International Journal of Research (IJR) Vol-1, Issue-9 October 2014 ISSN 2348-6848

Spintronics: A New Era in Electronics

Rahul Kumar* Richa Karnani* Mohit Kumar

Dronacharya College of Engineering,

Khentawas, Haryana, India

EMAIL – rahul07kumar93@gmail.com; richa14227dce@gmail.com; mohitkasturia@gmail.com

Abstract-

"Spintronics" – a relatively recent term is a revolution in the electronics era. The idea of spintronics is the storage and transfer of information via electron spins in addition to electron charge in conventional electronics. It provides a brief idea on how the spins of electrons with its different properties are focused to manipulate magnetization with current and vice versa. This paper is a brief survey based of readings on "spintronics" and it tries to address, related research topics, challenges ahead and possible applications.

***Keywords—* Angular Momentum; Conductivity; Dimensional Geometry**

I. INTRODUCTION

Spintronics is a branch of physics which is concerned with the storage and transfer of information via electronic spins in addition to an electron charge as in the conventional electronics". The spintronics came into research when the discovery of giant magneto-resistance came into existence in the late 80s/early 90s, which led to the increase of 100 times of its storage capacity of the hard drives in less than 10 years later. Since then it was differentiated mainly into three categories which was followed as: I) ferromagnetic metal spintronics, II) ferromagnetic semiconductor spintronics and III) paramagnetic semiconductor spintronics [1]. The ferromagnetic metal spintronics focuses on manipulating the magnetization with the current and vice versa. Similarly phenomena are followed for the ferromagnetic semiconductor spintronics which in addition to achieving a critical temperature well above the room temperature. Paramagnetic semiconductor spintronics focuses on the spin-orbit coupling effects. The term spin stands here either for the spin of the single electron s, which could be detected by their magnetic moment −gμbs where μb is the Bohr magneton and g is the electron g factor, or by its average spin of an ensemble of electrons which was manifested by its magnetization as depicted in figure 1.

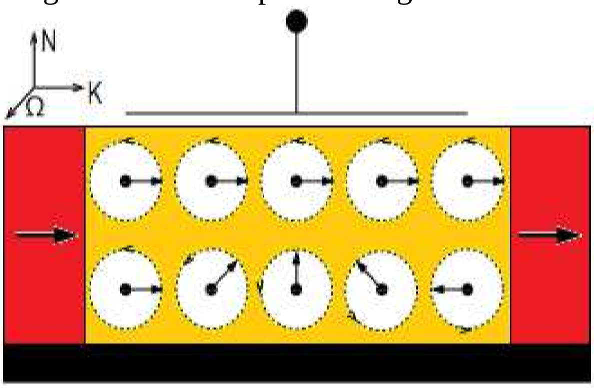


FIGURE: 1 Orientation of spin field-effect transistor

II. PRINCIPLE

Spintronics is based on the spin of the electrons which exists in two states namely spin up and spin down, with spins to be either at positive half or negative half. An electron can travel in either clockwise or anti-clockwise direction around its own axis with constant frequency. Spin is the basic and root cause for magnetism and is a kind of intrinsic angular momentum which a particle cannot gain or lose [2]. The two possible spin states are '0' or '1' which represents the logical operations. Spin is the characteristics that make an electron a tiny magnet complete with north and south poles. The orientation of tiny magnets depends on the spin of particles. Spin axes sometimes points 'up' or equal number points 'down'. The particles spin is associated with magnetic moment, which may be thought to handle the magnetic field torque of electron spins, so in ordinary materials, up moment cancels the down moments and hence no one piles up. For this, a ferromagnetic material like iron, cobalt or nickel is needed [3]. They have tiny regions referred as domain which have excess of electrons which points either up or down. The domains are randomly scattered and equally divided between majority up and majority down, but the externally applied magnetic field will move the barrier between the domains and line up all the domains in the direction of magnetic field.

