Orthogonal Spin Transfer MRAM (OST-MRAM™)

MRAM Continues to Progress

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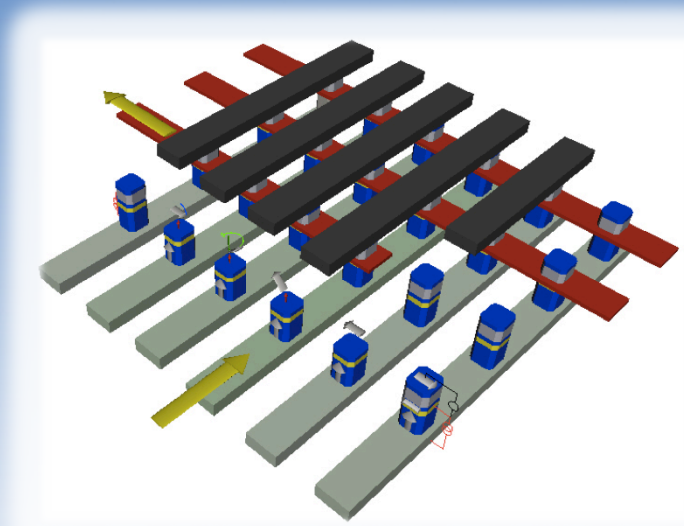
Market Drivers Exist

- Memory performance is a growing bottleneck in many system designs
- Power is becoming more critical for mobile, storage, & other applications
- Increasing demand for “Instant-on”
- Current memories are challenged
- Need for a more scalable, more energy efficient, higher performing, non-volatile memory

MRAM Building Momentum

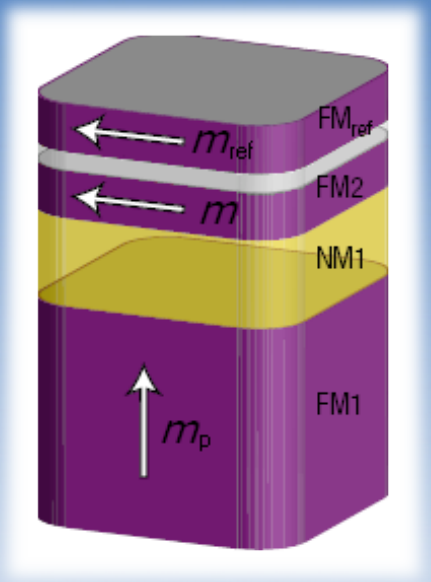
- Interest & collaboration in MRAM is growing
- Spin torque MRAM characteristics are compelling
  - Fast read/write, low power, ultra-high endurance, non-volatile, radiation hard
- MRAM is promising but has challenges
  - Stability, scalability, manufacturability
- Innovation continues to address these challenges



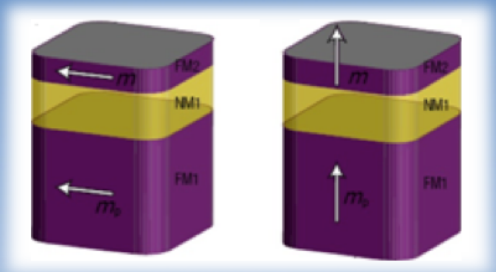
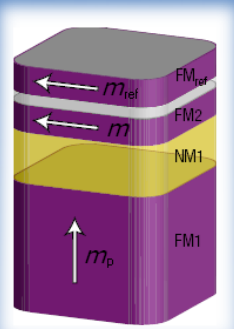
Orthogonal Spin Transfer (OST-MRAM™)

- OST-MRAM implements an orthogonal orientation between the polarizing vector & free vector
- Creates a deterministic switching torque, resulting in immediate high-speed switching & low energy consumption
- Other spin-torque MRAM approaches rely on thermodynamic fluctuations, resulting is an incubation delay in the onset of switching, requiring more time & energy

