

# EMERGING NON-VOLATILE MEMORY 2018

## Market & Technology report - November 2018

*After more than 15 years in development, PCM has finally taken off in stand-alone applications. STT-MRAM will lead the embedded memory race.*

### KEY FEATURES

- 2017 - 2023 market forecast in units, Gbit, \$US, and number of wafers
- Competitive landscape and market dynamics
- Emerging non-volatile memory (NVM) - potential applications and market drivers
- Technology roadmap, with time-to-market
- Price evolution, by application and technology
- Technology description and main technical trends by technology, along with overview of main players, and roadmap

### WHAT'S NEW

- Redefinition of embedded market segments, highlighting newly emerging artificial intelligence (AI) applications as well as eDynamic Random Access Memory (eDRAM)/Static Random Access Memory (SRAM) replacement in mobile AP and high-end processors
- Updated market forecast for phase-change memory (PCM), spin transfer torque MRAM (STT-MRAM) and resistive RAM (RRAM)
- Updated analysis of technical trends for PCM, (STT-)MRAM, and RRAM
- Updated analysis of the stand-alone and embedded memory markets
- Updated analysis of China's memory market, and a detailed list of emerging Chinese NVM players
- In-depth analysis of Non-Volatile Dual Inline Memory Modules (NVDIMM) technology and its market
- Analysis of PCM's development history, including the latest news on Micron and Intel's 3D XPoint activities
- Review of materials suppliers and equipment players
- Analysis of 3D XPoint products, and comparison with Samsung's Z-NAND
- Examination of newly emerging technologies, including Ferroelectric Field-Effect Transistor (FeFET) and Nanotube RAM (NRAM)
- Updated analysis of new entrants and startup funding
- Analysis of memory technologies for artificial intelligence (AI) applications

## EMERGING NVM SALES WILL GROW BY MORE THAN ONE ORDER OF MAGNITUDE IN THE NEXT THREE YEARS, THANKS TO SCM APPLICATIONS

Ever-growing data generation driven by mobile devices, the cloud, the internet of things (IoT), and big data, as well as novel AI applications, requires continuous advancements in memory technologies. Flash NAND (non-volatile) and Dynamic Random Access Memory (DRAM - volatile) are the stand-alone workhorse options, and will maintain their leading position for another several years thanks to new technical solutions that enable further scalability. However, there exists a large speed-capacity gap between NAND and DRAM, one which must be reduced to improve overall performance of computing systems. Storage-class memory (SCM) serves precisely this purpose and has long been awaited.

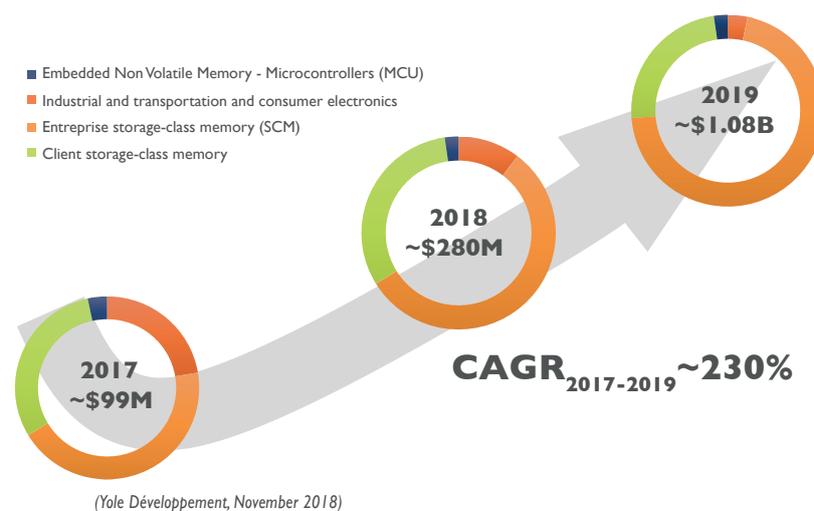
Hitherto, emerging non-volatile memories (NVMs) – e.g. phase-change memory (PCM), magnetoresistive random access memory (MRAM), spin transfer torque MRAM (STT-MRAM) and resistive RAM (RRAM) – have been restricted to niche applications because of poor scalability, high cost, and a lack of support from major memory makers. In 2015, Micron and Intel presented a new SCM technology, 3D XPoint, which uses phase-change memory (PCM) materials that the companies researched for more than 15 years. The first 3D XPoint products

