Spintronics Technology - A Brief Review

Sahil Bansal
Department of Physics

Abstract— Spintronics deals with the spin dependent electron transport phenomena. In a conventional electronic device, semiconductors like silicon and germanium are used, which are based on the phenomenon of electric charge transport. But the discoveries in 1980s led to the emergence of a new technology, called spintronics, which uses the spin of the electrons and not just the electronic charge in information transport. This technology gives way to create devices which are much smaller and give greater flexibility for their use in electronic circuits than the currently used circuit elements. This article reviews some such aspects of the spintronics technology.

Key words: Qubit, Fermion, MRAM

I. Introduction

Spintronics, or spin electronics, involves the study of active control and manipulation of spin degrees of freedom in solid state systems. Spin transport differs from charge transport in that spin is a non-conserved quantity in solids due to spin-orbit and hyperfine coupling. Spintronics aims at the study of the interactions between the particle spin and its solid state environment. The applications of the spintronics are based on the fact that single spins can be positioned and that their orientation can be precisely controlled and measured. The classical bit can contain the information in bit '0' or '1' only. But the single spin can be oriented in any direction. This gives greater freedom for the spin to carry more information than the classical bit.

II. Basic theory of spintronics

The electron has intrinsic spin angular momentum associated with its spin, in addition to its orbital angular momentum, which is due to the orbital motion of electron around the nucleus. Spintronics exploits this spin property of the electron. The electron being a fermion has half integral spin. The electronic spin can be detected as a magnetic field either spin-up or spin-down If the spins align parallel to each other then a ferromagnet is formed. An important process called spin polarization means creating a non equilibrium spin population. Using spins for information processing requires the complete control of the spin orientation. This can effectively be achieved via magnetic resonance. Traditionally used mechanism for spin orientation involves optical techniques in which the angular momentum of circularly polarized photons is transferred to the electrons. But for application of spintronics in devices which can be used in circuits efficiently, another technique called electrical spin injection is preferred. In this technique, a magnetic electrode is connected to the sample for which spin polarization is desired. When the current flows, it drives the spin polarized electrons from the electrode to the sample thus leading to a non-equilibrium spin accumulation in the sample. Another process called spin relaxation refers to randomizing the oriented spins. It tends to bring the non-equilibrium spin state back to equilibrium state. There are several relevant mechanisms of spin relaxation, most involving spin-orbit coupling, in combination with momentum scattering providing a randomizing force. Spin detection is also a part of spintronics which involves sensing the changes in the signal caused by the presence of non-equilibrium spin in the system. The main aim of the spintronic devices is to maximize the spin detection so that even slight changes in the spin states can be detected.

III. Applications

All spintronic devices act according to a simple scheme involving three steps. In the first step, the information is stored into spins as a particular spin orientation, either spin up or spin down. In the second step, the information stored in the spins is carried by the mobile electrons and in the last step the information is retrieved at the terminal. The electronic spin can be detected as a magnetic field either spin-up or spin-down. This provides two additional binary states to the conventional binary logic states which are generally represented by currents or voltages as either High or Low. So, by adding the spin states to the conventional logic states, we can have four states as Up-High, down-high, up-low and down-low. These states represent qubits (quantum bits). This concept is useful in Quantum computing.

Thus an electron can carry information in both its charge and spin. This increases the functional diversity of devices. The applications of Spintronics to various technologies rely on the successful incorporation of the spins of the particles to the semiconducting devices which requires a deeper understanding of the spin interactions of the particles with the solid state systems as a function of dimensions of the material and the electronic band structure. Still, applications of the spintronics in Information storage have been realized. For instance, Magnetic Random Access Memory(MRAM) can retain the memory even when the power is off while having the switching rates comparable to the conventional RAM. This field has emerged as one of the most active research areas in recent years because of its potential advantages of non-volatility, faster processing speed, and small power dissipation. The range of potential spintronic applications goes beyond the use of large magnetoresistive effects.

IV. Concluding remarks

This article provides an overview of Spintronics and gives an idea about possible applications of Spintronics. Future progress in spin-polarized transport will be largely driven by the materials advances. In the context of semiconductors, considering all-semiconductor structures rather than the hybrid structures with metallic ferromagnets will depend on the improvements in ferromagnetic semiconductors, for example, whether they can achieve higher mobility, higher Curie temperature,128 and a simple fabrication of high quality interfaces with nonmagnetic materials. Therefore, the area of spintronics continues to be a opportunistic research field for scientific exploration and for promising technological advancements.

REFERENCES

[1] A. Cho, Science 296, 246 (2002).
[2] Igor Zutic, Jaroslav Fabian, S. Das Sarma, Spintronics: Fundamentals and applications.
[3] N.-C. Yeh. ."A Perspective of frontiers in modern condensed matter physics." Association of Asia Pacific Physical Societies (AAPPS) Bulletin v.18 no.2, pp. 11-29 (2008).
[4] S. A. Wolf et al., Science 294, 1488(2001).