SPINTRONICS-A RETROSPECTIVE AND PERSPECTIVE

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ABSTRACT

This era of technological advancement have seen rise of a number of promising technologies one of them being-Spintronics. Spintronics also known as spinelectronis or fluxtronic is a technology exploiting both the intrinsic spin of the electron and its associated magnetic moment in addition to its fundamental electronic charge, in solid state devices. This research paper deals with the achievements made in this field in the past few years and perhaps highlighting the potentials this technology has in the upcoming future. The terms GMR and TMR used in industries today are all a part of this field Spintronics finds applications in spin valves,MRAM,quantum computers a disk read/write head and many more. Spintronic technology has been tested in mass storage component such as hard drives.It is still in research phase and has calibre of strengthening the world of digital electronics.

Keywords- Gmr, Mram, Spintronics, Tmr

I. INTRODUCTION

The formal definition of spintronic is “the study of the role played by electron spin in solid state physics, and possible devices that specifically exploit spin properties instead of or in addition to charge degrees of freedom”.Spintronics is a new branch of electronics in which electron spin, in addition to charge, is manipulated to yield a desired outcome.Adding the spin degree of freedom provides new effects,new capabilities and new functionalities. All spintronic devices act according to the simple scheme: (1) information is stored (written) into spins as a particular spin orientation (up or down), (2) the spins, being attached to mobile electrons, carry the information along a wire, and (3) the information is read at a terminal. Spin orientation of conduction electrons survives for a relatively long time (nanoseconds, compared to tens of femtoseconds during which electron momentum decays), which makes spintronic devices particularly attractive for memory storage and magnetic sensors applications, and, potentially for quantum computing where electron spin would represent a bit (called qubit) of information.

II. HISTORY OF SPINTRONICS

The origin of spintronics was cited first in 1988 with the development of Giant Magneto Resistance by French and German physicist Albert Fert of France and Peter Gruenberg of Germany respectively.With passing years this was seen as an emerging field of electronics as in 1989, IBM scientists made a string of key discoveries about the "giant magnetoresistive" effect in thin-film structures while in 1997,first GMR (Giant magnetoresistive) Harddisk head was introduced by IBM.The development of spintronics over the last two decades is based on the discovery of fundamental phenomena linking magnetism with electrical currents boosted by a strong synergy .This emerging technology has a promising future and has many revolutionary applications like the spin valves disk read/write head,quantumcomputers,m-ram and a number of other devices as well.

III. THEORY

In 1897,the physicist J.J THOMSAN discovered the electron in a series of experiments designed to study the nature of electric discharge in a high-vaccum cathode-ray tube.Two decades later in 1922,two physicists 0.STERN and W GERLACH,observed the splitting of one silver beam after the beam passed through an inhomogenous magnetic field.This observation suggested that electrons have a quantized intrinsic magnet momentum.The intrinsic magnetic property of an electron is referred to as a electron spin,which has two discrete levels,i.e.,spin-up and down.The "spin-up" electron is the electron with the z-component of their spin angular momentum Sz=+1/2h and the "spin-down" electron is the one with Sz=-1/2h. The spin of the electron has three states to it up,down,and in between. This in between state is the most important one. In today's world of computers this spin is ignored and you have either on/off,0/1,or up/down but with the spin of the electron one can have many states and not be limited with those two states.Because of these many states information can be processed a whole lot faster if an electrons spin carries data.

The employment of electron spin in electronics give rise to a new type of field referred to as "spintronics". It combines the advantages of both conventional electronics and spin,such that it may offer higher degree of integration, non-volatility, lower power consumption,higher speed and functionality.Thus,spintronics devices are trying to overcome the limit of conventional metal-oxide semi-conductor (MOS devices).

An approximate understanding of the nature of spin can be gleamed by analogy with the orbit of planets in the solar system.In this analogy,electrons orbit a nucleus in a fashion similar to the earth's orbit around the sun just as the earth rotates about its axis across the orbit, electrons have a quality of rotation called spin.The total magnetic moment of an electron is equal to the sum of its spin moments(on account of its spin about its own axis)and the orbital(on account of its orbit around nucleus of an atom).There are certain points regarding basic spin concepts which are polymatrices,spin polarization,spin relaxation and zeeman's splitting.

3.1 Magnetoresistive Effect

Nanoscalespintronic devices normally are structures consisting of metal,metal-insulator and semi-conductor.Magnetoresistive effect refers to the change in the electrical resistance of a material due to a external magnetic field. There are two main applications of MR effect: the GIANT MAGNETORESISTANCE (GMR) effect in magnetic metal multilayers is used as a field sensor in the read head of modern hard disk drive,and the TUNNEL MR effect in ferromagnet-insulator-ferromagnet(FM-I-FM)structures is used for non-volatile MAGNETIC RANDOM ACCESS MEMORY(MRAM) devices and as a field sensor.