– Optane™ Solid State Drives (SSDs) and storage accelerators – were introduced by Intel in 2017, and persistent-memory modules (Optane™ Dual Inline Memory Modules (DIMMs)) are expected in 2019. Despite the coming end of the Intel-Micron joint venture (IMFT), Micron has confirmed its continuing strategic involvement with 3D XPoint by announcing its acquisition of Intel's stake in IMFT, along with plans to introduce its own 3D XPoint products (QuantX™) in 2019.

Over the next three years, 3D XPoint sales will grow by more than one order of magnitude thanks to Intel's dominant position in the enterprise processor business. Optane DIMMs will be sold in combination with the latest generation of Intel's Xeon server processors (i.e. Cascade Lake). Moreover, Intel's new brand strategy for client systems that includes Optane caching pre-installed (Intel Core i+), will support sales growth.

Due to the rise of 3D XPoint sales, SCM is expected to be the dominant application for emerging NVMs in the coming years, reaching more than 90% of the emerging NVM market by 2019.

### Emerging non-volatile memory market – breakdown by application



## IN THE NEXT FIVE YEARS, PCM-BASED 3D XPOINT WILL DRIVE THE STAND-ALONE EMERGING NVM MARKET, WHEREAS STT-MRAM WILL LEAD EMBEDDED TECHNOLOGY

In the stand-alone business, emerging NVMs will not replace DRAM and NAND but will be used in combination with them inside memory modules, e.g. SSDs, DIMMs, and NVDIMMs. In 2023, PCM

will maintain its lead in the stand-alone memory market thanks to the increasing adoption of 3D XPoint as an enterprise and client SCM. It is worth noting that Samsung and Toshiba took a different

strategic path by developing 3D NAND-based SCM solutions such as Z-NAND (Samsung) and XL-Flash (Toshiba, showcased in August 2018). However, these technologies will be used in enterprise SSDs and will not compete with DDR4-compatible Optane DIMMs, which we expect will represent more than 50% of overall 3D XPoint sales.

Resistive RAM (RRAM) was expected to be the first stand-alone technology to compete with 3D XPoint, but it has suffered repeated delays due to technical challenges. We presume that RRAM could return in the race for SCM after 2020, and possibly start competing with NAND for mass storage applications.

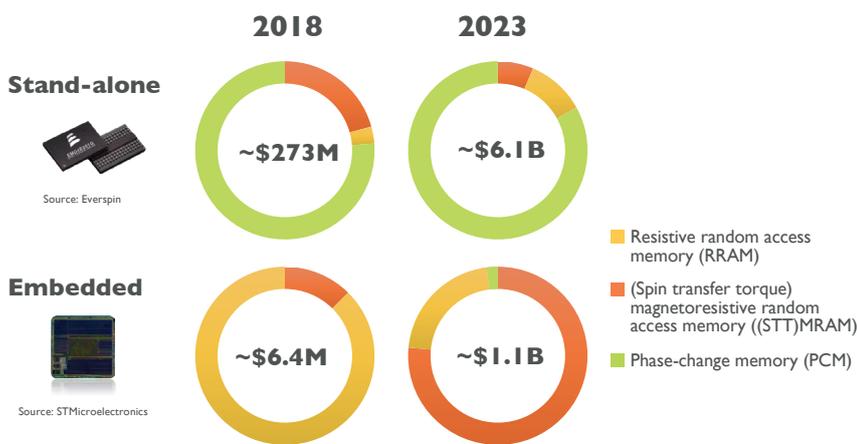
Spin transfer torque MRAM (STT-MRAM), thanks to its high speed and high endurance, is promising for enterprise storage SCM. However, its success will be much lower compared to stand-alone PCM due to higher costs, greater fabrication complexity, and challenging scalability.

