Ultrafast Energy-Efficient Spin-Torque Magnetic Random Access Memories

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Primary CNF Tools Used: ASML stepper, Veeco Icon, JEOL JBX-6300FS, ASML stepper, AJA sputtering

Abstract:

Spin-orbit torques [1-5] have been a hot topic in the research and technology communities due to their great promise for magnetic memories, oscillators and logic of post-Moore era. Here we demonstrate ultrafast energy-efficient magnetic random access memories (MRAMs) [6,7] fabricated at the Cornell NanoScale Science and Technology Facility.

Summary of Research:

We fabricated the spin-torque MRAM devices — schematically shown in Figure 1(a). The magnetic multilayer samples are patterned into three-terminal MRAM devices with a three-step procedure. First, we defined the spin Hall channel using DUV lithography (ASML stepper) and ion beam etching and measured the channel size to be 300 × 600 nm^2 by atomic force microscopy (Veeco Icon). We then defined the elliptical magnetic tunnel junction nanopillars with different aspect ratios and micron-size "via" pillars (as vertical connector between the bottom channel to top contact) onto the spin Hall channel with e-beam lithography (JEOL JBX-6300FS) and ion beam etching, and isolated the pillars with 80 nm thick SiO_2 deposited by an e-beam evaporator. Finally, contacts of Ti 5/Pt 50 were deposited on the top of the magnetic tunnel junction pillars and "via" pillars for electrical measurements by combining the DUV lithography (ASML stepper), AJA sputtering, and liftoff processes.

Figure 1(b) shows the characteristic switching behavior of the MRAMs as the write current in the spin Hall channel is ramped quasi-statically. The MTJs show abrupt switching at write currents of 20 µA. Since thermal fluctuations assist the reversal of a nanoscale MTJ device during slow current ramps, we carried out ramp rate measurements and determined that the zero-temperature switching current is 70 µA, The critical switching density in the Pt spin Hall channel is therefore $j_{C0} \approx 3.6 \times 10^7$ A/cm^2. Both the total critical switching and the low switching current density are the lowest yet reported for any spin-torque MRAMs. We also measured the fast switching behaviors of our spin-torque MRAMs and find deterministic switching even at 200 ps, which is also the fastest switching yet known.

References:

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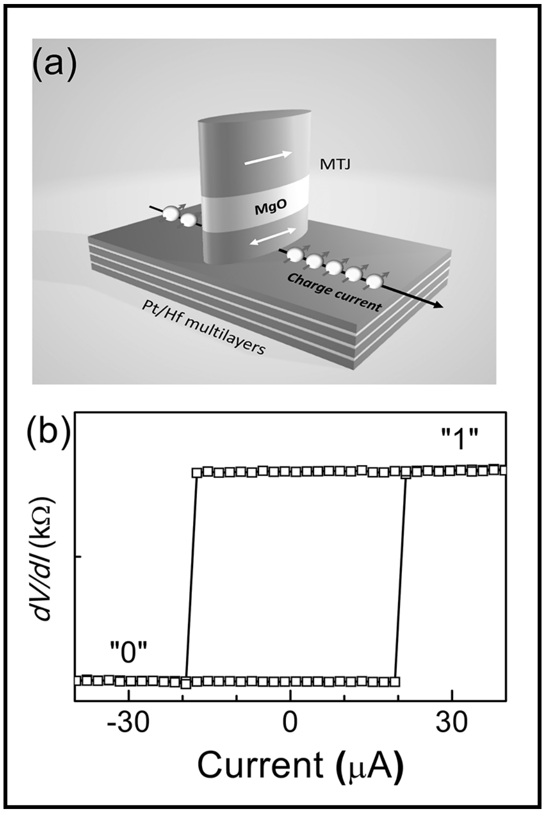

Figure 1: (a) Schematic of a spin-torque MRAM device; (b) Current-induced switching of the MRAMs.