Spin-Transfer Torque Switching in Magnetic Tunnel Junctions and Spin-Transfer Torque Random Access Memory

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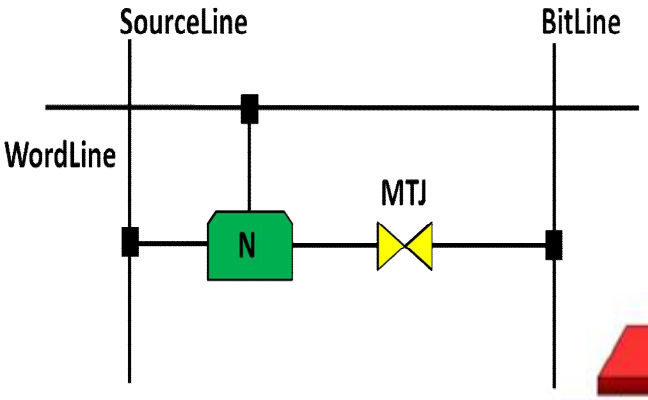
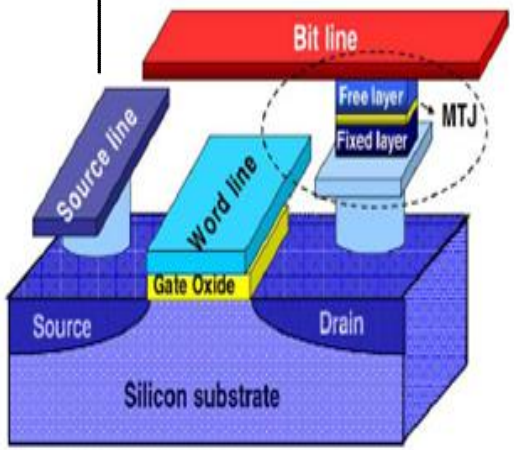
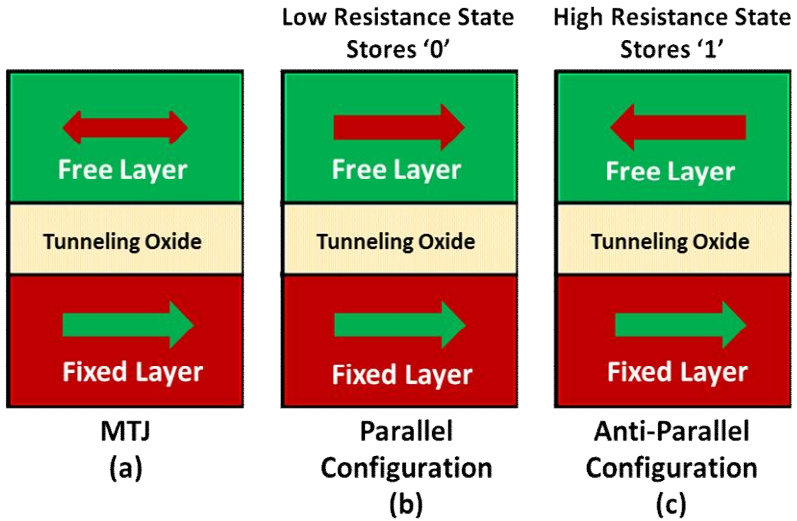
Published In:
Journal of Physics - 2007

Motivation

- **S**pin **T**ransfer **T**orque - **M**agnetoresistive **R**andom **A**ccess **M**emory (**STT-MRAM**) stores data using a **M**agnetic **T**unnel **J**unction (**MTJ**)