Compared to stand alone, the embedded emerging NVM market is relatively small, representing ~3% of the emerging NVM market in 2017. The market is dominated today by RRAM, since only a few RRAM-based microcontrollers (MCUs) are available on the market. However, all top foundries are now getting ready with 28/22nm technology processes for STT-MRAM whereas RRAM adoption has been delayed by approximately two years by SMIC and UMC. Therefore, we expect that STT-MRAM will be the first to take-off in the coming years and will lead the embedded emerging NVM market, especially MCUs, which represent the most important embedded segment.

Emerging memory will first replace eFlash, which is facing major scaling challenges due to rising fabrication complexity/costs for technology nodes  $\leq 28\text{nm}$ . The adoption of STT-MRAM as an embedded cache memory (SRAM or eDRAM) in high-end processors and mobile AP will occur later due to more strict scalability requirements ( $\leq 14\text{nm}$ ).

AI on the edge is the most innovative application for embedded emerging NVM. Crossbar recently demonstrated various AI applications, i.e. face recognition, through the use of RRAM chips. We expect that such RRAM-based AI devices will enter the market after 2021.

**Evolution of the emerging non-volatile memory market – breakdown by technology for stand-alone and embedded memories**



(Yole Développement, November 2018)

**EMERGING NVM PLAYERS WILL USE “TROJAN HORSE” STRATEGIES TO INTRODUCE THEIR TECHNOLOGIES TO THE MEMORY MARKET**

In the stand-alone business, emerging NVM brings new features and functionalities, but at a higher price. Thus, new solutions must be found for triggering this NVM’s market penetration. Among big IDMs, Intel has a unique position: it is both a stand-alone memory supplier and a Central Processing Unit (CPU) leader.

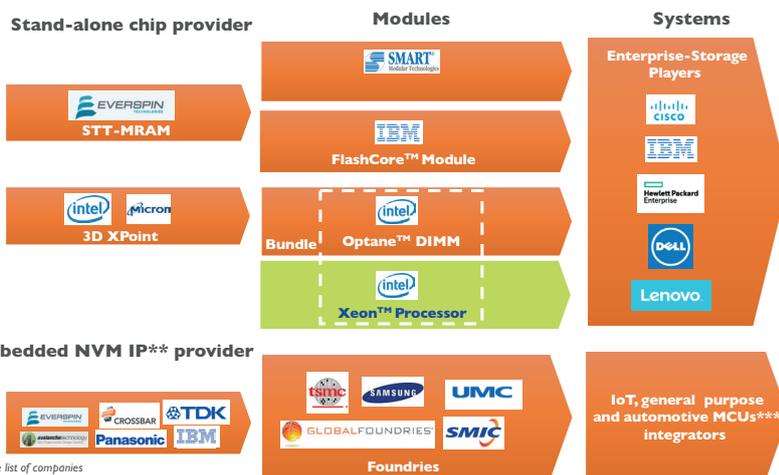
Intel can combine its 3D XPoint products with its new generation of Xeon processors, which will act as the aforementioned Trojan horse for introducing 3D XPoint into the data-center technology market.

STT-MRAM developers are rather small companies (e.g. Everspin, Avalanche, Spin Memory) that view memory module suppliers (Smart Modular, for example) as the ideal partner for entering the enterprise storage market. These module suppliers are mid-sized companies inclined to develop niche applications in the early stages.

In the embedded business, the top foundries are the key decision makers: they can promote the adoption of new embedded NVM in applications such as MCUs or cache memory. Therefore, it is critical for IP memory companies to convince foundries to develop edge-node (28/22nm) technology platforms for emerging NVM, a goal that has already been achieved by STT-MRAM players. In fact, RRAM has been adopted at 22nm by TSMC, but other foundries are hesitating to scale down to 28/22nm.

Yole Développement invites you to read our comprehensive analysis on the ecosystem and market landscape, highlighting the challenges and opportunities towards large adoption of emerging NVM.

