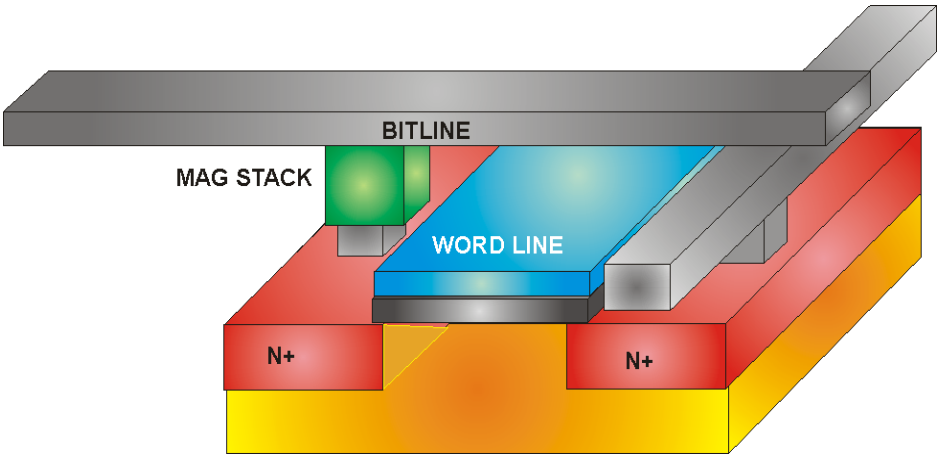
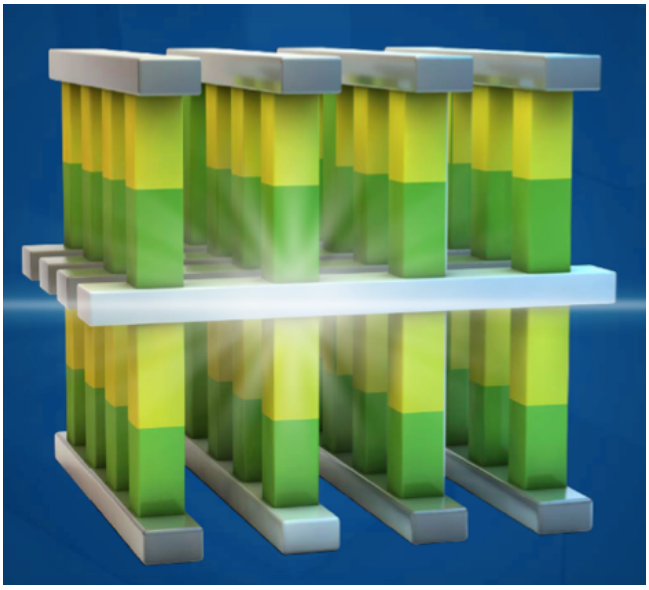
EMERGING MEMORIES POISED TO EXPLODE

An Emerging Memory Report





COUGHLIN ASSOCIATES
San Jose, California
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An Emerging Memory Report

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and

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SAN JOSE, CALIFORNIA

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THE AUTHORS

Tom Coughlin, President, Coughlin Associates: Tom Coughlin has worked for over 36 years in the data storage industry. He has over 1000 publications and six patents. Tom is active with the IEEE, SMPTE, IDEMA, and other professional organizations. Dr. Coughlin is an IEEE Fellow. He is co-chair of the iNEMI Mass Storage Technical Working Group, Education Chair for SNIA SSSI, he is President Elect of IEEE-USA and a member of the IEEE Consultants Network of Silicon Valley. His publications include the Digital Storage Technology Newsletter, Media and Entertainment Storage Report and other reports. Tom is the author of Digital Storage in Consumer Electronics: The Essential Guide, now in its second edition with Springer. He has a regular Forbes.com blog called Storage Bytes and does a regular digital storage column for the IEEE Consumer Electronics Magazine.

