Spintronics: A Revolution in Technology in Today's Era

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Abstract: ***This paper describes the revolution in today's technology by means of a new concept known as Spintronics As we know all conventional electronic devices relay on the transport of electric charge carriers termed electrons .But now-a days, physicists are trying to exploit the spin of the electron rather than its charge in order to create most remarkableSpintronics devices which are small in size, more versatile, more robust than conventional devices. Spintronics not only reduces the boot up time in computers but it also enables electronics devices to work more efficiently than conventional method.***

Keywords: Spin Valve, Gaint Magnetoresistaance, Degree of Freedom (DOF), Spin Valve Transistor

1. Introduction

Spintronics means electronics with spin.

In quantum mechanics, the fundamental particle that is electron possess a property known as spin. This spin is basically the angular or rotational momentum of electrons which creates its own tiny magnetic field .Spintronics can be a new term but the concept is quite exotic. Every electron exists in one of the two possible states namely spin up and spin down. This means an electron can rotate either clockwise or counter clockwise around its own axis with constant magnetic field. That is why, spin devices possess degree of freedom which make Spintronics devices more efficient with new capabilities and functionalities.

2. Why SPINTRONICS?

Spintronics in a new technology that implements the quantum property of the electron known as spin. In Spintronics devices electrons have two degree of freedom instead of one that are charge and spin. Every electron exists in one of the two possible states with its spin either +1/2 or -1/2 (Fig1and 2).It means the rotation of the electron is either clockwise or counterclockwise around its own axis with constant frequency. The two possible spin states represents'0' and '1' state in logical operations and due to this it is quite possible to make a thin layer of the gold atoms between two thin layers of the magnetic materials which act as a flow of electrons in one of the two states to pass. The charging of the filter can be done from one state to the other using brief and tiny burst of current.

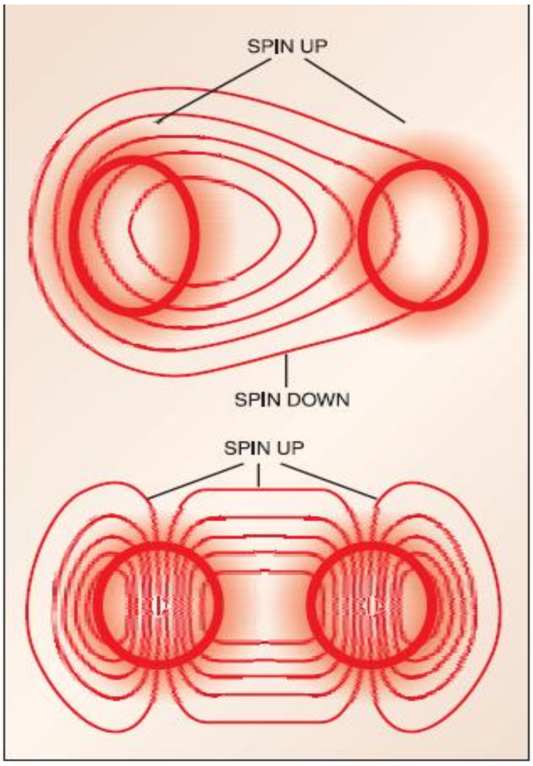


Fig. 1: Spin of electrons

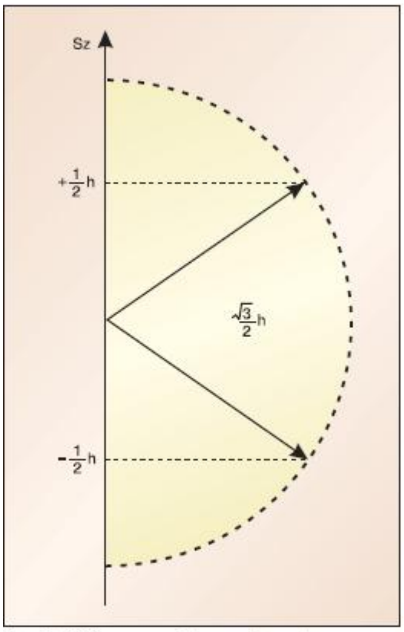
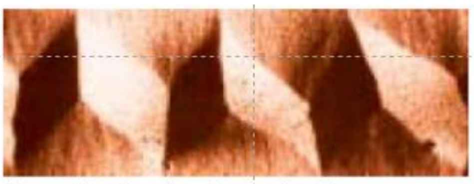


Fig. 2: Spin up and down allows two electrons for each set of spatial quantum numbers

As, In Spintronics devices the magnet tend to stay magnetized for a long period of time and that is why the chips which are being designed by means of this concept are quite fast whose contents will survive even after loss of power. These devices make use of ferromagnetic materials and hence the storage capability of such of devices is better than conventional devices. One of the inherent advantage of Spintronics devices over electronics devices is that the magnet tends to stay magnetized for a longer period of time and that is why the concept is widely used to replace conventional semiconductor components with magnetic ones. Also, another inherent feature of such type of devices is that it does not require unique and specialized semiconductor materials. It works with simple metals such as copper, aluminum and silver etc. and that is why the cost is unlikely to be high in the beginning. Fig3. Shows the Magnetic domains in spin valve.



