



Giant Magnetoresistance

Krylov Alexey 23422/2

St.Petersburg Polytechnical
University ,2014



Outline

- Introduction
- Science of GMR
 - Anisotropic magnetoresistance
 - Giant magnetoresistance
- Discovery of GMR
 - research by IBM
- Application of GMR
 - GMR-based spin valves in hard drives
- Impact of GMR on the storage media industry

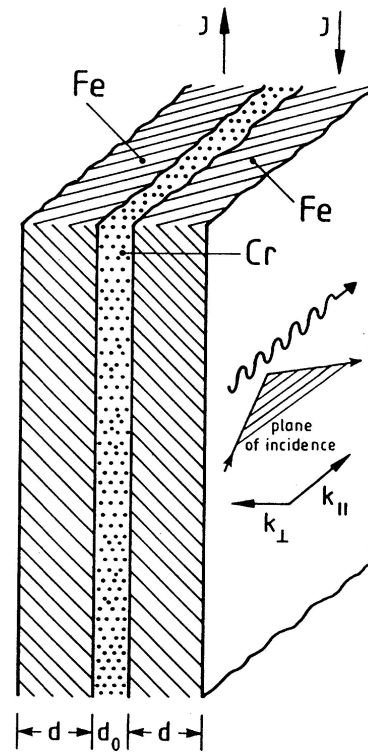
GMR – why is it useful?

- Discovery and application of the GMR phenomenon is responsible for the ubiquitous availability of economical, high density information storage in our society.
- Compact 160 GB Mp3 players and 1 TB hard drives, now widely available, owe their existence to GMR and subsequent related advances.

Science of GMR

Giant magnetoresistance

- System:
 - a thin layer of nonmagnetic material sandwiched between two layers of magnetic material.
- Right: a Fe-Cr-Fe trilayer used in Grünberg's original experiment.



Science of GMR

Mott Model

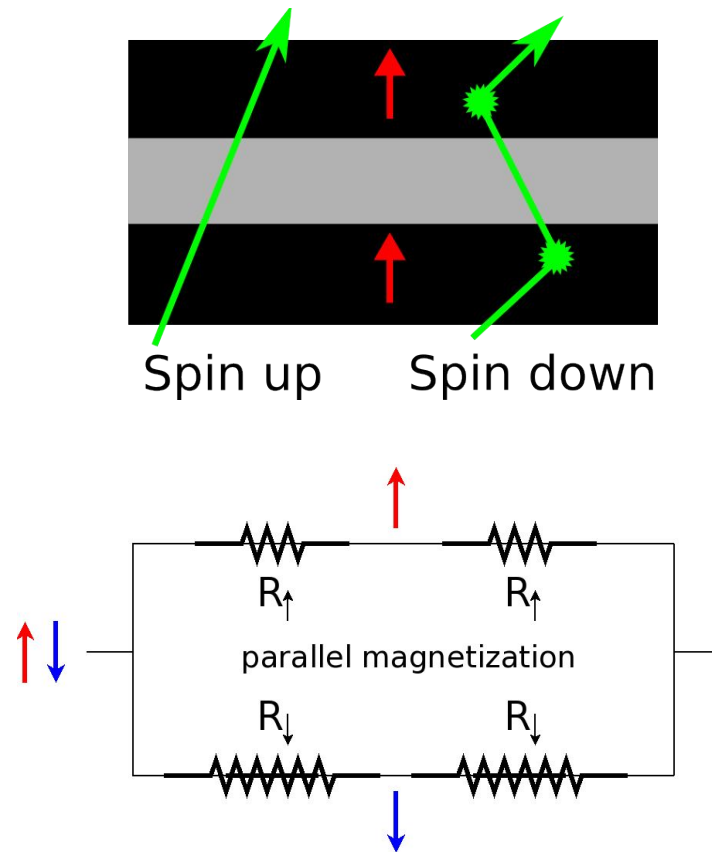
- The electrical conductivity in metals can be described in terms of two largely independent conducting channels, corresponding to the up-spin and down-spin electrons, and electrical conduction occurs in parallel for the two channels.
- In ferromagnetic metals the scattering rates of the up-spin and down-spin electrons are different.
- ❖ (We will assume that the scattering is strong for electrons with spin antiparallel to the magnetization direction and weak for electrons with spin parallel to the magnetization direction.)

Science of GMR

Giant magnetoresistance

- Parallel magnetization
- Up-spin electrons experience small resistance, down-spin electrons experience large resistance.
- Total resistance is

