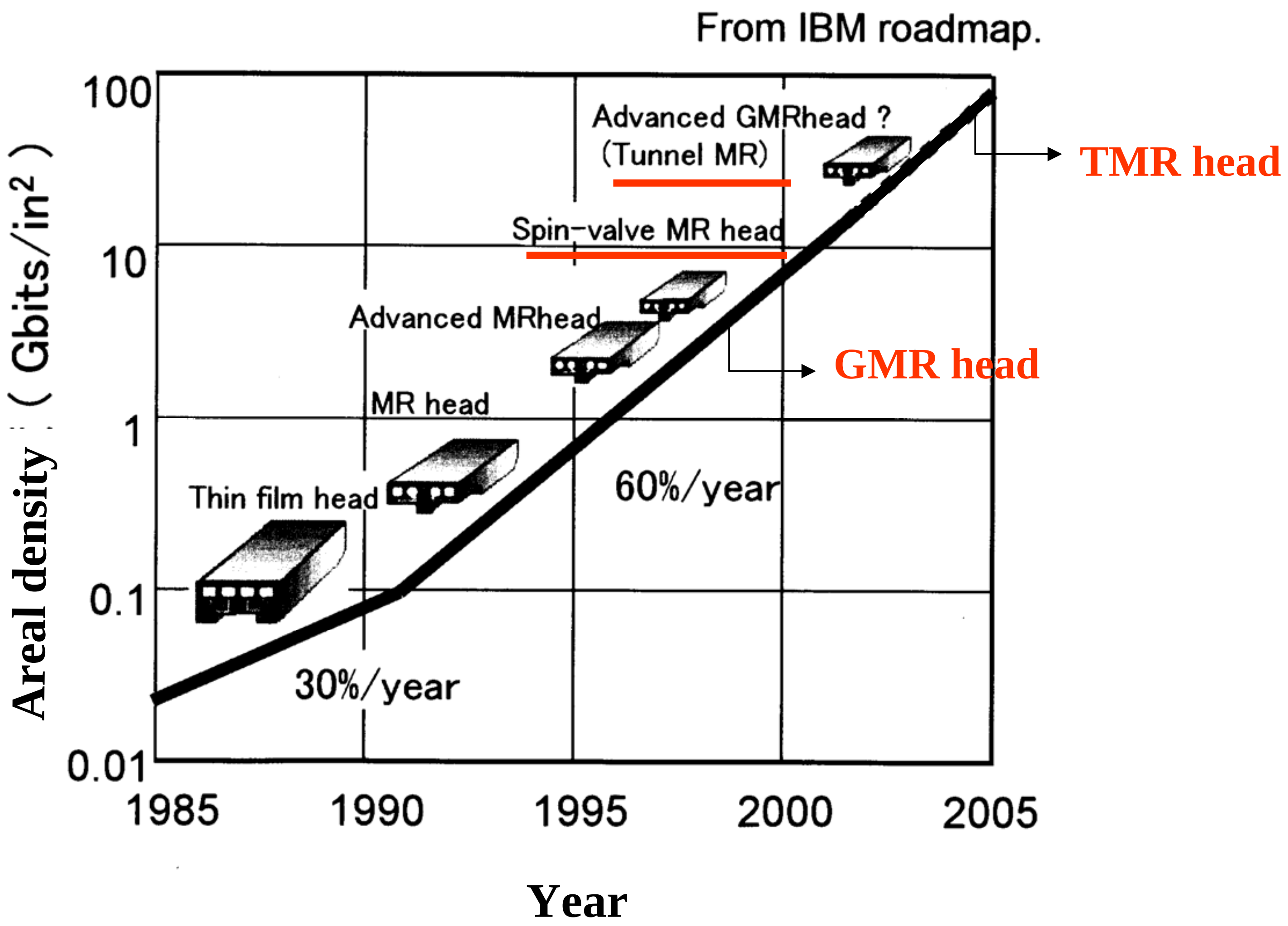
Disk moving direction

Read voltage

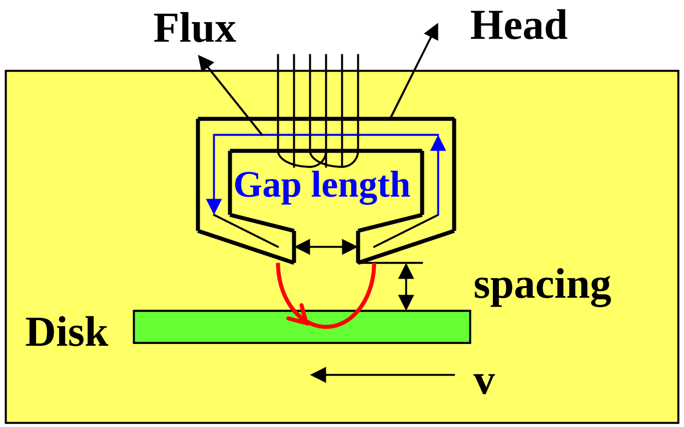
Lower velocity or higher f leads to smaller λ, namely Higher bit density.