He is the founder and organizer of the Annual Storage Visions Conference as well as the Creative Storage Conference. He was general Chairman of the annual Flash Memory Summit for 10 years. Coughlin Associates provides market and technology analysis as well as data storage technical and market consulting. For more information go to www.tomcoughlin.com

Jim Handy, Objective Analysis:
Jim Handy, a widely recognized semiconductor analyst, comes to Objective Analysis with over 30 years in the electronics industry including over 20 years as an industry analyst for Dataquest (now Gartner), Semico Research, and Objective Analysis. His background includes marketing and design positions at market-leading suppliers including Intel, National Semiconductor, and Infineon.

Mr. Handy is a member of the Mass Storage Technical Working Group of the International Electronics Manufacturing Initiative (iNEMI), and a member of the Storage Networking Industry Association (SNIA) Solid State Storage Initiative (SSSI). He is also a Leader in the Gerson Lehrman Group Councils of Advisors, serves on the Advisory Boards of the Flash Memory Summit and Storage Visions conferences. He is the author of three blogs covering SSDs (www.TheSSDguy.com), memory chips (www.TheMemoryGuy.com), and semiconductors for the investor (blogs.Forbes.com/JimHandy) and contributes to a number of other blogs.

A frequent presenter at trade shows, Mr. Handy is known for his widespread industry presence and volume of publication. He has written hundreds of articles for trade journals, Dataquest, Semico, and others, and is frequently interviewed and quoted in the electronics trade press and other media.

EXECUTIVE SUMMARY

Current memory technologies including flash memory (NAND and NOR), DRAM and SRAM are facing potential technology limits to their continued improvement. As a result, there are intense efforts to develop new memory technologies. Most of these new technologies utilize nonvolatile memory technologies and can be used for long-term storage or to provide a memory that does not lose information when power is not applied. This offers advantages for battery and ambient powered devices and also for energy savings in data centers.

The memories addressed in this report include PCM, ReRAM, 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 (ReRAM) appears to be a potential replacement for flash memory. However, flash memory has several generations of technologies that will be implemented before a replacement is required. Thus, this transition will not fully occur until the next decade at the earliest.

Micron and Intel's introduction of 3D XPoint Memory, a 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. Intel introduced NVMe SSDs with its Optane technology (using 3D XPoint) in 2017 and plans to ship NVDIMM Optane products in volume by 2019. 3D XPoint uses a type of phase change technology.

Magnetic RAM (MRAM) and spin tunnel torque RAM (STT MRAM) will start to replace some NOR, SRAM and possibly DRAM within the next few years and probably before ReRAM replaces flash memory. The rate of development in STT MRAM and MRAM capabilities will result in gradually lower prices, and the attractiveness of replacing volatile memory with high speed and high endurance nonvolatile memory make these technologies very competitive, assuming that their volume increases to reduce production costs (and thus purchase prices).

Ferroelectric RAM (FRAM) and some ReRAM technologies have some niche applications and with the use of HfO FRAM the number of niche markets available for FRAM could increase in number.

Moving to a nonvolatile solid-state 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 more stable computer architectures that retain their state even when power is off. Eventually spintronic technology, that uses spin rather than current for logic processes, could be used to make future microprocessors. Spin-based logic could enable very efficient in-memory processing.

The use of a nonvolatile 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, higher-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 MRAM has accelerated this trend and allows 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 nonvolatile and simpler MRAM and STT MRAM when compared with SRAM is significant. As MRAM $/GB costs approach those of SRAM, this replacement could cause significant market expansion.

We project that 3D XPoint Memory, with significant gigabyte shipments in 2020-2021, and with an assumed significant price advantage versus DRAM will grow to a baseline level of 30PB (petabytes) of shipping capacity by 2028. 3D XPoint revenues are projected to reach $3.0 B by 2028.

It is projected that MRAM and STT MRAM baseline annual shipping capacity will rise from an estimated…

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