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.

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)

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 spin orientation.

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.

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