Inductive to MR heads

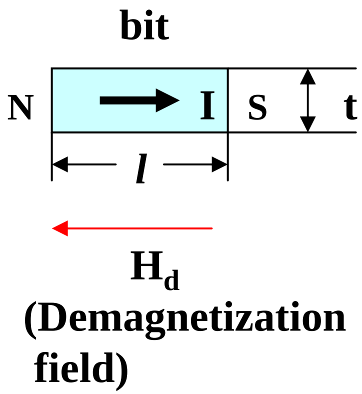
Bit density evolution in HDD



For Higher bit density recording

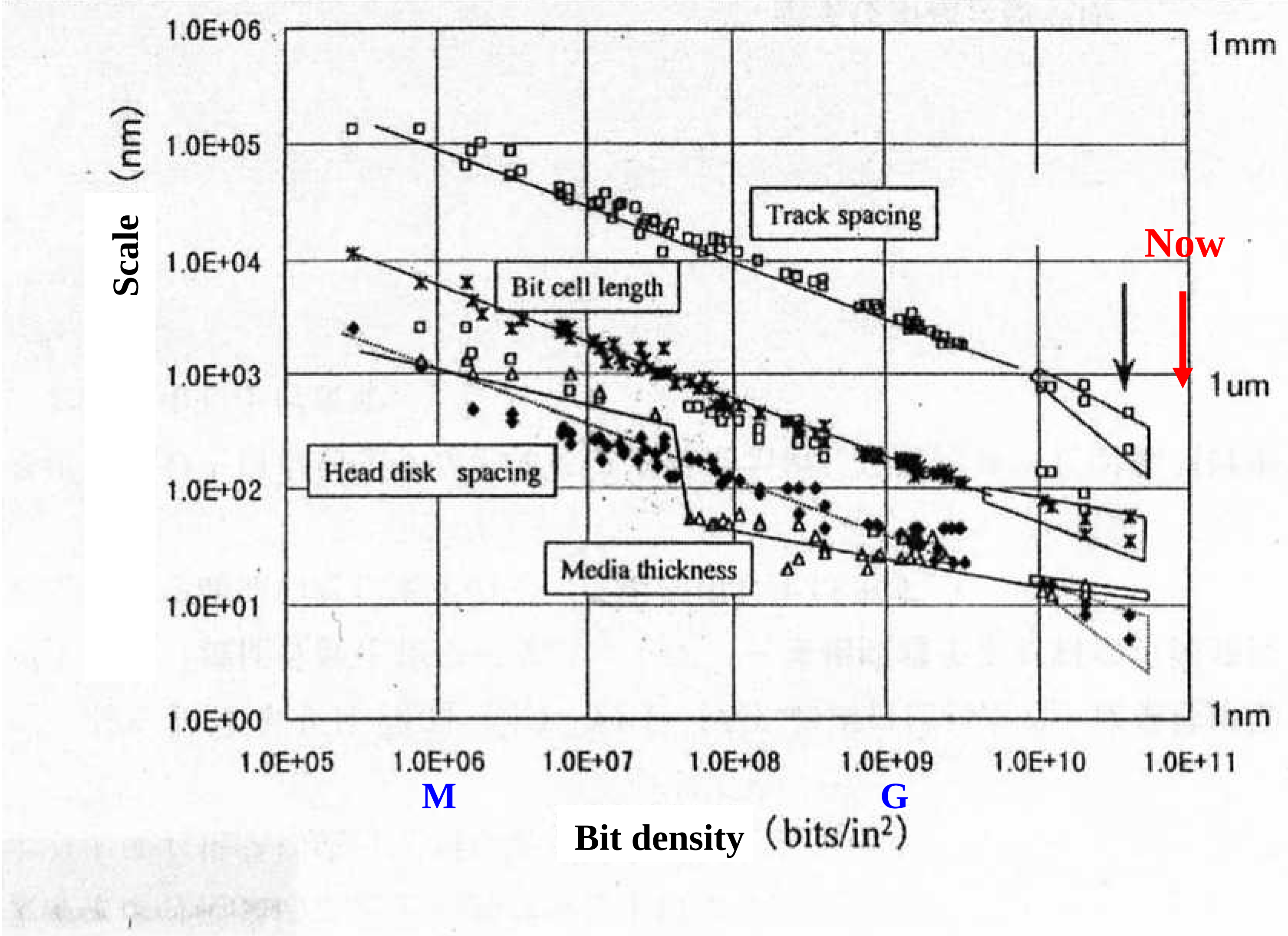


1. Small gap length
2. Small spacing
3. Thin media thickness
4. High coercivity media materials
5. High magnetization for write heads
6. Induction type to MR heads for reading
7. Longitudinal to perpendicular recording



$H_d \propto t / l$

Bit density vs. parameters



HDD is based on a very high technology.

