Is 3D NAND the Right Technology for Removable Devices?

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Agenda

- Global NAND memory demands by products
- Removable V.S Other devices
- Consumer V.S Industrial products
- Challenges of adopting 3-D NAND in Removable devices
  - Endurance and ECC requirements
- Technology Migration and Consistency in Reliability
- Operation mode & Corresponding Test
- WHEN? 3-D NAND Adoption
- Take away
Global NAND Memory Demands by Products

USB Drive
Memory card
Smartphone with Card Slot %

Memory card: removable & extended memory: Android Marshmallow (or higher) allows Saving and running apps on a card

Source: TrendForce, April 2017
# Removable V.S. Other Devices

<table>
<thead>
<tr>
<th></th>
<th>Removable Devices</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions</td>
<td>Smaller</td>
<td>Larger</td>
</tr>
<tr>
<td>External DRAM</td>
<td>No</td>
<td>Yes (Optional)</td>
</tr>
<tr>
<td>Capacitors</td>
<td>Limited Space</td>
<td>More space</td>
</tr>
<tr>
<td>Required capacity</td>
<td>Smaller</td>
<td>Larger</td>
</tr>
<tr>
<td>Performance</td>
<td>Slower</td>
<td>Faster</td>
</tr>
<tr>
<td>Power consumption</td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td>Cost (price)</td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td>Controller FW Algorithm</td>
<td>BCH ECC</td>
<td>LDPC (new)</td>
</tr>
<tr>
<td>Replacement/Rework cost</td>
<td>Lower</td>
<td>Higher</td>
</tr>
</tbody>
</table>
Consumer V.S Industrial Applications

3-D Yes

Consumer Electronics

2-D Yes

Networking/ Telecom

Avionics

Digital Signage

3-D ?

Automotive

Healthcare

Barcode Scanning & Data Collection

Ticketing System

Enterprise Mobility

Industrial PC/ Embedded Automation

Industrial Control System
## Consumer V.S. Industrial applications

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Industrial Application</th>
<th>Consumer Electronics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>Smaller (&lt;32GB)</td>
<td>Larger</td>
</tr>
<tr>
<td>Project longevity</td>
<td>Long (3~5 years)</td>
<td>Short (1~2 years)</td>
</tr>
<tr>
<td>Validation period</td>
<td>Longer</td>
<td>shorter</td>
</tr>
<tr>
<td>Data Integrity (Data retention / read disturb...)</td>
<td>Important</td>
<td>Less concerned</td>
</tr>
<tr>
<td>Power failure protection</td>
<td>Important</td>
<td>Less concerned</td>
</tr>
<tr>
<td>Performance</td>
<td>Consistence</td>
<td>Faster</td>
</tr>
<tr>
<td>Price</td>
<td>Total cost of ownership</td>
<td>Unit price is the key</td>
</tr>
<tr>
<td>Endurance TBW</td>
<td>Normal</td>
<td>Depends...</td>
</tr>
</tbody>
</table>
Challenges of adopting 3-D NAND in Removable devices

- **Cost**
  - Smaller density product with lower unit price don’t need LDPC controller which accounts higher % of BOM cost.
  - 3-D NAND 128Gbit and below don’t have cost advantages

- **Technology**
  - *Based on BCH ECC, 3-D TLC 10% of 2-D MLC Endurance*
  - *Read disturb: 3-D TLC 15% of 2-D MLC read cycles*
  - *Data retention: 100% P/E cycles 1 year @ low temp.*
  - SPOR is at higher risk when programming larger data size and there is limited space to add external DRAM or capacitors in removable devices

NOTE: Figures are subject to change by NAND suppliers, NAND grade and the maturity of new process.
Endurance and ECC requirement

NOTE: Compiled data for reference, figures are subject to change by NAND suppliers, NAND grade and the maturity of new process.
Technology Migration and Consistency in Reliability

- **Product Spec is not compromised?**
  - Identical Test Condition

- **Mission Profile**
  - Simulate user environment & application
    - e.g. Temperature profile, performance, product longevity, data retention, sudden power-off cycles...

- **Joint validation**
  - Test removable devices with host device

- **3-D pseudo MLC or pseudo SLC**
  - Considering supply (mainstream), reliability, performance, endurance...
  - This could be the option if there is cost advantage compared to 2-D NAND
Advanced Wear-leveling
- Block/Page management
- File Size Optimization

Sudden Power Off Recovery FW
- Multiple ISP and Link table back-up
- To close word line by padding scrambled data

Power Failure Protection

Endurance Protector

Retention Protector

Read Protector

High Reliability

Write Operation Mode

Read Operation Mode

AutoRefresh
- Monitor ECC
- Auto refresh in read operations

Dynamic Data Refresh
- Background refresh of non-accessed area

Operations? Read or Write Centric
Sudden Power-Off Test
• Power cycling test

Read Disturb Test
• Read assigned LBA
  Compared the whole content

Read Protector

Write Operation Mode

Power Failure Protection

Endurance Protector

WAI workload
Life monitoring tool

High Reliability

Retention Protector

Read Operation Mode

Data Retention
• Static-Baking device
• Dynamic-Baking device
  Read assigned LBA, compare non-accessed area for data retention

 Corresponding Test
Endurance: IC Level Test Example

2-D 1xnm MLC
Approx. 20,000 P/E cycles (BCH ECC 60 bits/1KB)

3-D first generation MLC
Approx. 21,000 P/E cycles (BCH ECC 72 bits/1KB)

Both Meet 3K P/E Cycles
Device Level NAND Screening Test

- To screen out weak NAND by checking error bits
- Still applicable for BCH ECC FW NAND devices (no matter 2-D or 3-D NAND)
- More restrict than traditional burn-in test, no need long term test period
WHEN? 3-D NAND Adoption

Consumer Electronics

Customer Need
- Capacity
- Price

Technology Migration
- Matured Process
- Reliability / Endurance
- Supply

WHEN?

Industrial Applications

- Edge Computing
- Advanced Driver Assistance Systems (ADAS)
- 3-D Image Content
2D and 3D NAND Bit Crossover
64-layer 3D NAND

**Price:**
Crossing the Threshold

**Supply:**
Mainstream vs Legacy

- Cost per bit: 30%

Micron 3D NAND Update
Take Away

• 2-D and 3-D NAND will coexist for a long period of time with lower densities continuing on in 2-D, higher densities migrating to 3-D.

• Industrial customers take longer time to embrace new technology, but it will be driven by customer needs (capacity, price) and technology migration (reliability, supply) eventually. The supply gap is increasing from 2017, 2019 will be a critical year.

• Current controller for removable NAND devices are still based on BCH ECC instead of LDPC.

• Future options under consideration include 3D TLC in SLC mode or MLC mode configure. Suitability for the running mode depends on the application requirements for endurance, retention, and other aspects of reliability.
Thank you!

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