Breaking Down the Barriers:
Bringing Disruptive Memory Technology to Market
How Radical Should Changes Be?

Disruptive
Interrupt the normal course of Technology

Evolutionary.
Continue to change from a lower to a higher, more complex, or better state of Technology
How Disruptive can Technology be?

• New Applications, New Infrastructure and New Market

OR

• Improve the existing applications
• More applications without creating a new infrastructure
How Disruptive Technology can be effective?

“In spite of the rare instances when disruptive technology has been successfully deployed in the memory industry, we operate under the assumption that it can and should be, without fully examining how to do it or even if we should.”

Spansion as one of the few companies that has successfully deployed a disruptive technology in the memory market.
Polarized Mainstream Memory Use

Defines infrastructure and ecosystem

Source: Gartner (February 2009)

* Excludes memory embedded in ASIC or ASSP components.
Memory Attributes

Keep discrete or combine in one technology?

**DRAM**
- Volatile + Refresh
- Most expensive
- Very fast read & write

**NOR**
- Non-volatile
- Low cost
- Fast read
- High reliability

**NAND**
- Non-volatile
- Lowest cost
- Fast write & erase

Best for
- Real time code execution cache
- Best for code storage and execution
- Best for media storage
Does Disruptive Technology = Disruptive Use?

Sometimes … but then it takes much longer to ramp

Source: Spansion
Next-Generation Memory Specification

Table stakes to deliver “acceptable” system benefits

- Competitive cost
- Compatible with high-volume manufacturing techniques
- Architecture balance
  - Performance
    - High speed read
    - High speed program, erase/overwrite
  - Low power
- Reliability
  - Data retention
  - Endurance

“Acceptable” defined by the infrastructure

- What is required from the memory device
- What can be exploited by the system software and hardware
## Technology & Infrastructure Maturity

<table>
<thead>
<tr>
<th>Technology</th>
<th>Mature</th>
<th>Evolving</th>
<th>Disruptive (Near Term)</th>
<th>Disruptive (Long Term)</th>
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<tbody>
<tr>
<td>Floating Gate</td>
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<tr>
<td>Charge Trapping</td>
<td></td>
<td></td>
<td>PCM</td>
<td>Other RCM RRAM MRAM</td>
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<td>(e.g. MirrorBit®)</td>
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| Mass Market Maturity | 20 years | 7 years | Years Away | Many Years Away |

Source: Spansion
Resistive Change Memory

Near term or long term technology solution?

1. 4-5F² MLC cell
2. Compact select device with sufficient drive current, e.g. vertical diode
3. Minimum pitch, fine-line, high conductivity interconnect in both directions
Near Term: Phase Change Memory

Challenges the industry has to overcome

<table>
<thead>
<tr>
<th>Issue</th>
<th>Risk</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td><strong>Performance:</strong> Programming speed</td>
<td>High</td>
<td>High current limits parallelism in programming</td>
</tr>
<tr>
<td><strong>Manufacturability:</strong> Process complexity</td>
<td>High</td>
<td>Challenging integration with significant number of critical masking steps</td>
</tr>
<tr>
<td><strong>Cost and Manu:</strong> Multi-level capability</td>
<td>High</td>
<td>Resistance drift challenges state placement</td>
</tr>
<tr>
<td><strong>Cost</strong> Complexity vs. existing technology</td>
<td>High</td>
<td>SLC significantly more complex process</td>
</tr>
<tr>
<td><strong>Cost</strong> Cell size</td>
<td>High</td>
<td>Compromises for shrink from 12F²</td>
</tr>
<tr>
<td><strong>Cost and Manu. Scalability</strong></td>
<td>High</td>
<td>Select devices may not scale. GST area is already sub-lithographic</td>
</tr>
<tr>
<td><strong>Bit alterability</strong></td>
<td>Low</td>
<td>Truly disruptive for NVM</td>
</tr>
</tbody>
</table>
Charge Trapping: Innovation at the Cell – Evolution in the System
Disruptive Scalability

Source: Spansion estimates
Evolutionary Ramp

New technology must be “acceptable” for the customer

Source: Spansion
NOR Cell Size Scaling Example

50% reduction

MirrorBit® cell

Floating gate NOR cell

Source: Spansion estimates
What It Takes to Make “It” Work!

- Intimate Technology, Design, Product Eng, Test Collaboration
  - New & old technology aren’t the same – Different mindset required
  - What works in the lab doesn’t necessarily work in production

- Specific MirrorBit® technology design innovations

<table>
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<tr>
<th>Advanced Program and Erase Algorithms</th>
<th>Advanced Read</th>
<th>Advanced Process</th>
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</thead>
<tbody>
<tr>
<td>• Temperature and cell location compensation</td>
<td>• Increases margin by reducing parasitic currents</td>
<td>• Creating the highest technique in process</td>
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<tr>
<td>• Compact, uniform cell distributions</td>
<td>• Opens up sensing window</td>
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<td></td>
<td></td>
<td>• Stabilizes cell behavior</td>
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<td>• Optimizes data retention</td>
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</table>
Charge Trapping Next Steps with MirrorBit® NAND Technology

“Evolution of Technology”
The Technology

- SONOS-like cell structure
- Cells connected in NAND array
- Highly scalable
- SLC and MLC capable
- Leverages proprietary MirrorBit® charge trapping technology and manufacturing know-how
- Different technology but excellent process compatibility with MirrorBit NOR for production in same fabs

MirrorBit® NAND Technology

Cell Size ~ 4.0\(\lambda^2\)
Efficient Die Size

Relative Die Size Comparison

* Source: Spansion estimates of MirrorBit® NAND versus 4xnmm Floating gate SLC NAND solutions
What Will the Future Look Like?

Moving closer to the ideal memory

Cost & Scalability Challenge

High

Low

Flexibility

Hard Drive

Source: Spansion
What Will the Future Look Like?

Moving closer to the ideal memory

Source: Spansion
Conclusion

Existing industry is structured for evolution
• Even in Silicon Valley!
• Disruption can be risky – for both customers and suppliers
• It takes a long time to create new Infrastructure in a new Eco-System

New technology is never adopted quickly
• Memory doesn’t exist in a vacuum
• Even evolution takes a while
• Disruption needs H/W and S/W infrastructure to change

Tomorrow’s technologies...
• Must be relevant and must be viable
• Must offer more than today’s technology ... otherwise why change?
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