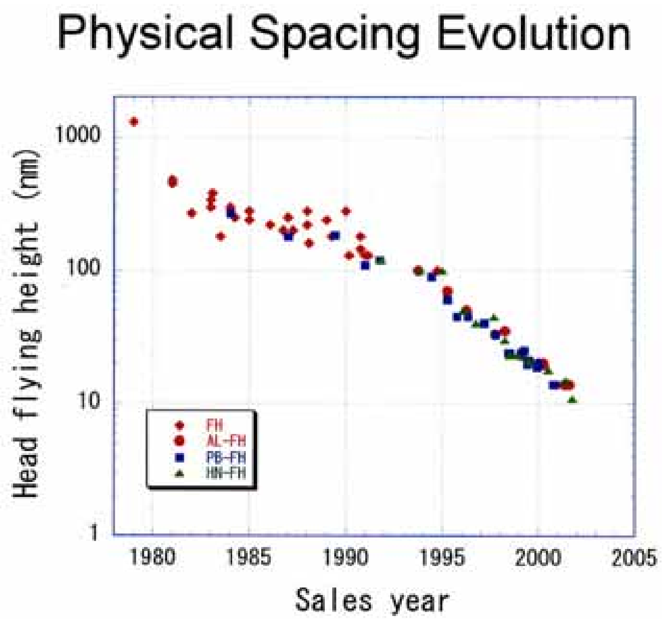
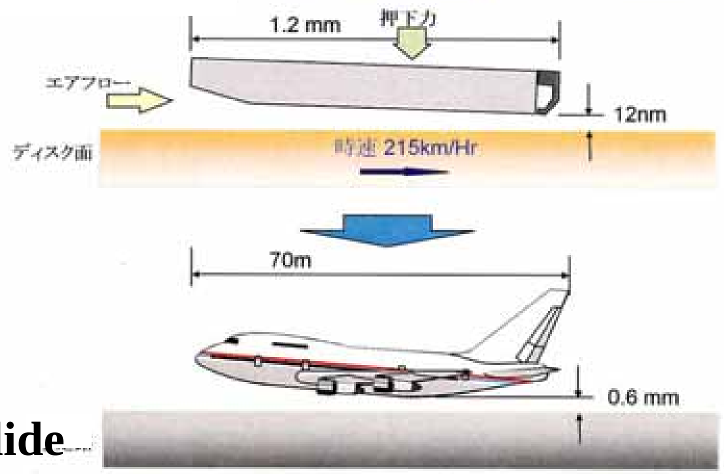


Image for spacing



glide

Head-medium relative speed = 215 km/H

Write heads

The current through the **N** turns enclosing the core of the write head provides the magnetic potential or magnetomotive force, $\mathbf{V_m = NI}$, which generates the field H_g in the gap.

$$NI = l_c H_c + 2gH_g$$

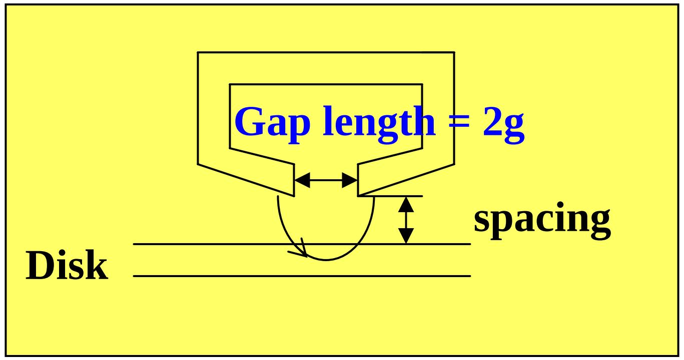
where the gap length is 2g and the flux path length in the core is l_c.

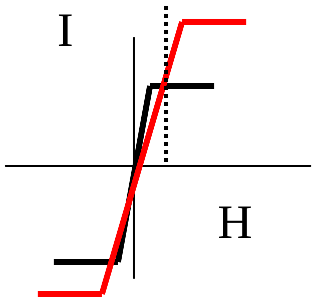
$$H_g = (NI/2g)\frac{1}{1 + l_c/2\mu g} \qquad (H_g = \mu H_c = B)$$

The head efficiency η is the fraction of V_m that appears as field in the gap:

$$\eta = \frac{2gH_g}{NI} = \frac{1}{1 + l_c/2\mu g} \approx 1 - l_c/2\mu g$$

Write heads require high μ and high I_s.





