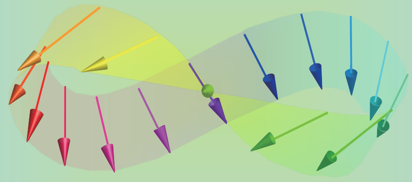
Information Storage and Spintronics 04



Atsufumi Hirohata

Department of Electronic Engineering

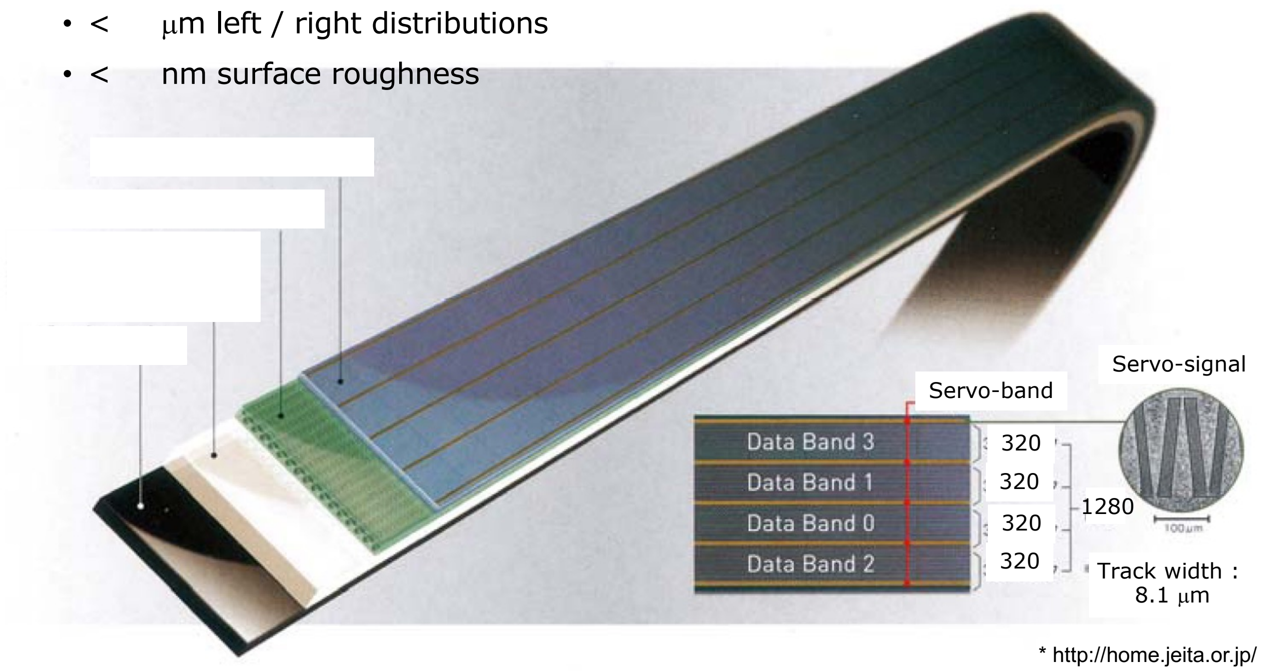
THE UNIVERSITY of York

14:00 Thursday, 13/October/2022 (SLB 101)

Quick Review over the Last Lecture

LTO Storage :

- 12.65 mm wide tape / tracks
- Track width : μm
- Length : m
- < μm left / right distributions
- < nm surface roughness



* http://home.jeita.or.jp/

04 Development of Hard Disk Drives

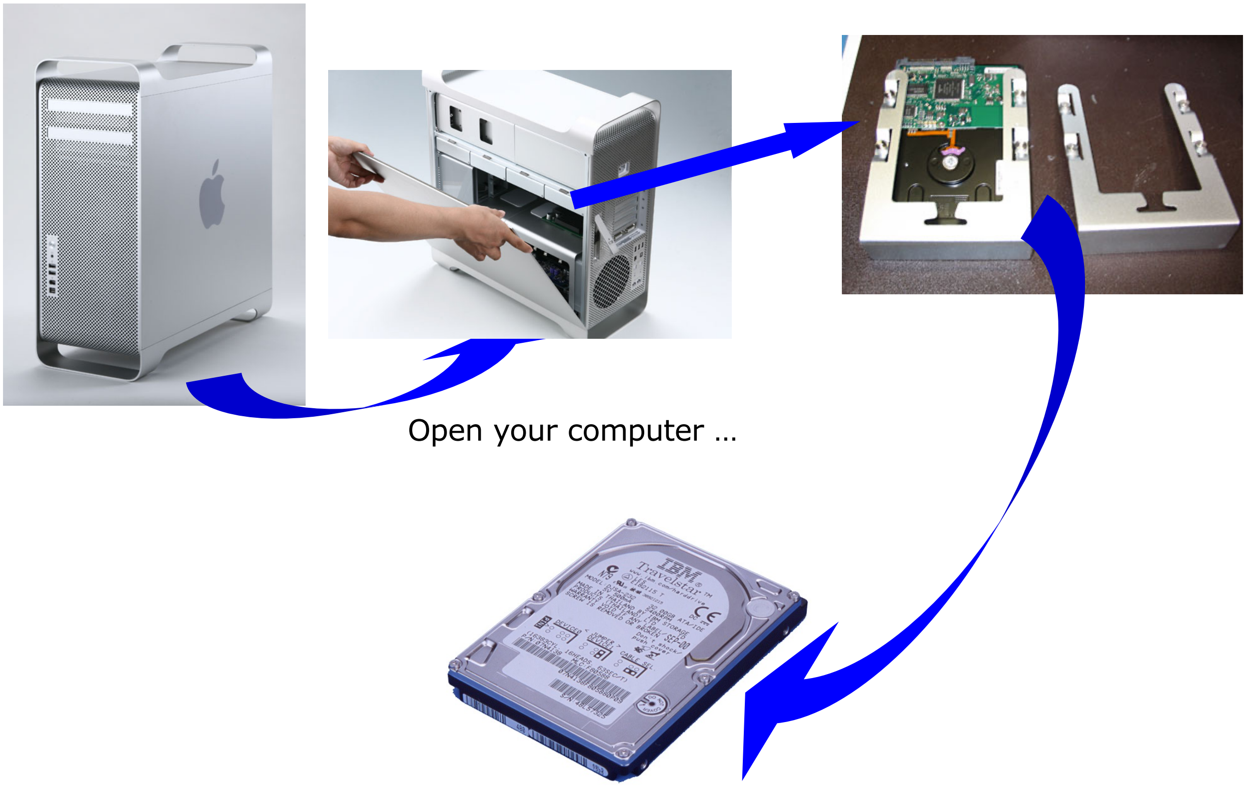
- Design
- Write / read operation
- MR / GMR heads
- Longitudinal / perpendicular recording
- Recording media
- Bit size
- Areal density
- Tri-lemma

