TOSHIBA Memory Solutions

Memory Division
Semiconductor & Storage Products Company
Toshiba Corp.

Sept/2015
Toshiba & Semiconductor market Introduction
Worldwide Semiconductor Devices Market Trend

Semiconductor Market grows continuously.

W/W market size (B$)

Source: result = WSTS. Estimation = TOSHIBA
Growth of the storage market with the rapid expansion of available information. Continuous high bit growth for NAND Flash due to replacement of HDD/ODD.

Overall Information

CAGR 62%

Storage Market

HDD

Optical

Flash

Exa bytes [1e18 bytes]


1800EB

161EB

5.4EB

Source: by TOSHIBA based on TSR(HDD), JRIA(CD/DVD/BD) & IDC White Paper (formation and available storage)
SSDs are biggest driver for Si GB expansion, TOSHIBA SSD supports it!

Mobile is still big GB eater, TOSHIBA e-MMC and UFS support it!

* Different grades of NAND for Enterprise, SSD, OEM and Retail

Source: TOSHIBA
Toshiba NAND Flash Memory Products lineup

Toshiba NAND Flash Die and Controller Technology:
- create a wide variety of products
- support market requirements

NAND Flash Memory / BiCS FLASH™

microSD / SD card / CF card / FlashAir™ / SeeQVault™ / USB

BENAND™, e·MMC™, UFS

Client SSD
Enterprise SSD

MCP / eMCP

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SeeQVault is a trademark of NSM Initiatives LLC.
e·MMC is a trademark of JEDEC/MMCA.
# Toshiba’s commitment to NAND Flash market

| **NAND Flash die** | • The finest process migration with reliable quality and the advance circuit design *(Cost & Quality)*  
|                    | • Adopting **high performance** architecture, next gen. of Toggle DDR  
|                    | • Original design circuit technology achieve **Low power** consumption to overcome heat issue |
| **NAND Flash controller** | • Development of the best solution by memory div.  
|                    | ~ TOSHIBA knows TOSHIBA NAND Flash ~ |
| **Packaging** | • Advances packaging technology to enable the **largest density** product in the industry with the thinnest/smallest size |
| **Research & Development** | • Large investment to new memory technologies as 3D Flash Memory and STT-MRAM |
| **Flexible product output** | • Capital Investment of Yokkaichi Operations |
| **Focus in Customer Satisfaction** | • Local Technical Support for World Wide Customers |

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Wireless and Storage Trend
Info.-Plosion (Higher Resolution Screen/Camera/Various Sensors) will be required. Thus, demand for Higher Performance and Higher Density on Storage Memories will be maintained from long term market perception.
**UFS v.s. e-MMC Overview**

e-MMC features **Parallel I/F** which has a restriction for further performance improvement beyond HS400 (400Mbps). Meanwhile, UFS features high-speed **Serial I/F** which maintains a performance scalability to extend in the future.

<table>
<thead>
<tr>
<th></th>
<th>e-MMC</th>
<th>UFS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year</strong></td>
<td>Since 2007</td>
<td>Introduced in 2014</td>
</tr>
<tr>
<td><strong>Architecture</strong></td>
<td>MMC I/F (Bus, Parallel I/F)</td>
<td>UFS I/F (Serial I/F)</td>
</tr>
<tr>
<td><strong>I/F</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Speed</strong></td>
<td>400Mbps (=400MB/s, Ver.5.0 or higher) *Restricted for further improvement</td>
<td>5.8Gbps x 2 Lanes (=1160MB/s, Ver.2.0)</td>
</tr>
<tr>
<td><strong>Pin count</strong></td>
<td>11 (8 I/O and 3 control)</td>
<td>6 (4 I/O and 2 control) or 10 (in case of 2 lanes)</td>
</tr>
<tr>
<td><strong>Signal amp.</strong></td>
<td>1.8V or 1.2V</td>
<td>200mVp-p</td>
</tr>
<tr>
<td><strong>Duplex</strong></td>
<td>Half (In serial to send and/or receive the data)</td>
<td>Full (Simultaneously to send and receive the data)</td>
</tr>
<tr>
<td><strong>Command Queue</strong></td>
<td>Supported in Ver.5.1</td>
<td>Support (to improve Random performance)</td>
</tr>
<tr>
<td><strong>Command Set</strong></td>
<td>MMC</td>
<td>SCSI</td>
</tr>
</tbody>
</table>

**e-MMC features Parallel I/F which has a restriction for further performance improvement beyond HS400 (400Mbps). Meanwhile, UFS features high-speed Serial I/F which maintains a performance scalability to extend in the future.**
UFS in Application Area

UFS
Can resolve performance limitation with Hi-Speed Serial I/F and new features. World’s first smartphone adopted UFS as its memory storage was released in the market in 2015. UFS will take over e-MMC’s position eventually.

e-MMC
Current De fact standard solutions for Smart Phone, Tablet and other mobile applications.