Larger magnetization for writing heads

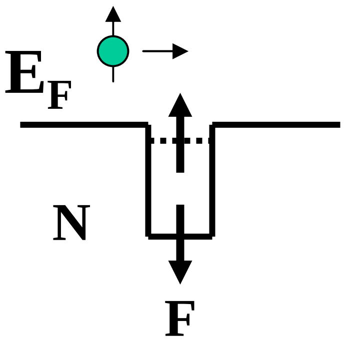
GMR read heads

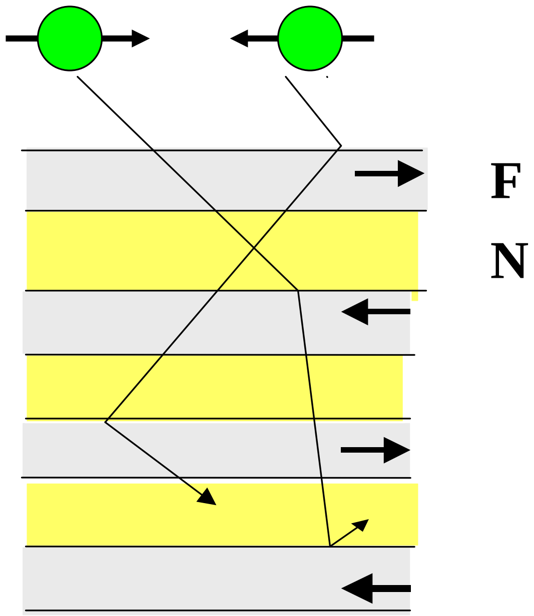
Mechanism of GMR

Current in-plane

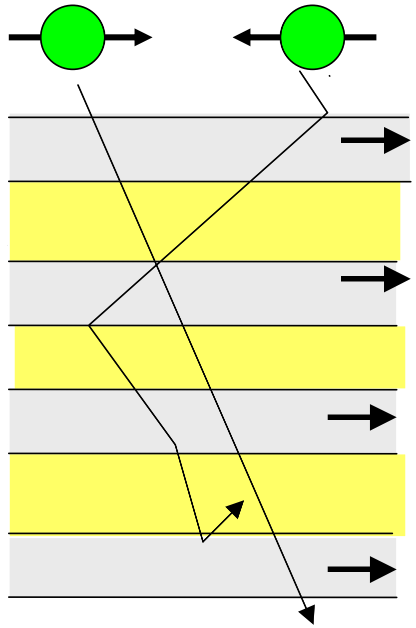
Multilayer

F: Ferromagnet
N: Nonmagnet





(a)Antiparallel configuration
