

MRAM's Journey from Specialty to Mainstream Memory

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Magnetoresistive random access memory (MRAM) is a superior form of non-volatile working memory because of its high speed, robust endurance, and system power savings. Since the first commercial MRAM was launched in 2006, the memory capacity and market size have greatly expanded [1]. In this paper, we focus on the evolution of the MRAM technology from Toggle to STT-MRAM and its commercialization. We review the challenges ahead and newer magnetic based technologies being explored for continued scaling and performance.

The first commercial MRAM utilized magnetic field switching [Fig. 1(a)], so called toggle switching, and was brought to volume manufacturing by Freescale Semiconductor in 2006 as a 4 Mb discrete part. Since then, Everspin, a spinoff from Freescale, has further developed toggle MRAM and brought to the market a range of parts from 128 kb to 32 Mb, which are used in industrial area, RAIDs, automotive, and aerospace. Spin Transfer Torque switching offers an attractive solution for scaling to higher densities while lowering the write current per bit. Everspin commercialized STT-MRAM (a 64Mb product) in 2015 using in-plane magnetic tunnel junctions (iMTJ) [Fig. 1(b)]. MTJs with perpendicular magnetic anisotropy (pMTJ) were also being developed to allow an even lower writing current and a higher density memory [Fig. 1(c)]. In 2017, a discrete 256 Mb STT-MRAM part using pMTJs became commercially available followed by a 1 Gb STT-MRAM part in 2019 [2]. Currently, new technologies to further scale STT-MRAM and even new switching mechanisms are being developed.

Discrete STT-MRAM are being deployed as non-volatile write buffer memory in solid state drives. STT-MRAM has also found applications in embedded memories where eFlash and SRAM face scaling difficulties. Thus, three major foundries and two other companies are pursuing MRAM as well. These companies' entry into MRAM market and the achievement of 1Gb memory capacity in 2019 indicate that MRAM is a promising candidate for a mainstream memory technology.

- [1] S. Ikegawa, F. B. Mancoff, J. Janesky, and S. Aggarwal, "Magnetoresistive random access memory: present and future," to be published in *IEEE Trans. Electron Devices*, Apr. 2020.
- [2] S. Aggarwal et al., "Demonstration of a reliable 1 Gb standalone spin-transfer torque MRAM for industrial applications," in *IEDM Tech. Dig.*, Dec. 2019, pp. 2.1.1-2.1.4.

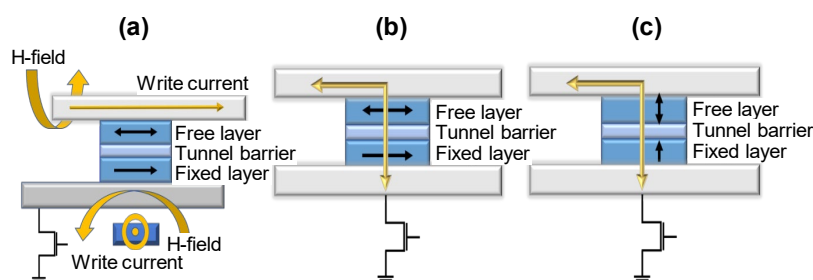


Fig. 1. Three generations of MRAM: (a) Magnetic fields-switched MRAM, (b) STT-MRAM with iMTJ, and (c) STT-MRAM with pMTJ.