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RESEARCH ARTICLE OPEN ACCESS

# Spintronics

RajanO.Rajpayle
Department Electronics and Telecommunication Engineering Email: rajana.rajpayle@gmail.com Contact No. - 7755993311

**ABSTRACT**
Spintronicsisa new era of microelectronics relate to the study. That utilizes a fundamental quantum property of the electron known as spin instead of charge.Spin relaxation and spin transport in semiconductors as well as metal are of fundamental research from being basic solid state physics issues, & also for the already demonstrated potential these phenomena have in electronic technology physicists are trying to exploit the 'spin' of the electron rather than its charge to create a remarkable new generation of 'spintronic' devices .advantage is In increased data processing speed, decreased electric power consumption, and increased integration densities compared with conventional semiconductor devices.

**Keywords–** spin, spintronics, electron, moore, spintronics device.

## I. INTRODUCTION

### 1.1. Spin Physic Fundamental

Moore's Law says the number of transistors that fit on a computer chip will double every 18 months but be a limit to how many transistors they can cram on a chip and also arise the problem of energy loss, heat dissipation, as signals pass from one transistor to the next. to overcome this problem by manipulating a neglected electron property. the spin orientation is characterized as spin up ” or "down.” The existing spintronics device is giant magneto resistive (GMR) which is actually sandwich structure, consists of alternating ferromagnetic (permanently magnetized) and nonmagnetic metal layers. According to the orientation of the magnetizations in the magnetic layers, the electrical resistance through the layers changes from small (parallel magnetizations) to large (antiparallel magnetizations). Now scientist discover to use the change in resistance (called magneto resistance, and “giant” because of the large magnitude of the effect in this case) to construct exquisitely sensitive detectors of changing magnetic fields, application of marking the data on a computer hard-disk platter. These disk drive read/write heads have been wildly successful; permitting the storage of tens of gigabytes of data on notebook computer hard drives, and has created a huge earning per year to industry.

Now we are going to develop nonvolatile memory elements using these materials. Researchers and developers of spintronic devices currently take two different approaches. In the first, they seek to perfect the existing GMR-based technology either by developing new materials with larger populations of oriented spins (called spin polarization) or by making improvements in existing devices to provide better spin filtering. The second effort, which is more radical, focuses on finding novel ways both to generate and to utilize spin-polarized currents—that is, to actively control spin dynamics. The intent is to thoroughly investigate spin transport in semiconductors and search for ways in which semiconductors can function as spin polarizers and spin valves. This is crucial because, unlike semiconductor transistors, existing metal-based devices do not amplify signals (although they are successful switches or valves). If spintronic devices could be made from semiconductors, however, then in principle they would provide amplification and serve, in general, as multi-functional devices. Perhaps even more importantly, semiconductor-based devices could much more easily be integrated with traditional semiconductor technology

### 1.2. REASON BEHIND SPINTRONICS

The miniaturization of electronics devices is the main moto of any developing electronics industry. Shrinking of the physical size of semiconductor electronics will soon approach a fundamental barrier after failure of Moore’s law and also all conventional electronics devices works on electric charge whrere if there is problem of power failure or power cut then information is get lost which is stored in form of electiccharge to resolve this issue we are getting solution of using spintronics devices wihich uses the spin of electrons.

### 1.3. SPINTRONICS DEVICE

All spintronic working manner: (I) 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 which makes successful technology for memory storage and magnetic sensors applications, and electron spin would represent a bit (called qubit) of information.A microelectronics designer was the field effect spin transistor proposed in 1989 by Supriyo Datta and Biswajit Das of Purdue University.

