SPINTRONICS AND SPINTRONIC DEVICES

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23^{rd},August 2011

Table Of Contents

What is Spintronics?

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- Spintronics:also known as magnetoelectronics,manipulates the electron spin and resulting magnetic moment,to achieve improved funcionalities – e.g. Spin transistors, memories etc.

A Brief History

- 1920s: Spin concept
- 1921 : Stern-Gerlach Experiment
- The Moore'sLaw
- 1988: Discovery of Giant Magnetoresistance

A Brief History

- 1991: Invention of Spin Valve by IBM
- 1994: Magnetic Tunnel Junction with large Magneto resistance ratio.
- 1997: First GMR Hard disk Head introduced by IBM
- 2002: Plastic Shows promise for SpintronicsMagnetic Computer memory
- 2005: Commercialization of MTJ Read head

RECENT DEVELOPMENTS

GIANT MAGNETO-RESISTANCE

- Discovered in 1988 France
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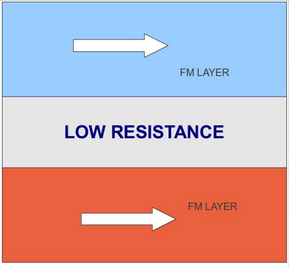

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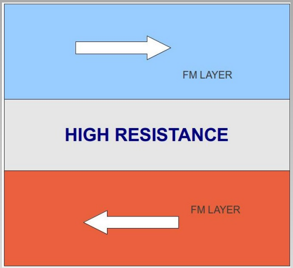
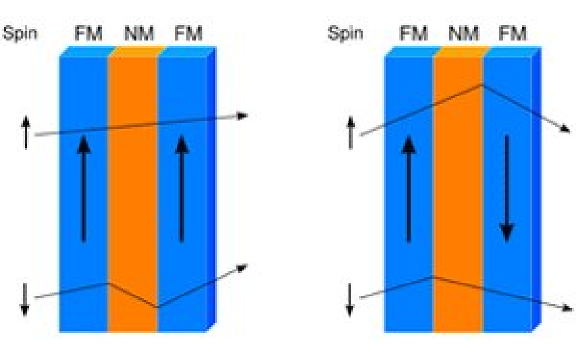
- Conversely when magnetization vectors are antiparallel, high R

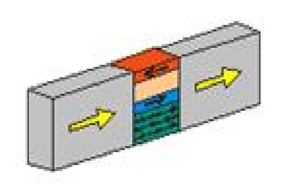


GIANT MAGNETO-RESISTANCE



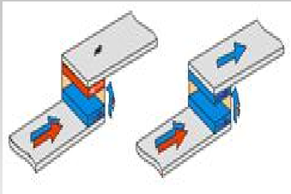
PARALLEL CURRENT

- Current runs parallel between the ferromagnetic layers
- Most commonly used in magnetic read heads
- Has shown 200% resistance difference between zero point and antiparallel states



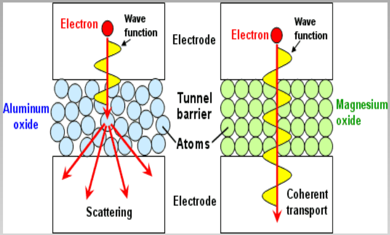
PERPENDICULAR CURRENT

- One FM layer as spin polarizer and other as detector
- Has shown 70% resistance difference between zero point and antiparallel states
- Basis for Tunneling MagnetoResistance



Magnetic Tunnel Junctions

- Two conducting electrodes are separated by a thin dielectric layer with a thickness ranging from a few angstroms to a few nanometers.
- The electron tunneling phenomenon arises from the wave nature of the electrons.
- MgO barrier junctions have produced 230% MR

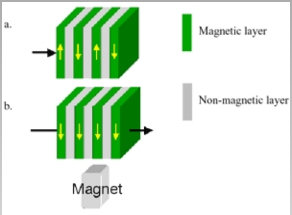


Advantages of MTJ over GMR

- Higher TMR effect
- Low power operation
- High reliability

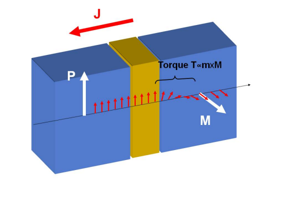
SPIN VALVE

- Simplest and most successful spintronic device
- Used in HDD to read information in the form of small magnetic fields above the disk surface

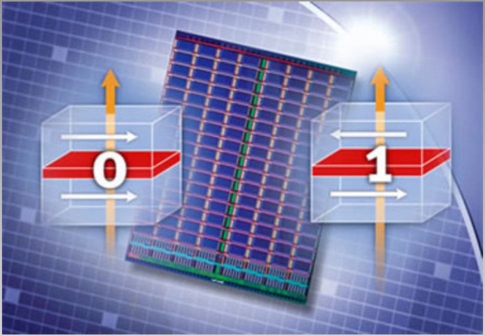


SPIN TRANSFER TORQUE

- This effect has been formalized theoretically by Slonczewski and Berger in 1996
- Current passed through a magnetic field becomes spin polarized
- This flipping of magnetic spins applies a relatively large torque to the magnetization within the external magnet
- This torque will pump energy to the magnet causing its magnetic moment to precess
- If damping force is too small, causes the unwanted flips in spin valves
- Possible applications in memory writing

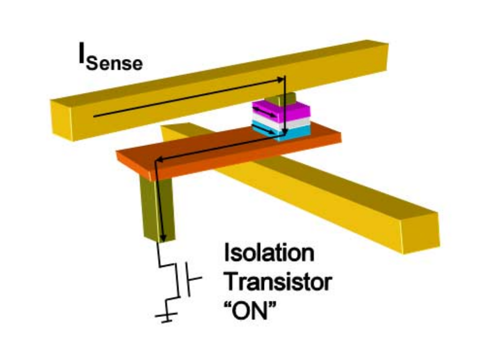


MRAM



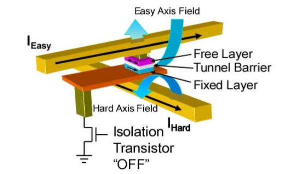
- MRAM uses magnetism rather than electrical power to store bits of data.
- Tunnel junctions are used to read the information stored in MRAM and STT is used to write data.