Use Case of UFS and e-MMC
- Car Navigation
- Mobile PC
- Tablet PC
- Music Player
- DVC
- Smartphone

e-MMC and UFS can be found in everywhere!
# Toshiba Memory on Qualcomm Platforms

<table>
<thead>
<tr>
<th>Qualcomm Platform</th>
<th>eMCP</th>
<th>e-MMC</th>
<th>UFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSM 8996</td>
<td></td>
<td>32GB</td>
<td>32GB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>64GB</td>
<td>64GB</td>
</tr>
<tr>
<td>MSM 8994</td>
<td></td>
<td>16GB</td>
<td>32GB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32GB</td>
<td>64GB</td>
</tr>
<tr>
<td>MSM 8992</td>
<td></td>
<td>16GB</td>
<td>64GB</td>
</tr>
<tr>
<td>MSM 8976/56</td>
<td></td>
<td>16GB</td>
<td></td>
</tr>
<tr>
<td>MSM 8952</td>
<td>16GB</td>
<td>16GB + 16Gb LP3</td>
<td></td>
</tr>
<tr>
<td>MSM 8929</td>
<td>8GB</td>
<td>8Gb + 8Gb LP3</td>
<td></td>
</tr>
<tr>
<td>MSM 8916 MSM 8909</td>
<td>8GB</td>
<td>8Gb + 8Gb LP2/LP3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16GB</td>
<td>16Gb + 8Gb LP3</td>
<td></td>
</tr>
</tbody>
</table>
Toshiba NAND Flash Memory Strategy

~ from 2D to 3D and Low Power for denser storage solutions ~
Design Rule Evolution

~ 15nm : world finest geometry for NAND Flash ~

Wafer

Water flea ~2mm
Honeybee ~15mm

Cedar pollen ~30μm
Hair ~60μm

Influenza virus ~100nm
Lactic acid bacterium ~1.2μm

DNA width ~2nm

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Process Shrink trend and TOSHIBA strategy

**To Date**
Process Shrink → Cost Down → Market expansion

**From now on**
Shrink Speed getting slower → Less cost effectiveness

How to get denser storage at similar area size??

3D Technology!!

* Average of Memory/Logic

Source: TOSHIBA based on ITRS
Memory Cell Comparison

NAND Flash Memory Cell

- Metal Gate
- Block Layer
- Floating Gate
- Tunnel Layer
- Silicon

2D

BiCS FLASH Memory Cell

- Metal Gate
- Block Layer
- Charge Trap
- Tunnel Layer
- Silicon

3D

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Toshiba Developed World's First 48-layer 3D Flash memory

**MLC 128Gb Press Release on March 26, 2015**

Since making the world’s first announcement of technology for 3D Flash memory, Toshiba has continued development towards optimizing mass production. Toshiba today announced development of the world’s first 48-layer 3D Flash memory called BiCS FLASH, a MLC 128Gb device. Sample shipments of products using the new process technology start today.

**TLC 256Gb Press Release on August 4, 2015**

Toshiba today unveiled the new generation of BiCS FLASH, a 3D Flash memory. The new device is the world’s first 256Gb (32GB) 48-layer device and also deploys industry-leading TLC technology. Sample shipments will start in September.

Achievement of memory performance improvements with 3D Flash memory

Toshiba is also readying for mass production in the new Fab2 at Yokkaichi Operations, that’s now under construction and will be completed in the first half of 2016.
Developed World’s First 16st NAND Flash Memory with TSV Technology

This new NAND flash memory provides the ideal solution for low latency, high bandwidth and high IOPS/Watt in flash storage applications, including high-end enterprise SSD.

Press Release on August 6, 2015

Toshiba announced the development of the world’s first 16-die (max.) stacked NAND flash memory utilizing TSV* technology.

*Through Silicon Via: TSV technology utilizes the vertical electrodes and vias to pass through the silicon dies for the connection

Prototype verification

- Enables high speed data input
  TSV technology achieves an I/O data rate of over 1Gbps which is higher than any other NAND flash memories.

- Reduces power consumption
  TSV technology reducing power consumption by approximately 50% with a low voltage supply: 1.8V to the core circuits and 1.2V to the I/O circuits and approximately 50% power reduction of write operations, read operations, and I/O data transfers.

<table>
<thead>
<tr>
<th>The General Specification of Prototype</th>
</tr>
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<tbody>
<tr>
<td><strong>Package Type</strong></td>
</tr>
<tr>
<td><strong>Storage Capacity (GB)</strong></td>
</tr>
<tr>
<td><strong>Number of Stacks</strong></td>
</tr>
<tr>
<td><strong>External Dimension (mm)</strong></td>
</tr>
<tr>
<td>W</td>
</tr>
<tr>
<td>D</td>
</tr>
<tr>
<td>H</td>
</tr>
<tr>
<td><strong>Interface</strong></td>
</tr>
</tbody>
</table>
Toshiba next generation memory  STT-MRAM

~ Volatile to Non-Volatile ~
Future computing Architecture with STT-MRAM

STT-MRAM (Non Volatile Memory) can bring.....

Less Data Moving / Less volatility management

✓ No or Less backup (refresh) required
✓ No huge battery backup required
✓ Less leakage current
✓ Get smaller die size or larger cache size (cache use case)
✓ Better radiation resistant
✓ ....etc....

Better system performance and TCO (Total Cost of Ownership)
Future computing Architecture with MRAM

**Now**

- Host
- CPU Core
- L1 Cache
- L2 Cache
- L3 Cache
- DRAM (e.g. 16GB/DIMM)
- RAID Card
- HDD / SSD
- BIOS/Cache
- eDRAM (Intel/IBM)
- SoC(ASIC)/FPGA
- SRAM Cache
- DRAM Cache
- BIOS Flash
- For Controller SoC

**Possible future**

- Host
- CPU Core
- L1 Cache
- L2 Cache
- L3 Cache
- eMRAM for Cache/FlipFlop
- Virtual Memory/Storage
- S/W Architecture
- MRAM for Cache/Buffer/ In-Memory w/ or w/o DRAM
- RAID Card
- HDD / SSD
- eMRAM Cache for SoC
- DRAM Cache
- SoC(ASIC)/FPGA
- eMRAM Cache/Buffer

**Volatile**

- Non-Volatile

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