Where Can We Find a Hard Disk Drive (HDD) ?

Most popular recording media now :

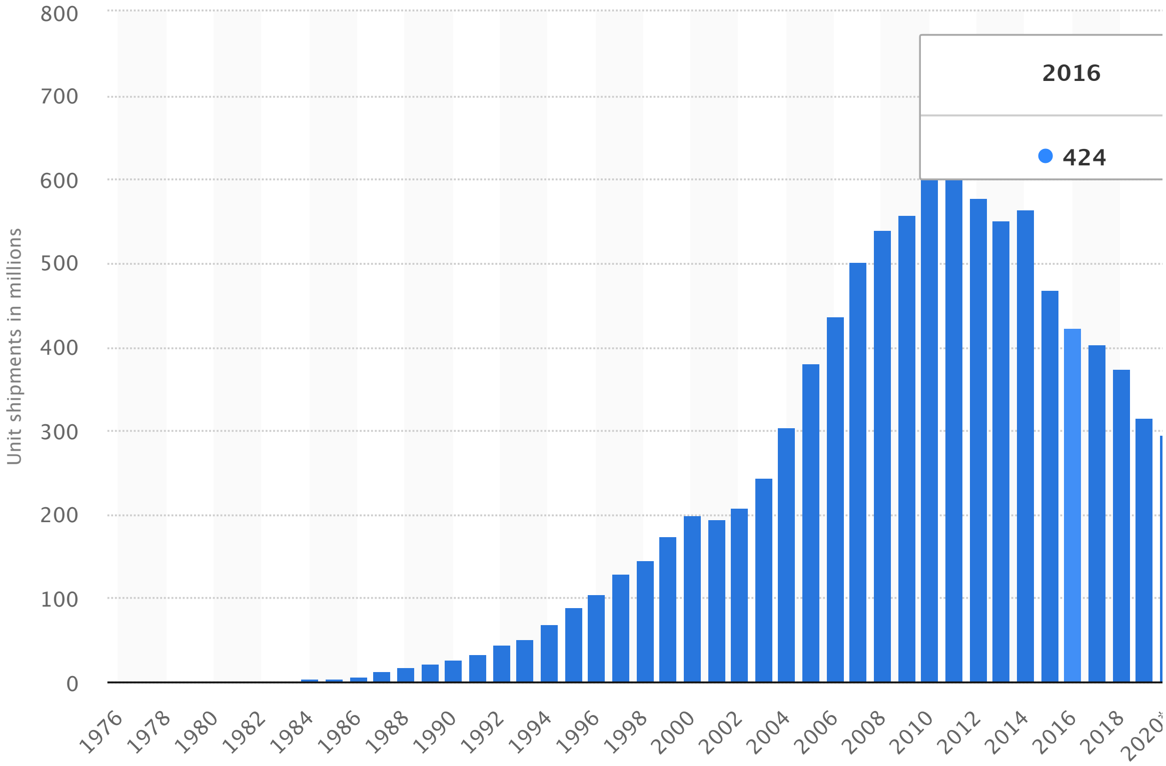
-
-
-
-
-
-

How to Access HDD ?



HDD Shipments

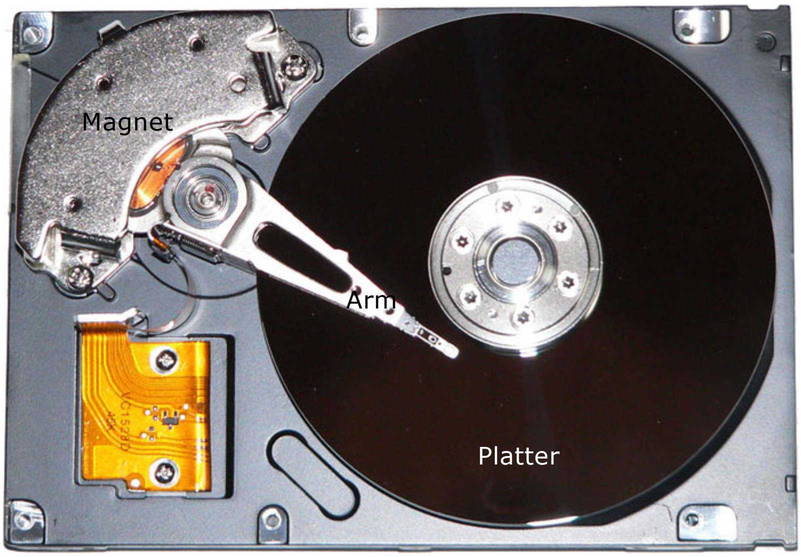
Worldwide unit shipments of hard disk drives (HDD) from 1976 to 2025 (in millions) : *



