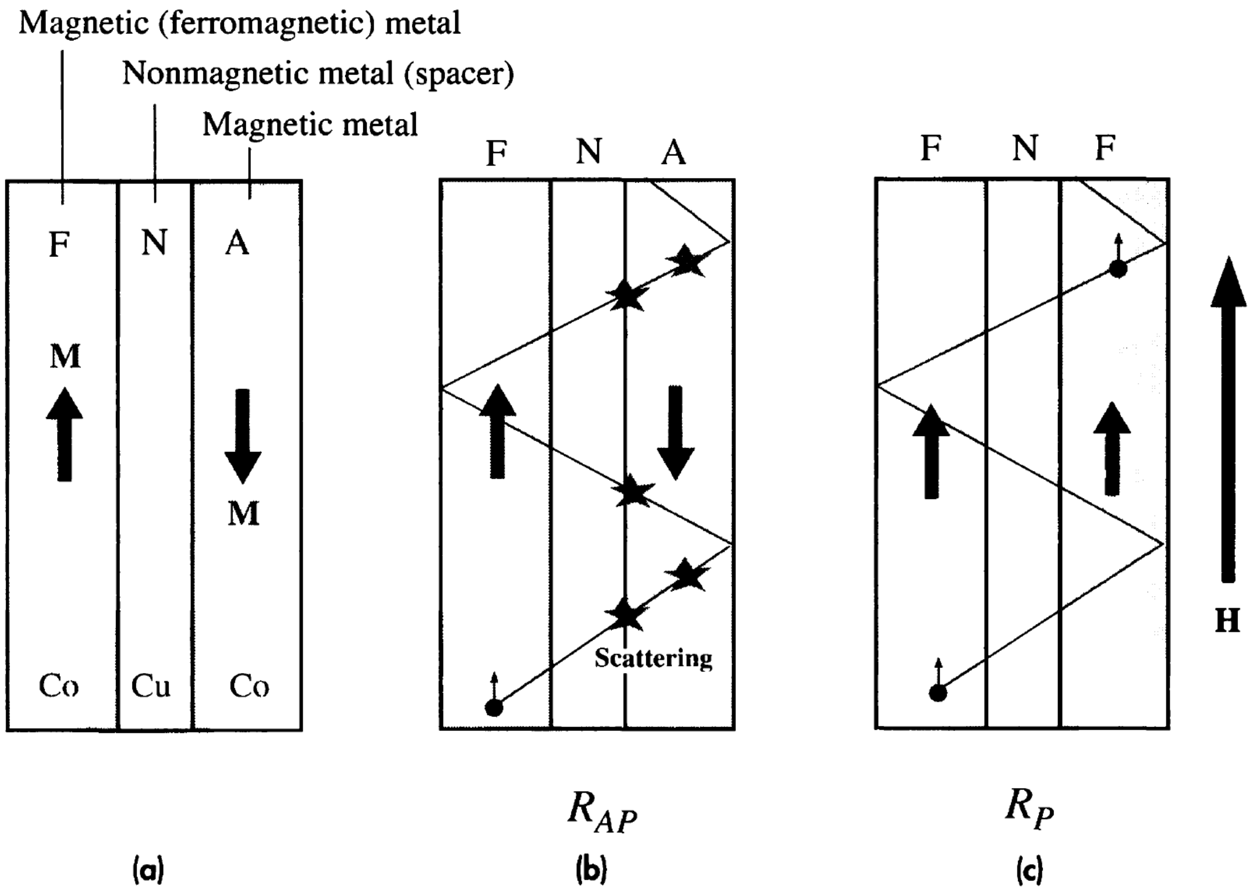
# PYL 102

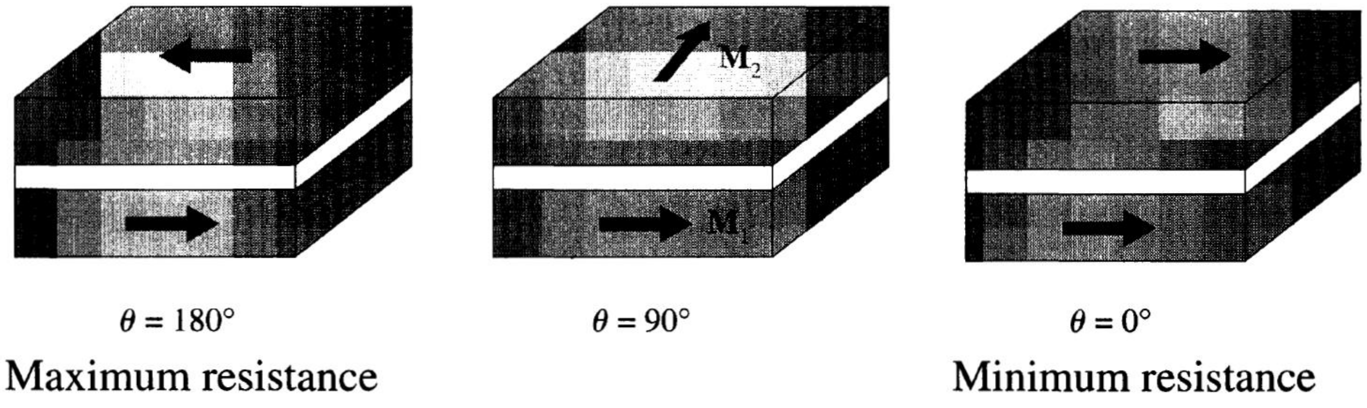
Thursday, Nov. 7, 2024

Giant magnetoresistance, GMR head




The magnetic layers are thin (<10 nm), and the nonmagnetic layer is even thinner. The magnetizations of the two ferromagnetic layers are not random, they depend on the thickness of the spacer because the two layers are coupled indirectly through this thin spacer. In the absence of an external field, two magnetic layers are coupled in such a way that their magnetizations are antiparallel. This arrangement is also called an antiferromagnetically coupled configuration. We can apply an external magnetic field to one of the layers and rotate its magnetization so that the two magnetizations are now in parallel. This parallel configuration is frequently called ferromagnetically coupled layers. The two structures have a giant difference in their resistances, hence the term giant magnetoresistance.

