Enabling MLC Flash SSD In Enterprise Storage

Gary Tressler
IBM Corporation
gtressle@us.ibm.com

August 17, 2010
Agenda

- Enterprise MLC SSD Enablement: Current Trend
- MLC NAND Scaling Trend & Outlook
- Enterprise Support Challenges: MLC SSD Controllers
- Enterprise Support Challenges: MLC Flash Media
- Dwell Time: Key Lever for SSD Reliability Improvement
- SSD Small Factor Innovation Required for Enterprise
- Summary
MLC SSD Enablement: Current Trend

- MLC Flash component endurance support has been extended to between consumer MLC and SLC for a given technology
  - Achieved via early signal processing implementation or program time degradation
- Power off data retention now optimized for Enterprise SSD
  - Duration requirement reduced from traditional 1-year to 3-months
    - Aligned with Enterprise field maintenance strategies
    - Further optimization may be required as technology advances
  - Temperature support reduced from 55°C to 40°C
    - Consistent with most data center environments
- ECC support per sector enhanced by industry SSD controllers
  - Required to satisfy 3x/2xnm MLC targets
  - Continuing improvements required in architecture / support level
- NET: MLC Flash provides leadership Enterprise SSD performance and lifespan today based on existing storage infrastructure
  - Higher capacity and lower cost structure enabled
### MLC NAND Scaling Trend & Outlook

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology (nm)</strong></td>
<td>3x</td>
<td>2x</td>
<td>2y</td>
<td>2y/1x</td>
<td>1x</td>
<td>1x</td>
<td>1y</td>
</tr>
<tr>
<td><strong>Cell Architecture</strong></td>
<td>Floating Gate</td>
<td>Floating Gate</td>
<td>Floating Gate</td>
<td>Floating Gate</td>
<td>Floating Gate</td>
<td>Charge Trap Device / 3D</td>
<td>Charge Trap Device / 3D</td>
</tr>
<tr>
<td><strong>Bit Line Architecture</strong></td>
<td>Shared Bit Line / All Bit Line</td>
<td>Shared Bit Line / All Bit Line</td>
<td>All Bit Line</td>
<td>All Bit Line</td>
<td>All Bit Line</td>
<td>&lt;New Sensing Scheme&gt;</td>
<td>&lt;New Sensing Scheme&gt;</td>
</tr>
<tr>
<td><strong>MLC Density (Gb)</strong></td>
<td>32</td>
<td>64</td>
<td>64</td>
<td>128</td>
<td>128</td>
<td>256</td>
<td>256</td>
</tr>
</tbody>
</table>

- Floating gate NAND cell scaling likely to continue to 1xn technology node range in ~ 2013, based on conventional immersion lithography.

- NAND scaling expected to continue beyond 2013 @ lower 1x nm NAND nodes, based on charge trap device and 3-D NAND cell & process architecture, reaching MLC NAND densities of 256Gb & higher.

- NAND scaling rate and pace is based on consumer and not enterprise reliability requirements.

- Ongoing enhancements (e.g., signal processing) required to achieve Enterprise-level MLC reliability requirements vs. time.

**NET:** NAND scaling expected to continue via floating gate extension & charge trap / 3D cell architectures to 1xn technology node range and 256Gb MLC density.

- Ongoing reliability enhancements required to satisfy Enterprise-level MLC requirements vs. time.
# Enabling MLC Flash SSD in Enterprise Storage

## Enterprise Support Challenges: MLC SSD Controllers

<table>
<thead>
<tr>
<th>Controller Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced wear leveling</td>
<td>• Continuing innovation to spread Flash usage as evenly as possible to help maximize SSD life</td>
</tr>
<tr>
<td>Flash usage management</td>
<td>• Implementation of various potential techniques such as compression, de-duplication, etc. to help limit Flash wear</td>
</tr>
</tbody>
</table>
| Forward-looking ECC architecture / coverage | • Advanced architecture capability  
• Multiple Flash technology node support |
| Write amplification optimization            | • Provide maximum media lifespan capability                                |
| Advanced signal processing support          | • Flash component partnership likely required  
• Key next-generation Flash reliability improvement mechanism |
| System-level throttling capability          | • Innovative methods to help manage Flash bandwidth to achieve improved SSD lifespan |
| Response time improvement                  | • Drive average and maximum response time improvements with increased SSD complexity |
| Trim command support / utilization         | • Vehicle for improving mature SSD performance / lifespan                   |
| Power consumption reduction                | • Manage power with increased performance  
• Subsystem-level RAID level power will increase with Flash optimization |
| End-to-end data integrity support          | • Fundamental requirement for Enterprise SSD                              |
Enterprise Support Challenges: MLC NAND Flash Media