* http://www.kayoo.info/jyouhou-kiki/sozai/1504/index.html

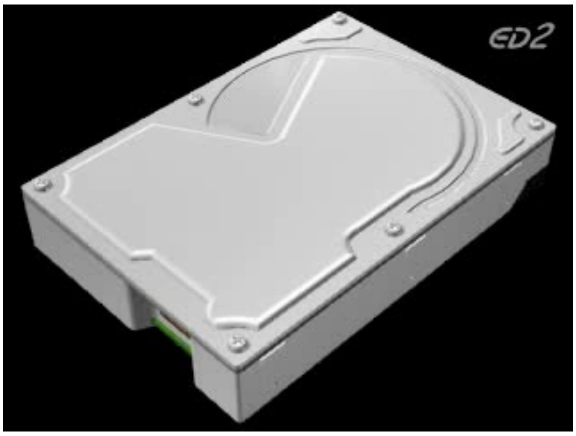
Do NOT Try This at Home !

Open a metal frame of HDD …



- Arm is operated by a linear motor with a very strong permanent magnet.
  - Arm moves ~ times/sec.
  - Platter records data.
  - Platter rotates rpm.

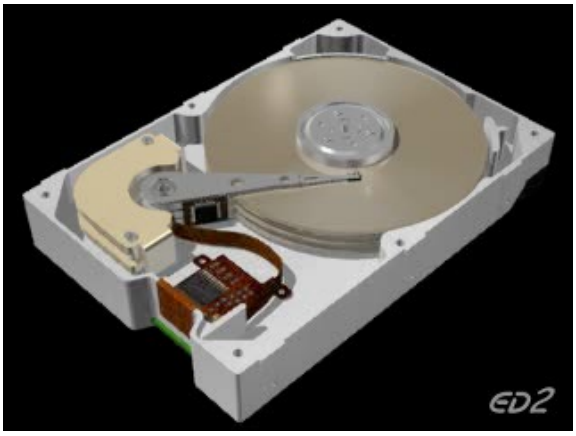
HDD Operation



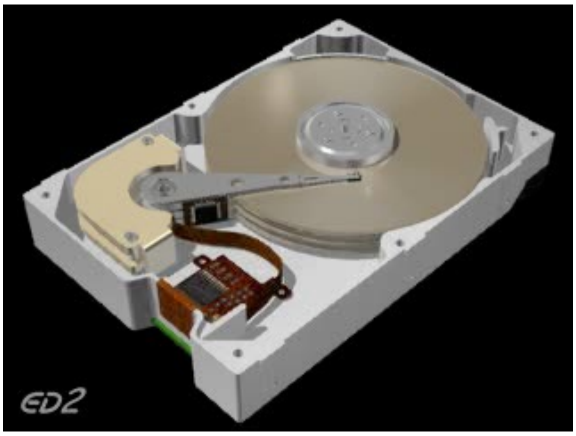
* http://www.kayoo.info/jyouhou-kiki/sozai/1504/index.html

HDD Writing / Reading Operation

HDD writing operation : *



HDD reading operation : *



* http://www.kayoo.info/jyouhou-kiki/sozai/1504/index.html

HDD Writing / Reading Operation

HDD writing operation : *

1 0 0 1 1 1 0 1

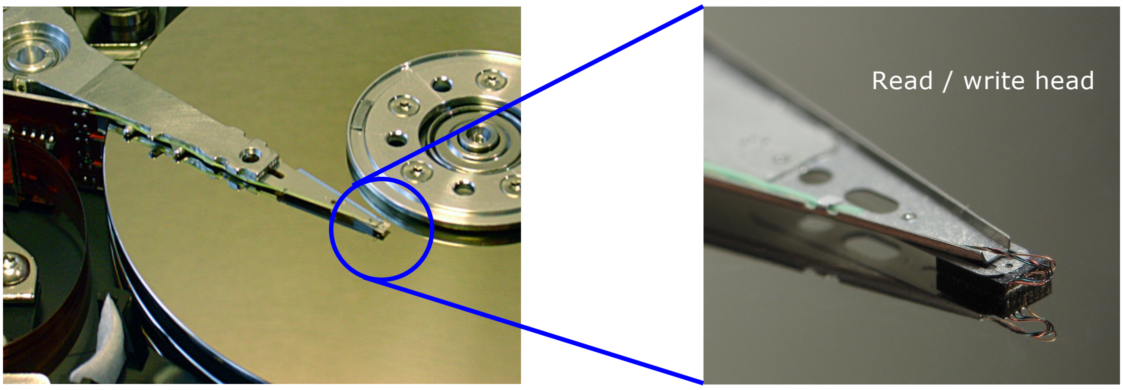
HDD reading operation : *

* http://www.kayoo.info/jyouhou-kiki/sozai/1504/index.html

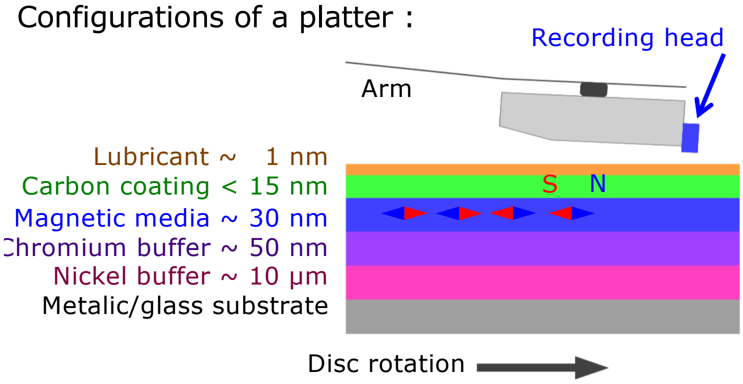
Write / Read Head

Recording media ...

