Fully Electrically Read- Write Magneto Logic Gates

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Spin based technologies are promising candidates for future electronic devices because of their fast switching capability, high endurance, and non-volatility. Furthermore the use of spin as a computational degree of freedom permits the combination of information storage and processing in a single device creating a fully non-volatile information processing system, allowing an even denser integrated circuits layout made of simplified building blocks. Recently a fully electrical read-write 1 bit demonstrator memory device out of a ferromagnetic semiconductor has been shown [1]. It was also proposed to extend this device to a logic XOR gate [1], however, up to now neither the feasibility of this gate nor the extensibility to further logic gates could be shown. In this work we present our simulations for the proposed logic gate [2]. Assuming disk radii of 160nm, 80nm, and 40nm, a constriction length and width of 15nm, a saturation magnetization M_S of 3200A/m, a cubic anisotropy with the easy axis oriented parallel to the leads and a cubic anisotropy constant K_C of 2000J/m^3 for the (Ga,Mn)As film, we have been able to show that indeed the magnetization of the disks can be switched by current pulses of 20ns to 100ns with current densities between $4 \cdot 10^{10}$A/m² and $8 \cdot 10^{10}$A/m² (see Fig.1) applied between the opposite terminals (diagonal flow in Fig.1). We also demonstrate that due to the dependence of the resistance of the constriction between the two discs on the relative angle between the current flow path and the magnetization at the constriction [3] also AND and OR gates, in addition to a XOR gate, can be realized (see Tab.1).

This research is supported by the European Research Council through the Grant #247056 MOSILSPIN.

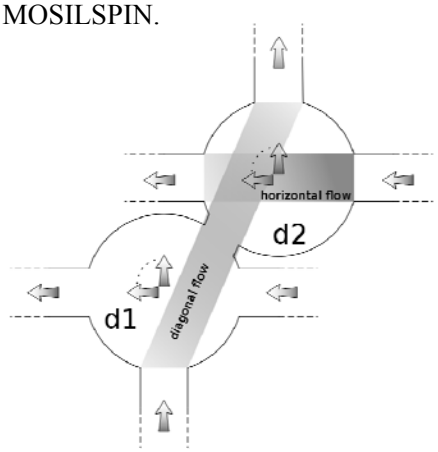

Fig.1 : Switching paths to change the magnetization of the disks.

φ	d1	d2	constriction	current	relative	resistance
45°	90°	90°	90°	23.031°	66.969	Low
45°	90°	180°	135°	23.031°	111.969°	Low
45°	180°	90°	135°	23.031°	111.969°	Low
45°	180°	180°	180°	23.031°	159.969°	High
90°	90°	90°	90°	46.2818°	43.7812°	High
90°	90°	180°	135°	46.2818°	88.7812°	Low
90°	180°	90°	135°	46.2818°	88.7812°	Low
90°	180°	180°	180°	46.2818°	133.7812°	High
0°	90°	90°	90°	0.0°	90.0°	Low
0°	90°	180°	135°	0.0°	135.0°	High
0°	180°	90°	135°	0.0°	135.0°	High
0°	180°	180°	180°	0.0°	180.0	High

Tab.1: Three examples showing the feasibility of AND, XOR, and OR gate behavior for different relative disk position and current flow paths.

References:

[1] S. Mark et al., **Phys. Rev. Lett. 106**, 057204 (2011)
[2] http://math.nist.gov/oommf, (2011)
[3] K. Pappert et al., **Nature Phys. 3**, 573 (2007)