DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

18PYB101J-Electromagnetic Theory, Quantum Mechanics, Waves and Optics

Module II- Lecture-9

Elementary ideas of Spintronics, Giant Magnetoresistance (GMR)

Spintronics

A revolutionary new class of semiconductor electronics based on the spin degree of freedom of an electron (as opposed to the charge degree of freedom) to process electronic data.

Spintronics refers to devices that utilize the spin properties of electrons for their functionality. Because spins can be manipulated faster and at lower energy cost than charges, spintronics has the potential advantages of increasing data processing speed and decreasing electric power consumption.

One of the major technological breakthroughs of spintronics is in data storage industry.

The discovery of giant magnetoresistance (GMR) effect, used in read-head sensors in hard drives has allowed increasing the storage density to ~ 1 Tbyte/inch^2 and more. This field received a special recognition with a Nobel prize for Physics in 2007.

Currently, there is an increased activity from materials research perspective to understand and develop spintronics devices using new interesting materials like, carbon nanotubes, graphene, topological insulators and also organic semiconductors (OSs) for technological applications

Advantages of spintronic devices

- Spintronic devices offer the possibility of enhanced functionality, higher speed, and reduced power consumption.
- Information is stored into spin as one of two possible orientations.
- Spin lifetime is relatively long, on the order of nanoseconds.
- Spin currents can be manipulated.
- Spin devices may combine logic and storage functionality eliminating the need for separate components.
- Magnetic storage is nonvolatile
- Binary spin polarization offers the possibility of applications as qubits in quantum computers.

Magnetoresistance

Magnetoresistance is the property of a material to change the value of its electrical resistance when an external magnetic field is applied to it. The effect was first discovered by William Thomson (more commonly known as Lord Kelvin) in 1856, but he was unable to lower the electrical resistance of anything by more than 5%. This effect was later called ordinary magnetoresistance (OMR).

The magnetoreisitance effect occurs in metals only at very high magnetic fields and low temperatures. For example, in pure copper at 4 K a field of 10 T produces a factor of 10 change in the resistance.Because of the large fields and low temperatures, magnetoresistance in metals originally had few potential application possibilities.

The magnetoresistance of conventional materials is quite small; but materials with large magnetoresistance have been synthesized now. Depending on the magnitude, it is called either as Giant magnetoresistance (GMR) , Tunnel magnetoresistance (TMR)or Colossal magnetoresistance (CMR).

Giant magnetoresistance (GMR)

It is a quantum mechanical effect, a type of magnetoresistance effect, observed in thin film structures composed of alternating ferromagnetic and nonmagnetic metal layers.

The effect manifests itself as a significant decrease in electrical resistance in the presence of a magnetic field..

Giant magnetoresistance (GMR)

In the absence of an applied magnetic field, the direction of magnetization of adjacent ferromagnetic layers is antiparallel due to a weak anti-ferromagnetic coupling between layers, and it decreases to a lower level of resistance when the magnetization of the adjacent layers align due to an applied external field.

The spins of the electrons of the nonmagnetic metal align parallel or antiparallel with an applied magnetic field in equal numbers, and therefore suffer less magnetic scattering when the magnetizations of the ferromagnetic layers are parallel.

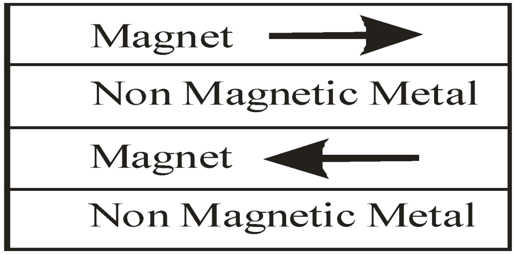

Fig. Schematic representation of layered structure for GMR

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A schematic of the layered structure and the alternating orientation of the magnetization in the ferromagnetic layer .

The effect was first observed in films made of alternating layers of iron and chromium, but since then other layered materials composed of alternating layers of cobalt and copper have been made that display much higher magnetoresistive effects.

The magnitude of the change in the resistance depends on the thickness of the iron layer and it reaches a maximum at a thickness of 7 nm.

Thank you