عناوین

۱- مقاومت مغناطیسی عظیم(Giant magnetoresistance:GMR)

مقاومت مغناطیسی عظیم :Giant magnetoresistance

Introduction

Giant magnetoresistance (GMR) is a quantum mechanical magnetoresistance effect observed in multilayers composed of alternating ferromagnetic and non-magnetic conductive layers. The 2007 Nobel Prize in Physics was awarded to Albert Fert and Peter Grünberg for the discovery of GMR.

The effect is observed as a significant change in the electrical resistance depending on whether the magnetization of adjacent ferromagnetic layers are in a parallel or an antiparallel alignment. The overall resistance is relatively low for parallel alignment and relatively high for antiparallel alignment.

The magnetization direction can be controlled, for example, by applying an external magnetic field. The effect is based on the dependence of electron scattering on the spin orientation.

The main application of GMR is magnetic field sensors, which are used to read data in hard disk drives, biosensors, microelectromechanical systems (MEMS) and other devices. GMR multilayer structures are also used in magnetoresistive random-access memory (MRAM) as cells that store one bit of information.

What is GMR?

- Way to control electrical resistance at the nanoscale using magnetic field
- Nonmagnetic metal sandwiched between magnetic layers
- Apply magnetic field
  → parallel magnetization
  → decreased resistance

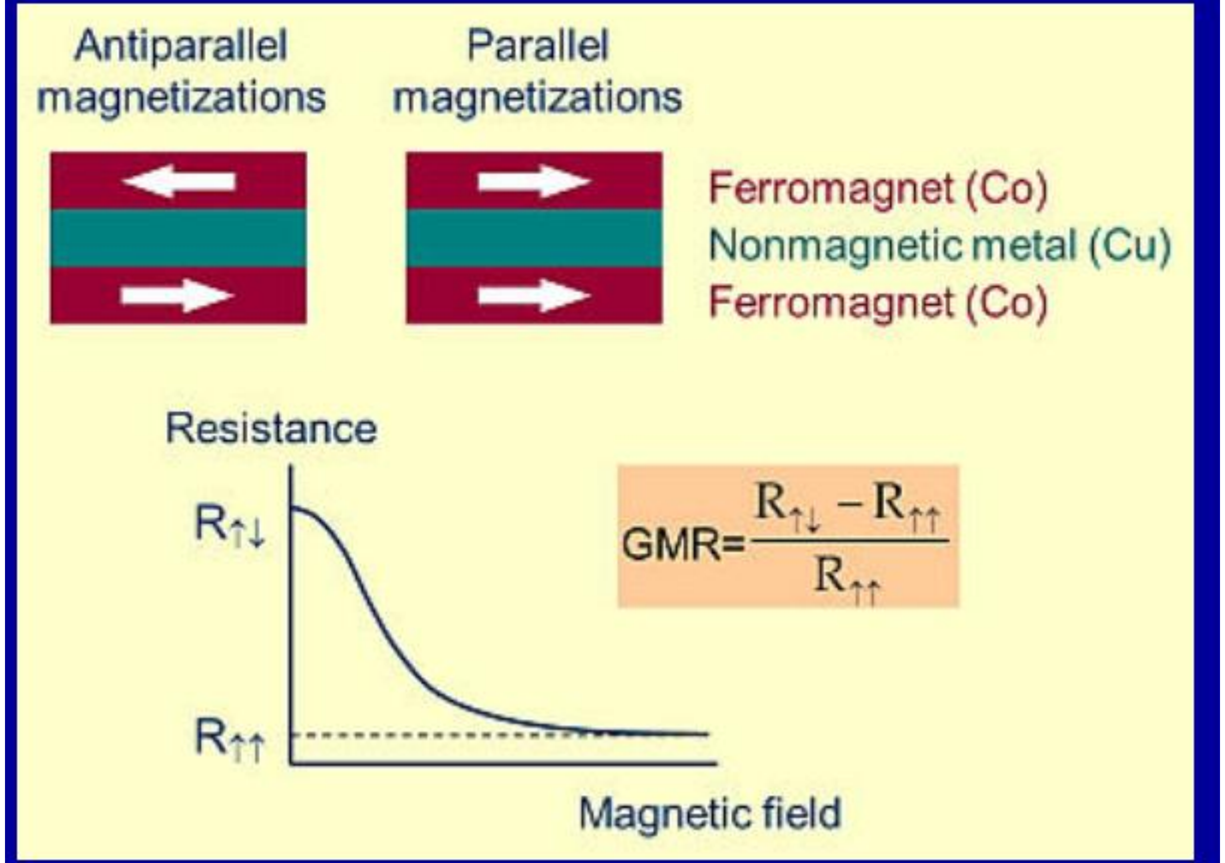

Figure 1. Fundamentals of GMR

Nobel Prize in Physics (2007)