The difference in the resistances Rp and Rap in this simple trilayer is roughly 10% or less. But, in multilayered structures, which have a series of alternating magnetic and nonmagnetic layers, the change in the resistance can be large, exceeding 100% at low temperature and 60-80% at room temperature.




The GMR effect is often measured by quoting the change in the resistance with respect to Rp,

$$\left(\frac{\Delta R}{R_p}\right)_{\text{GMR}} = \frac{R_{\text{AP}} - R_P}{R_p}$$

If the angle between the magnetization vectors M1 and M2 of the two magnetic layers is θ

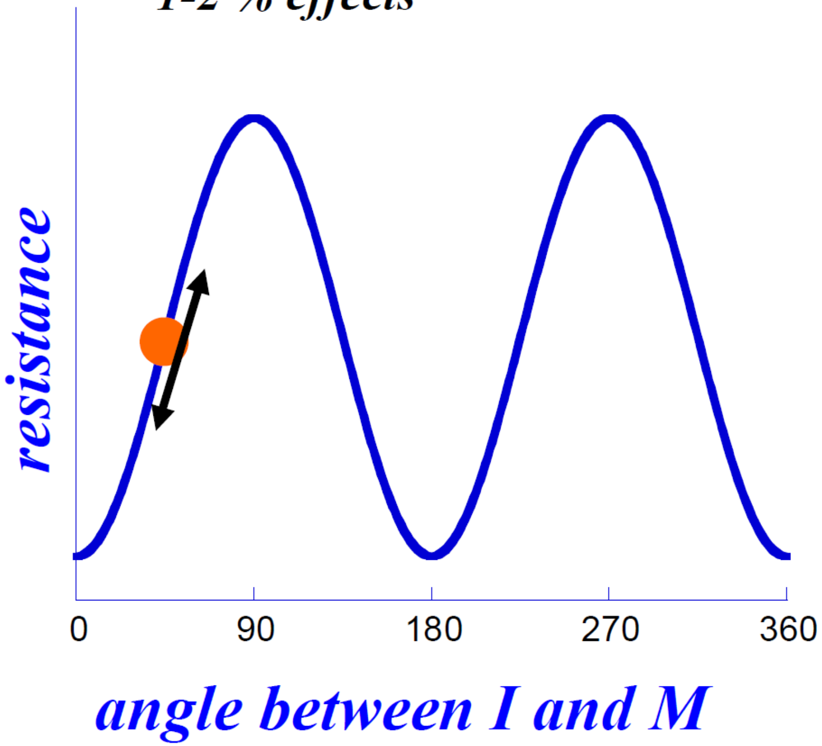
$$\frac{\Delta R}{R_P} = \left(\frac{\Delta R}{R_P}\right)_{\text{max}} \frac{1 - \cos\theta}{2}$$

