GMR
Giant Magnetoresistive head in the hard drive

JM Broto LNCMP, TOULOUSE
Electrical measurements under pressure and high magnetic field (Toulouse pressure cell)

- ULA (Merida) – LNCMP (Toulouse) – LPMC (Paris VI)

- Diameter 20 mm, B~60 T, P ~40 GPa, T~ 2–300K, sample ~60 microns * 60 microns *20 microns

- ALFA : grant Ch Power 6 monthes Toulouse

- CNRS : Invited profesor J. Gonzalez 6 monthes Toulouse
  Financial support 80 kEuros (cell, pressure, gasket, salary)
The GMR

• An example of the interest of fundamental research

• Spin dependant transport (Mott 50’s, Fert Campbell,..)
  In magnetic metal the electronic scattering depend on the orientation of the spin with the magnetization. (majority spins – minority spins)

• Artificial metallic multilayers alternatively magnetic, no magnetic.
The GMR

Fig. 1. Magnetoresistance curves at 4.2 K of (Fe/Cr) multilayers [1].

Fig. 2. Variation of the CPP and CIP GMR as a function of the nonmagnetic Cu thickness [9].

Fig. 4. Potential landscape seen by spin + and spin − conduction electrons in the P and AP configurations. The intrinsic potential is represented by a periodic array of steps. The bulk and interface scattering potentials are represented by spikes.
The GMR
EXCHANGE ANISOTROPY

Fig. 1. Hysteresis loop, $m(H)$, of a Fe/Cr bilayer at $T = 10$ K after field cooling [72]. The exchange bias, $H_E$, and the coercivity, $H_C$, are indicated in the figure.

Fig. 8. Schematic diagram of angles involved in an exchange bias system. Note that the AFM and FM anisotropy axes are assumed collinear and that the AFM sublattice magnetization $M_{AFM}$ has two opposite directions.

$$E = -HM_{FM}t_{FM} \cos(\theta - \beta) + K_{FM}t_{FM} \sin^2(\beta) + K_{AFM}t_{AFM} \sin^2(\alpha) - J_{INT} \cos(\beta - \alpha),$$

$$H_E = \frac{J_{INT}}{M_{FM}t_{FM}}.$$
SPIN VALVE COMPOUND

Magnétorésistance d'un composé à vanne de spin (NiO 275A/Co30A/Cu20A/Co2A/Ni$_{80}$Fe$_{20}$ 70A). En a, courbe de magnétorésistance complète obtenue en faisant varier le champ sur une gamme suffisamment large pour provoquer les retournements des aimantations de la couche magnétiquement douce (Ni$_{80}$Fe$_{20}$) et de la couche piégée (Co). En b, cycle d’hystérésis mesuré en réduisant le balayage du champ de sorte que seule l’aimantation de la couche douce se retourne. La courbe violette correspond au champ croissant et la rouge au champ décroissant.

Tête pour enregistrement sur disques durs
Société Silmag
Research in mechanical technologies for hard disk drives

Antiferromagnetically coupled media structure
FIGURE 3: READING DATA FROM A STORAGE MEDIUM

SIGNAL VOLTAGE (V)

SENSE CURRENT (I)

MAGNETIC FIELD FROM MEDIUM

GMR ELEMENT RESISTANCE (R ± 4R)

CLOCK TICKS
FIGURE 4: INTEGRATED WRITE - READ HEAD

WAFER SUBSTRATE (NON-MAGNETIC)

SHIELD 1

SHIELD 2 & POLE 1

COIL

POLE 2

OVERCOAT

HEAD - MEDIUM SPACING

MAGNETIC LAYER

DISK SUBSTRATE (NON-MAGNETIC)

GMR ELEMENT

WRITE GAP
What is this thing called Fly Height?

**Fly height:** The distance from the ABS surface to the mean disk surface. In the ABS code, the disk is idealized as a perfectly flat surface at 0 fly height.

**Take Off Height:** The flying height at which contact with highest asperities occurs.

**Glide Height:** The flying height at which asperities are detected with a slider equipped with a PZT sensor. (Glide Height > TOH)
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<th>Magnetic Spacing (nm)</th>
<th>Disk Overcoat Thickness (nm)</th>
<th>Flying Height (nm)</th>
<th>PTR + Lube Nominal Value (nm)</th>
<th>Slider Overcoat Thickness (nm)</th>
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Hitachi Global Storage Technologies, Inc.
ABS and the Suspension

- Dimple
- LAUL Tab
- Gimbal
- Load Beam
- Flexure

IBM Almaden Research Center
The anatomy of a typical negative pressure type air bearing is shown below.

Shallow Etch (Typically 0.2 to 0.3μm)

Deep Etch (typically 1 to 2 μm)

Magnetic Element

“Negative” Pressure Pocket

ABS Pads (in green)

IBM Almaden Research center
Equivalent for an AIRBUS to fly at 1 m of the ground with a speed of 920 Km/h
Performance Bottlenecks

- Electronic Packaging
- Interconnects
- Circuit Design
- R/W Head Modeling
- Disk Magnetics

Diagram components:
- Disk Electronics (DE) Board
- AE Electronics
- Suspension Interconnect
- DE Board Conductors
- DE Connector
- Flex Cable
- Channel Interconnect
- R/W Heads
- Media Dynamics
Tunnel Junction Array

MagRAM Architecture

Reading a bit

Writing "0"

Writing "1"

MTJ MagRAM promises
- density of DRAM
- speed of SRAM
- non-volatility
MRAM
An enlargement of the active layers in an MRAM device. The red and green spheres represent electrons spinning in opposite directions in the magnetic layers. The very thin insulator allows electrons to quantum-mechanically tunnel through it. Information is stored in the top layer by forcing its electrons to spin in one direction or another. Information is retrieved by measuring the amount of current that travels through the tunnel insulator, which depends on the spin direction of the electrons in the top layer.
This animation demonstrates in detail the writing and reading operations of an MRAM cell. To write "1", IBM scientists simultaneously force one current to flow through the top electrode and another through the write word line; writing "0" requires the same process except that the current through the top electrode flows in the opposite direction. To read "1" and "0", the scientists force another lesser current to flow from the bottom electrode through the stack of magnetic layers and out the top electrode. The magnetic stack allows greater current flows to the top electrode for reading "1" than for reading "0".