Resistance = R_{AP}

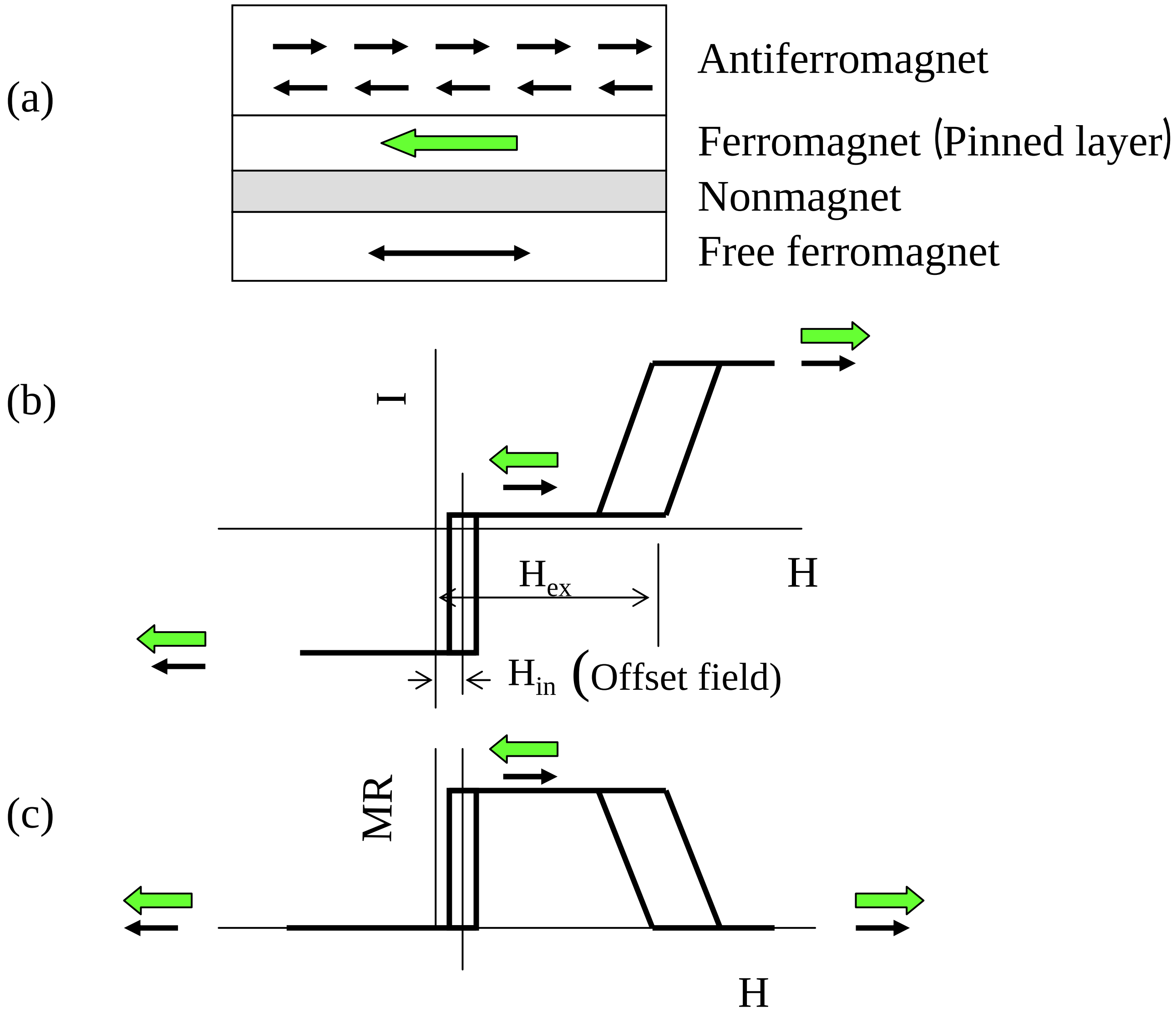


(b)Parallel configuration
Resistance = R_P

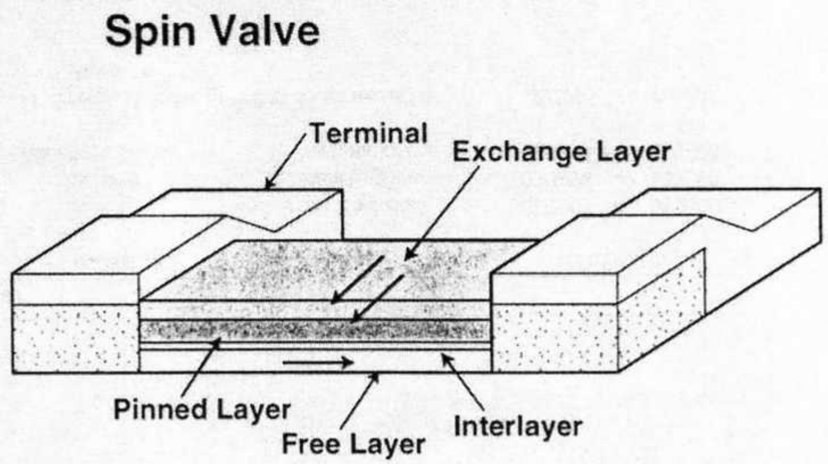
Spin-dependent scattering at interface

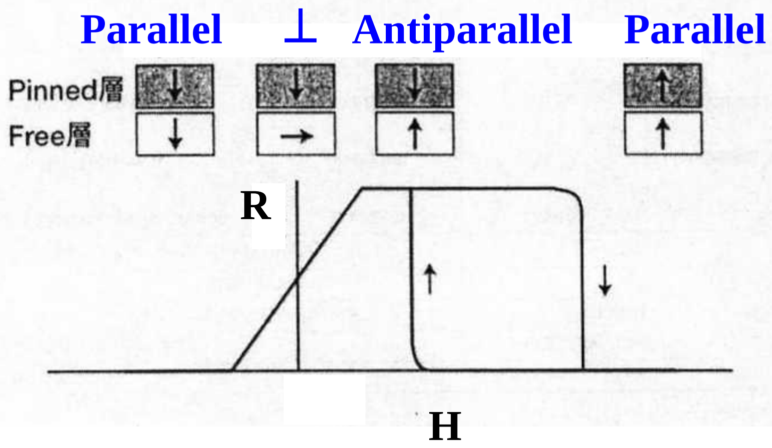
$$R_{AP} > R_P \qquad GMR = (R_{AP} - R_P) / R_P$$