III. SPIN INJECTION EXPERIMENT

EMF's will appear in the proximity of the ferromagnetic material and the spin polarized non-magnetic material. Analysis of the conductance from the F/I/S to F/I/F junctions for change in conductance between the parallel (↑↑) and anti-parallel (↑↓) magnetization in the two ferromagnetic regions F1 and F2 is depicted in figure 2. The magneto resistance (TMR) of the magnetic material junction is given by:

$$TMR = \frac{\Delta R}{R_{\uparrow\uparrow}} = \frac{R_{\uparrow\downarrow} - R_{\uparrow\uparrow}}{R_{\uparrow\uparrow}} = \frac{G_{\uparrow\uparrow} - G_{\uparrow\downarrow}}{G_{\uparrow\downarrow}},$$

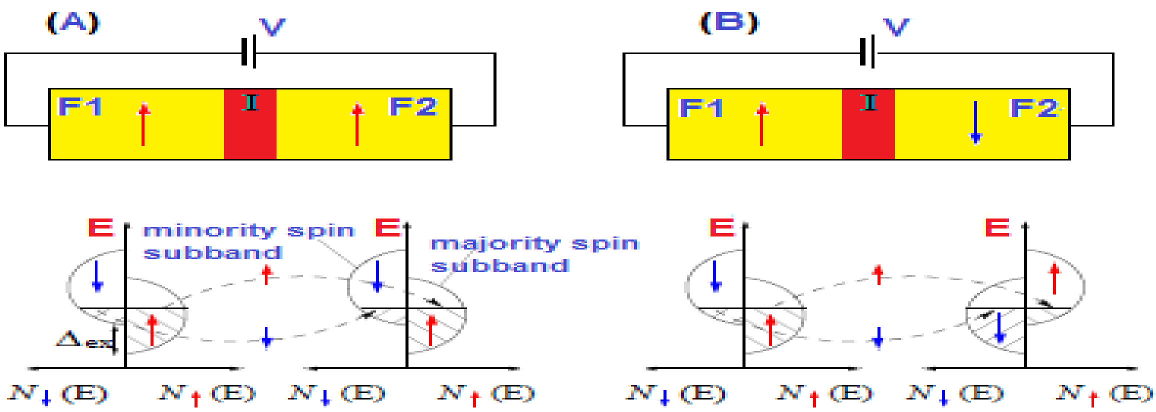


FIGURE: 2 Spin of the electrons in the magnetic materials junction.

(A) Parallel orientation

(B) Anti-parallel orientation

IV. GENERATION OF SPIN POLARIZATION

The methods such as transport, optical and resonance (as well as their combined form) all have been used to create non-equilibrium spins. After the spin polarization in solid state concept was introduced, it gave a picture of electronic spin injection and detected polarized carriers [4]. There are several factors for detection of spin polarization. Spin polarization not only for the electrons but also for nuclei, excitation and holes can be defined as

$$P_X = X_S / X$$

Where $X_S = X_C - X_F$ and $X = X_C - X_F$.

In the ferromagnetic materials, with the increase or decrease of carriers with magnetic moment parallel or anti-parallel to the magnetization or equivalently to the carriers with majority or minority spins. In semiconductors, the terms majority or minority is usually referred for charge carriers which was taken along the light propagation or applied magnetic field [5]. The spin polarization for the electrical current or current density generated in a non-magnetic region was used to describe the efficiency of the electrical spin junction. It was suggested that the non-equilibrium density polarization in the N-region or its magnetization will act as a source for the spin electromotive force and produces measurable spin coupled voltage denoted as Vs. This concept also referred as "spin charge coupling" is used for detection technique which consists of two ferromagnetism property magnets F1 and F2 as shown in figure 3 separated by non-magnetic region. F1 is a spin injector and F2 is a spin detector.