- Providing Enterprise support while driving aggressive technology advancement / cost reduction for Consumer applications with reduced reliability requirements is critical Flash industry challenge.
- MLC NAND technology lifespan must be extended to support Enterprise product requirements.
- New MLC component designs must offer additional spare area per sector to accommodate advanced ECC algorithms required for Enterprise.
- Next key technology transition is advanced signal processing access capability provided by MLC suppliers to SSD controller designers / manufacturers.
- Component read disturb specifications must be better understood by controller companies / users.
  - JEDEC read disturb specification needed.
- Drive-to goal for Enterprise Flash storage must be to apply consumer MLC to enterprise SSD applications with sufficient controller Flash management and reliability.
Dwell Time: Key Lever For SSD Reliability Improvement

- **Definition**
  - Dwell time – elapsed time between program operations for individual Flash component cells
  - Typically 2-10 min. for current industry component qualifications based on density and endurance targets – result based on qualification goals not Enterprise system requirements

- **Concept**
  - Increased dwell time allows for improved Flash cell recovery (de-trapping)
  - Initial test data shows increased dwell time improves retention UBER and RBER at both 25°C and 85°C
    - Data on different suppliers and various technology nodes
  - **NET:** Flash component endurance can be increased at constant data retention with extended dwell time

- **SSD / system applications**
  - Flash component dwell time is on average significantly longer in system environment behind host and SSD controllers with Flash management architectures
  - System- and storage subsystem-level characterization in process

- **Recommendation**
  - **Drive Flash component dwell time specification for Enterprise SSD based on available component-, SSD- and system-level data**
    - Significant reliability improvement opportunity exists
Small Form Factor Innovation Required for Enterprise

- **SSD**
  - **1.8” Enterprise SFF SSD** enables high capacity and throughput per system space allocated
    - MLC Flash media is key to value proposition
    - Enterprise data integrity requirements must be satisfied
    - SATA interface now, migrate to SAS by YE11
    - Industry defined Micro SAS connector SFF (8486)
    - Connector power requirements must be defined for 6 and 12Gbps interface speeds, enabling maximum SSD performance
  - Application opportunities
    - Boot drives for systems requiring small footprint and minimum space (e.g., blades)
    - Low-end rack servers
    - PCI-e adapter card building block
- High performance **one-chip SSD controller** solutions without dependence on external caches required
- New approaches needed for **super capacitor** designs (if required) to help improve reliability and reduce space occupancy
  - Discrete capacitors
  - Other backup mechanisms (e.g., phase change memory)
Small Form Factor Innovation Required for Enterprise

- **NAND Flash Media**
  - 12mm x 18mm BGA body size support must be drive-to goal with advanced technology and increased density
    - Enables increased number of controller channels / Flash sites
  - Packaging innovation required to support **greater than 8 dice per Flash package** for increased capacity with similar reliability
Summary

- MLC Flash currently provides leadership Enterprise SSD performance and lifespan today based on existing storage infrastructure
  - Higher capacity and lower cost structure enabled
- NAND scaling expected to continue via floating gate extensions & charge trap / 3D cell architectures to 1xnm technology node range and 256Gb MLC density
  - Ongoing reliability enhancements required to satisfy Enterprise-level MLC requirements vs. time
- Enterprise SSD controller and Flash media challenges must be overcome to ensure MLC support through time
- Flash component dwell time is likely new lever for Enterprise SSD reliability improvement
- Small form factor innovation is required for Enterprise storage to enable improved capacity, performance and reliability