Spin-valve GMR



Spin-valve read heads



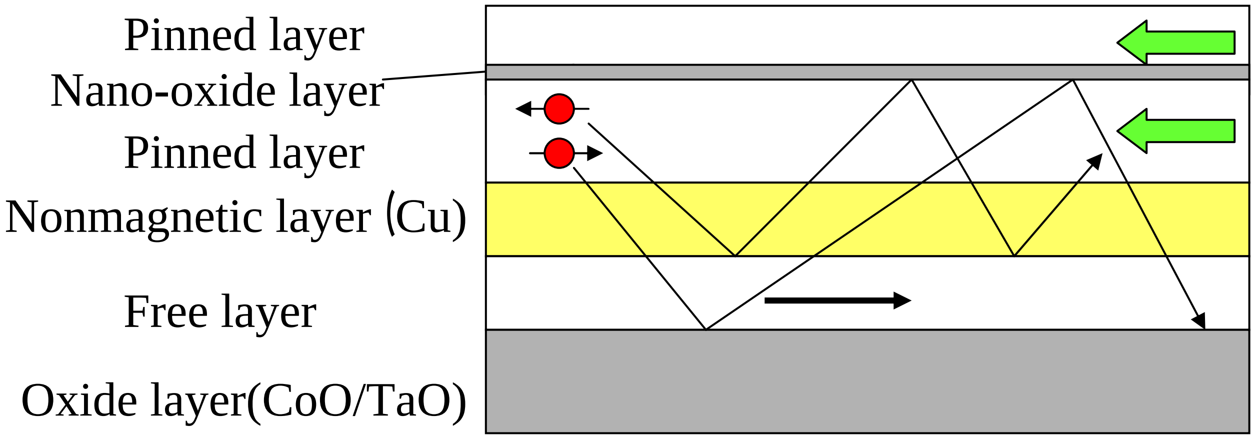


Free layer and pinned layer magnetizations are perpendicular to each other.

Enhancement of GMR

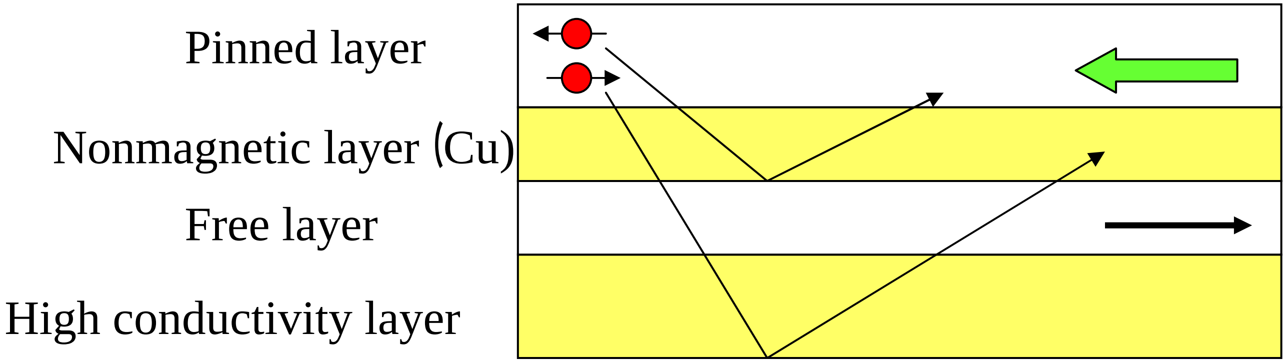
(a) Specular spin-valve

Icreases spin-dependent interfacescattering



(b) Spin-filter spin-valve

Majority spins have larger spin diffusion length.



Media

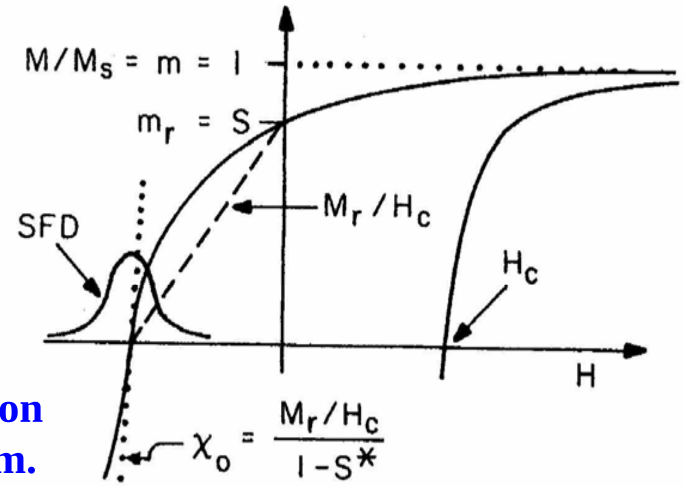
Read signal is proportional to remanence M_r **$S = M_r/M_s$** is a indicator of the strength of the read signal. Another measure of squareness that includes the field needed to switch the magnetization is the ratio of **M_r/H_c**. This parameter measures the average susceptibility in the second quadrant.