- Awarded jointly to Albert Fert and Peter Grünberg
- Discovered independently in 1988
- Product of nanotech revolution of 1980's
- Revolutionized hard drives/data storage

Figure 2. Albert Fert

Figure 3. Peter Grunberg

Outline

- Background
- Discovery of GMR
- Some basic theory
- Applications: magnetic field sensors, hard drive read heads, magnetic RAM

Background

- Ordinary magnetoresistance (OMR) discovered in 1856 by Lord Kelvin
- Resistance of iron changes up to 5% with external magnetic field
- Little progress in MR effect through 1980

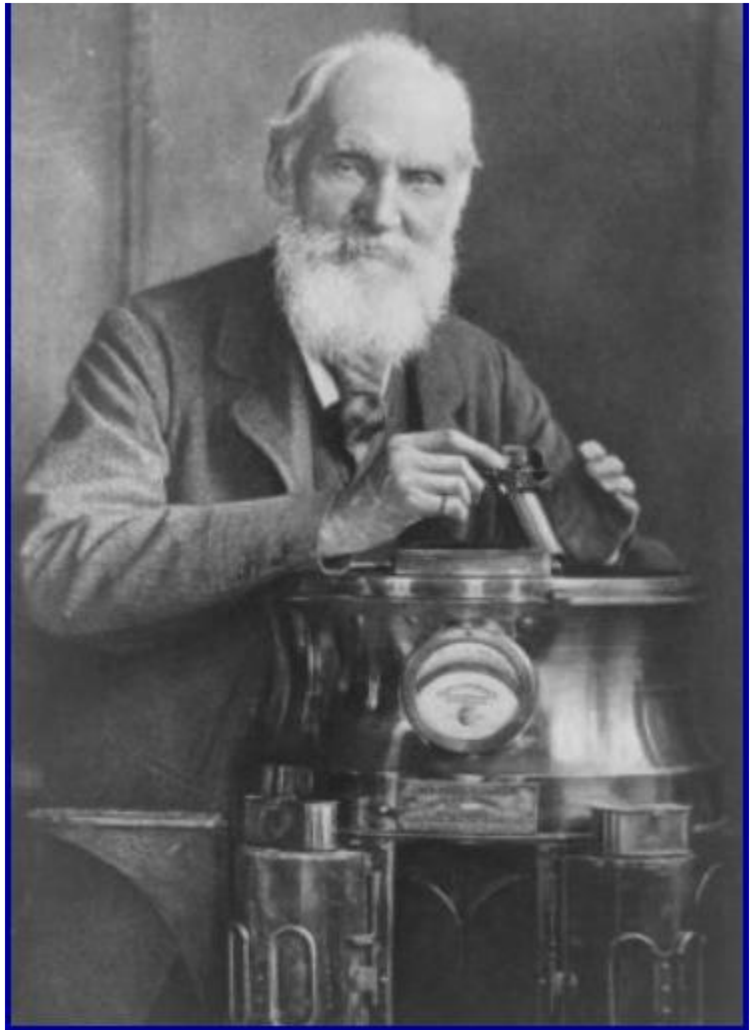

Figure 4. Lord Kelvin

Discovery

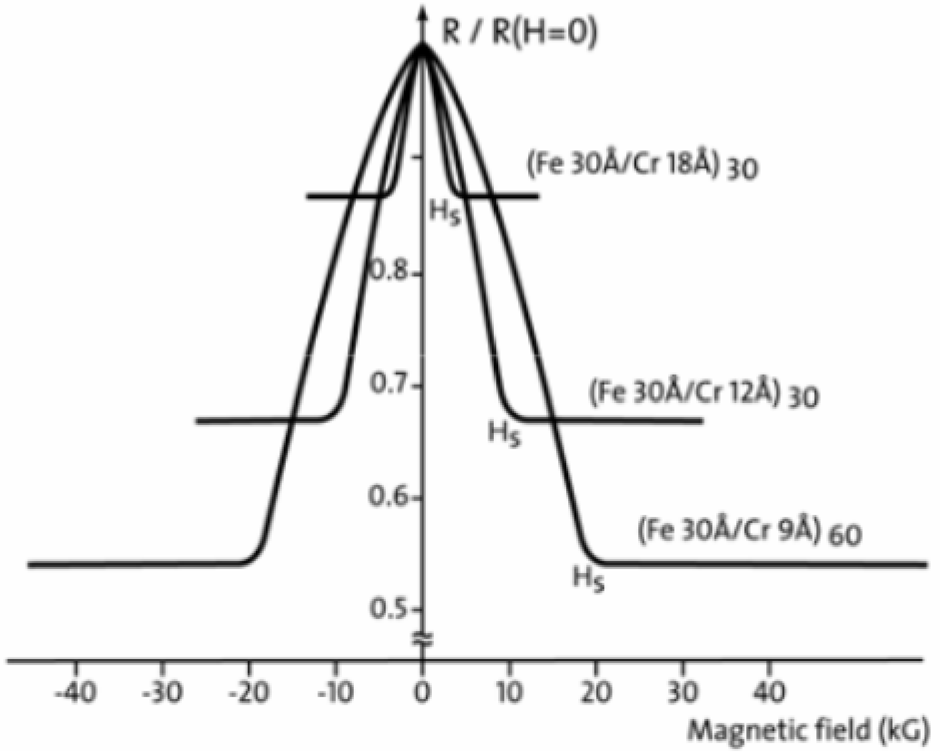

Figure 5. Albert Fert's experimental data (1988)

- Multilayers of Fe/Cr prepared by molecular beam epitaxy
- Fe is **ferromagnetic:** can be permanently magnetized
- Cr is nonmagnetic
- Magnetoresistive effect ~50% (vs. 5% previously)

Basic Mechanism

- Electron spin & atom magnetic moments in parallel → weak scattering
- Antiparallel → strong scattering
- More scattering = higher electrical resistance