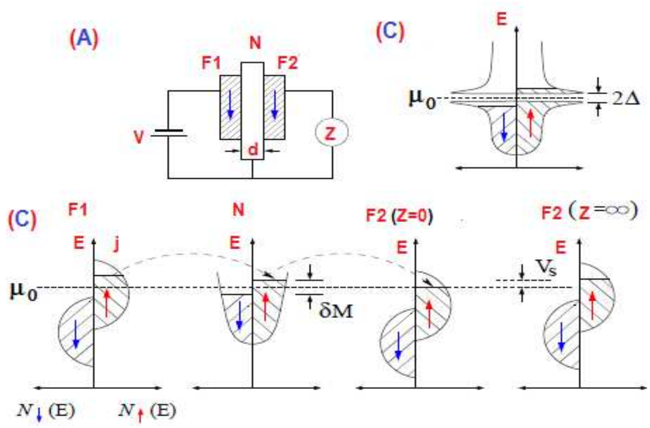


FIGURE: 3 Spin injections, Spin accumulation and Spin detection

(a) two polarized ferromagnets F1 and F2 with parallel magnetizations

(b) density of state diagrams for spin injection F1 into N

(c) spin accumulation in region between F1 and F2

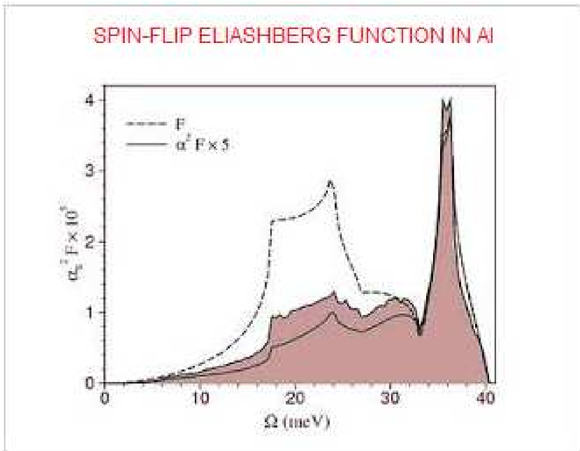
V. OPTICAL SPIN ORIENTATION

The photo excited spin-polarized electrons and holes in semiconductor exist only for time t, before they recombine. If the carriers initial orientation survives longer than the recombination time, that is, if t<t a, where t a is the relaxation time, the luminescence will be slightly less polarized.

symmetry		wave function
T6	$\|1/2, 1/2\rangle$	$\|S\uparrow\rangle$
	$\|1/2, -1/2\rangle$	$\|S\downarrow\rangle$
T7	$\|1/2, 1/2\rangle$	$\|-(1/3)^{1/2}[(X+iY)\downarrow -Z\uparrow]\rangle$
	$\|1/2, -1/2\rangle$	$\|(1/3)^{1/2}[(X-iY)\uparrow +Z\downarrow]\rangle$
T9	$\|3/2, 3/2\rangle$	$\|(1/2)^{1/2}(X+iY)\uparrow\rangle$
	$\|3/2, 1/2\rangle$	$\|(1/6)^{1/2}[(X+iY)\downarrow +2Z\uparrow]\rangle$
	$\|3/2, -1/2\rangle$	$\|-(1/6)^{1/2}[(X-iY)\uparrow -2Z\downarrow]\rangle$
	$\|3/2, -3/2\rangle$	$\|(1/2)^{1/2}(X-iY)\downarrow\rangle$

TABLE: 1 Angular and spin part of wave function

For instance, the basic phenomena of optical orientation of GaAs which is representative of huge class of III-V and II-VI zincblende semiconductors. The structure is depicted in figure 3. The band gap Eg = 1.62 eV at temperature 0 Kelvin. The total angular momentum and its projection are along positive direction Z-axis. The band wave functions are shown in table 1. The graph-1 shows the Spin-Flip Eliashberg Function in Al.