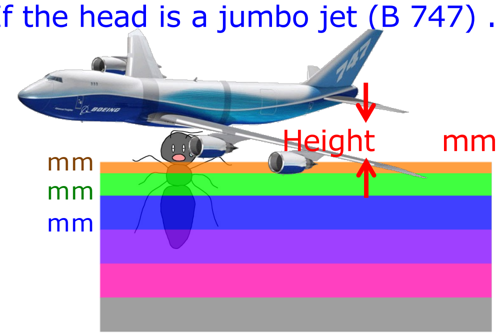
Recording head ...



Configurations of a platter :

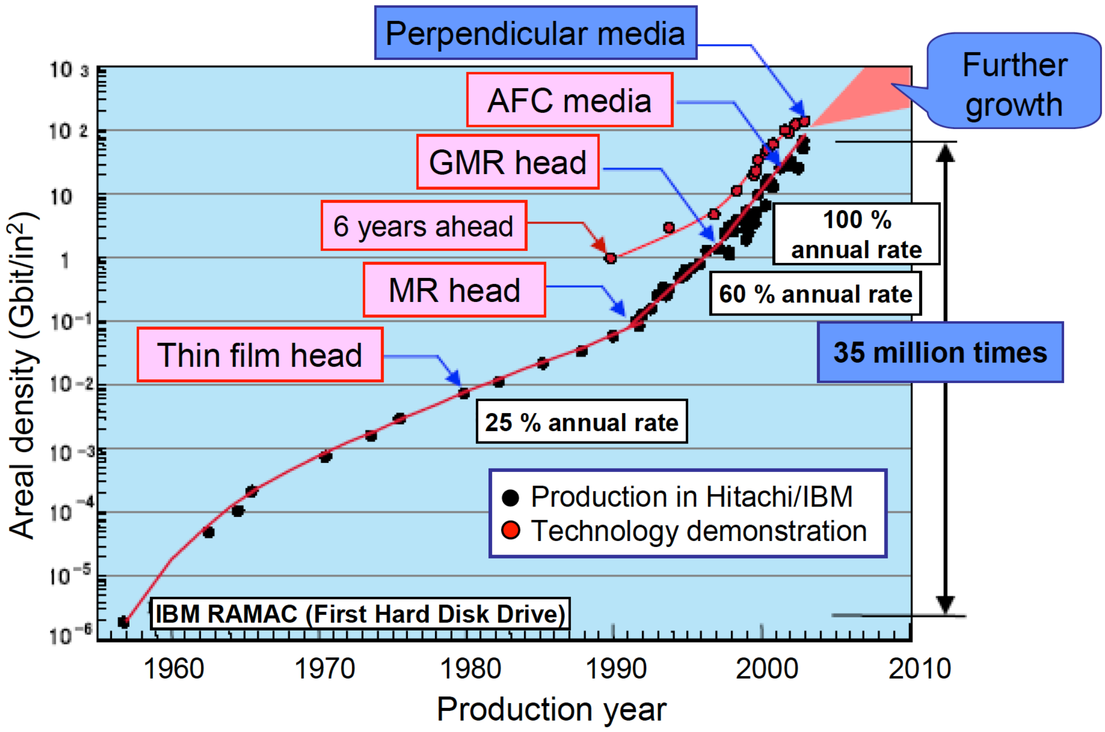


If the head is a jumbo jet (B 747) ...



Increase in Recording Density of Hard Disk Drives

Similar to Moore's law : *

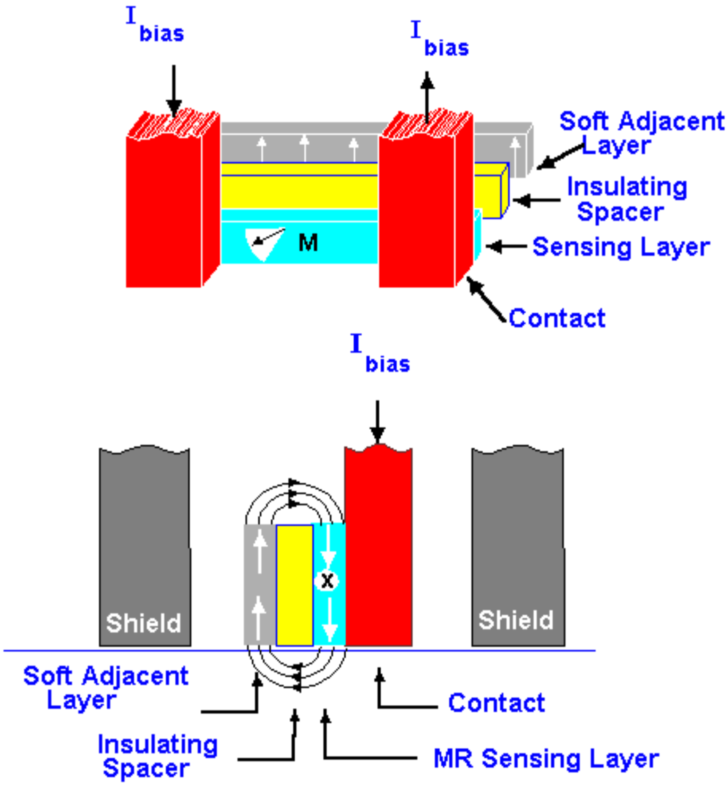


After Hitachi Global Storage Technologies

* http://dspace.wul.waseda.ac.jp/dspace/bitstream/2065/28765/6/Honbun-4557_03.pdf

Anisotropic Magnetoresistive Head

Anisotropic magnetoresistance (AMR) : *



Mainly permalloy ($Ni_{80}Fe_{20}$) alloys have been used as a sensing layer since 1991 by replacing ferrite bulk heads.