**Examples of market entry strategies for stand-alone and embedded emerging non-volatile memory\***



\* Non exhaustive list of companies  
 \*\* Non Volatile Memory Intellectual Property  
 \*\*\* Microcontrollers

(Yole Développement, November 2018)

## OBJECTIVES OF THE REPORT

Present an overview of the semiconductor memory market:

- NAND, DRAM, NVDIMM, embedded MCU, and mobile AP - main markets, market forecast, and main trends
- Current technological status and roadmap for the coming years
- Market landscape

Provide an understanding of emerging NVM applications:

- A total of eight application fields - four for stand-alone and four for embedded: total addressable market, market drivers and challenges, technology roadmap, players, main trends
- Roadmap with time-to-market, by application

Deliver market forecasts for emerging NVM businesses:

- 2017 - 2023 market forecast in units, Gb, \$US/Gb, and number of wafers
- Price evolution, by application and technology
- Forecast for eight applications and three technologies (MRAM/STT-MRAM, RRAM, PCM)

Describe emerging NVM technologies:

- Working principle, manufacturing methods, advantages/limitations, development status, price, time-to-market
- Roadmap with technology nodes, chip-density evolution, and main players
- Latest product development status for each key market player

Detail and analyze the competitive landscape:

- Recent acquisitions and funding
- Latest company news
- Key players, by technologies and applications

## COMPANIES CITED IN THE REPORT (non exhaustive list)

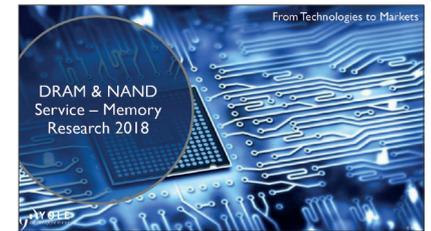
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  - Posting any Product to any other online service (including bulletin boards or the Internet);
  - Licensing, leasing, selling, offering for sale or assigning the Product.
- 6.3 The Buyer shall be solely responsible towards the Seller of all infringements of this obligation, whether this infringement comes from its employees or any person to whom the Buyer has sent the Products and shall personally take care of any related proceedings, and the Buyer shall bear related financial consequences in their entirety.
- 6.4 The Buyer shall define within its company point of contact for the needs of the contract. This person will be the recipient of each new report in PDF format. This person shall also be responsible for respect of the copyrights and will guaranty that the Products are not disseminated out of the company.
- 6.5 In the context of annual subscriptions, the person of contact shall decide who within the Buyer, shall be entitled to access on line the reports on I-micronews.com. In this respect, the Seller will give the Buyer a maximum of 10 password, unless the multiple sites organization of the Buyer requires more passwords. The Seller reserves the right to check from time to time the correct use of this password.
- 6.6 In the case of a multisite, multi license, only the employee of the buyer can access the report or the employee of the companies in which the buyer have 100% shares. As a matter of fact the investor of a company, the joint venture done with a third party etc...cannot access the report and should pay a full license price.

## 7. TERMINATION

- 7.1 If the Buyer cancels the order in whole or in part or postpones the date of mailing, the Buyer shall indemnify the Seller for the entire costs that have been incurred as at the date of notification by the Buyer of such delay or cancellation. This may also apply for any other direct or indirect consequential loss that may be borne by the Seller, following this decision.
- 7.2 In the event of breach by one Party under these conditions or the order, the non-breaching Party may send a notification to the other by recorded delivery letter upon which, after a period of thirty (30) days without solving the problem, the non-breaching Party shall be entitled to terminate all the pending orders, without being liable for any compensation.

## 8. MISCELLANEOUS

All the provisions of these Terms and Conditions are for the benefit of the Seller itself, but also for its licensors, employees and agents. Each of them is entitled to assert and enforce those provisions against the Buyer.  
Any notices under these Terms and Conditions shall be given in writing. They shall be effective upon receipt by the other Party. The Seller may, from time to time, update these Terms and Conditions and the Buyer, is deemed to have accepted the latest version of these terms and conditions, provided they have been communicated to him in due time.

## 9. GOVERNING LAW AND JURISDICTION

- 9.1 Any dispute arising out or linked to these Terms and Conditions or to any contract (orders) entered into in application of these Terms and Conditions shall be settled by the French Commercial Courts of Lyon, which shall have exclusive jurisdiction upon such issues.
- 9.2 French law shall govern the relation between the Buyer and the Seller, in accordance with these Terms and Conditions.