Graph: 1 Spin-Flip Eliashberg Function in Al

VI. THEORIES OF SPIN INJECTION

The spin injection materials range from semiconductors to high temperature semiconductors which have addresses the implications for device operation in solid state [6]. Further to degenerate conductors, it gives result for non degenerate semiconductors in which violation of neutrality, carrier bending and electric fields requires the Poisson equation to be solved [7]. Consider a steady state flow of electron in z-direction in a three dimensional geometry for ferromagnetic metals (for region x<0) and paramagnetic metals (for region x>0) [8].

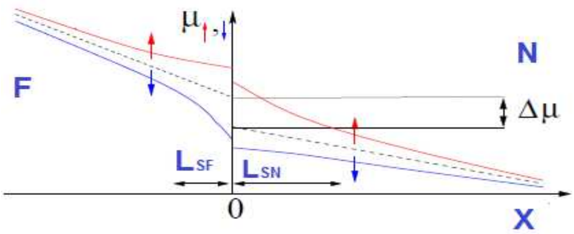


Figure: 4 Variation of potentials near spin selective interface at the junction. At x=0, spin potentials and average potentials are discontinuous.

The two regions F and N forms contact at region X=0 is depicted in figure 4. The relative magnitude of the given three characteristic resistances determines the degree of current polarization into a non-magnetic material [9][10]. These are the resistances whose characteristic are given as the ratio of spin diffusion length and effective bulk conductivity in their corresponding region.

VII. APPLICATIONS

These are used in field of engineering as in information technology where it is divided as in processing category and in storage category. It is shown in the figure 5. They are used in hard drives, non volatile memory magnetic RAMS, as in logic elements such as FET which are shown in figure 6.

