



01000001 01110010 01110100 01101001 01100110 01101001 01100011 01101001 01100001 01101100 00100000 01001001 01101110 01110100 01100101 01101100 01101100 01101001 01100111 01100101 01101110 01100011

01100101 00100000 01100011 01101111 01101101 01100101 01110011 00100000 01101100 01101111 00100000 01110001 01110101 01100001 01101110 01110100 01110101 01101101 00100000 01100011 01101111 01101101 01110000 01110101 01110100



3D Xpoint Optane Media Memory Markets

Bits, Revenue, Costs

Session A-3

Mark Webb

MKW Ventures Consulting LLC

www.mkwventures.com

Mark@mkwventures.com



Flash Memory Summit



Contents

- 3D Xpoint/Optane Background and History
- 3D Xpoint Products
- Models for Technology (Gen 1/Gen 2*)
- Estimated Performance Metrics 2020
- Bits, Revenue
- Costs vs Other Memory Technologies
- Summary



What is 3D Xpoint

- Micron/Intel Technology announced in July 2015
 - Disclaimer: Intel doesn't have 3D Xpoint anymore. It is “Intel®Optane™ Memory Media”
- It is a Phase Change Memory technology in a crosspoint array with $\sim 4F^2$ Cell (which is then stacked). $\sim 20\text{nm}$ Lithography
- Faster than NAND, Slower than DRAM. Cheaper than DRAM, More expensive than NAND
- 2nd Gen includes 4 Deck/layers



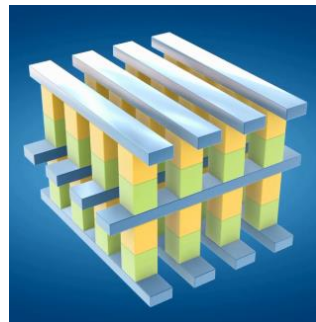
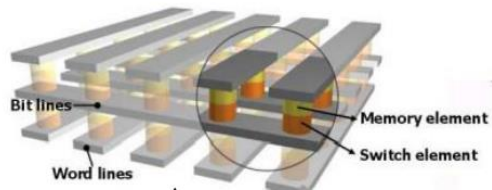
Memory Technologies Compared

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

- Separate presentation to look at status of all of these technologies
- Key Takeaway: 3DXP/Optane is a NAND-DRAM middle ground technology with demonstrated HVM Capability



Simple Architecture Overview



Source: Intel

2nd Gen
4-Deck



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 from Techinsights
- Intel Architecture Day 2020

FROM PREVIOUS FMS PRESENTATION

Current and Emerging Memory Technology Landscape
Atwood FMS 2011
Note: 9 Years ago.
Papers in 2001, 2005, 2009



Product Update 2020

- Intel Gen 1 Products
 - Fastest SSD, with best SSD endurance, selling millions of units
 - DIMMs Launched in April 2019, sales growing steadily... still in relatively low attach rate. <5% of servers sold have Optane DIMMS
 - More Optane/3D Xpoint bits sold annually than all other emerging memories **combined**.
- Intel Gen 2* Products
 - Cell/Chip Speed and endurance are not significantly changed on Gen 2 Chip
 - DIMM speed increased due to controller and bus speed
 - GEN 2 (“Barlow Pass” or “Blue”) Available with newest CPUs
 - SSD speed greatly increased due to PCIe Gen 4 and Controller
- Micron products will ramp on GEN 2 but are still in development (2022 Revenue)



Product Forecasts

- Optane (and eventually Micron) 3D Xpoint SSDs will differentiate themselves MORE from Fast NAND Products in 2021+
 - Controller improvements
 - PCIe Gen 4 allows Chip/Cell speed differentiation to shine through
- Optane DC persistent Memory will grow steadily
 - Gen 1 and Gen 2 DIMMs will continue to sell and grow steadily BUT...
 - The Future of Persistent Memory is not on the DRAM bus
 - The right answer for multiple sources, growth, and easier development is a new Bus (CXL and others). This will lead to inflection point in 2023 timeframe



Technology Update 2020

- We had Gen 1 Chips for first SSDs, DIMMS, Memory modules.
 - 128Gbit, 20nm, ~200mm², 2 layer stack. Endurance grew to 200K+
- We have Gen 2 in upcoming Intel PCIe Gen 4 SSDs in late 2020
 - Accurately Predicted to be 4-Layer 256Gb Chip. Similar Chip/cell performance
- Then Intel announced Barlow pass, PMM200 2nd gen DIMMs.
 - Shocking item was no change in DIMM density (128,256,512GB)
 - Why: Customers want lower density product (128GB)
 - One online publication stated that it is actually a Gen 1 Chip
 - We “guesstimate” something in between. “Not quite Gen 2” Chips are in some “Gen 2” DIMMS. Details coming soon



3D Xpoint Capacity/Manufacturing

- 3D Xpoint is manufactured only in IMFT facility in Lehi, Utah
- Intel/Micron have 2020 Supply agreement to supply Intel's needs for future
- Micron still is using minimal capacity and has minimal revenue other than Intel
 - X100 SSD is more of a development vehicle for future products (~2022 Micron revenue)
- Looking at some financial records and estimates of volume shipped, the Lehi Factory is not a limiter in the near future. No new capacity needed.