More appropriate susceptivility is $\chi_0 = [\partial M / \partial H]_H$ at M = 0.In general **$\chi_0 > M_r/H_c$**, so **local squareness** is proportionalto the magnitude of the ratio **$\chi_0 /(M_r/H_c)$**. To express this ratio as a squareness parameter that varies from 0 to 1, **the coercivity squareness S*** is defined as

$$S^* = 1 - M_r / \chi_0 H_c (0 \le S^* \le 1)$$

A value of S or S* approaching unity indicates an *I-H* loop with a sharp second quadrant change in magnetization with changing field.

A large S* implies that a spacially sharp magnetization transition can be written and sustained in the medium.



Part of M-H loop showing various measures of loop squareness

Particulate media

Particulate media generally consist of **single-domain particles** because of their high coercivity, which are suspended in a polymer matrix. Thus, particulate media are more suitable than metal Films, when soft substrates such as tape or polyester floppy disks are used.

Summary of Characteristics of Various Particulate Media

	Dimensions (Length, mm)	Source of Anisotropy	M_s (G)	H_c (Oe)	Application
γ-Fe_2O_3	10:1 acicular	Shape	350	350	Audio and low-density data
CrO_2	Acicular	Shape and crystal	350 ± 50–90	550 ± 50	Audio/video and data tape
Co^{2+}-γFe_2O_3	10:1 acicular (0.1–0.25)	Shape	350	900 ± 100	Audio/video
α-Fe	10:1 acicular (0.1–0.25)	Shape	750–900	1500	8-mm video and digital audio
$BaO \cdot 6Fe_2O_3$	Hexagonal platelets (0.01 × 0.1)	Crystal	300	Broad	range, typically 500–1200

Thin film media

Comparison of Properties of Various Thin-Film Compositions for Media

	H_c	Substrate	M_s	Thickness (mm)	Method or Application
CoP	1000	Plastic	—	0.3	Plate
MET[a] CoNiCr	1500	Polyester	—	—	Evaporated Sony 8-mm video
γ-Fe_2O_3	1000	NiP/Al	250	0.12	Sputter
CoNiPt	900	NiP/Al	800	0.03	Sputter
Co	1000	Cr/NiP/Al	—	—	Sputter
CoCrTa	1400	Cr/NiP/Al	—	—	Sputter
CoCrM (M = Pt, Ta, Zr)	—	Cr/NiP/Al	—	0.05	Sputter
CoNiCr	2000	CrGd/NiP/Al	—	—	RF-biased sputter

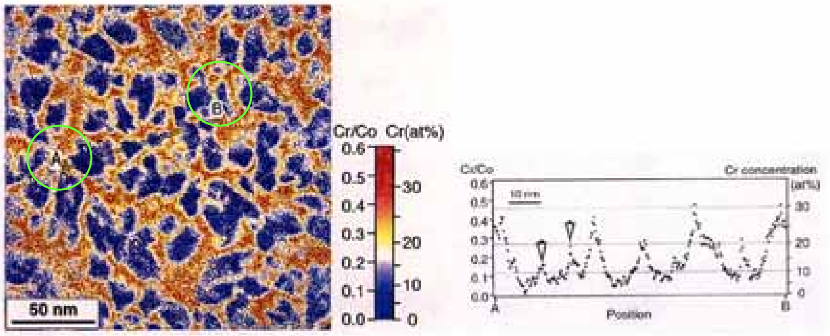
[a] Metal evaporated tape.

Example of thin film medium

Co particle is surrounded by nonmagnetic Cr

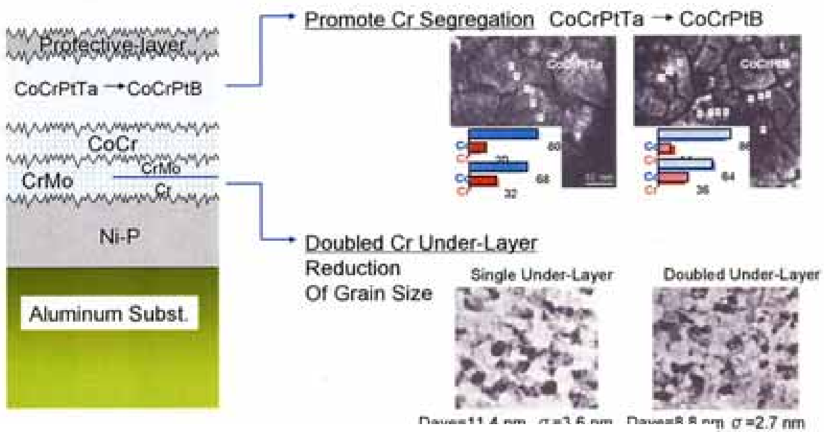
Compositional Separation in $Co_{72.8}Cr_{17}Ta_{4.8}$