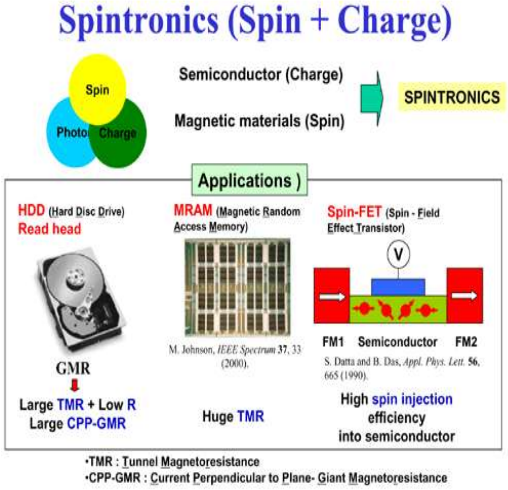

**Fig. 1.1 Application Area Of Spintronics**

In a conventional field effect transistor, electric charge put through a source electrode and collected at a drain electrode. A third electrode, the gate, generates an electric field that changes the size of the channel through which the source-drain current can flow, akin to stepping on a garden hose. This results in a very small electric field being able to control large currents. In the Datta-Das device, a structure made from indium-aluminum-arsenide and indium-gallium-arsenide provides a channel fortwo-dimensional electron transport between two ferromagnetic electrodes. One electrode acts as an emitter, the other a collector.

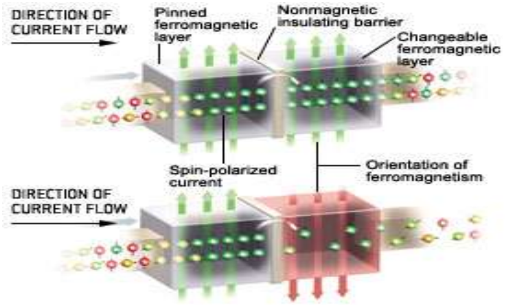

**Fig 1.2: Quantum Physics of Spintronics**

The emitter emits electrons with their spins oriented along the direction of the electrode's magnetization, while the collector (with the same electrode magnetization) acts as a spin filter and accepts electrons with the same spin only. In the absence of any changes to the spins during transport, every emitted electron enters the collector. In this device, the gate electrode produces a field that forces the electron spins to precess, just like the precession of a spinning top under the force of gravity. The electron current is modulated by the degree of precession in electron spin introduced by the gate field: An electron passes through the collector if its spin is parallel, and does not if it is antiparallel, to the magnetization. The Datta-Das effect should be most visible for narrow band-gap semiconductors such as InGaAs, which have relatively large spin-orbit interactions (that is, a magnetic field introduced by the gate current has a relatively large effect on electron spin). Despite several years of effort, however, the effect has yet to be convincingly demonstratedexperimentally.

### 1.4. Quantum transport in semiconductor spintronics

Another interesting concept is the all-metal spin transistor developed by Mark Johnson at the Naval Research Laboratory. Its trilayer structure consists of a nonmagnetic metallic layer sandwiched between two ferromagnets. The all-metal transistor has the same design philosophy as do giant magnetoresistive devicesThe current flowing through the structure is modified by the relative orientation of the magnetic layers, which in turn can be controlled by an applied magnetic field.