| | Capacity End 2020 | Capacity Q4 2021 |
|-------|--------------------------|-------------------------|
| Gen 1 | 40M GB/Month | 30M GB/Month |
| Gen 2 | 25M GB/Month | 55M GB/Month |

NOTE: Capacity is not shipments. Micron is underloading the Factory



3D Xpoint Applications

- Fastest NVMe SSDs available on benchmarks [probably]
- Optane™ Memory for PCs
 - It's a cache for HDDs and speeds storage. Millions units sold
 - Intel announced QLC NAND/Optane combination in one M.2
 - Cost effective performance vs TLC SSDs
- Intel Optane DC Persistent Memory (DIMMS)
 - Memory Mode: Large main memory, cached in DRAM, not persistent
 - App direct mode: True Persistent Memory!! This is main Focus
 - Also can act like SSD on DRAM bus ... block modes, file modes, etc
- Coming Soon: Optane Persistent Memory on New Bus (CXL)



Is 3D Xpoint Now Making Money?



- Short answer: No. Operating margins are very negative
 - SSDs were first product and the sales were in Intel NSG group. Reasonable math showed losses on Xpoint of >\$300M per quarter
 - Low volume, expensive development, difficult product. Not good
 - NSG losses dropped... but some of this is due to moving focus, expenses and bits to DCG and much better NAND prices on enterprise SSDs.
 - Our model shows a large negative margin impact to DCG as Persistent memory sales increase.
- AND ... It doesn't Matter. Persistent Memory is great for Datacenter and Intel Architecture and differentiation from **AMD Competition**. Margin on Storage/memory is not the goal for Intel



3D Xpoint Competition

- Competing PCM technologies: All companies have worked on PCM, Many showed information at recent conferences.
 - We STILL expect Crosspoint PCM announcements from multiple companies (Hyinix, Samsung, etc)
- MRAM: Great for speed, embedding, but cannot ever compete on cost or density. Its competition is SRAM, not DRAM/NAND
- ReRAM: Crosspoint ReRAM technologies are most direct comparison to 3D Xpoint.
 - Cell Size, Cost, Speed, Cycling, applications are potentially similar
 - 2019 IEDM presentations and lack of new products seem to indicate we are finding issues at same speed we are fixing them. We are not closer to production than we were at FMS 2019
- Fast NAND: Fast NAND+DRAM solutions from NAND/NVDIMM companies will compete in both DIMM and SSD formats and on new memory bus.



Cost and Price for 3D Xpoint DIMMS



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

Estimate as to DIMM cost and price

| | Cost 2020 | Cost 2022 | Price |
|--------------|-----------|-----------|---------------------|
| Xpoint Gen 1 | 0.6x DRAM | 0.5x DRAM | List=DRAM, ASP less |
| Xpoint Gen 2 | NA | 0.4x DRAM | List=DRAM, ASP less |

ASP projection is very difficult. Intel is looking to drive growth at the expense of margins. It is expected that Intel is providing strong incentives for large customers to implement. This also impacts revenue projections

NOTE: Cost is with Factory running at forecast utilization numbers Margins mentioned previously are OM



3D Xpoint Revenue



| Aug 2019 | 2020 | 2022 | 2024 |
|---------------------|---------|---------|--------|
| 3DXP (Non-DIMM) | \$650M | \$750M | \$800M |
| 3DXP (DIMM) | \$700M | \$1.9B | \$2.8B |
| 3DXP (Total) | \$1.35B | \$2.65B | \$3.6B |
| **NOV 2020 NEW!* | 2020 | 2022 | 2024 |
| 3DXP (Non-DIMM) | \$500M | \$750M | \$800M |
| 3DXP (DIMM/NEW BUS) | \$600M | \$1.0B | \$2.8B |
| 3DXP (Total) | \$1.10B | \$1.75B | \$3.6B |

This is for Micron and Intel. Micron is minimal impact until 2022+. Significant Micron ramp would be upside
Non-DIMM Data based on projections for Optane SSDs and memory sales
DIMM data based on assumptions for Cascade/Cooper lake share, server DIMM attach rate, average Optane density
Intel may report out Revenue numbers in preparation for Hynix Sales of NAND unit.



Summary

- 3D Xpoint ramp has been slower than we projected ramp BUT it has surpassed all other new memories in shipments
- Rev 2 3D Xpoint is shipping today. Teardowns coming soon!
- Focus is on 3D Xpoint DIMMS for persistent memory
 - DIMMS are shipping today, bits are growing steadily since mid 2019
- 3D Xpoint SSD revenue is expected to grow in future based on Intel and Micron shipments and new PCIe4 products
- DIMM Revenue is growing steadily today and persistent memory revenue will take off at faster rate with launch on new bus architecture in late 2022.
- Total revenue is just over \$1B in 2020 growing to \$3.6B in 2024



01000001 01110010 01110100 01101001 01100110 01101001 01100011 01101001 01100001 01101100 00100000 01001001 01101110 01110100 01100101 01101100 01101100 01101001 01100111 01100101 01101110 01100011

01100101 00100000 01100011 01101111 01101101 01100101 01110011 00100000 01101000 01101111 00100000 01110001 01110101 01100001 01101110 01110100 01110101 01101101 00100000 01100011 01101111 01101101 01110000 01110101 01110100



Mark Webb
MKW Ventures Consulting LLC
www.mkwventures.com

Mark@mkwventures.com