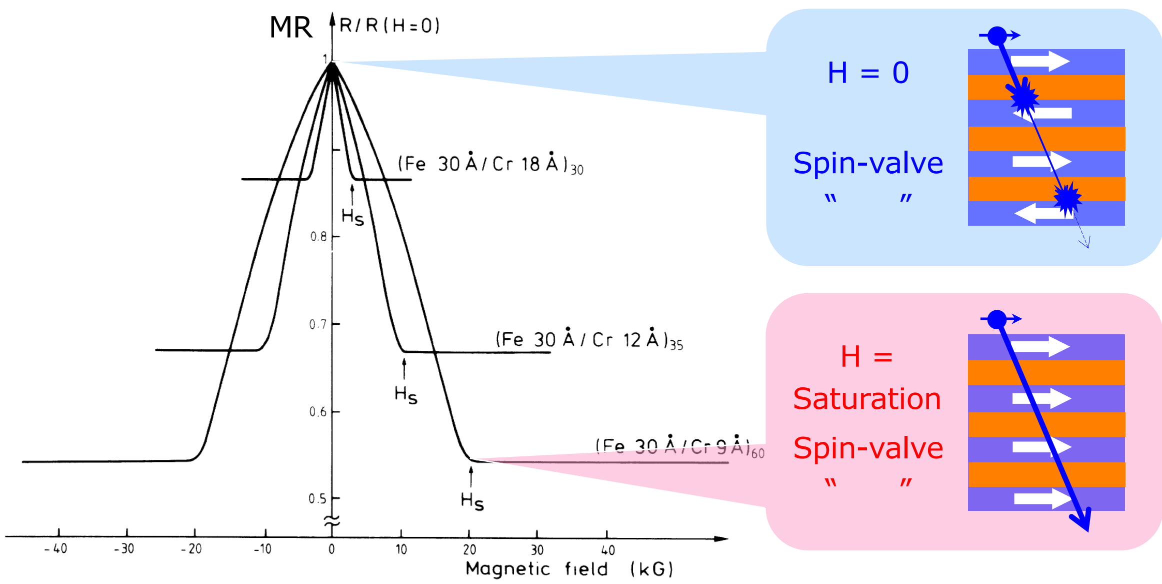
Areal density in a HDD increased % per year (from % per year).

* http://www.hitachigst.com/

Discovery of Giant Magnetoresistance

Giant magnetoresistance (GMR) :

[3 nm Fe / 0.9 nm Cr] × 60 *

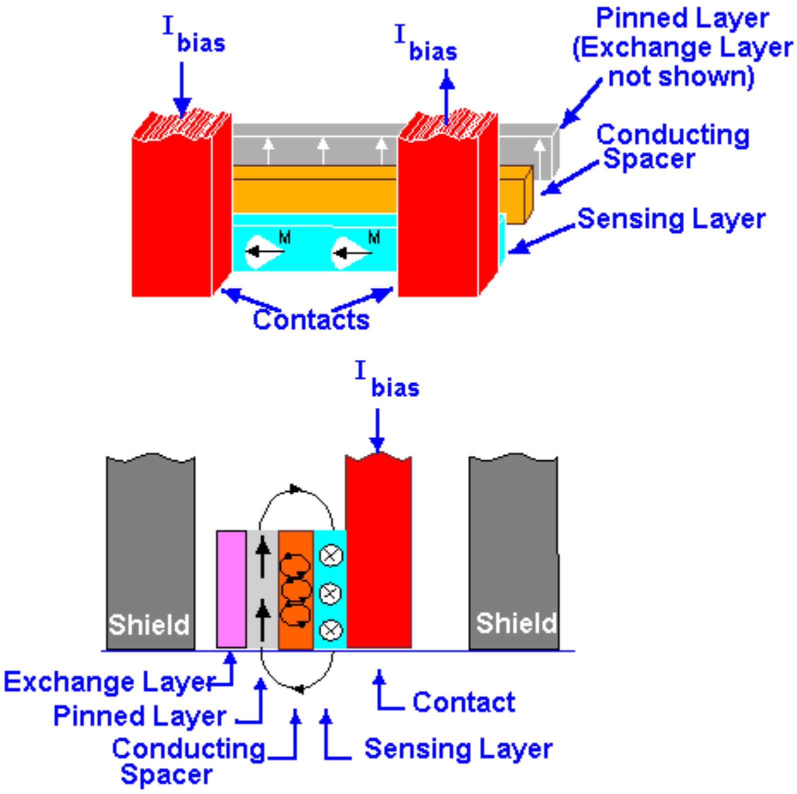


50 % resistance change at 4.2 K

* M. N. Baibich *et al.*, *Phys. Rev. Lett.* 61, 2472 (1988); P. Grünberg *et al.*, *Phys. Rev. Lett.* 57, 2442 (1986).

