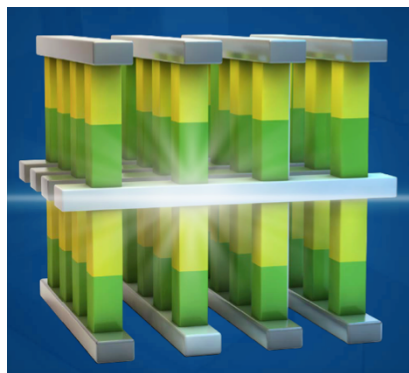
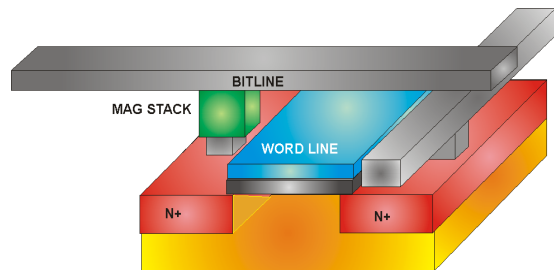
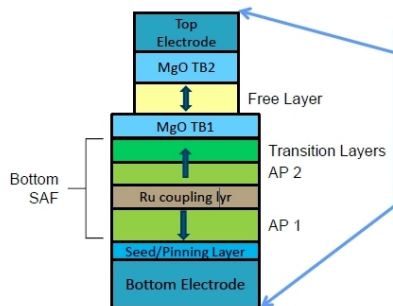


2015 EMERGING NON-VOLATILE MEMORY & SPIN LOGIC TECHNOLOGY AND MANUFACTURING REPORT



COUGHLIN ASSOCIATES
San Jose, California
September 2015

**2015 Emerging NV Memory and Logic & Memory
Manufacturing Report**

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and
Dr. Edward Grochowski**

**COUGHLIN ASSOCIATES
SAN JOSE, CALIFORNIA**

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EXECUTIVE SUMMARY

Current memory technologies including flash memory, DRAM and SRAM are facing technology limits to their continued improvement. Adding new materials to enhance gate oxide performance and reliability can only add to circuit costs. As a result there are intense efforts to develop new memory technologies. Most of these new technologies are non-volatile memories and can be used for long-term storage or to provide a memory that does not lose information when power is not applied to the electronics.

The memories addressed in this report include PRAM, RRAM, FRAM, MRAM, STT MRAM and a variety of less mainstream technologies such as carbon nanotubes. Based upon the level of current development and the characteristics of these technologies, resistive RAM (RRAM) appears to be a potential replacement for flash memory. However, flash memory has several generations of technologies that could be implemented before a replacement is required. Thus this transition will not fully occur until the next decade. Recently SanDisk and HP (inventor of the memristor RRAM) created a strategic alliance to develop next generation RRAM technology. In addition, Sony introduced a resistive memory technology in 2014.

Micron and Intel's introduction of 3D XPoint non-volatile memory technology that has high endurance, performance much better than NAND, although somewhat slower than DRAM, and higher density than DRAM; could impact the need for DRAM for high performance in-memory processing and L3 caching applications. The companies intent to introduce NVMe SSDs with this technology in 2016 with memory channel DIMM's introduced in 2017 to accompany a new enterprise server chip family. The company claims that this is a resistive memory technology but not based upon filament formation. Many people speculate that this is a form of phase change memory.

Magnetic RAM (MRAM) and spin tunnel torque RAM (STT MRAM) will start to replace SRAM and DRAM within the next few years and probably before RRAM replaces flash memory. The rate of development in STT MRAM and MRAM capabilities will result in lower prices, and the attractiveness of replacing volatile memory with high speed and high endurance non-volatile memory make these technologies very competitive.

Moving to a non-volatile main memory and cache memory will reduce power usage directly as well as enable new power saving modes, provide faster recovery from power off and enable stable computer architectures that retain their state even when power is off. Eventually spintronic technology, that uses spins rather than current for logic processes, could be extend from STT-RAM memories to the processors themselves. Spin-based logic could enabling very efficient in-memory processing.

The use of a non-volatile technology as an embedded memory combined with CMOS logic has great importance in the electronics industry. As a replacement for a multi-transistor SRAM, STT MRAM could reduce the number of transistors and thus provide a low cost, high-density solution. A number of enterprise and consumer devices use MRAM, based on field switching, to act as an embedded cache memory, and this trend will continue. The availability of STT RAM will accelerate this trend and allow higher capacities. Because of the compatibility of MRAM and STT-RAM processes with conventional CMOS processes, these memories can be built directly on top of CMOS logic wafers. Flash memory doesn't have the same compatibility with conventional CMOS. The power savings of non-volatile and simpler MRAM and STT MRAM when compared with SRAM is significant.

We project that 3D XPoint Technology, with significant shipping capacities in 2016 and with an assumed significant price advantage versus DRAM will grow to between 2.25 EB (exabytes) and 5.25 EB of shipped capacity by 2020 with a medium projection shipped capacity of 3.75 EB. 3D XPoint revenues are projected to be between \$663 and \$1.48 B by 2020 with a medium projection of \$1.06 B. The negative impact on DRAM of these sales will be a loss of \$6.7 B to \$15.6 B.

It is projected that MRAM and STT MRAM annual shipping capacity will rise from an estimated 240 TB in 2014 to between 15 and 35 PB in 2020 with a medium projection of 25 PB. MRAM and STT-RAM revenues are expected to increase from about \$300 M in 2014 to between \$1.35 B and \$3.15 B by 2020 with a medium projection of \$1.35 B. Much of this revenue gain will be at the expense of SRAM and some DRAM, although STT-RAM is developing its own special place in the pantheon of shipping memory technologies.

The demand for MRAM and STT-RAM will drive demand for capital equipment to manufacture these devices. While MRAM and STT-RAM can be built on standard CMOS circuits supplied by large semiconductor fabricators, MRAM and STT MRAM do require specialized fabrication equipment that is similar to or the same as that used in manufacturing the magnetic read sensors in hard disk drives.

The increasing demand for non-volatile memory based upon MRAM and STT MRAM will drive total manufacturing equipment revenue used for making the MRAM devices to rise from an estimated \$58.8 M in 2014 to between \$159 M to \$294 M by 2020 with a medium projected spending of \$224 M.

Coughlin Associates

Emerging Storage Technologies and Their Manufacture

Coughlin Associates announces the upcoming publication of our second detailed report addressing technology developments on solid state storage and memory technologies and the impact on manufacturing and test equipment. New solid-state storage products will impact the digital storage hierarchy including hard disk drives and flash memory. Dr. Thomas Coughlin, President, Coughlin Associates and Dr. Edward Grochowski, Computer Storage Consultant are the authors of this upcoming comprehensive and authoritative report. Order your PDF copy today and get a 10% discount on the publication price. The report includes a PDF document and a power-point file with all figures and tables from the report to use within your company. You will also receive a free subscription to the Digital Storage Technology Newsletter.

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