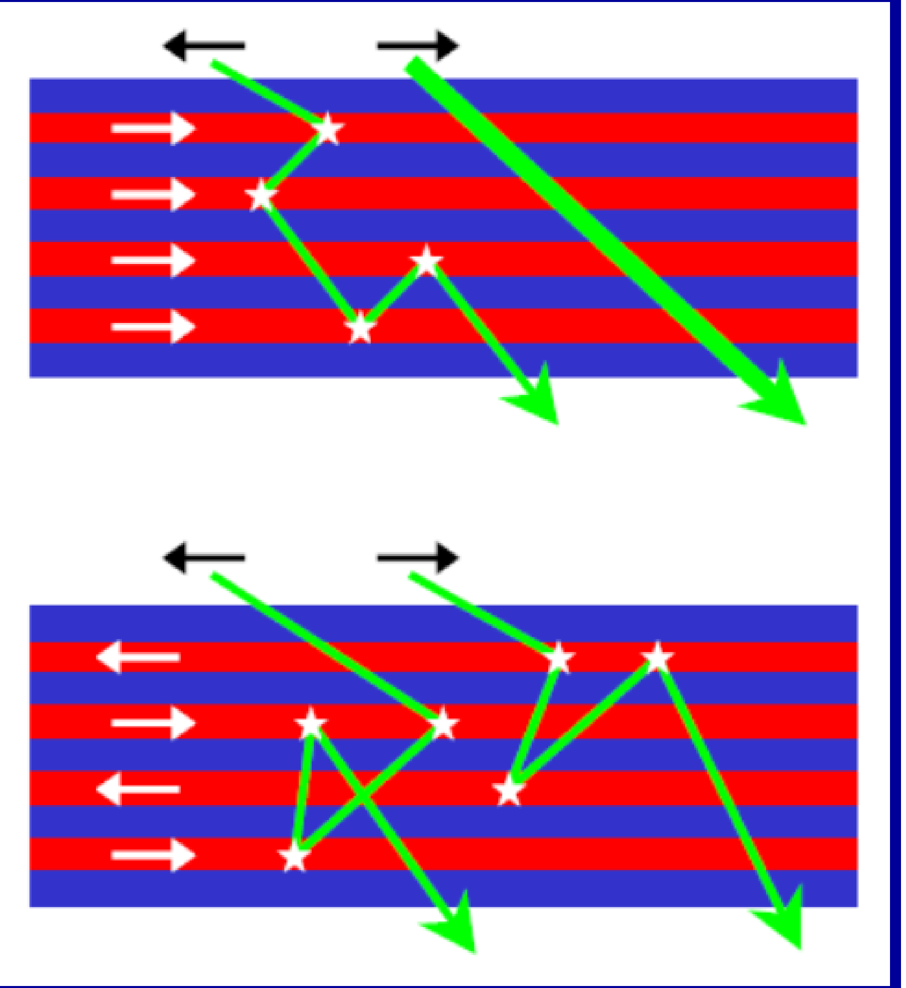

Figure 6. Schematic of Spin-Dependent Scattering

Spin-Valve Sensors

- Layers
  1. Silicon substrate
  2. Free layer (3 nm Fe)
  3. Non-magnetic layer (1-3 nm Cu)
  4. Fixed layer (3 nm Fe)
  5. Protective layer
- Find magnetic field by measuring electrical resistance

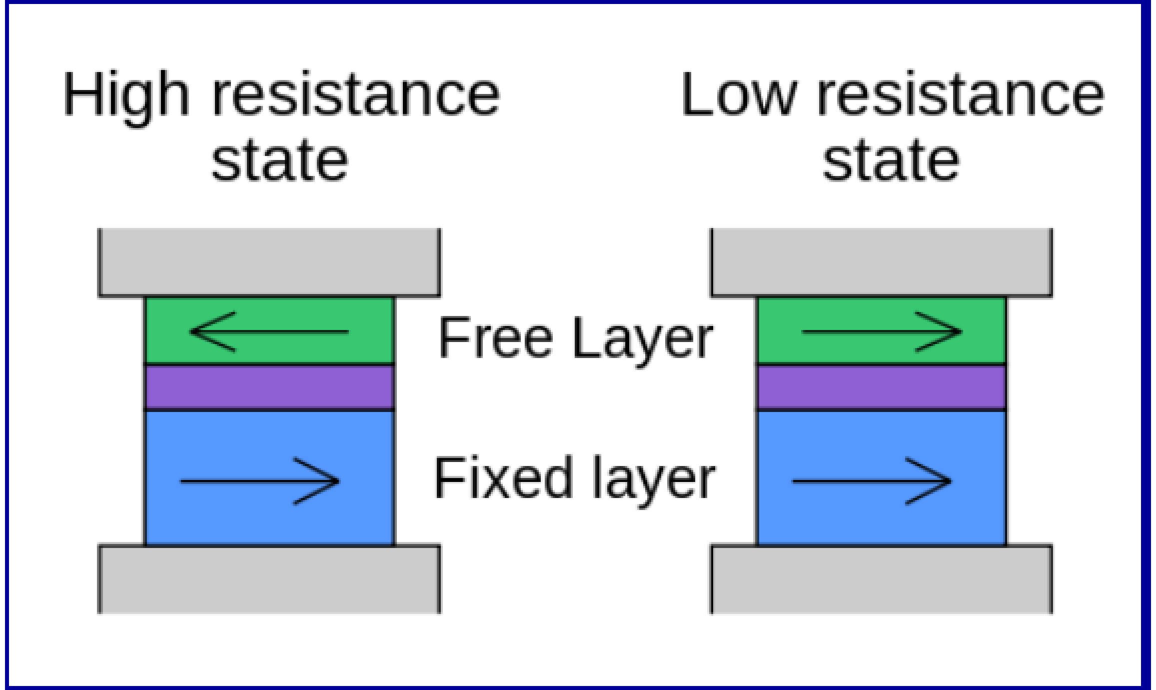

Figure 11. Magnetic Field Sensor

Hard Drives

Figure 12. Hard Disk Drive (HDD)

- Information encoded in magnetic domains
- Spin up/down corresponds to logic levels 0 and 1
- Read heads sense magnetic fields: relay information as electrical signals
- Before GMR, used induction coils and OMR

Magnetic RAM (MRAM)

Figure 15. MRAM prototype

- Grid of spin-valves
- Stored bits encoded in magnetization direction of sensor layers
- Advantages:
  - Independent of power supply
  - Low power consumption
  - High speed

Summary

- Up to 50% change in resistance under external magnetic field
- Nonmagnetic metal sandwiched between antiferromagnetically coupled layers
- Result of spin-dependent scattering, intrinsically quantum effect
- Huge impact on magnetic field sensors and hard drives