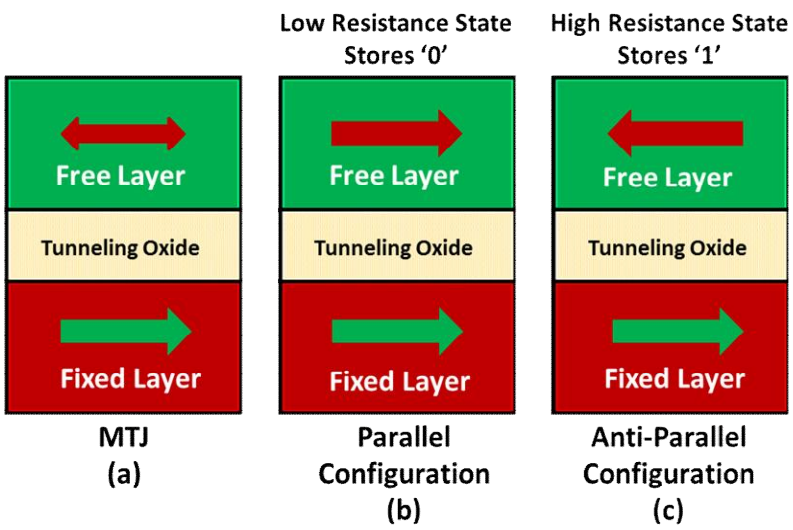


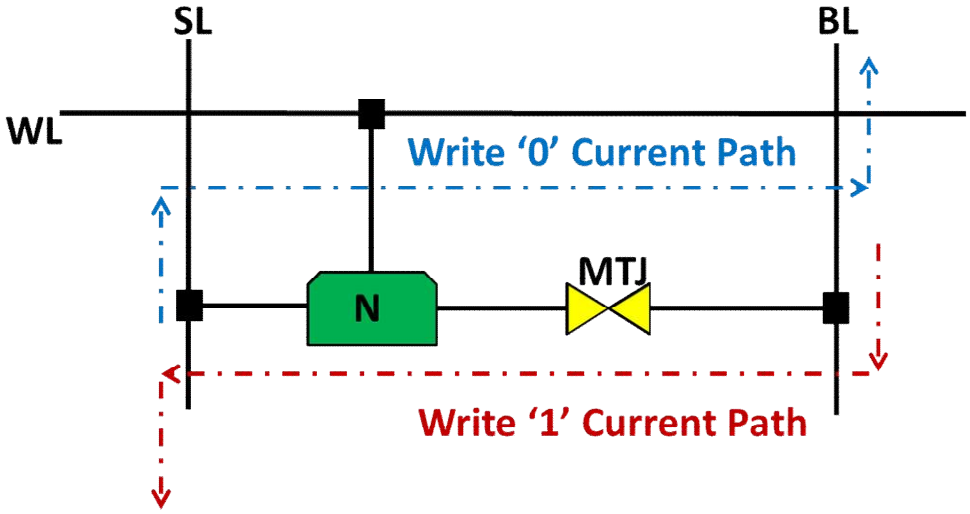
Motivation

STT-MRAM is considered as a potential "Universal Memory"

	SRAM	DRAM	STT-MRAM
Cell Area [F^2]	50-120	6-10	6-20
Volatility	Volatile	Volatile	Non-Volatile (Default)
Endurance	10^{16}	10^{16}	10^{15}
Read Time [ns]	1ns	15ns	2-20ns
Write/Erase Time [ns]	3ns	8ns	20ns
Read Energy	Low	Low	Low
Write Energy	Low	Low	High

STT-MRAM Write Operation





❑ Critical Current (I_{C0}) or Critical Current Density (J_{C0}):

The minimum current required to make the MTJ free layer instable enough to cause a switching of its magnetic orientation

- **Deciding factor in write energy consumption**
- **Dependent on temperature**

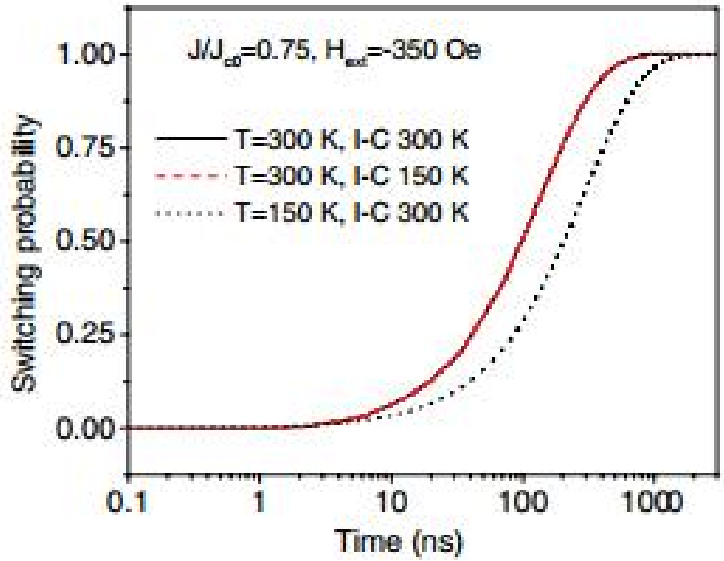
MTJ Switching Techniques

1. Thermal Activation:

- If the temperature remains unchanged during the switching process, the switching probabilities are exactly the same
- With two different temperatures during the switching process, the probability is strikingly different even with the same initial conditions