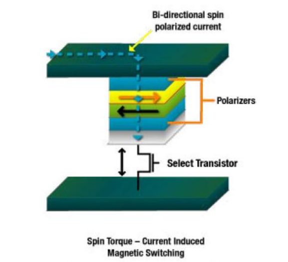
MRAM read



- Transistor is "ON"
- Measuring of electrical resistance of a small sense current from a supply line through the cell to the ground.

MRAM Write

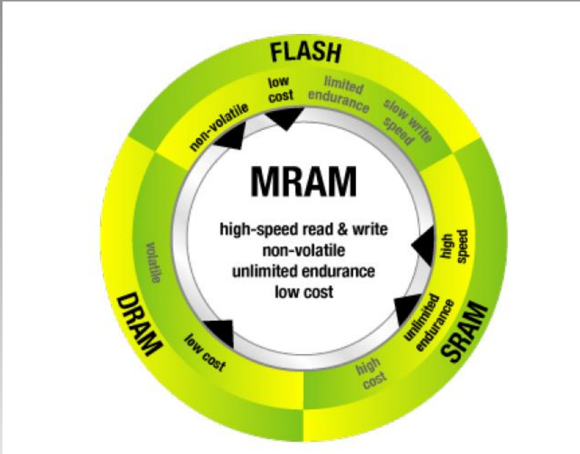




- Transistor is "OFF"
- When current is passed through the write lines,induced magnetic field is created at the junction, which alters the polarity of the free layer

- No applied magnetic field
- Utilizes heavily spin polarized current
- The magnetization of nano-elements is flipped back and forth

COMPARISON OF EXPECTED MRAM FEATURES WITH OTHER MEMORY TECHNOLOGIES				
	SRAM	DRAM	Flash	MRAM
Read Time	Fast	Moderate	Moderate	Moderate-Fast
Write Time	Fast	Moderate	Slow	Moderate-Fast
Nonvolatile	No	No	Yes	Yes
Refresh	N/A	Yes	N/A	N/A
Minimum Cell Size	Large	Small	Small	Small
Low Voltage	Yes	Limited	No	Yes

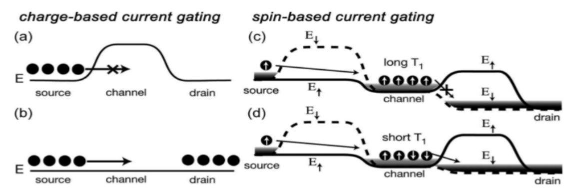

FLASH
low cost
limited endurance
slow write speed
non-volatile
MRAM
high-speed read & write
non-volatile
unlimited endurance
low cost
high speed
unlimited endurance
SRAM
high cost
DRAM
low cost
volatile

MRAM STATUS

- 2003 - A 128 kbit MRAM chip was introduced
- 2004 - Infineon unveiled a 16-Mbit prototype
- 2005 - Sony announced the first lab-produced spin-torque-transfer MRAM
- 2007 - Tohoku University and Hitachi developed a prototype 2 Mbit Non-Volatile RAM Chip employing spin-transfer torque switching
- 2008 - Scientists in Germany have developed next-generation MRAM that is said to operate with write cycles under 1 ns.
- 2009 - Hitachi and Tohoku University demonstrated a 32-Mbit spin-transfer torque RAM

SPIN VALVE TRANSISTOR

- The Datta Das Spin Transistor was first spin device proposed in 1989
- Spin transistors would allow control of the spin current in the same manner that conventional transistors can switch charge currents
- consists of a silicon emitter, a magnetic multi-layer as the base and a silicon collector

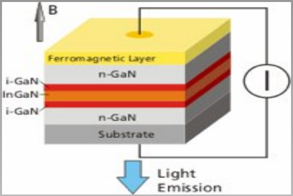


SPIN VALVE TRANSISTOR

These transistors are used in:

- data storage
- signal processing
- automation and robotics with less power consumption
- Quantum computing

SPIN LEDs



- spin LED functions much the same as a typical semiconductor-based light emitting diode
- The emitted light will then possess a polarization dependent on the spin-polarization of the charge carriers involved in the recombination.
- spin LEDs can be used in the study and development of other spintronics devices where analysis of the polarization of the emitted light provides information about the spin states of the charge carriers in the device.

Overview

Advantages

- Non-volatile memory
- Low power consumption
- Spintronics does not require unique and specialised semiconductors
- Spin lifetime is relatively long, on the order of nanoseconds
- compared to normal RAM chips, spintronic RAM chips will:
  - increase storage densities
  - have faster operation

Limitations

- Controlling spin for long distances.
- Difficult to INJECT and MEASURE spin.
- Interfernce of fields with nearest elements.
- Control of spin in silicon is difficult.

CONCLUSION

Interest in spintronics arises, in part, from the looming problem of exhausting the fundamental physical limits of conventional electronics.
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.
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

QUESTIONS ?