



Magnetic Tunnel Junction (MTJ) Logic Devices without Sense Amplifiers (20110171, Dr. Jian-Ping Wang)

IP Status: Issued US Patent; **Application #:** 13/475,544

CMOS is Reaching Limits

The increased miniaturization of CMOS logic devices (complementary metal-oxide semiconductor), which is the dominant technology for constructing integrated circuits, have led to challenges such as increased power dissipation and device variability. Moore's law for CMOS is approaching fundamental physical limits. There is a concerted effort to identify alternative or hybrid technologies without similar scaling issues as a replacement to CMOS.

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Spin Logic is Alternative to CMOS

Spin logic is proposed as a replacement to CMOS, where the information is stored in the orientation of magnetic fields, rather than the charge-based storage of information found in transistors. A spin-polarized current can transfer its spin angular momentum to a small magnetic element and switch magnetic field orientation in a write operation. With this medium of magnetic logic, a magnetic tunnel junction (MTJ) is used to transfer information on the magnetic state from the circuit. MTJs are current-controlled devices, where their input signal must be in the form of a current and the output is in resistance. If two stages are to be connected, the output resistance must be converted into a current so that it is compatible with the next stage of logic. Normally, this is done using a sense amplifier to detect the resistance, convert the resistance to a voltage and use the voltage to trigger a current source which is then used as the input to the logic element.

Magnetic Tunnel Junction without Sense Amplifiers

The sense amplifier in MTJs can be avoided and the magnets can be directly linked to the logic element through nanochannel communication. This reduces size and power requirements by eliminating the need for intermediate sense amplifiers and allows complex and multistage logic

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to be realized in MTJ-based spin electronics in comparison to other spin electronics. Since MTJs are non-volatile, there is potential to reduce leakage current by powering down the logic circuits when not in use as compared to CMOS. Each MTJ also has different size (area) with the same tunneling layer which provides different switching thresholds and ease of manufacturing.

Magnetic tunneling without sense amplifiers has the potential for increased scaling of microchips beyond CMOS limits. This technique can also leverage knowledge based on integration of spin transfer torque MRAM with CMOS.

FEATURES AND BENEFITS OF MAGNETIC TUNNEL JUNCTION WITHOUT SENSE AMPLIFIERS:

- Reduces size and power requirements by eliminating the need for intermediate sense amplifiers
- Allows complex and multistage logic to be realized in MTJ-based spin electronics in comparison to other spin electronics
- Potential to reduce leakage current by powering down the logic circuits when not in use as compared to CMOS

Phase of Development Experimentally demonstrated a world-first magnetic tunnel junction (MTJ)-based circuit that allows direct communication between elements without intermediate sense amplifiers.

Other technologies related to magnets by Jian-Ping Wang:

- [Nanoparticle Synthesis System with High Deposition Rate](#)
- [Giant Magnetoresistance Biomolecule Sensing System](#)

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