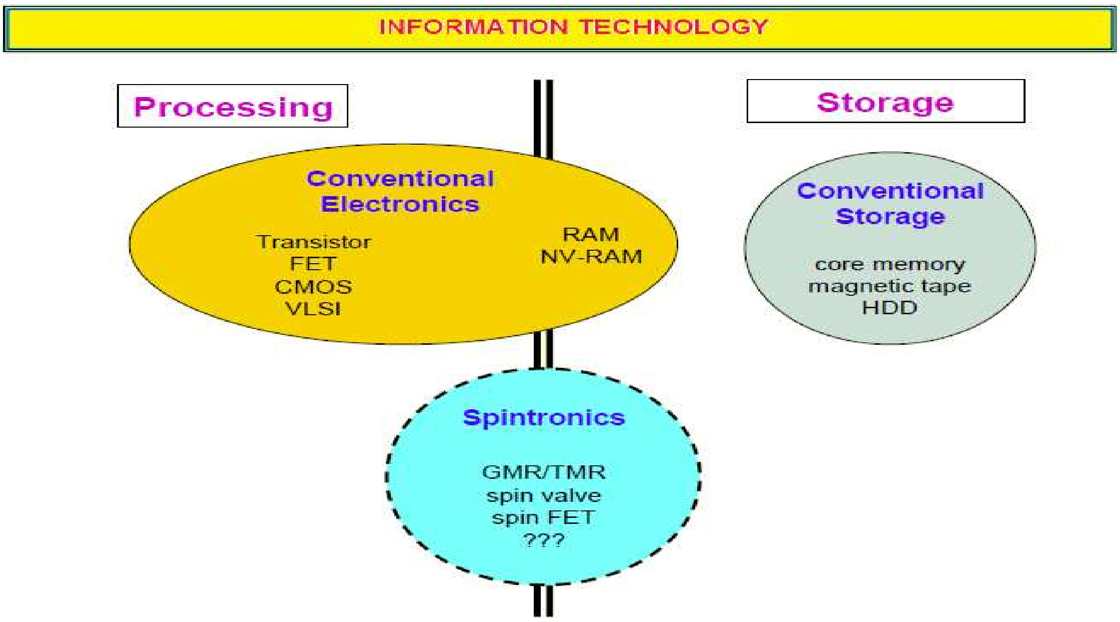


Figure: 5 Applications of Spintronics in IT

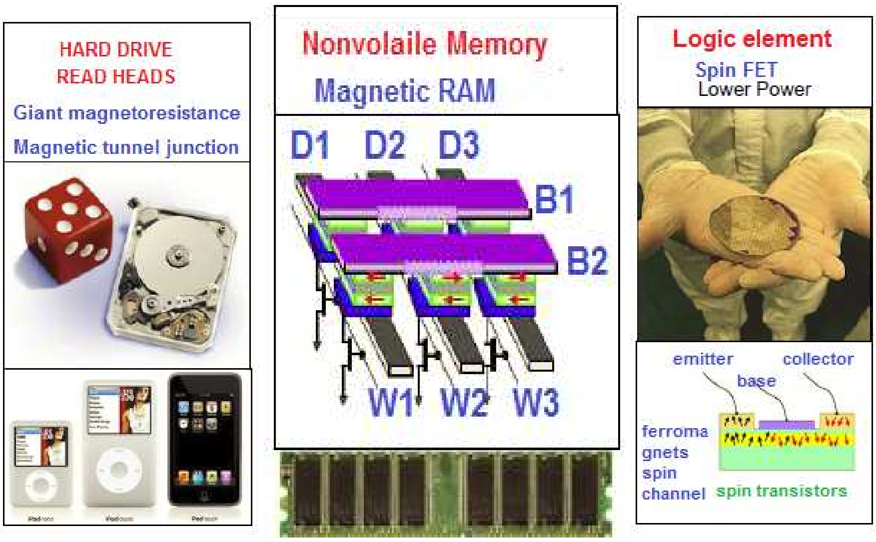


Figure: 6 Applications for Spintronics

FUTURE SCOPE

The desire to build fast, compact and inexpensive electronics has prompted the large number of researchers to try using the "spin" of an electron in transistors. These spintronic transistors would consumes very less energy and do more computation than traditional transistors in a smaller space. Moreover, it increases the data carrying capacity in various optoelectronic instruments like lasers and LED's. The spacing of the atoms in the material layers is a near-ideal match which thus creates a smooth interface between the layers, and therefore increasing the chances of producing a workable spintronics device. With the absence of a clean interface, when the electrons travel across the barrier between the metal and semiconductor, they could lose their original spin, ruining the device. The further testing is required to confirm that electrons will maintain their spin characteristics while traveling from metal to semiconductor. Spin can be maintained even if the power is off, and a spintronic circuit would use less power because a current wouldn't need to be constantly applied. Therefore, the spin based solid state memory semiconductors are required in this era and need to be explored.

CONCLUSION

"Spintronics" which depends on spin of the electron, has the great capability of spinning in an unexpected digital atomic world which has the capability of manipulating at the atomic level which can be made even further smaller with the help of integration with the new emerging yet overcoming technology which is referred as "Nanotechnology". This would make the things even smaller and cheaper which can be affordable to a common man. This is the aim of the research that whatever may be the discovery or invention made, it will have its impact and is worth only if it finds its use in common man's life.

REFERENCES

[1]. Mechanism of spin relaxation in electron system by J. Fabian and S. Das Verma.

[2]. Spintronics, a new nanotechnology adventure by Jo de boeck and mieke van bavel, Belgium.

[3]. Euro physics news (2004) vol. 34. No.6.

[4]. Spintronics fundamentals and its application by jarosiav Fabian and s. das verma.

[5]. Introduction to spintronics by Stuart wolf.

[6]. New spin transistors nature July 6.2002.

[7]. Spintonics by marc Johnson.

[8]. Spintronics nature and their fundamentals by john gullevia.

[9]. New technology of electrons spins by marc Houston.

[10]. Nanotechnology by Stuart Waugh.