A Review of Spintronics based Data Storage

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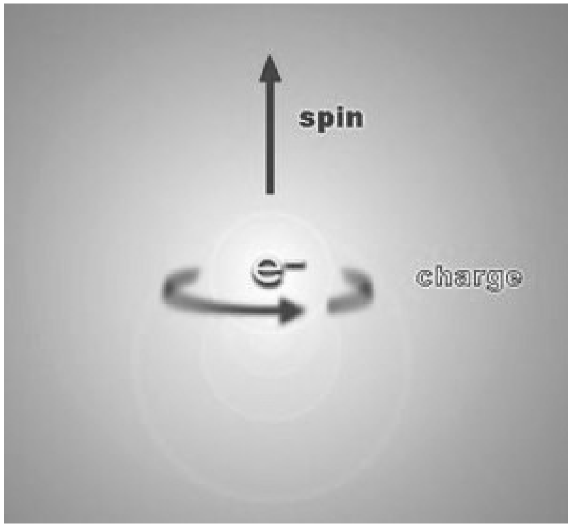
INTRODUCTION

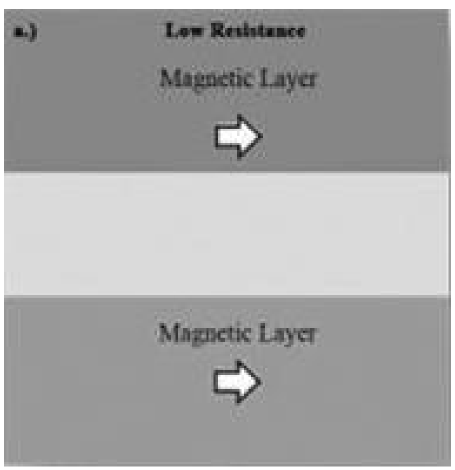
- Electrons have three basic properties: mass, charge and spin.
- Until recently most data storage and processing devices made use of only the charge property of an electron.
- In Spintronics the aim is to use the spin state as well, which can be "up" or "down" depending on the direction.



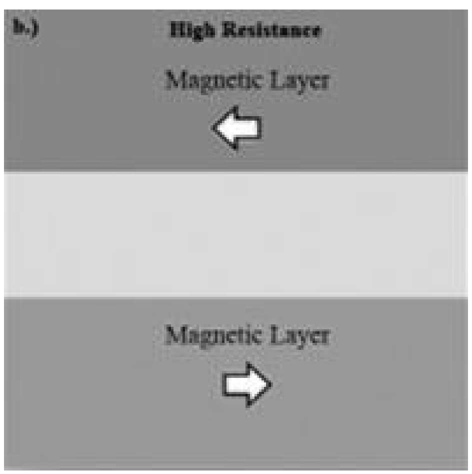
- The spin of an electron creates a tiny magnetic field that makes the electron act like a tiny magnet.
- The “up” and “down” states of the spin of an electron can be used to store data.
- Unlike volatile charge-based data storage spin-based storage is non-volatile. (e.g.: Magneto Resistive RAM).
- To increase the processing speed and functionalities modern electronics relies on the miniaturization of semiconductor devices.
- Spintronics employs two degrees of freedom - the charge as well as the spin - of conducting electrons to create a new class of electronic devices that will be smaller in size but with a quantum increase in processing speed and functionalities.

GIANT MAGNETO RESISTANCE (GMR)

- The first major breakthrough in Spintronics was the discovery of the Giant Magneto Resistance (GMR) effect in 1988 by Albert Fert and Peter Gruenberg.
- A GMR device is made of at least two ferromagnetic layers separated by a spacer layer.
- When the two magnetization vectors of the ferromagnetic layers are aligned, the electrical resistance will be lower than if the ferromagnetic layers are anti-aligned.



Magnetic Layers aligned



Magnetic Layers anti-aligned

Two variants of GMR have been applied in devices:

1. **Current-in-Plane (CIP):** In this type of device the electric current flows parallel to the layers. It is most commonly used in magnetic read heads.

2. **Current-Perpendicular-to-Plane (CPP):** In this type of device the electric current flows in a direction perpendicular to the layers. It is the basis for Tunnel Magneto Resistance (TMR).

- Data on hard disc drives is stored as a directed magnetic field in particles.

- GMR technology is an extremely sensitive means of detecting this magnetic field and its direction.

- With GMR technology there has been a 10,000 fold increase in the capacity of hard disc drives.

