



Flash Memory Summit

# Markets for 3D-Xpoint

## Applications, Performance and Revenue

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# Memory Technologies Compared

	Latency	Density	Cost	HVM ready
DRAM	*****	***	***	*****
NAND	*	*****	*****	*****
MRAM	*****	*	*	***
3DXP	***	****	****	****
ReRAM	***	****	****	**
NRAM	***	**	**	*
Other	***	**	**	*

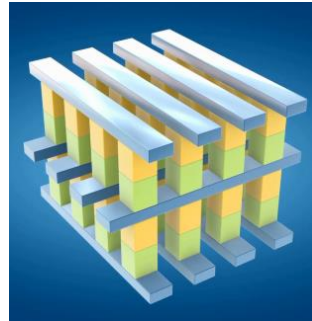
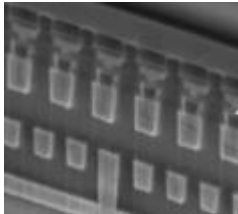
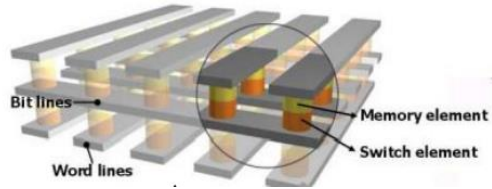


# What is 3D Xpoint

- While initial Intel and Micron were initially evasive on the technology, we now know more details
  - PCM technology, 20nm lithography
  - Cross point array, Selector in stack
  - We have cross sections and details
  - 10+ years in the making, multiple publications by Intel, Micron, Numonyx, IP providers, etc



# Simple Architecture Overview



Source: Intel

Speculated details on Technology based on:

- Memory and SSD modules sold
- EE-Times/Techinsights
- The register/Ron Neale/Chris Mellor Feb 1 2016
- ISS 2016 (Jan 12)
- Dave Eggleston FMS2015
- Plus multiple FMS presentations including this session from Techinsights

Current and Emerging Memory Technology Landscape

Atwood FMS 2011

Note: 7 Years ago.

Papers in 2001, 2005, 2009



# 3D Xpoint Hype-Reality Challenge

- Announced in July 2015 with great fanfare
  - “In manufacturing today, 1000x faster than NAND, 1000x the endurance of NAND”... will change everything ... Products in 2016”
  - We now know much of that was over-hyped and reality set in.
- Reality is different but still pretty amazing
  - 3D Xpoint will have more revenue than all the other “new NVM” combined. A lot more (details to come)
  - Fastest SSD, with best SSD endurance, selling millions of units
  - DIMMs are quite delayed but could outsell all other NVDIMMS combined in 2019



# Intel-Micron Different Perspectives

- Intel and Micron roll out of 3D Xpoint has been quite different
  - Micron low key, no products, some samples to key customers
  - Intel high visibility, multiple products, elaborate parties!
- Intel has both need and capability to lead on Xpoint
  - Intel needs to push new compute technologies and differentiation to sell more servers/systems
  - Intel can optimize processors/architecture to take advantage of memory/storage capability and limitations
- Micron has the technology but cannot influence architecture like Intel and is less inclined to shake up DRAM business/margins



# 3D Xpoint Applications

- [probably] Fastest NVMe SSDs available on benchmarks
  - Yes, they are also the most expensive and sell in relatively low volumes.
- Optane™ Memory for PCs
  - It's a cache for HDDs and speeds storage. Is it memory? 😊
  - Over a millions units sold
- Optane Persistent Memory
  - This is the REALLY big deal. Best application for Xpoint, More memory, persistent, cheaper than DRAM
- Mobile/CE/other: No announcements by Intel or Micron





# 3D Xpoint Persistent Memory Model

- A model for what 3D Xpoint chips could be....
  - 128Gbit Chip with >10% overprovisioning on the chip itself
  - Read Latency: ~125ns, Write Latency: “higher”
  - Endurance: ~200K cycles spec with management techniques
    - Note: cycling capability is at a certain fail rate which is managed by controller.
  - It is a very fast, high endurance, byte addressable, NVM replacement (at much higher cost than NAND)
    - Not DRAM replacement.



# 3D Xpoint Persistent Memory (DIMM)

- Model: Optane persistent memory won't replace DRAM, It supplements it.
- Proposed server configurations with Optane DIMMS have above average DRAM capacity installed as well
- Systems with Optane DIMMS have Xpoint:DRAM ratio of ~5:1
- Memory controller manages endurance and performance by moving data between Xpoint and DRAM.
- If >90% of reads and writes are to DRAM, occasional R/W to slower Xpoint is not impactful
- CPU/memory controller is optimized to work with this configuration
- DRAM+NVM Solution is the OPTIMAL persistent memory solution



# 3D Xpoint Competition

- Other presentations cover all NVM and detailed comparisons.
- MRAM: Great for speed but cannot compete on cost or density
- ReRAM: Crosspoint ReRAM technologies are most direct comparison to 3D Xpoint.
  - Cell Size, Cost, Speed, Cycling, applications are potentially similar
  - Scalability, manufacturing stability, required tool capital will emerge
- Competing PCM technologies: Memory companies have investigated and developed multiple PCM chips. Will they come to market?
- Fast NAND: Fast NAND+DRAM solutions from NAND/NVDIMM companies will compete in both DIMM and SSD formats.