3.2 Gmr

This marks the beginning point of modern spintronics.It refers to a large change in resistance (10-20%) when the devices are subjected to a magnetic field,compared with a maximum sensitivity for a few percentfor other type of magnetic sensors.In a GMR spintronicdevice,the first magnetic layer polarizes the electronic spins.The second layer scatters the spins strongly if its moment is not aligned with the polarizer's moment.If the second layer's moment is aligned, it allows the spins to pass the resistance therefore changes depending on whether the moments on magnetic layers are parallel (low resistance)or anti-parallel(high resistance).

3.3 Tmr

The tunnel magneto resistance(TMR) is a magneto resistive effect that occurs in magnetic tunnel junctions(MTJ's).This is a component consisting of two ferromagnet separated by a thin insulator.If the insulating layer is thin enough(typically a few nanometres),electrons can tunnel from one ferromagnet into the other.Since this process is forbidden in classical physics,the TMR is a strictly quantum mechanical phenomena.MTJ's are manufactured in thin film technology.

IV APPLICATIONS

4.1 Spin Valve

A spin valve is a device, consisting of two or more conducting magnetic materials, whose electrical resistance can change between two values depending on the relative alignment of the magnetisation in the layers. The resistance change is the result of Giant Magnetoresistive effect. The magnetic layers of the device align "up" or "down" depending on an external magnetic field.Spin valve works because of quantum property of electrons(and other particles) called spin. The physical volume of magnetic nanoparticles limits their magnetic moments and hence their magnetic firing fields. Therefore, the nanoparticles sensor is required to possess high field sensitivity. For that reason, a GMR spin valve has been chosen as the sense element for magnetic nanoparticle detection because of it high sensitivity to low magnetic fields. The spin valve with a synthetic antiferromagnet pinned layer is preferred structure for its large dynamic range of field, good thermal stability, and design flexibility.

4.2 Mram

MRAM (magnetoresistive random access memory) is a method of storing data bits using magnetic charges instead of the electrical charges used by DRAM (dynamic random access memory). Magnetoristive RAM, or magnetic RAM is a relatively new technology. It however has so many advantages that it may eventually become the leader in the memory and thus become a truly universal memory. MRAM has been proposed for devices in as many fields as: PCs, digital cameras, notebooks, smart cards, aerospace and military system, cellular telephones, battery-backed SRAM replacement, cellular base stations, black box solutions, book readers and media players, among other uses.MRAM is one of the several evolutions in memory technology designed to make applications perform faster by removing bottlenecks in getting the data from storage to the processor.The basic MRAM cell is the so called Magnetic Tunnel Junction (MTJ) which consists of two magnetic layers sandwiching thin insulating layer. Nevertheless, the nature of magnetism is such that as long as thermal stability is achieved, MRAM are inherently fast (magnetization switches in nanoseconds or less), non-volatile, and radiation hard and aging-insensitive.

4.3 Quantum Computer

A quantum computer is a computer is a computer design which uses the principles of quantum physics to increase the computational power beyond what is attainable by a traditional computer. Quantum computers have been built on the small scale and work continues to upgrade them to more practical models.

A quantum computer, on the other hand, would store information as either a "1" or "0", or a quantum superposition of two states. Such a "quantum bit", called a qubit, allows for a far greater flexibility than the binary system. Specifically, a quantum computer would be able to perform calculations on a far greater order of magnitude than traditional computers- a concept which has serious concerns and an applications in the realm of cryptography and encryption.

4.4 Disk Read/Write Head

Disk read/write heads are mechanisms that read data from or write data to disk drives. The heads themselves started out similar to the heads in tape recorder- simple devices made out of a tiny C-shaped piece of highly magnetisable material called ferrite wrapped in a fin wire coil. When writing, the coil is energized, a strong magnetic fields forms in the gap of the C, and the recording surface adjacent to the gap is magnetized. When reading, the magnetized material rotates past the heads, the ferrite core concentrates the field and a current is generated in the coil. Metal in Gap (MIG) heads are ferrite heads with a small piece of metal in the head gap that concentrates the field. This allows smaller features to be read and write.

V. CONCLUSION AND FUTURE SCOPE

Sometime in the near future hopefully our quest for smaller and smaller, and faster and faster devices will be found in the new realm of spintronics, and we will see the effects that spintronics has on the realm of electronic devices.The next area being developed right now is the use of spintronics in semiconductors. This area would allow for "ultrafast switches and fully programmable all-spintronicsmicroprocessors. This avenue of research may lead to a new class of multifunctional electronics that combine logic, storage and communications on a single chip.Already tested in hard drives,spintronics are poised to replace current information technology,providing increased data transfer speeds,processingpower,memory density and storage capacities.Spintronics is an emerging field of nanoscale electronics involving the detection and manipulation of electronic spin. It can bring a new revolution in the existing era of technology. It has already entered our homes as we use spintronic device in our desktop (since the read head of hard drive today use GMR to read information on the drive). MRAM devices are on the horizon and offer the promise of laptop computers that do not need to boot up and cell phones with increased battery time and increased capabilities. This technology promises cheaper, compact and faster electronic gadgets. It is still in research phase and we hope that this technology can be used in labs to look at problems that interest researchers.

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