$$R_{para} = \frac{2R_{\uparrow}R_{\downarrow}}{R_{\uparrow} + R_{\downarrow}}$$

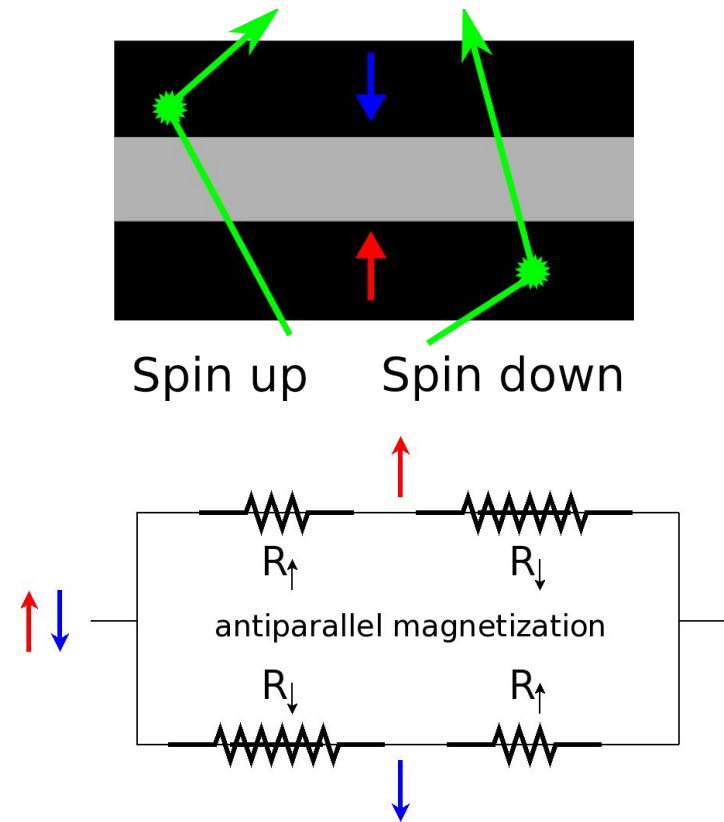


Science of GMR

Giant magnetoresistance

- Antiparallel magnetization
- Both electron spins experience small resistance in one layer and large resistance in the other.
- Total resistance is

$$R_{antpara} = \frac{1}{2} (R_{\uparrow} + R_{\downarrow})$$



Discovery of GMR

Fert and Grünberg

- Discovered by independently by Professor Albert Fert of Université Paris-Sud in France and Professor Peter Grünberg of Forschungszentrum in Jülich, Germany.
- Both groups submitted papers to *Physical Review* in the summer of 1988.

Discovery of GMR

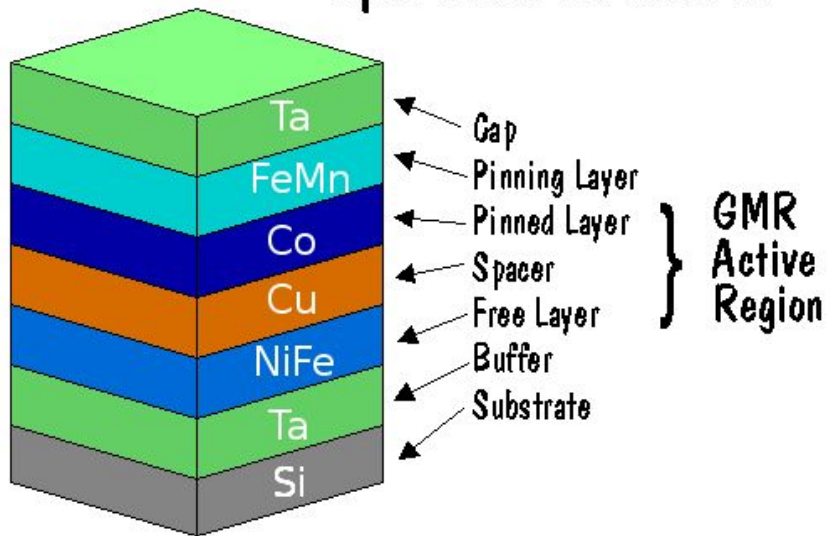
IBM

- Stuart Parkin of IBM attempted to reproduce the effect using the sputtering technique
- Fert and Grünberg used molecular beam epitaxy, a more precise but slower and more expensive method.
- Parkin's group succeeded, observing GMR in the first multilayer sample's produced.
- Parkin's group began experimenting with various sample compositions and layer thicknesses to better understand GMR and how to integrate it into magnetic storage.

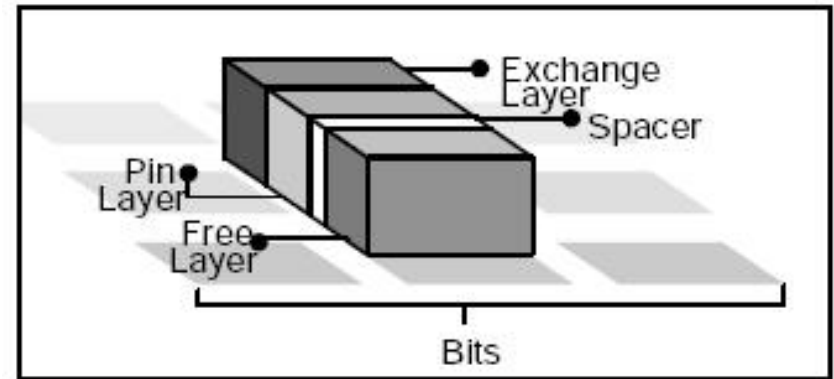
GMR in practice

Spin Valve

Spin-valve structure.



[7].



[8]

Read/Write Head



GMR's effect on hard drive industry

- First GMR hard drive deployed:
 - Deskstar 16 GP by IBM
 - Date: 1997
 - Storage: 16.8 GB
 - 2.7 billion bits per square inch.
- Current largest hard drive:
Deskstar 7K1000 by Seagate
 - Date: 2014
 - Storage: 8 TB