# Anisotropic Magneto-resistance (AMR)


*high resistance*

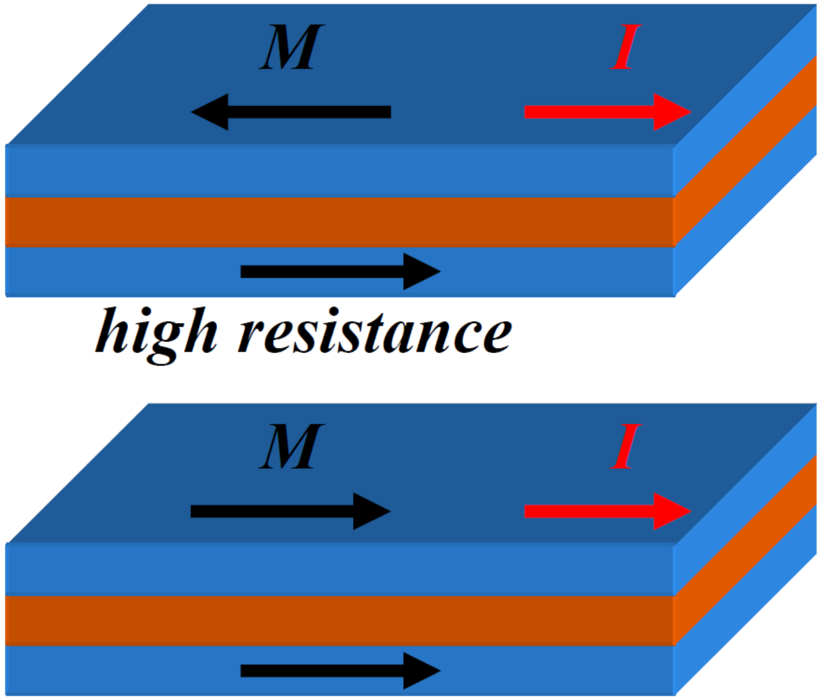

*low resistance*

*1-2 % effects*

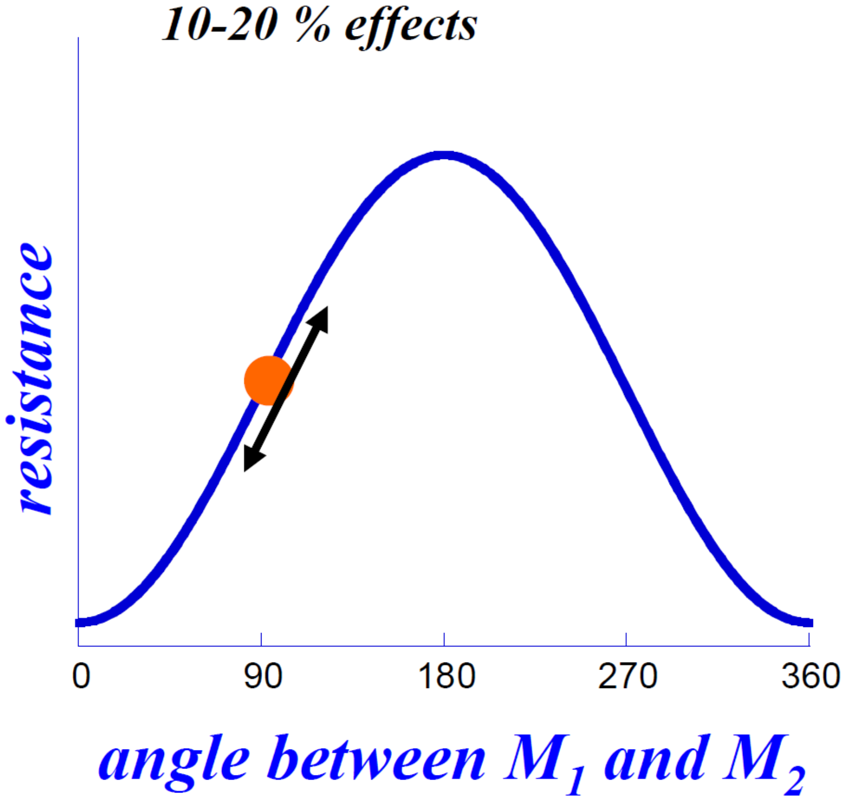



*Bulk property of magnetic materials*

# Giant Magneto-resistance (GMR)



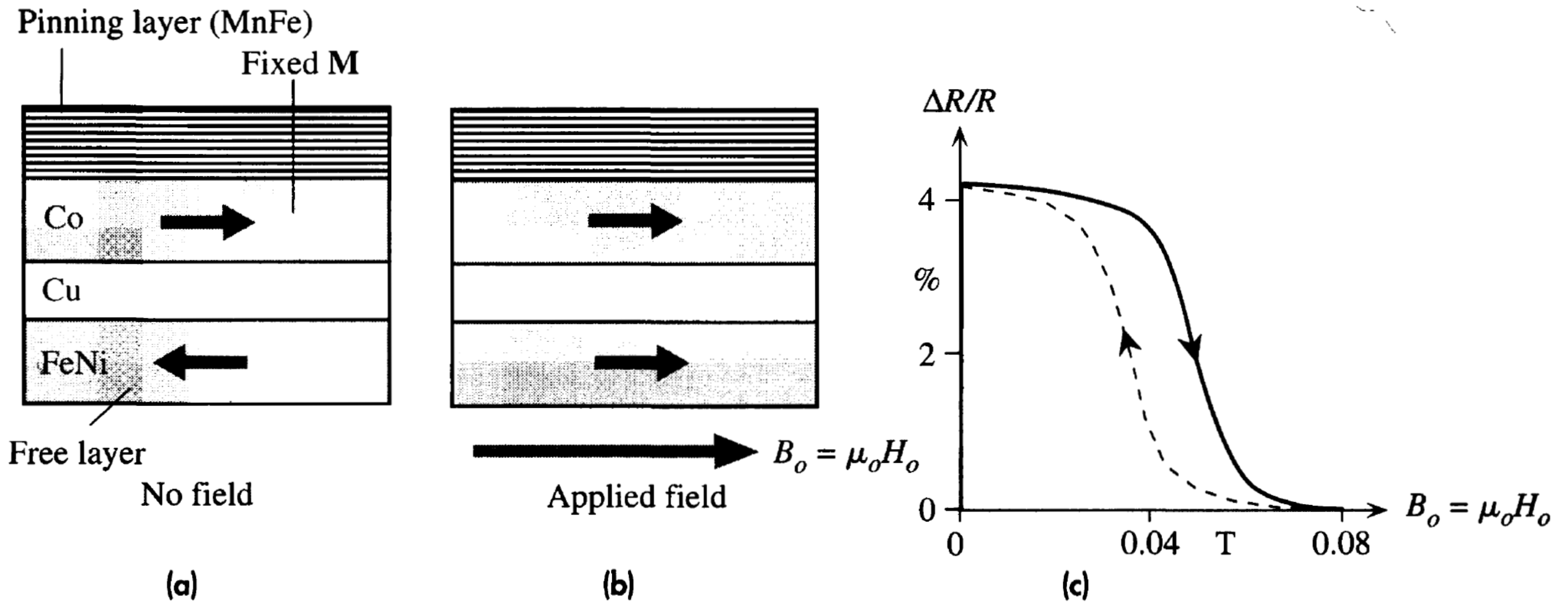

*low resistance*




*Interface property of magnetic materials*

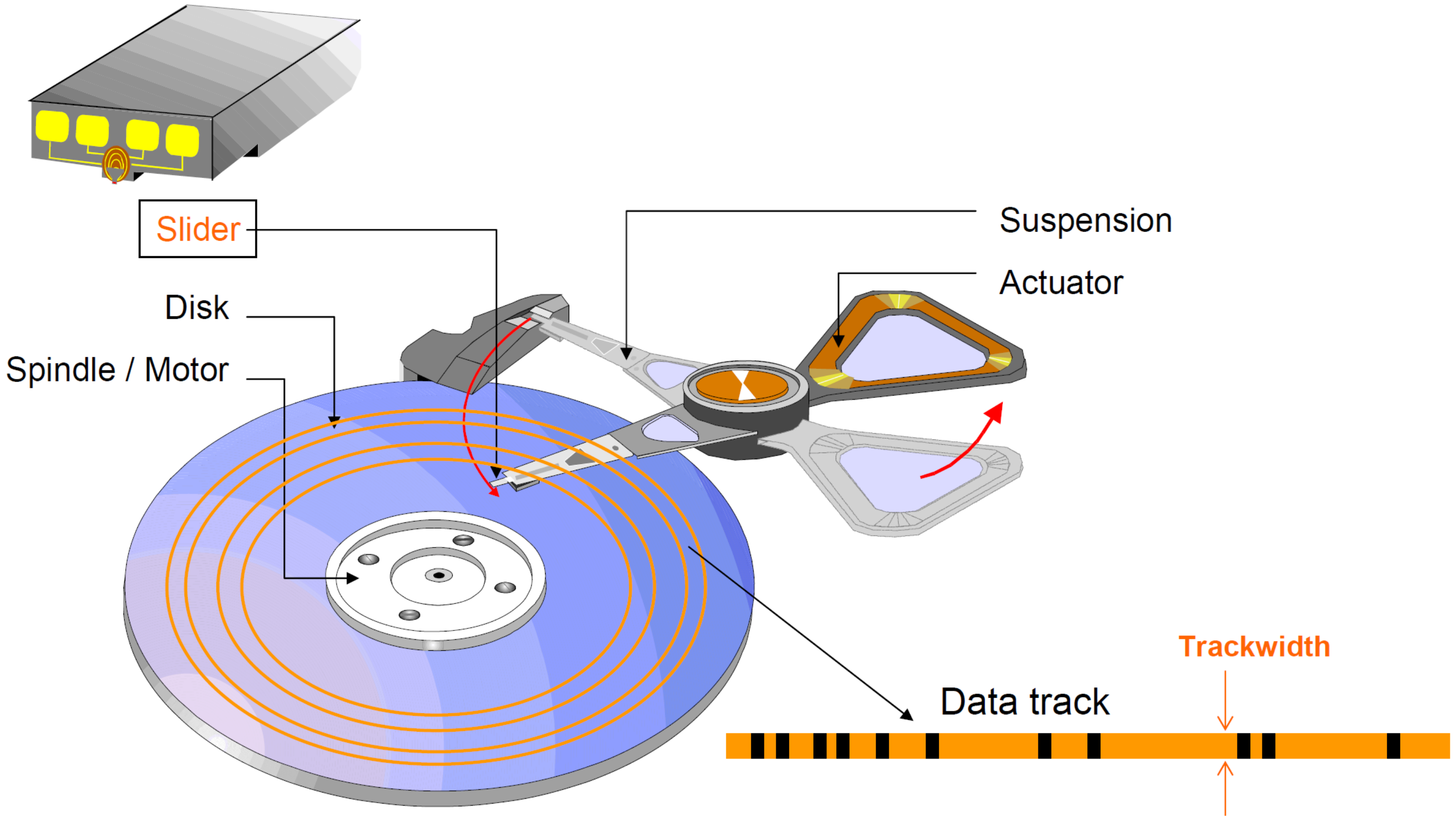
# Spin valve

The current flow/resistance of the valve is controlled by an external applied magnetic field. The magnetization of the Co magnetic layer is fixed i.e. pinned by having this layer next to an antiferromagnetic layer, called the pinning layer. The exchange interaction between the ferromagnetic Co layer and the antiferromagnetic MnFe layer effectively pins the direction of the Co layer. A Cu spacer layer separates the Co and the next magnetic FeNi layer (free layer). The FeNi layer magnetization can be changed by an external magnetic field.
In the absence of a field, the magnetization of the FeNi layer is antiparallel to the Co layer, and the structure has a high resistance RAp. An applied external field can rotate the FeNi layer's magnetization and can easily align it fully in parallel with that of Co so that the resistance becomes minimum Rp.




Resistance change versus applied magnetic field (schematic) for a FeNi/Cu/FeNi spin valve.