Giant Magnetoresistive Head

Giant magnetoresistance (GMR) : *

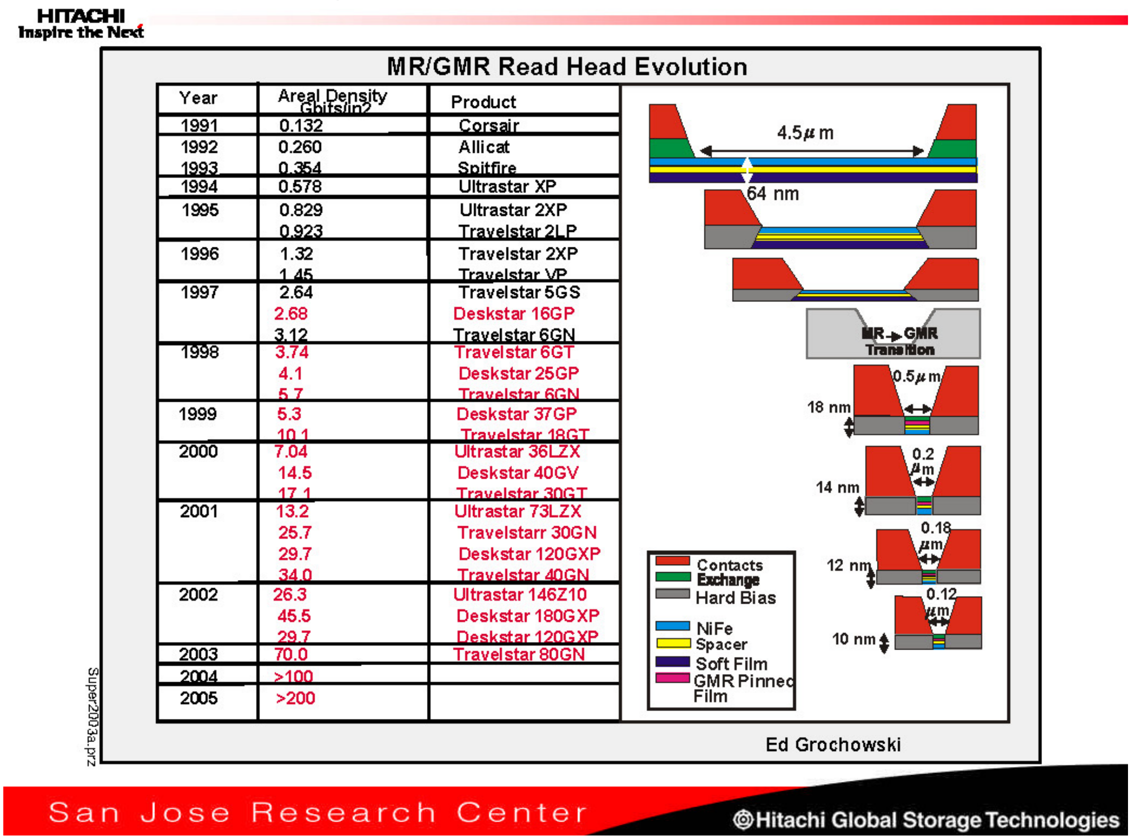


After GMR implementation by IBM and Toshiba independently, areal density increased % per year (1998 ~).

* http://www.hitachigst.com/

Miniaturisation in Head Design

Size evolution of a recording head in HDD :



Year	Areal Density Gbits/in2	Product
1991	0.132	Corsair
1992	0.260	Allicat
1993	0.354	Spitfire
1994	0.578	Ultrastar XP
1995	0.829	Ultrastar 2XP
	0.923	Travelstar 2LP
1996	1.32	Travelstar 2XP
	1.45	Travelstar VP
1997	2.64	Travelstar 5GS
	2.68	Deskstar 16GP
	3.12	Travelstar 6GN
1998	3.74	Travelstar 6GT
	4.1	Deskstar 25GP
	5.7	Travelstar 6GN
1999	5.3	Deskstar 37GP
	10.1	Travelstar 18GT
2000	7.04	Ultrastar 36LZX
	14.5	Deskstar 40GV
	17.1	Travelstar 30GT
2001	13.2	Ultrastar 73LZX
	25.7	Travelstarr 30GN
	29.7	Deskstar 120GXP
	34.0	Travelstar 40GN
2002	26.3	Ultrastar 146Z10
	45.5	Deskstar 180GXP
	29.7	Deskstar 120GXP
2003	70.0	Travelstar 80GN
2004	>100	
2005	>200	

Longitudinal Recording Technology

Longitudinal recording : *

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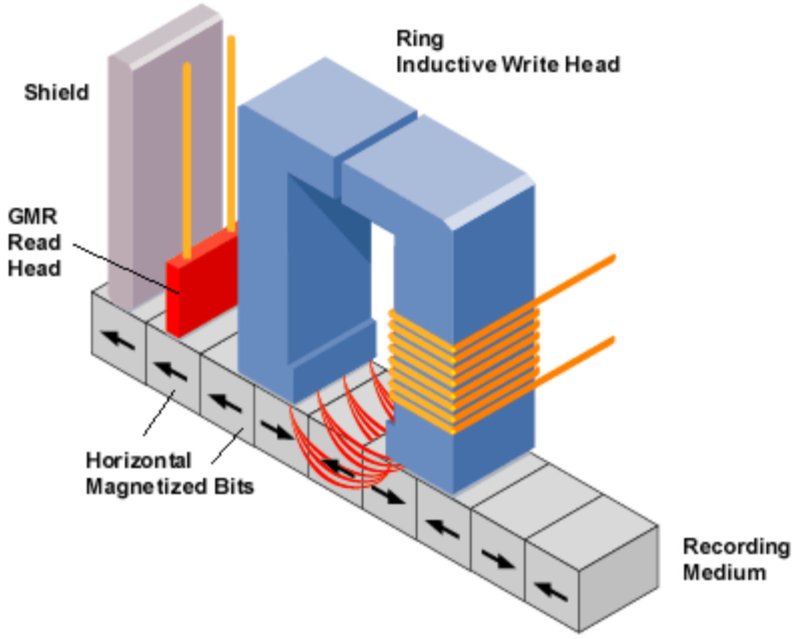

~ 2005.

* http://www.hitachigst.com/

Perpendicular Recording Technology

Perpendicular recording : *

Originally proposed by Shun-ichi Iwasaki in .