OST-MRAM

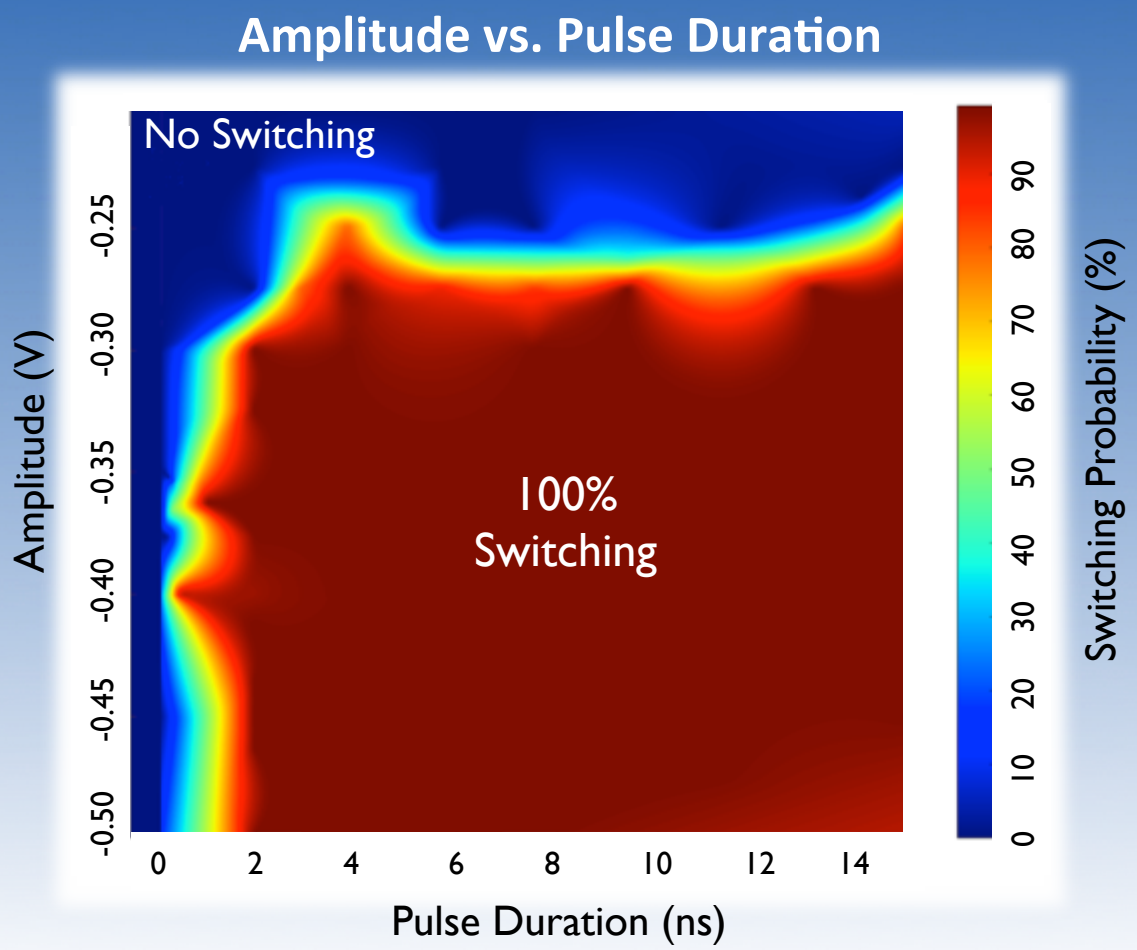


OST-MRAM Comparison

	Conventional spin-torque MRAM	OST-MRAM
Configuration	Parallel (collinear) orientation of polarizing & free magnetic vectors 	Orthogonal orientation of polarizing & free magnetic vectors 
Switching Process	✗ Stochastic	✓ Deterministic
Switch Time	✗ Incubation delay in onset	✓ No delay in onset
Current	✗ Larger currents needed to induce quicker switching	✓ Switching at low currents allows smaller transistors
Scalability	✗ Limited scalability	✓ Scalable to smaller dimensions

Faster Switching

- OST-MRAM manufactured with industry partners using mainstream equipment/flows
- 1ns switching times observed at 99% probability
- Switching times observed as low as 0.1ns



Flash Memory SUMMIT

Summary

- Innovation has increased interest in MRAM
- Conventional MRAM is promising but has challenges
- OST-MRAM™ provides lower power, faster performance, and a path to higher densities
- About Spin Transfer Technologies
  - Developing and commercializing OST-MRAM
  - Established by Allied Minds & New York University (NYU)
  - Originated by the work of Dr. Andrew Kent, NYU
  - Demonstrated sub-ns switching speeds
  - Demonstrated sub-pJ switching energies
  - Moving to CMOS integration

Technical Papers

- Orthogonal Spin Transfer MRAM (Invited)
  D. Bedau, H. Liu, D. Backes, J. A. Katine, J. Langer and A. D. Kent; Device Research Conf.; Jun. 2011
- Magnetic Tunnel Junction based Orthogonal Spin Transfer Devices (Invited)
  A.D. Kent , H. Liu, D. Bedau, D. Backes, J.A. Katine and J. Langer; IEEE International Magnetics Conference; Apr. 2011
- Ultrafast Switching in Magnetic Tunnel Junction based Orthogonal Spin Transfer Devices
  H. Liu, D. Bedau, D. Backes, J. A. Katine, J. Langer, and A. D. Kent; March Meeting of the American Physical Society; Mar. 2011
- Ultrafast switching in MTJ based orthogonal spin transfer devices (Invited)
  A.D. Kent; 1st CSIS International Symposium on Spintronics-based VLSIs and the 7th RIEC International Workshop on Spintronics; Feb. 2011
- Ultrafast switching in magnetic tunnel junction based orthogonal spin transfer devices
  H. Liu, D. Bedau, D. Backes, J. A. Katine, J. Langer, and A. D. Kent, Applied Physics Letters 97, 242510; Dec. 2010
- MTJ-based Orthogonal Spin Transfer MRAM, Talk HC-07
  D. Backes, D. Bedau, H. Liu, J. A. Katine, J. Langer, and A. D. Kent; 55th Annual Magnetism & Magnetic Materials Conference; Nov. 2010
- Spin-Transfer in Nanopillars with a Perpendicularly Magnetized Spin Polarizer
  J-M. L. Beaujour, D. B. Bedau, H. Liu, M. R. Rogosky and A. D. Kent, Spintronics II, Proc. of SPIE Vol. 7398, 73980D; (2009); doi: 10.1117/12.829018
- First realization of thin film layer with perpendicular magnetic anisotropy and high spin polarization—of importance for OST-MRAM polarizer
  J. M. Beaujour and A.D. Kent; European Physical Journal B 59, 475; Oct. 2006
- Spin-transfer-induced precessional magnetization reversal
  A. D. Kent, B. O¨zyilmaz, and E. del Barco; Applied Physics Letters Volume 84, Number 19; Apr. 2004

Thank You

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