# Hard Disk Storage with GMR sensor



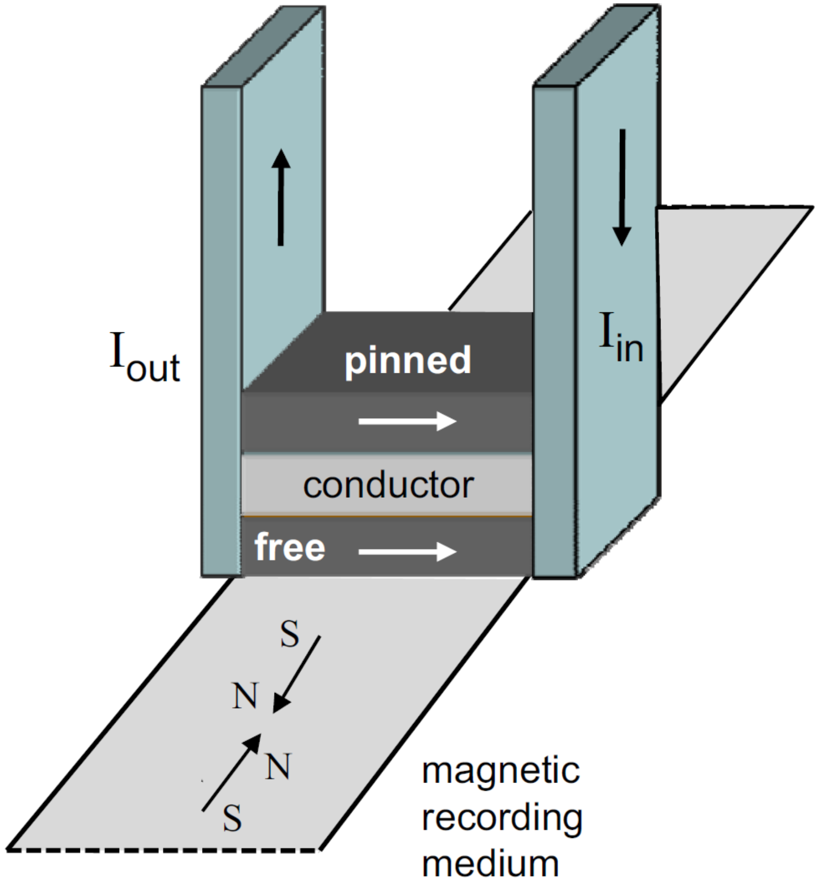

The storage medium is a thin film of magnetic material coated on a disk substrate, which rotates inside the hard drive. The information is recorded as magnetization patterns on this thin-film. Both the write and the read heads are in a single compact assembly that moves radially across the rotating disk to write or read the information into tracks. The total area storage density depends on the information density in the track and the track density on the disk. The read head is a tiny giant magnetoresistance (GMR) sensor whose resistance depends on an external magnetic field.

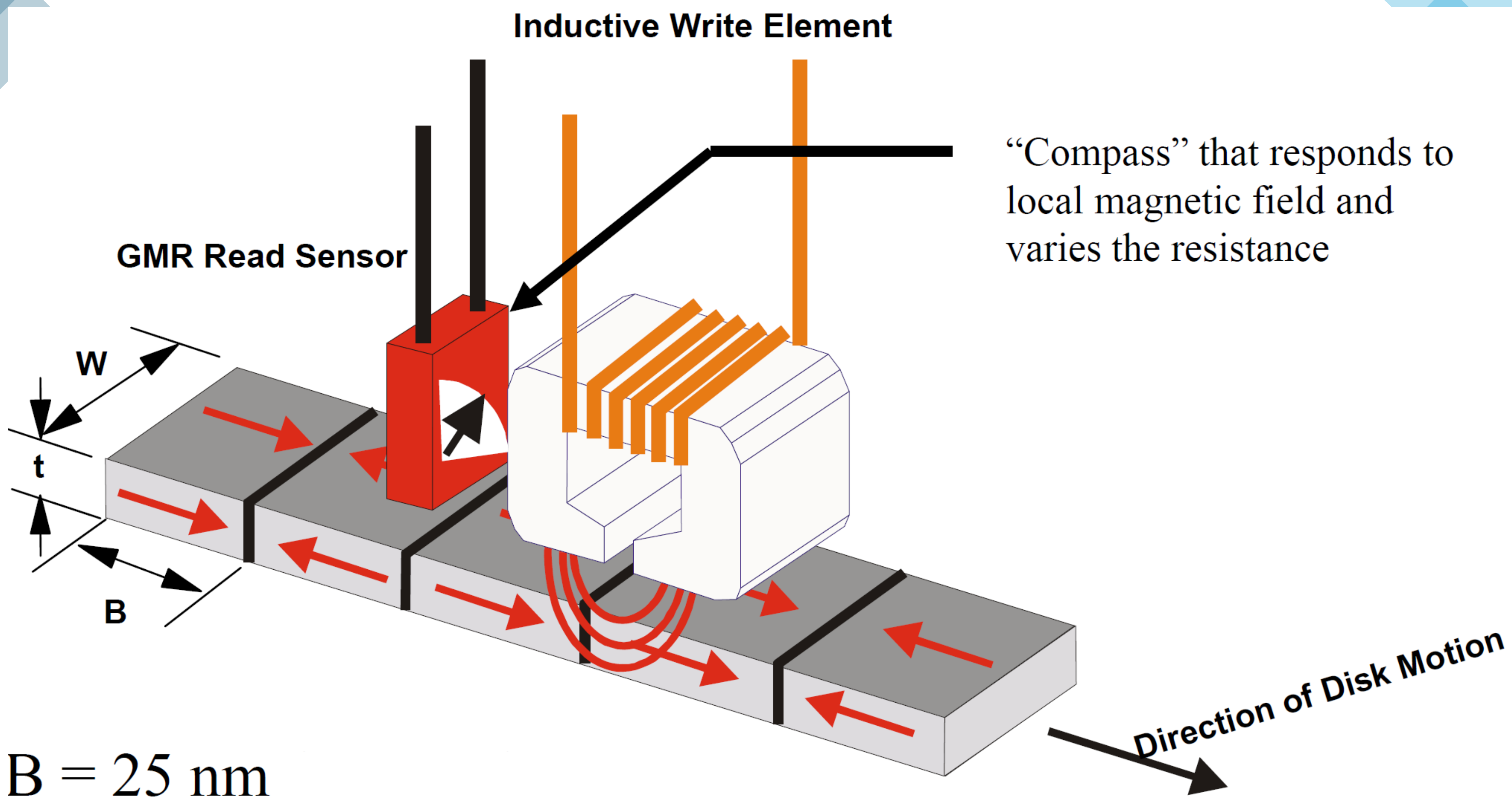
# GMR read head

This device is based on spin-valve concept.