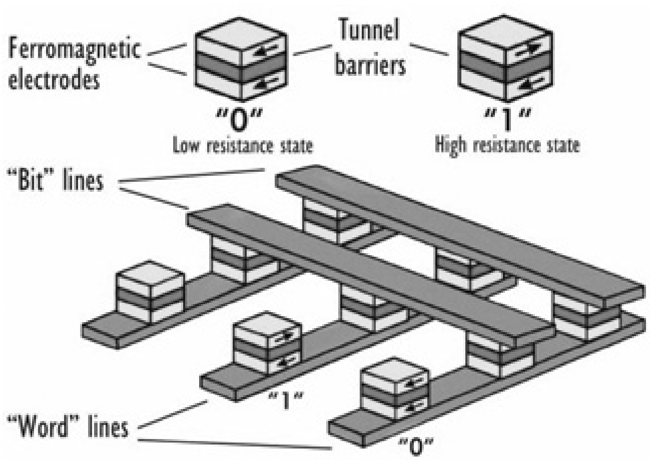
TUNNEL MAGNETO RESISTANCE (TMR)

- Tunneling Magneto Resistance (TMR) is a device where two ferromagnetic layers are separated by a thin (about 1 nm) insulator layer and the electric current tunnels through or flows in a direction perpendicular to the layers (CPP).
- The change in the tunneling current between the magnetic layers depends on the relative magnetization directions of the two ferromagnetic layers.
- The resistance is normally higher in the anti-aligned case as compared to aligned case and hence more sensitive.
- This has application in MRAM devices.
- In 2007, MgO based TMR devices completely displaced CIP based devices.

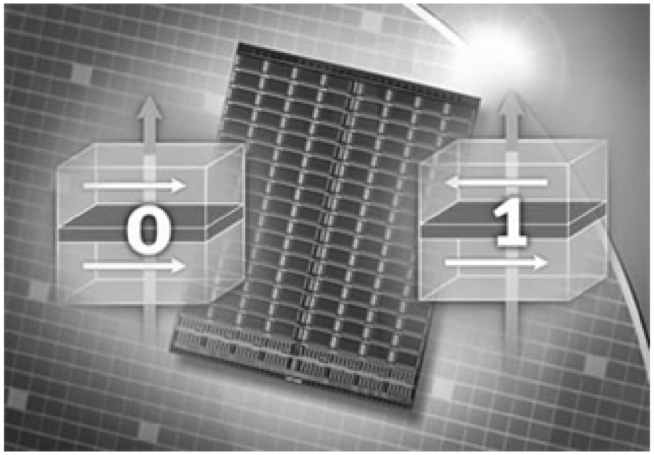
MAGNETO RESISTIVE RAM (MRAM)

- Another recent breakthrough product in Spintronics is Magneto Resistive RAM (MRAM), which uses electron spin to store information.
- MRAM is a non-volatile computer memory (NVRAM) technology, which has been under development since the 1990s.
- Proponents of MRAM claim that the advantages are so great that MRAM will eventually become dominant for all types of memory.

- Conventional RAM chip technologies store data as electric charge or current flows.
- In MRAM tunnel junctions are used to store the information, typically ”0” for aligned state and “1” for anti - aligned state.