# Cost and Price for 3D Xpoint DIMMS

- Key 3D Xpoint feature is lower cost than DRAM. This enables MORE total memory

## Estimate as to cost and price

	Cost (Aug 2018)	Cost (Aug 2019)	Price (list)
Xpoint Gen 1	0.6x DRAM Cost	0.3x DRAM (HVM)	0.5x DRAM

Gen 2 (2020) is estimated to be a 30% cost reduction over the gen 1 HVM cost



# 3d Xpoint Revenue

<b>**NEW!**</b>	<b>2018</b>	<b>2020</b>	<b>2022</b>	<b>2024</b>
3DXP (Non-DIMM)	\$650M	\$700M	\$800M	\$900M
3DXP (DIMM)	\$100M	\$800M	\$1.9B	\$2.8B
3DXP (Total)	\$750M	\$1.5B	\$2.7B	\$3.7B

Non-DIMM Data based on projections for Optane SSDs and memory sales in 2018

DIMM data based on assumptions for Cascade lake share, server DIMM attach rate, average Optane density

DRAM prices has potentially large effect on demand for Optane DIMMS



# Summary

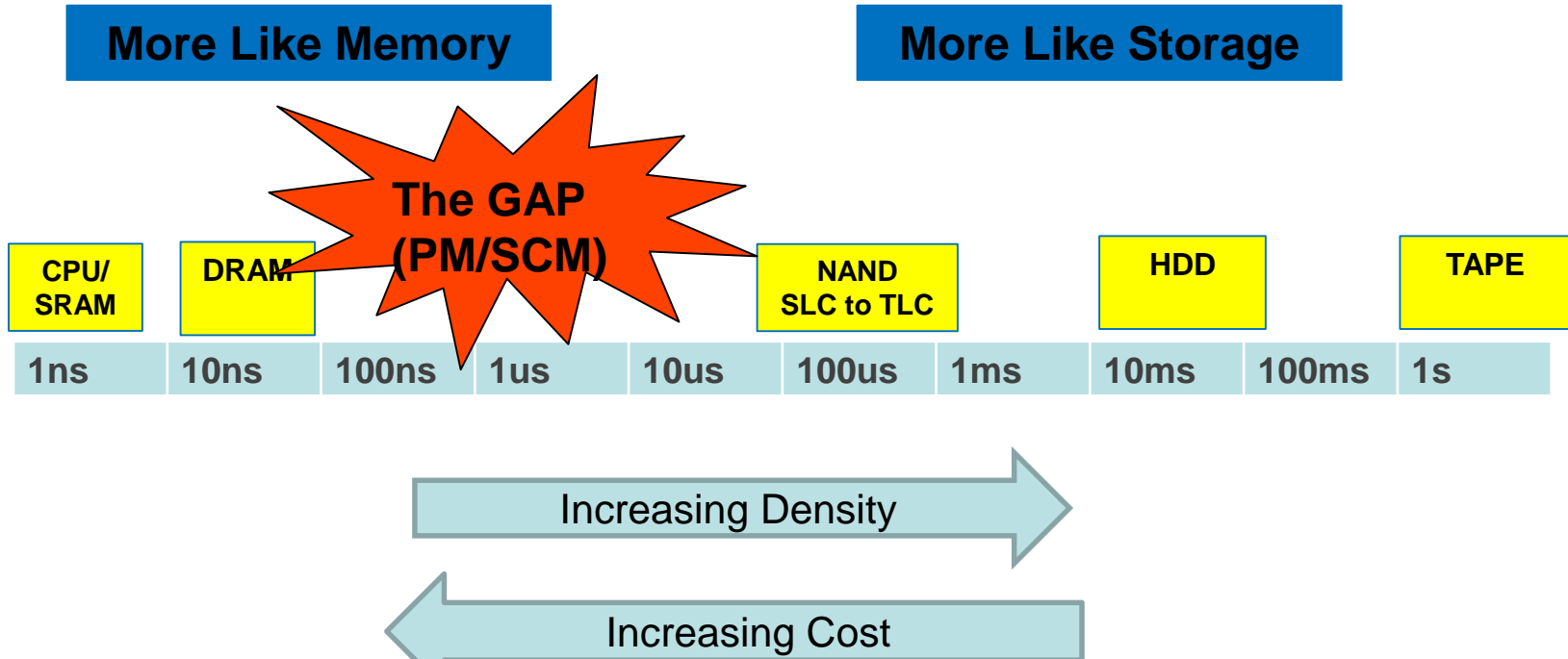
- 3D Xpoint was over-hyped and much delayed BUT it will surpass all other new memories
- Due to limitations and speed it is not replacing DRAM and due to cost it will not directly replace NAND
- Optane Persistent Memory is a CPU managed combination of DRAM DIMMs and Xpoint DIMMS
  - Addresses speed and endurance challenges of XPoint
  - Example Ratio is 5:1 Xpoint : DRAM
- Xpoint Revenue is expected to grow significantly once DIMMs are released



# Backup



# The Latency Spectrum and Gaps ~2015







# The Latency Spectrum and Gaps Future