K. Kimoto et al., Jpn. J. Appl. Phys., **34**, L352 (1995).



Atomic ratio (Cr/Co) map   Line profile along A-B

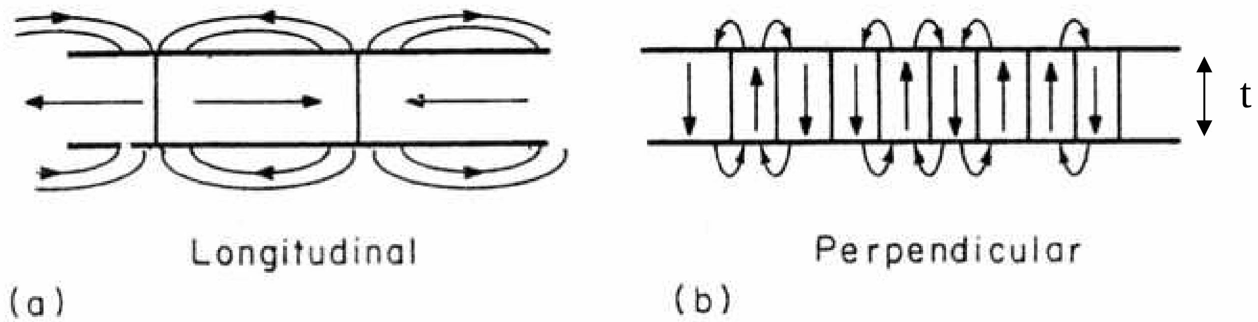
Approaches for Medium Noise Reduction



31

Longitudinal vs. perpendicular recording

Comparison of recorded bits in longitudinal (a) and perpendicular (b)



As recording density increases in a longitudinal medium, the demagnetization factor of the recorded bits, proportional to $\boldsymbol{M_r t/\lambda}$ becomes more unfavorable, because reduced thickness reduces the read signal strength, which is proportional to $M_r t$.

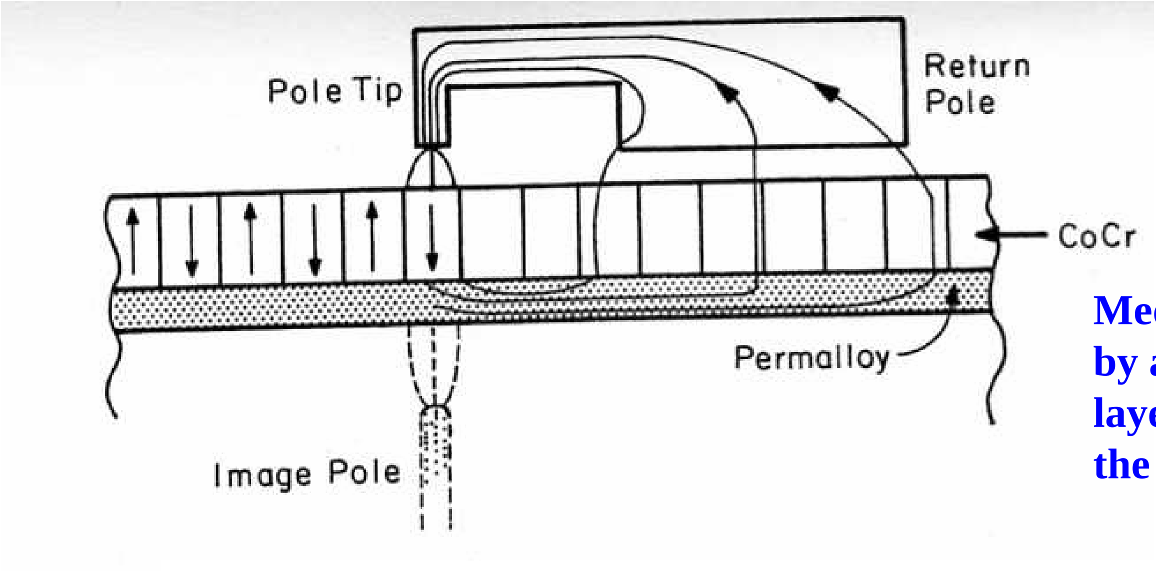
For a perpendicular medium, higher information density stabilizes the bit against demagnetization, where the demagnetization factor in this case goes to $\boldsymbol{M_r \lambda/t}$.

However, at increased densities the fringe field of a perpendicular medium is confined closer to the medium. This makes inductive reading of perpendicular media more difficult.

→ **MR heads**

Perpendicular recording using flux closure layer beneath the medium

Single pole tip head



Medium is backed by a high-permeability layer for focusing the field from the head.

Perpendicular recording using flux closure beneath the medium.

HDD using the perpendicular recording was commercialized in 2005.
Perpendicular recording, which was proposed by Iwasaki in 1979,
will become the mainstream of HDD in future.

Magnetics (magnetism, magnetic materials and devices) are always fascinating and exciting.

Thank you