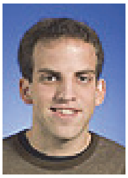
All-Magnetic, Nonvolatile, Addressable Chainlink Memory

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The search for dense, low power, nonvolatile memory has focused a spotlight on MRAM in recent years. Our approach to providing such a technology is chainlink memory, an addressable, nonvolatile magnetic shift register (Fig. 1). A magnetic nanowire, or *link*, stores a domain wall (DW) representing a bit of data. Data is moved along a link by spin transfer torque (STT) and propagates to an adjacent, electrically-insulated link via exchange coupling through a magnetic material where the links overlap. Distinct and separately clocked current pulses are applied to serial chains of these coupled and insulated links, such that a bit can only propagate to the next link and no further. This ensures adjacent DWs never annihilate data bits, an issue that can occur in similar technologies. Micromagnetic simulation of bit propagation is shown in Fig. 2. The simulations solve the STT Landau-Lifshitz-Gilbert equation on a cubic mesh. For the DW to enter the next link, it must overcome an energy barrier due to the increased height at the coupling site, as wall energy is proportional to cross-sectional area. With no applied current, the DW cannot overcome this barrier and so the data is stable within a link, with a barrier greater than $50k_BT$ at room temperature. A 2 ns pulse of J=5 MA/cm^2 allows the bit to propagate, which is just 3 μA for a link 20 nm wide and 3 nm thick. For a link resistance of 200 Ω, this implies the switching energy is (2)(3 μA)^2(200 Ω)(2 ns) = 7.2 aJ per shift per bit, as a domain wall must cross two links to shift one bit position. The coupled chains form a shift register, though multiple shift registers can be addressed and accessed independently. A bit is read when shifted past a sensor (e.g. MTJ) positioned somewhere along a chain. Each shift register can be arranged as a circular buffer to allow data to circulate after reading without additional storage regions.

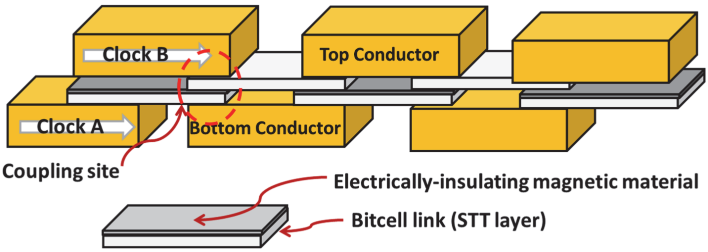

Fig. 1: Chainlink cross-section.

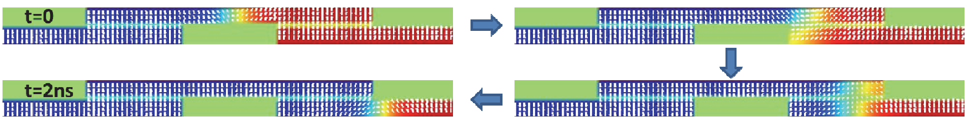

Fig. 2: Micromagnetic simulation of bit propagation.