NAND Flash Memory Roadmap
June 2016
# Expected 2D & 3D NAND Releases

<table>
<thead>
<tr>
<th>Manufacturers</th>
<th>2012</th>
<th>2013</th>
<th>1H14</th>
<th>2H14</th>
<th>1H15</th>
<th>2H15</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Samsung</strong></td>
<td>21 nm</td>
<td>19 nm</td>
<td>16 nm</td>
<td>(14 nm)</td>
<td>12 nm</td>
<td>24 L</td>
<td>MLC</td>
<td>TLC</td>
<td>SSD</td>
</tr>
<tr>
<td><strong>Toshiba</strong></td>
<td>24 nm</td>
<td>19 nm</td>
<td>A-19 nm</td>
<td>15 nm</td>
<td>12 nm</td>
<td>48 L</td>
<td>MLC</td>
<td>TLC</td>
<td>SSD</td>
</tr>
<tr>
<td><strong>SanDisk</strong></td>
<td>20 nm</td>
<td>16 nm</td>
<td>TLC</td>
<td>SSD</td>
<td>X-Point</td>
<td>32 L(FG)</td>
<td>MLC</td>
<td>TLC</td>
<td></td>
</tr>
<tr>
<td><strong>Micron</strong></td>
<td>25 nm</td>
<td>20 nm</td>
<td>16 nm</td>
<td>(14 nm)</td>
<td>12 nm</td>
<td>32(36) L</td>
<td>MLC</td>
<td>48 L</td>
<td>64 L</td>
</tr>
<tr>
<td><strong>SK Hynix</strong></td>
<td>20 nm</td>
<td>16 nm</td>
<td>TLC</td>
<td>SSD</td>
<td>32 L(FG)</td>
<td>48 L</td>
<td>MLC</td>
<td>64 L</td>
<td>64 L</td>
</tr>
</tbody>
</table>
Samsung 3D V-NAND

- 1st Generation (V1, 2012 ~ 2013): 24 Layers/128Gb
Samsung 3D V3-NAND

- 3rd Generation (V3 V-NAND): 48 Layers/256Gb, TLC

Announced at FMS2015
Samsung 3D V3-NAND

- 3rd Generation (V3 V-NAND): 256Gb V3 SSDs in Production
- For 850 EVO (2015 3Q ~)

Announced at FMS2015
Samsung 3D V2-NAND with 32 Layers

Cross-section
Samsung PM1633a (3D V3-NAND)

PM1633a (15.36 TB) to ship early 2016

PM1725, a one million IOPS 6.4TB NVMe PCIe SSD
Samsung SAS & NVMe

**NVMe**

**SAS**

By Samsung at FMS2015
SK-Hynix 3D NAND

- 1st Generation (V1, 2014 4Q): Prototype (24L, 32L)
- 2nd Generation (V2, 2015 3Q CS): 32 Layers, 3D SSD
- 3rd Generation (V3, 2015 4Q ES): 48 Layers, 3D SSD

By SK-Hynix at FMS2015
SK-Hynix 3D NAND Portfolio (Technology & Solution)

By SK-Hynix at FMS2015
Toshiba/SanDisk 3D-NAND (BiCS)

- Toshiba/SanDisk 3D NAND structure is ‘BiCS’ instead of ‘P-BiCS’
- 128Gb 3D 48L BiCS MLC: CS (since March 26, 2015), but not in production yet. Currently sampling as of Aug. 2015
- 256Gb 3D 48L BiCS TLC: CS (since Aug. 4, 2015) and will be revealed on the market 4Q 2015
Toshiba/SanDisk 3D-NAND (BiCS)

SanDisk Technology Roadmap

2013 | 2014 | 2015 | 2016 | 2017
--- | --- | --- | --- | ---
2D NAND

BiCS

Bit Cost Scalable 3D NAND

3D ReRAM

3D Resistive RAM

Source: http://thememoryguy.com/category/nand-flash/
Intel-Micron did disclose that their design utilizes a traditional floating gate, whereas the other 3D NAND designs use a charge trap technology.

- Intel-Micron’s 3D NAND details still being unveiled
- 256Gbit MLC samples are now shipping to select customers and mass production will likely begin in the second half of this year or in the first half of 2016.
Micron 3D-NAND

- >20% cost benefit of logic under array
- Continued 3D NAND performance gains through process improvements

Source: Feb. 12, 2016 Micron
Latest NAND Flash report listings:

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<thead>
<tr>
<th>NAND Flash</th>
<th>Analysis</th>
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<tr>
<td>Micron 32L 3D V-NAND</td>
<td>Structural</td>
</tr>
<tr>
<td>Toshiba/SanDisk, Micron/Intel, SK Hynix and Samsung 1x and 1y nm NAND</td>
<td>Process Comparison</td>
</tr>
<tr>
<td>SanDisk-Toshiba 15 nm</td>
<td>Structural Waveform</td>
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<td>CircuitVision</td>
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<tr>
<td>Samsung 3D V-NAND</td>
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<td></td>
<td>Transistor Characterization</td>
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<td>Samsung 16 nm</td>
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