Magnetic fringe field emanating from bits written on the hard disk change the direction of magnetization of the other, close by, ferromagnetic layer as they pass by. For ferromagnetic layers having parallel magnetization with that of the bits, the resistance to current flow is small, while antiparallel magnetization yields large resistance. At constant potential, the change in current passing through the films is sensed by an external electronic circuit to read out the bits (zeros and ones) of memory.

A GMR magnetic media reading head.

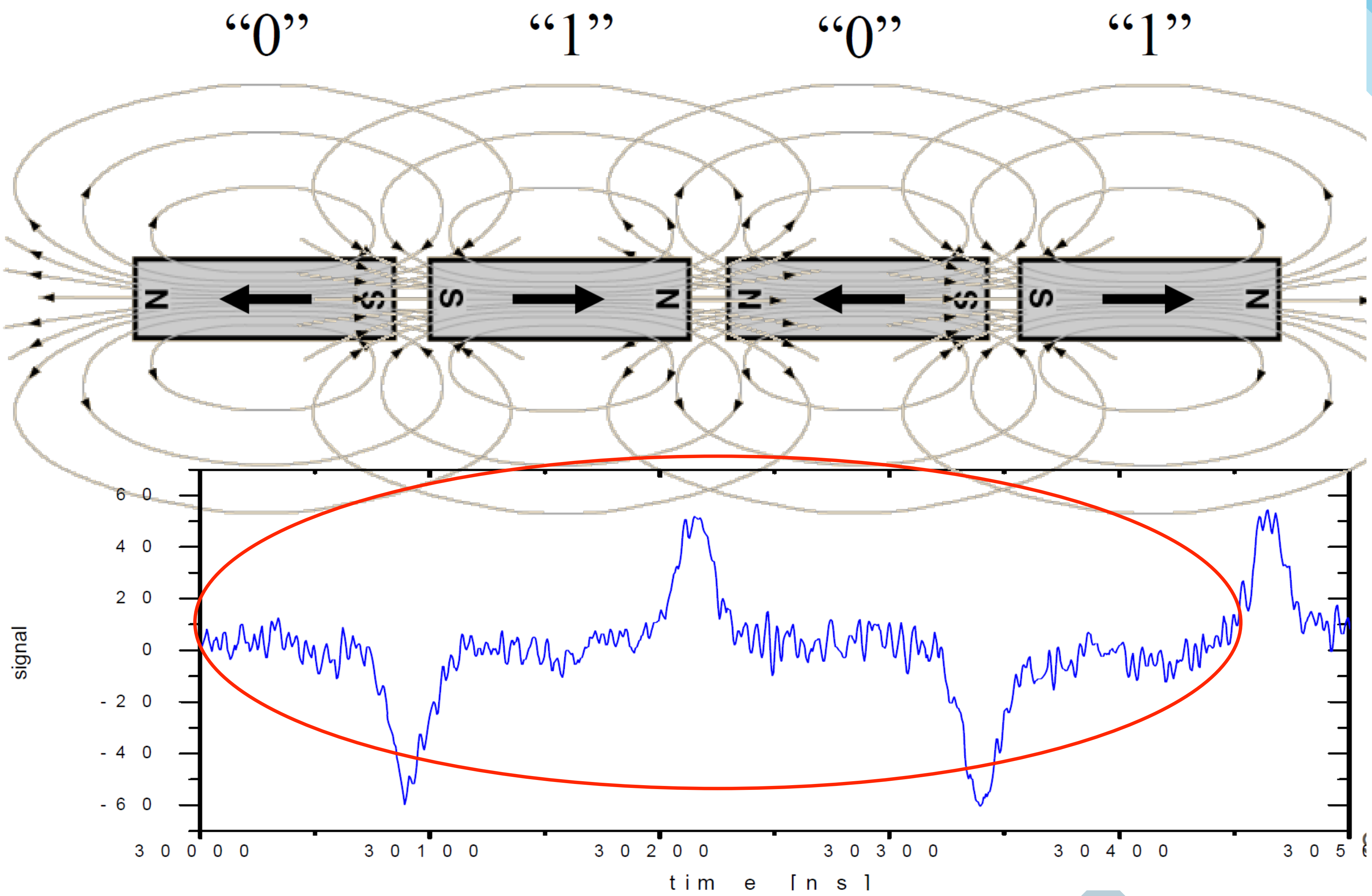