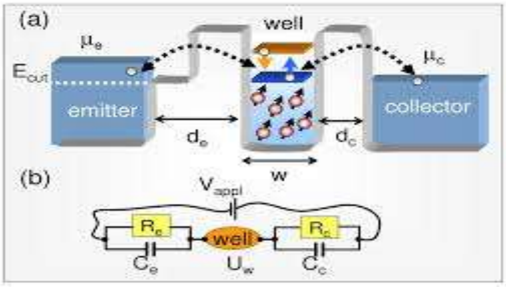

**Fig 1.3: Spin Transportation in FET**

In this scheme, a battery is connected to the control circuit(emitterbase), while the direction of the current in the working circuit (base-collector) is effectively switched by changing the magnetization of the collector. The current is drained from the base in order to allow for the working current to flow under the "reverse" base-collector bias (antiparallel magnetizations). Neither current nor voltage is amplified, but the device acts as a switch or spin valve to sense changes in an external magnetic field. A potentially significant feature of the Johnson transistor is that, being all metallic, it can in principle be made extremely small using nanolithography techniques important disadvantage of Johnson's transistor is that, being all-metallic, it will be difficult to integrate this spin transistor device into existing semiconductor microelectronic circuitry. As noted previously, a critical disadvantage of metal-based spintronic devices is that they do not amplify signals. There is no obvious metallic analog of the traditional semiconductor transistor in which draining one electron from the base allows tens of electrons to pass from the emitter into the collector (by reducing the electrostatic barrier generated by electrons trapped in the base). Motivated by the possibility of having both spin polarization and amplification, my group has recently studied a prototype device, the spin polarized p-n junction. (In the p, or positive, region the electrons are the minority carriers, holes the majority; in the n, or negative, region the roles are reversed.) In our scheme we illuminate the surface of the p-type region of a gallium arsenide p-n junction with circularly polarized light to optically orient the minority electrons. By performing a realistic device-modeling calculation we have discovered that the spin can be effectively transferred from the p side into the n side, via what we call spin pumping through the minority channel. In effect, the spin gets amplified going from the p to the n region through the depletion layer. One possible application of our proposed spin-polarized p-n junction is something we call the spin-polarized solar cell. As in ordinary solar cells, light illuminates the depletion layer of a semiconductor (such as gallium arsenide), generating electron-hole pairs. The huge built-in electric field in the layer (typically 104 volts per centimeter) swiftly sweeps electrons into the n region and holes into the p region. If a wire connects the edges of the junction, a current flows. If the light is circularly polarized (from filtered solar photons, for instance), the generated electrons are spin polarized. (Holes in III-V semiconductors—for example, gallium arsenide, indium arsenide and others—which are most useful for opto-spin-electronic purposes lose their spin very quickly, so that their polarization can be neglected.) As the spin-polarized electrons created in the depletion layer pump the spin into the n region, theresulting current is spin polarized. Hence, photons of light are converted into oriented spins.

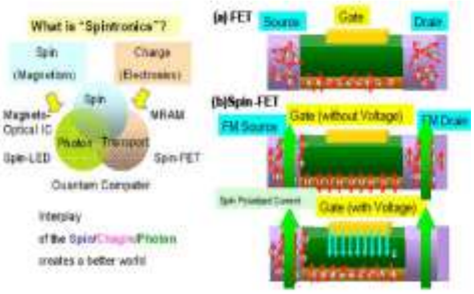

**Fig 1.4: Spintronics Explanation Scheme**

Field effect transistors operate with an applied electric field (voltage) along the junction, as the width of the depletion layer is sensitive to the voltage. We propose to use instead a magnetic field. If the n or p region (or both) is doped with magnetic impurities, an external magnetic field produces a physical effect equivalent to applying an external voltage and could effectively tailor the width of the junction. (At the same time, this affects spin-up and spin down electrons differently: A spin-polarized current results as well). Such adevice could find use in magnetic sensor technology such as magnetic read heads or magnetic memory cells.

If spintronic devices are ever to be practical, we need to understand how spins move through materials and how to create large quantities of aligned spins. Thirty years ago, pioneering experiments on spin transport were performed by Paul Tedrow and Robert Meservyof MIT on ferromagneticsuperconductor sandwiches to demonstrate that current across the interface is spin polarized. Today, the range of materials we can study has significantly increased, including novel ferromagnetic semiconductors, high-temperature superconductors and carbon nanotubes. But several questions— such as the role of the interface separating different materials and how to create and measure spin polarization— still remain open and are of fundamental importance to novel spintronic applications. As devices decrease in size, the scattering from interfaces plays a dominant role. In these hybrid structures the presence of magnetically active interfaces can lead to spin-dependent transmission (spin filtering) and strongly influence operation of spintronic devices by modifying the degree of spin polarization. One way to test these ideas is by directly injecting spins from a ferromagnetic, where the spins start out in alignment, into a nonmagnetc semiconductor.