Magnetic domains in a spin valve

Figure 3: Magnetic domains in spin Valve

3. Working Methodology

3.1 Spin Valve

A spin valve device can be constructed by a ferromagnetic material separated by antiferromagnetic materials. The direction of one of the ferromagnetic material is pinned by an antiferromagnetic layer. The magnetization of second ferromagnetic material is being down when the sensor is passed over the magnetic medium. This in turn causes the reduction in the resistance of spin valve device. The reduction of the reversal of magnetization is complex due to the interaction between pinned ferromagnetic and antiferromagnetic layer.Fig4 shows the schematic of spin valve.

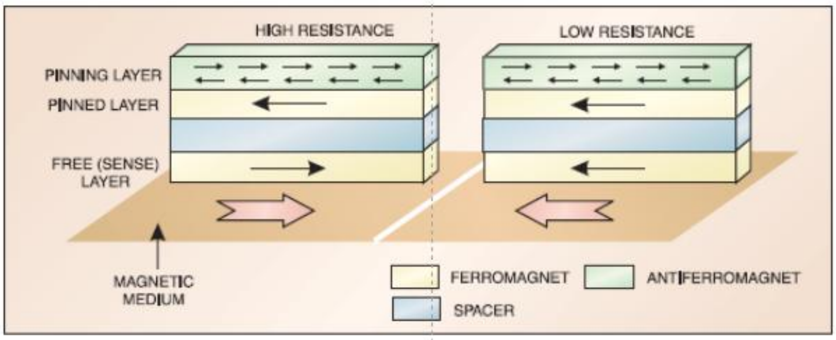


Figure 4

3.2 Giant Magnetoresistance

When electron spins are aligned (all spin-up or all spin-down), these create A large-scale internet magnetic second as visible in magnetic substances like iron and cobalt. Magnetism is an intrinsic physical property associated with the spins of electrons in a material. Magnetism is already exploited in recording gadgets which includes laptop difficult disks. Datais recorded and stored as tiny areas of magnetized iron or chromium oxide. To get admission to the information, a study head detects the minute adjustments in magnetic subject because the disk spins under it. This induces corresponding changes in the head's electrical resistance- a phenomena called Magnetoresistance. GMR is 200 times stronger than ordinary Magnetoresistance.

Fig4. Shows the basic GMR device is a three-layer sandwich of a magnetic metal (such as cobalt) with a nonmagnetic metalfilling (such as silver)**. *A current passes through the layers consisting of spin-up and spin down electrons.*** The electrons oriented in the same direction as the electron spins In a magnetic layer by skip thru pretty easily, whilst the ones orientated withinside the contrary path are scattered.

If the orientation of one of the magnetic layers is changed by the presence of a magnetic field, the device will act as a filter or a spin valve, letting through more electrons whenthe spin orientations in the two layers are the same and fewer electrons when the spin orientations are oppositelyaligned. The electrical resistance of the device can therefore be changed dramatically.

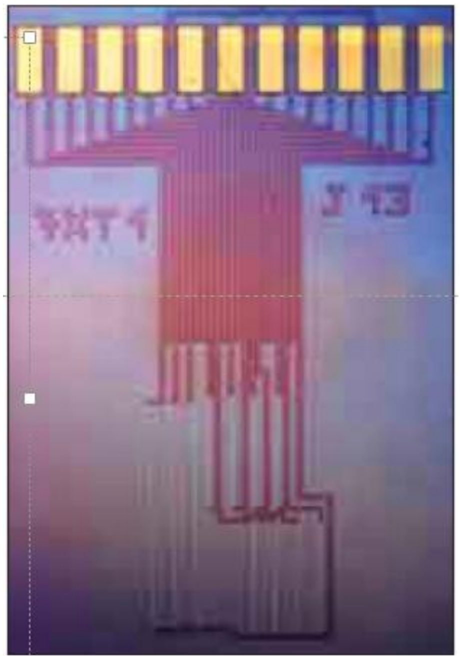


Figure 5: A magnetic Field Sensor made of GMR multilayers (iron nickel with Silver) for an angular encoder

3.3 Memory Chips

Physicists have been quick to see further possibilities of spin valves. The spin valves are not only the highly sensitive magnetic sensors but these can also be made to act as switches byflipping the magnetization in one of the layers. This allows information to be stored as 0'sand 1's (magnetisations of the layers parallel or antiparallel) as in a conventional transistormemory device. An obvious application is the magnetic version of the RAM used in your Computer.

3.4 Sensors

GMR sensors are already being developed in the UK. Applications include:

- Fast and accurate position and motion sensing of mechanical components in precision engineering and in robotics.
- All types of automobile sensors for gasoline managing systems, digital engine control,anti-skid systems, speed control, and navigation.
- Missile guidance.
- Position and movement sensing in laptop video games.
- Key-hole surgery and post-operative care.