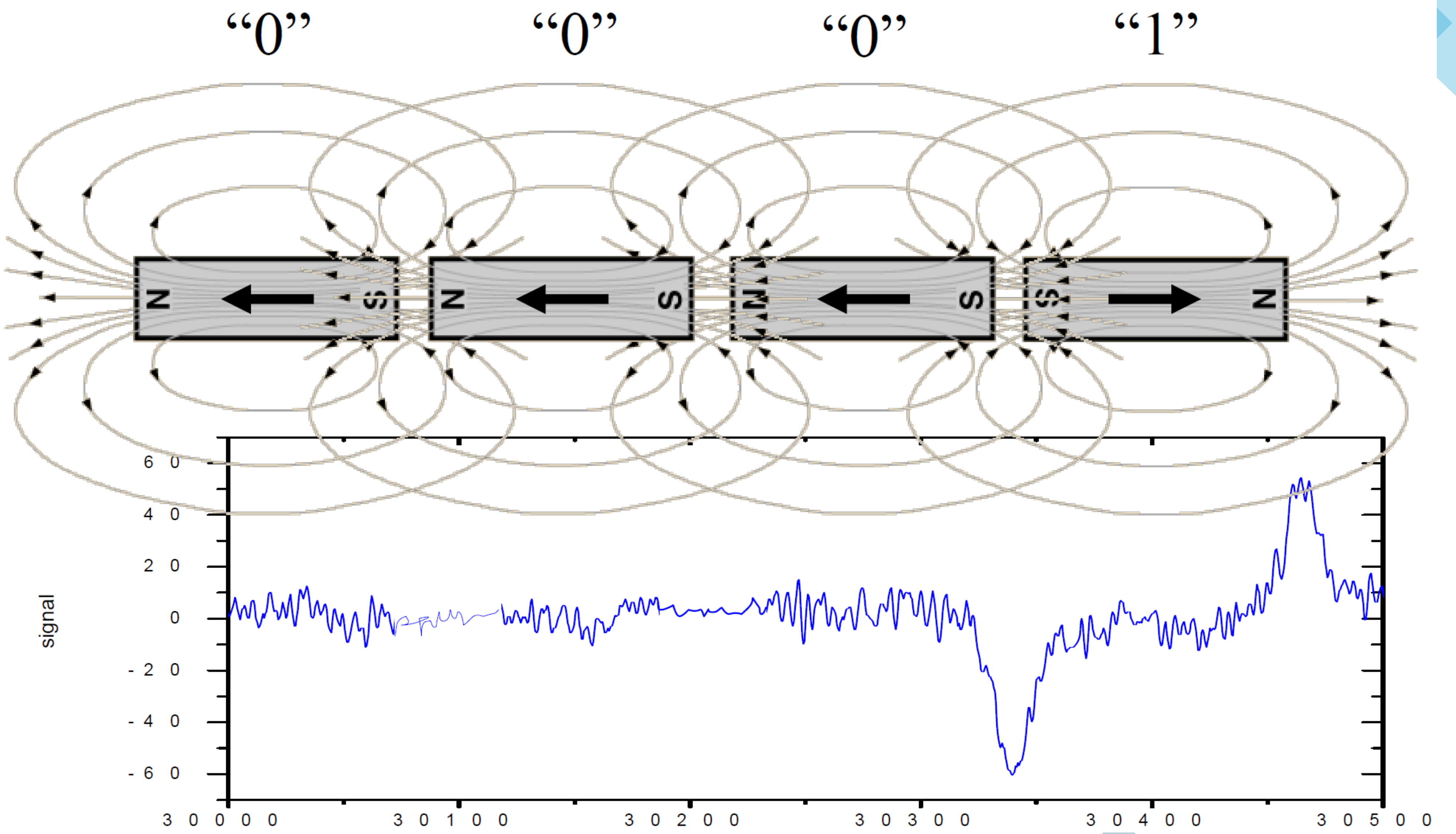



“Compass” that responds to local magnetic field and varies the resistance

B = 25 nm

W=150 nm, t = 14 nm


"0"
"1"
"0"
"1"
N
S
S
N
N
S
S
N
60
40
20
0
-20
-40
-60
signal
30000
30100
30200
30300
30400
time [ns]


"0"
"0"
"0"
"1"
N
S
N
S
N
S
S
N
signal
60
40
20
0
-20
-40
-60
30000
30100
30200
30300
30400
30500

Reasons for using a GMR sensor instead of a conventional inductive read head.

(i) GMR sensor is so much smaller than the inductive head that it can probe a much smaller region of the magnetic medium 50 nm.

(ii) GMR is much more sensitive than the inductive head.