When will MRAM take over the world?

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After years of unfulfilled promises, spintronics now appears to be ready to make a splash in the microelectronics world. As underlined by its recent adoption by the ITRS, spin-transfer torque magnetic random access memories (MRAM) are one of the "emerging memory technologies recommended for accelerated research and development leading to scaling and commercialization of non volatile RAM to and beyond the 16 nm generation". Semiconductor giants such as Samsung, Hynix and Micron are now deeply involved in STT-RAM development with the replacement of DRAM in sight. Whilst this is a huge market, accounting for nearly half of the memory market, it may only be the tip of the iceberg.

What makes MRAM so unique in the memory landscape is the combination of nonvolatility, infinite endurance and speed. MRAM is by no means a champion: it is slower then SRAM, bigger and more expensive then Flash, and does not reach the truly infinite endurance of DRAM and SRAM. However, whilst SRAM is ultra-fast, it is by nature volatile and expensive at ~100F^2 cell size; DRAM is impossible to embed and has severe issues below 20 nm nodes; Flash, the only nonvolatile memory of the band, is sluggish at best and has limited endurance. Emerging technologies, such as phase-change or resistive RAM, suffer from limited endurance, regardless of all other issues inherent to any promising-yet-unproven technology. In a winter RAM Olympics, MRAM would not compete for any single event medal, but would be king in the "alpine combine", where the rewards go to the skier which can achieve the best combined results in all disciplines.

This unique combination of properties is most advantageous in microprocessors and advanced SoC where power consumption is becoming a major issue. The majority of the dissipated power is due to static leakage in the memory itself (now accounting for >50% of the chip area) and to dynamic *RC* loss in the hundreds of kilometres of wiring between the logic chip and the surrounding memory. The only solution to circumvent this problem by embedding nonvolatile memory within the logic circuit will become mandatory: no more static loss (nonvolatility) and minimized dynamic loss (reduced wire count/length). And as the icing on the cake, having memory cells distributed within the logic circuit will allow fractions of the chip to be turned on and off almost on-demand, paving the way for the future "instant-on/normally-off computing". As stated by the same ITRS workgroup: "Nanodevices that implement both logic and memory in the same device would revolutionize circuit and nanoarchitecture implementation".

One would guess from the above, that with such an industry pull, MRAM would already have taken the memory world by storm. But like every new technology, it is easier said than done. Over the past decade, MRAM has had its share of promises that fell short when implemented in a product, to the point that the once believed "universal memory" fell out of favour with many players pulling out. However, things appear to have changed radically over the past few years, with the onset of STT-MRAM as the next promising candidate … and the epiphany from the industry that there was no other viable technology in sight that would combine the same attributes as MRAM. So what is missing still?

Several foundries have now implemented MRAM technology and will soon offer it to customers, so this box is ticked. Models and CAD tools that emulate/hide the underlying physics are becoming available for circuit designers, another box ticked. It all comes down to the basics: producing a magnetic cell technology that delivers the expected performance. Many different routes are being pursued in parallel (thermally-assisted MRAM, planar and perpendicular STT, spin-orbit torque, …) and the jury is still out on the potential winner. Nevertheless, the question is no longer "whether" MRAM will come, but "when" will it come. One way or another, MRAM will bite into the semiconductor market and never look back.