3.5 Spin –Valve Transistor

A new type of magnetic field sensor is the spin-valve transistor (Fig. 5). This transistor is based on the magnetoresistance found in multilayers (for example, in Co/ Cu/Co).

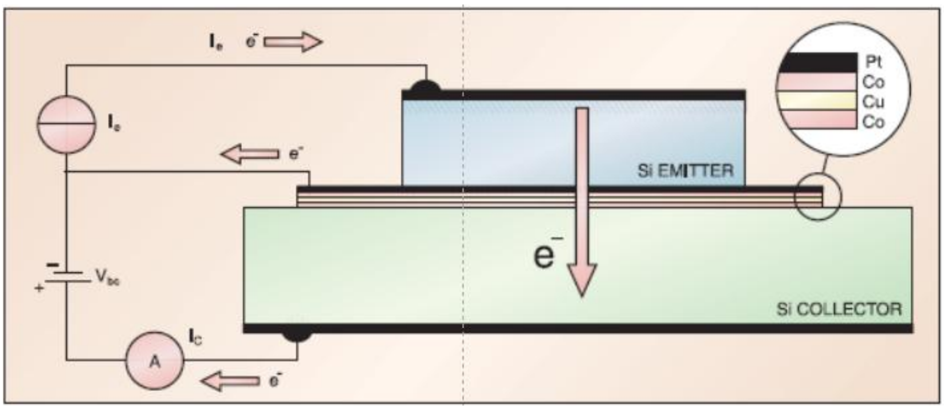


Figure 6: Band Structure of Spin-valve transistor

3.6 Fabrication

The spin-valve transistor consists of silicon emitter, a magnetic multilayer as the base, and silicon collector (Fig. 6). Electrons are injected from the emitter, passing the first Schottky barrier (semiconductor-metal interface) into the base. Because of the thin base multilayer (10 nm), most electrons are not directed to the base contact and travel perpendicular through the multilayer across the second Schottky barrier. These electrons form the collector-current.

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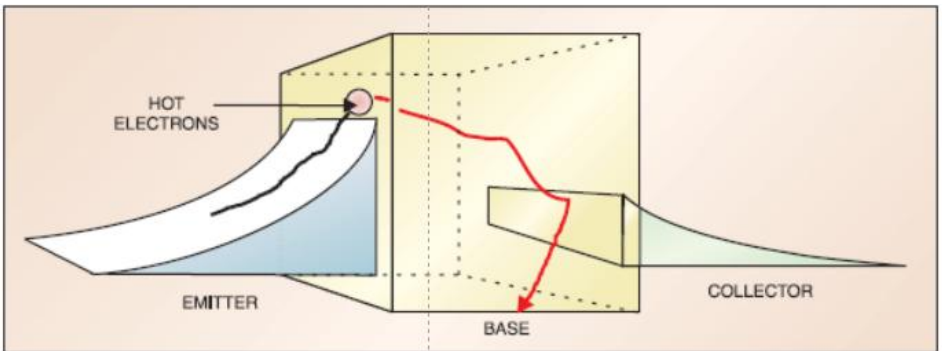

Figure 7: Schematic Cross-Section of the Spin-valve transistor

3.7 Magnetic sensitivity

The quantity of electrons that attain the collector will increase exponentially with the imply loose course of the electrons withinside the base. The mean free path varies with the applied magnetic field, hence the collector current becomes strongly magnetic field-dependent.

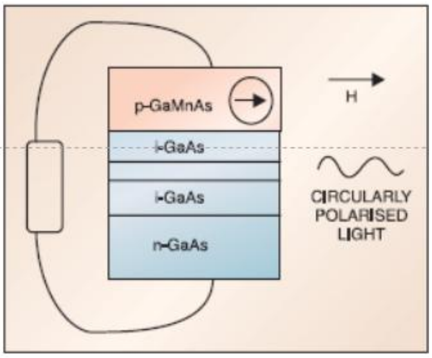

Figure 8: Example of a LED Structure Device with Magnetic Semiconductor

The collector modern version at low temperatures is extra than four hundred in keeping with cent. Even larger variations are expected with higher-quality bases. (The hysteresis is caused by the hysteresis of the magnetic layers.) The extreme magneto sensitivity makes the transistor an interesting device for high-technology read-heads for high-density hard disks and magnetic RAMs.

The statistics is stored (written) into spins as a specific spin orientation (up or down).Spin orientation of conduction electrons survives for a noticeably lengthy time (nanoseconds, as compared to tens of femtoseconds in the course of which electron momentum decays). This makes spintronics devices particularly attractive for memory storage and magnetic sensor applications, and for quantum computing where electron spin would represent a bit (called qubit) of the information.

4. Future Prospects of Spintronics

Various experiments demonstrated huge progress in transporting spins over long distances and in high electric fields. Electrical spin injection, one of the main remaining obstacles of spintronics, is on the way to be solved. Techniques for highly efficient spin injection with planar contacts are being developed by various groups and will probably prove successful in the near future.

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