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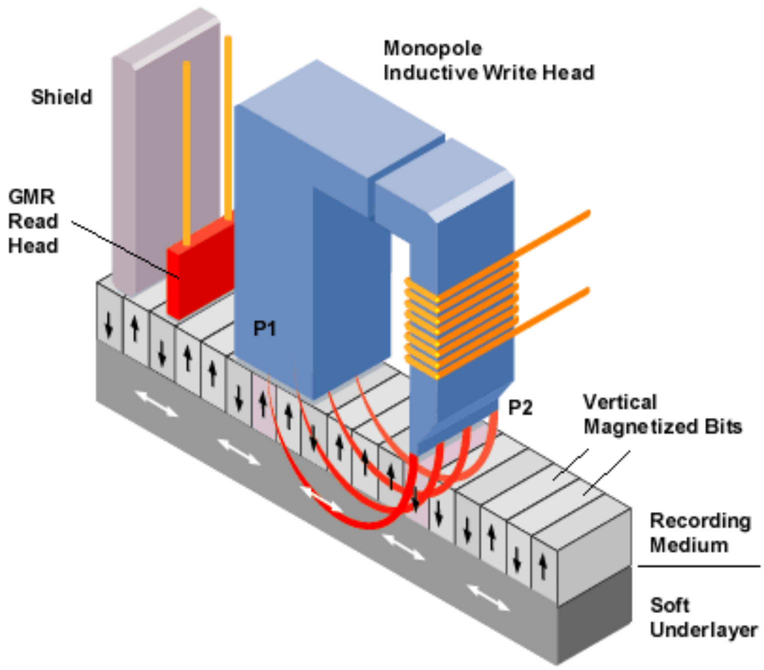
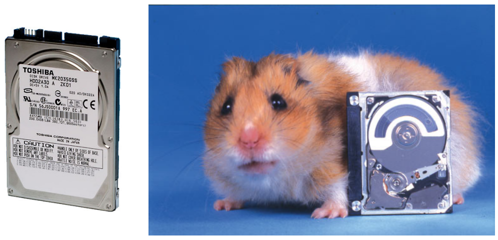


Toshiba introduced in .

* http://www.hitachigst.com/

Development of HDD

Recording density increases at 100% / year :



First HDD in the world :

RAMMAC 305 (1956, IBM)

60 cm platter × 50 =

Mbit / inch^2

Current HDD :

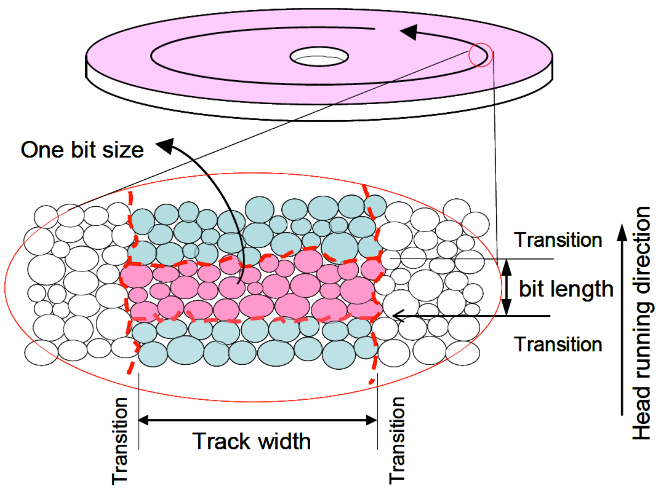
MK2035GSS (2006, Toshiba)

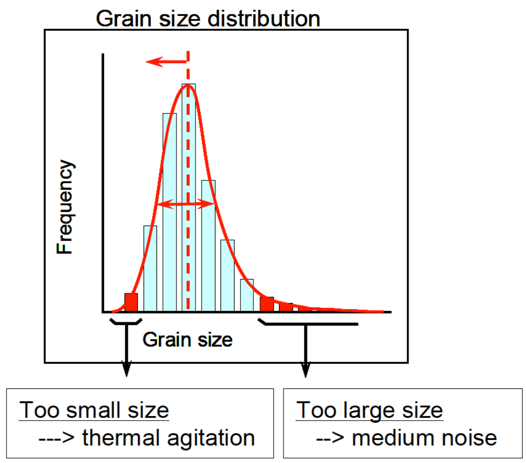
6.4 cm platter × 2 =

Gbit / inch^2

Recording Media

Polycrystalline recording media : *





* http://dspace.wul.waseda.ac.jp/dspace/bitstream/2065/28765/6/Honbun-4557_03.pdf