$J = 0.75J_{CO}$

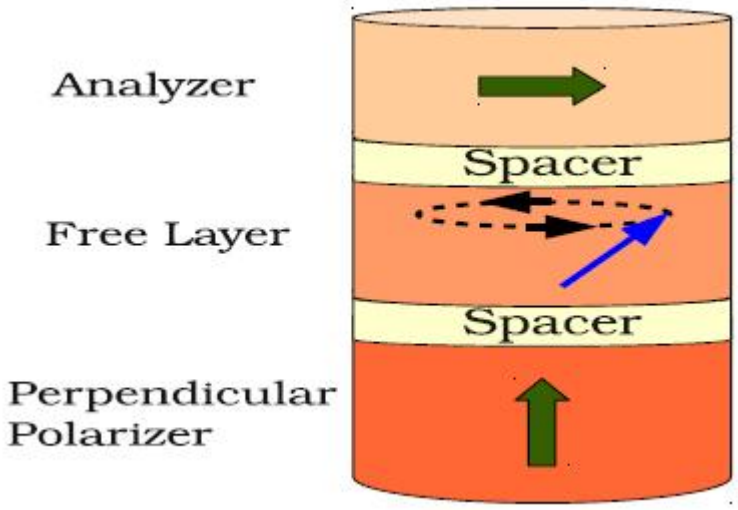
Switching Pulse Width > 100 ns



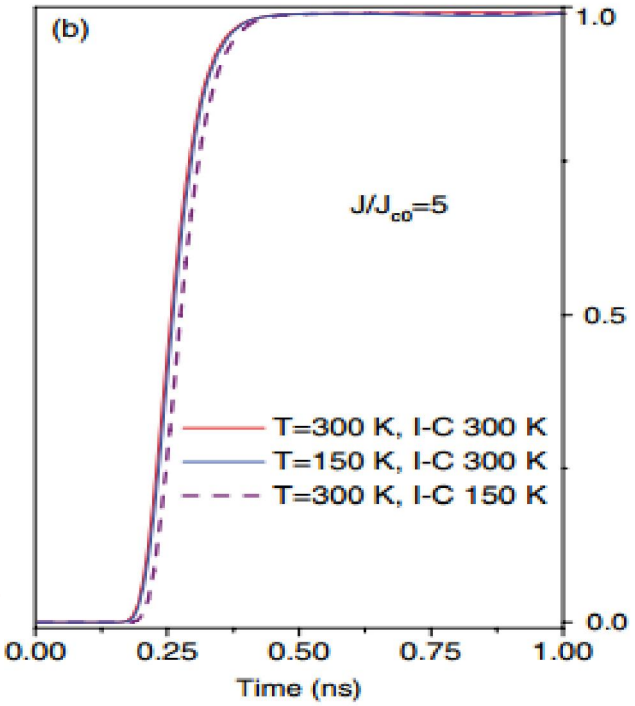
MTJ Switching Techniques

2. Precessional Process:

- Polarizer sends RF signal to assist switching
- the magnetization switching is mainly dependent on the initial thermal distribution



$J = 5J_{CO}$
Switching Pulse
Width = 0.25 ns

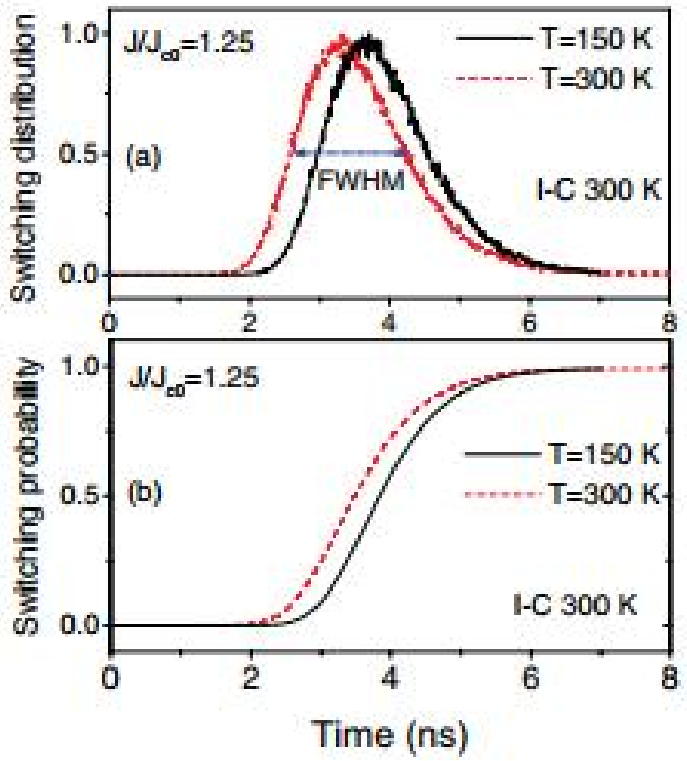


MTJ Switching Techniques

3. Dynamic Reversal:

Dynamic reversal is a combination of Precessional and Thermally activated switching.

The magnetization reversal is determined both by the initial thermal distribution and the thermal agitation during the switching process.



$J = 1.25J_{CO}$
Switching Pulse Width = 4 - 6 ns

Summary

Switching Technique	Switching Current (J)	Switching Pulse Width (ns)
Thermal Activated Switching	0.75 J_{C0}	> 100 ns
Precessional Switching	5 J_{C0}	0.25 ns
Dynamic Reversal Switching	1.25 J_{C0}	4 – 6 ns

- **Authors conclude that the Dynamic Reversal Technique provides the optimum performance.**
- **Based on possible future development of Precessional Switching, it can give us SRAM like writing latency for STT-MRAM, without relaxation techniques**

Thank you

Questions?