Understanding this kind of spin injection is also required for hybrid semiconductor devices, such as the Datta-Das spin transistor discussed in the previous section. But this situation is very complicated, and a complete picture of transport across the ferromagnetic-semiconductor interface is not yet available. In its absence, researches have been studying a simpler case of normal metal – semiconductor contacts. Unfortunately, experiments on spin injection into a semiconductor indicate that the obtained spin polarization is substantially smaller than in the ferromagnetic spin injector, spelling trouble for spintronic devices. In this case, where spins diffuse across the interface, there is a large mismatch in conductivities, and this presents a basic obstacle to achieving higher semiconductor spin polarization with injection. An interesting solution has been proposed to circumvent this limitation. By inserting tunnel contacts—a special kind of express lane for carriers—investigators found that they could eliminate the conductivity mismatch. Moreover, to reduce significant material differences between ferromagnets and semiconductors, one can use a magnetic semiconductor as the injector. While it was shown that this approach could lead to a high degree of spin polarization in a nonmagnetic semiconductor, it only worked at low temperature. For successful spintronic applications, future efforts will have to concentrate onfabricating ferromagnetic semiconductors in which ferromagnetism will persist at higher temperatures. The issues involving spin injection in semiconductors, as well as efforts to fabricate hybrid structures, point toward a need to develop methods to study fundamental aspects of spin-polarized transport in semiconductors.

We recently suggested studying hybrid semiconductor-superconductor structures for understanding spin transmission properties, where the presence of the superconducting region can serve as a tool to investigate interfacial transparency and spin-polarization. In addition to charge transport, which can be used to infer the degree of spin-polarization, one could also consider pure spin transport. Igor Zuticˇ ´ and I have been able to calculate this in a hybrid semiconductor structure with our model of the interface. We choose geometry where semi-infinite semiconductor and superconductor regions are separated by an interface at which particles can experience potential and spin-flip scattering. In this approach we need to identify the appropriate scattering processes and their corresponding magnitudes. We find that although spin conductance shows high sensitivity to spin polarization, there remains an experimental challenge to directly measure the spin current, rather than the usual charge current.

Because of the quantum property of superposition, it may represent arbitrary combinations of both values- that is, an infinite number of possibilities between 0 and 1. To perform a computation, some initial state is imposed on the spins, and this state is allowed to evolve in time through a process of entanglement. (Quantum entanglement means that the spins of particles polarized together remain correlated, even though they may become spatially  These properties give a quantum computer the ability to, in effect, operate in parallel making many computations simultaneously. Quantum computation requires that the quantum states remain coherent, or undisturbed by interactions with the outside world, for a long time, and the states need to be controlled precisely. Because of the requirement of very long coherence time for a quantum computer, both nuclear spin and electron spin have been proposed as qubits, sincespins inherently have long coherence times because they are immune to the long-range electrostatic Coulomb interactions between charges. I will review only a few of the representative schemes proposed during the past several years and discuss some recent work with my colleagues on electron spin based quantum computation. One such scheme usesthe spin of a single electron trapped in an isolated structure called a quantum dot as its qubit. Local magnetic fields are used to manipulate single spins, while inter-dot interaction is used to couple neighboring qubits and introduce two-qubit entanglement. A single trapped electron in a quantum dot implies an extremely low carrier density, which means very low coupling with the outside world. Thus the electron spins should remain coherent much longer than even their already long coherence times in the bulk. However, to trap a single electron in a gated quantum dot is a difficult task experimentally. In addition, to apply a local magnetic field on one quantum dot without affecting other neighboring dots and trapped spins may also be impossible in practice. We recently showed that in principle it is possible (albeit with great difficulties) to overcome both of these problems. Regarding the difficulty of trapping single electrons in an array of quantum dots, Xuedong Hu and I carried out a multi-electron calculation and showed that, subject to certain conditions, an odd number ofelectrons trapped in a quantum dot could effectively work as a qubit. The problem of the local magnetic field maybe solved by the method of quantum error correction. The lack of a purely local magnetic field that acts on just a single qubit is essentially a problem of an inhomogeneous magnetic field that the other qubits feel. Such a field may come from magnetic impurities or unwanted currents away from the structure. We have done a detailed analysis and found that there is an error proportional to the field inhomogeneity. Using realistic estimates for such an inhomogeneous magnetic field onnanometer scale quantum dots showed that the error introduced by the field can actually be corrected (with great difficulty).

## II. Conclusion

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