Bit Sizes of Recording Media

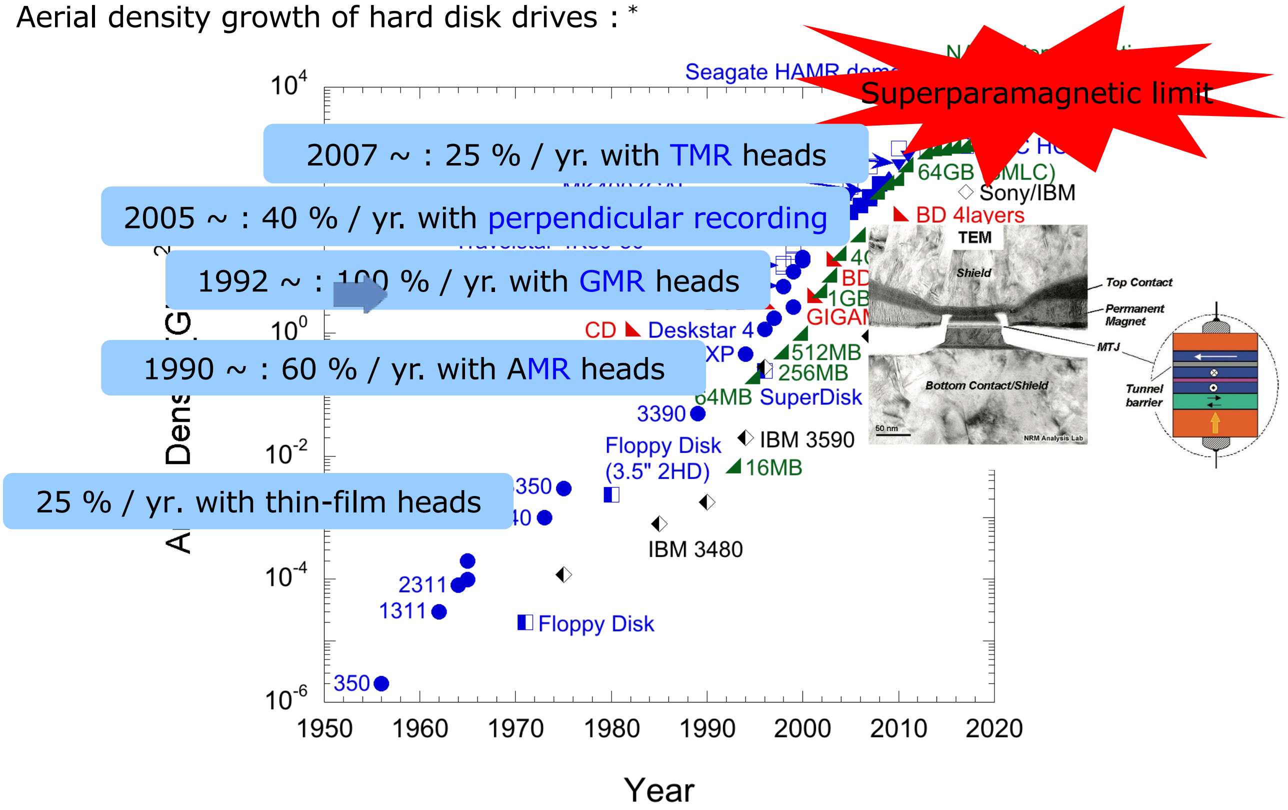
Required bit sizes for higher-density recording : *

Areal density	Typical one bit size	Number of grains (assumed ϕ8 nm/grain
10 Gbit/in^2	803 nm, 80 nm	~1280 grains
100 Gbit/in^2	180 x 36 nm	~130 grains
200 Gbit/in^2	125 x 25 nm	~65 grains
500 Gbit/in^2	80 x 16 nm	~26 grains
1000 Gbit/in^2 (1 Tbit/in^2)	36 x 18 nm (25 x25 nm)	~13 grains

* http://dspace.wul.waseda.ac.jp/dspace/bitstream/2065/28765/6/Honbun-4557_03.pdf

Aerial Density Increase by GMR Introduction

Aerial density growth of hard disk drives : *

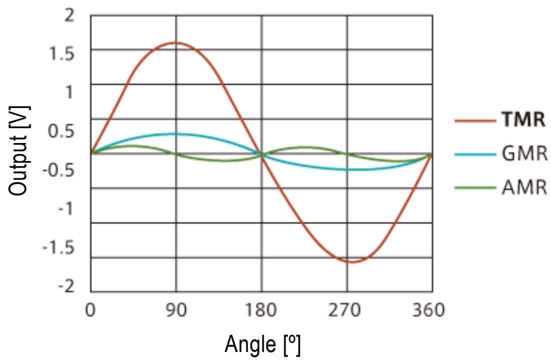


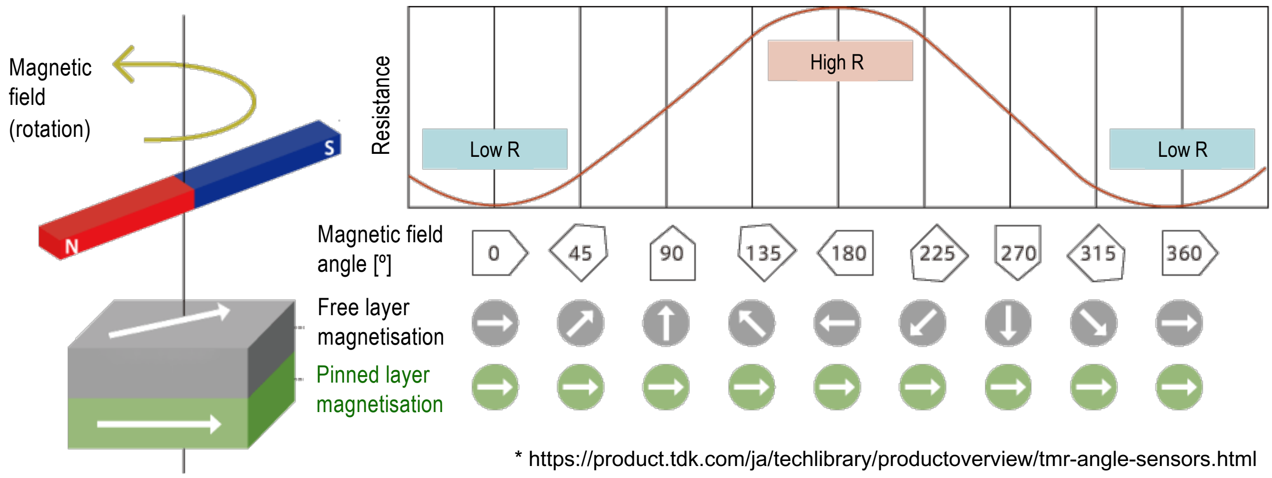
* J.-G. Zhu *et al.*, *Mater. Today* **7-8**, 22 (2003).

Advantages of TMR Junctions

Comparison between AMR, GMR and TMR : *

	AMR	GMR	TMR
MR ratios [%]	3	12	100
Output [mV]	150	560	3300
Temperature dependence [%/K]	- 0.29	- 0.23	- 0.13





* https://product.tdk.com/ja/techlibrary/productoverview/tmr-angle-sensors.html

Tri-Lemma in HDD

Requirements for higher-density recording :