XPoint Memory Comparison

Process & Architecture

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- XPoint Memory Overview
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  - Process Integration & Materials
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- Leading, Competing or Chasing?
  - Comparison with DRAM & 3D NAND
Memory Device Roadmap

Flash Memory Summit 2017
Santa Clara, CA

NAND

Emerging Memory

DRAM
Questions About XPoint

*PCM? Materials?
*Selector? Ternary/Quaternary Phase? As doped?
*Multi-Stacked?
*Layouts? PCM patterning? Double patterning used?
*Memory density? Memory array efficiency?
*Overall memory cell design & architecture?
*Technology Node?
*Die floor plan?
*CMOS under Memory Array?
*Functional blocks? Circuits?
*Top/Middle/Bottom electrodes connection?
*Performance? Transistor parameters? Cell set/reset Current?
*Replace NAND? Replace DRAM?
*# Masks? # Process steps? Process sequence?
*Cost? Cost effective product?
*N+1?, N+2?
*Differences from Micron QuantX?
*Throughput? Yield?
* etc.
XPoint Memory Overview

- 16GB single die in a PKG
- Memory efficiency: 91.4%
- Memory density (/Die): 0.62 Gb/mm²
- Memory density (/Array): 0.69 Gb/mm²

<table>
<thead>
<tr>
<th>Package dimensions</th>
<th>18.0 mm x 14.0 mm x 1.10 mm thick</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer, part number, downstream</td>
<td>Intel, MEMPEK1W016GAXT, Optane™ 16GB memory module</td>
</tr>
<tr>
<td>Wafer size, foundry, process type</td>
<td>300 mm, Intel, 3D XPoint memory cell over CMOS</td>
</tr>
<tr>
<td>Die markings</td>
<td>&lt;Intel logo&gt; $15C (M) © 2014</td>
</tr>
<tr>
<td>Die size (from die seal)</td>
<td>16.16 mm x 12.78 mm (206.5 mm²)</td>
</tr>
<tr>
<td>Die thickness</td>
<td>220 μm</td>
</tr>
<tr>
<td>Number, type of metals</td>
<td>5, 4 Cu and 1 Al and W used as word and bit lines</td>
</tr>
<tr>
<td>Minimum observed contacted logic gate pitch</td>
<td>0.38 μm</td>
</tr>
<tr>
<td>Minimum observed logic transistor gate length</td>
<td>0.086 μm</td>
</tr>
<tr>
<td>Minimum metal pitch</td>
<td>84 nm</td>
</tr>
<tr>
<td>3D XPoint memory bit line (word line) pitch</td>
<td>38.5 nm</td>
</tr>
<tr>
<td>3D XPoint memory word line (bit line) pitch</td>
<td>40 nm</td>
</tr>
<tr>
<td>Memory cell area</td>
<td>0.0015 μm²</td>
</tr>
<tr>
<td>Technology generation</td>
<td>20 nm</td>
</tr>
<tr>
<td>Feature measured to determine process generation</td>
<td>Half bit line (word line) pitch</td>
</tr>
</tbody>
</table>
XPoint: Process Integration

- GST-based PCM (Phase Change Memory) between M4 and M5
- Storage layer vertically stacked on Selector
- Se-Ge-Si ternary phased OTS Selector with As doped
- Double memory cell stacked
- 1 Poly Si (Co-silicide), 5 Metals (excluding memory/WL/BL layers)
XPoint: Memory/OTS Elements

- Top & bottom cell stacked
- TWL/TE/PCM/ME/OTS/BE/BL2/BL1/TE/PCM/ME/OTS/BE/BWL
- PCM: $\text{Ge}_{0.12}\text{Sb}_{0.29}\text{Te}_{0.54}(\text{Si}_{0.05})$, OTS: $\text{Se}_{0.44}\text{As}_{0.29}\text{Ge}_{0.1}\text{Si}_{0.17}$.
XPoint, could be ……

✓ 1,000 times faster than NAND Flash
✓ 10 times denser than DRAM
✓ 1,000 times better endurance than NAND

Really? vs. 3D NAND?
XPoint vs. DRAM: Memory Density

- Memory Density: x3.2 (vs. SS 18nm DRAM), x6.6 (vs. M 20nm DRAM)
XPoint vs. DRAM: Cell Size

- Memory Cell Size: 58% (vs. SS 18nm DRAM), 36% (vs. M 20nm DRAM)

![Bar Chart](chart.png)

DRAM Cell Size for Samsung, SK Hynix, Micron vs. Intel XPoint

(x10^-4 µm^2)
XPoint vs. 3D NAND: Memory Density

- Memory Density: 24% (vs. SS 48L V-NAND TLC), 18% (vs. Toshiba/SanDisk 64L)
XPoint vs. 3D NAND: Array Efficiency

- Memory Array Efficiency … may not represent Effective Memory Cell Area Efficiency
XPoint vs. 3D NAND: Array Efficiency

- Comparison of Effective Memory Cell Area Efficiency: Higher the better

![Memory Cell Area Efficiency Chart]

- Toshiba/SanDisk 15nm 2D NAND
- SK-hynix 3D NAND 36L MLC
- Micron 3D NAND 32L TLC (CuA)
- Toshiba/WD 3D NAND 48L TLC
- Samsung V-NAND 48L TLC
- Toshiba/WD 3D NAND 64L TLC
- XPoint
- Intel Optane 128Gb Xpoint

Effective Memory Cell Area Efficiency: 43.9% for 2D NAND, 53.2% for 3D NAND 64L, and 53.2% for XPoint.
XPoint vs. 3D NAND: Unit Cell Area

- Comparison of Effective Unit Cell Area: Lower the better
XPoint is …

vs. DRAM

6 times denser than Micron 20 nm DRAM
3 times denser than Samsung 1x DRAM

vs. NAND

18% memory density of Toshiba/SanDisk 64L NAND
Higher memory cell area efficiency than 2D NAND
Relatively lower cell area efficiency than 3D NAND