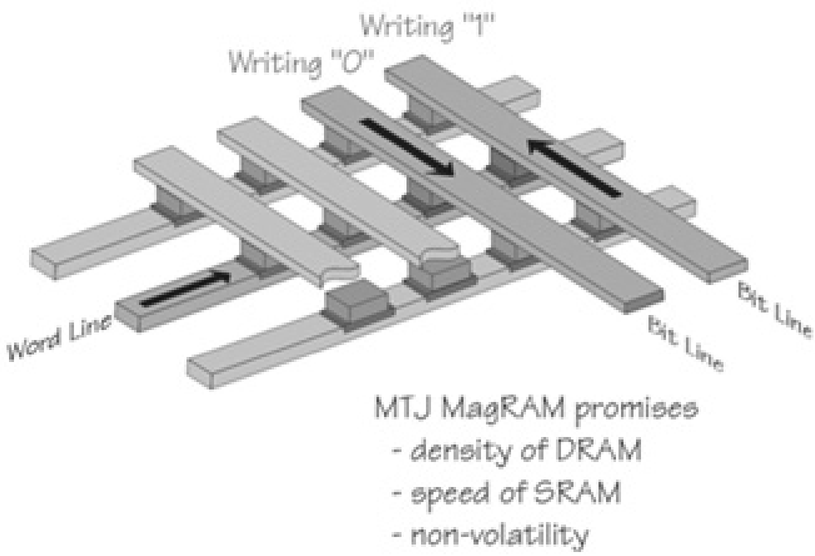


Working of MRAM

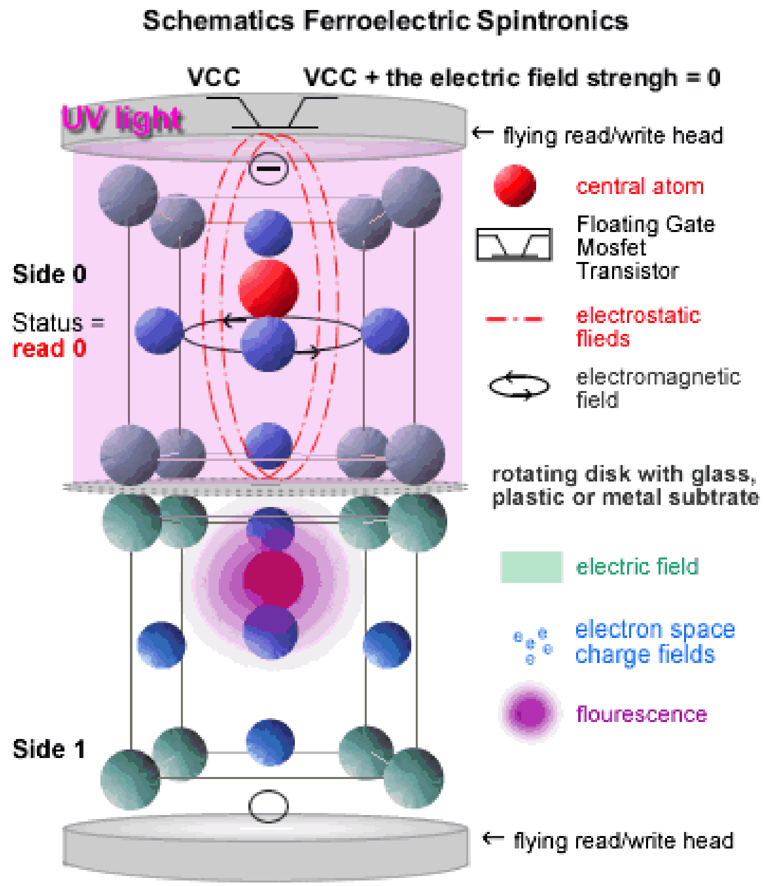


MRAM Computer chips

- It combines the density of DRAM (Dynamic Random Access Memory) with the speed of SRAM (Static Random Access Memory) and the non-volatility of Flash memory.



FERROELECTRIC SPINTRONICS



design by sonja thomas

- The two layers in a GMR device are made up of two different ferromagnetic materials.
- The spin of the electrons in the upper layer (orientation) change direction depending on the electromagnetic field due to the flow of the current, be it CIP or CPP.
- Whereas, the spin of the electrons in the lower layer (orientation) do not change direction (due to the current flow) but are influenced by the change of direction in the spin of the electrons in the upper layer.

- Laser or photons cannot be used on ferromagnetic material used in disk drives because photons severely damage or destroy the orientation of the 0s and 1s.
- Today's hard drives cannot use electromagnetic flux transversal to write or cause individual electron spin.
- In general, they cause many magnetic particles in an area on the disk to change magnetic direction.
- The number of magnetic particles needed for the GMR head to be able to tell 0s and 1s apart is defined by terms like margin, bit density, resolution, overwrite, signal to noise ratio, write and erase currents, bandwidth of the data channel, track density and many other parameters related to the magnetic recording material.

- Colossal Storage proposes using ferroelectrics because the bit densities can be scaled down to the nanometer while still maintaining non-volatility of the bits using interference, diffraction, reflection, entanglement, electrostatic fields, electromagnetic fields, and Spintronics for data detection.
- Optical Spintronics for optical data storage is the future because it can use much higher electro magnetic spectrum frequencies with functions taking advantage of controlling the electrons for use in reading and writing of stored information while maintaining non-volatility and extending the shelf life beyond magnetic hard drives capabilities.

PLASTIC SPINTRONICS

- Spintronics uses magnetic fields to control the spin (orientation) of electrons.
- In the current issue of the Journal of Advanced Materials, Epstein and his coauthors report using a magnetic field to make nearly all the moving electrons inside a sample of plastic, spin in the same direction, an effect called spin polarization.
- Achieving spin polarization in plastic is the first step in converting this material into a read/re-writable memory storage medium.

- Using plastic may solve another problem currently faced by developers: spinning electrons must be able to move smoothly between components made of different materials - transition.

- But transition from one material to another can sometimes alter the spin of an electron (orientation) and hence the data stored in that electron's spin would be lost.

- Plastic Spintronics devices would weigh less than traditional electronics devices and cost less to manufacture.

- The advent of plastic electronics opens up many opportunities for new technologies such as flexible displays and inexpensive solar cells.

CONCLUSION

- Interest in Spintronics arises, in part, from the looming problem of exhausting the fundamental physical limits of conventional electronics.
- However, complete reconstruction of industry is unlikely and Spintronics is a “variation” of current technology.
- The spin of the electron has attracted renewed interest because it promises a wide variety of new devices that combine logic, storage and sensor applications.
- These devices are smaller, faster and multi-purpose devices with larger storage capacity and low power consumption.
- Moreover, these "Spintronic" devices might lead to quantum computers and quantum communication based on electronic solid-state devices, thus changing the perspective of information technology in the 21st century.

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THANK YOU