Analysts Weigh In On Persistent Memory

Moderator:
Michael Oros, Executive Director, SNIA
Today’s Presenters

- Jim Handy and Tom Coughlin on How Persistent Memory Will Succeed
- Randy Kerns with An Analyst Perspective – IT Clients
- Gil Russell and Alan Niebel on Persistent Memory Dynamics
How Persistent Memory Will Succeed

Jim Handy, Objective Analysis & Tom Coughlin, Coughlin Associates
Who Wants Persistent Memory?

- If it’s more costly than DRAM (NVDIMMs)
  - High-availability systems
  - Financial databases
  - Some hyperscale applications

- If it’s cheaper than DRAM (XPoint, etc.)
  - Everybody will want it!
  - It’s improves cost/performance
    - Persistence is of secondary importance
  - This will drive its success
PM Must Fit Memory/Storage Hierarchy

Bandwidth (MB/s) vs. Price per Gigabyte

- Tape
- HDD
- SSD
- DRAM
- L1
- L2
- L3

Source: *A Close Look at the Intel/Micron 3D XPoint Memory*, Objective Analysis 2015
A Lesson From Planar NAND

❖ **SLC NAND vs. DRAM**
  - Same die size
  - Same process geometry
  - Similar complexity
  - Twice as many bits
    › Should cost half as much

<table>
<thead>
<tr>
<th></th>
<th>DRAM</th>
<th>SLC NAND</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Die Area</strong></td>
<td>~100mm²</td>
<td>~100mm²</td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td>44nm</td>
<td>44nm</td>
</tr>
<tr>
<td><strong>Density</strong></td>
<td>4Gb</td>
<td>8Gb</td>
</tr>
</tbody>
</table>

❖ Yet NAND prices were higher than DRAM’s until 2004!
  - NAND wafer production reached 30% that of DRAM
Scale Drove NAND Cost Below DRAM

Average Price per Gigabyte


From: Hybrid Drives: How, Why, & When?
A Lesson From 3D NAND

- Wholesale change is incredibly difficult!
  - 3D NAND is 3 years behind schedule
- Silicon itself is a challenge
  - New materials will prove even harder
- Revolutionary change is expensive!
How Will PM Reach Ubiquity?

- It must approach DRAM volume
  - Wafer production within an order of magnitude
  - This will drive sub-DRAM prices
  - Only Intel is motivated to do this

- Persistence requires software support
  - SNIA & others are making this happen

- Other applications will use it for cost/performance
  - Initially persistence won’t be used
Phase Change Memory (PCM)

- **3D XPoint**
  - Optane NVMe SSDs available ($31.39 for 480 GB, $1.32/GB at Amazon)
  - Intel plans to launch Optane DIMM in 2H 2018
  - Micron hasn’t announced a ship date for its QuantX Technology
  - New Micron/Intel Fab JV focuses on 3D XPoint rather than 3D flash
Magnetic RAM (MRAM)

- Everspin received revenue for 256Mb STT-MRAM products in Q4—production ramp to follow
- Samples of 28nm 1 Gb chips from Everspin
- First 1-2 GB MRAM PCIe SSDs
- Global Foundries shipping MRAM for many embedded apps.
- Spin Transfer Tech. samples 80nm OST-MRAM chips
- Planned MRAM intros in 2018 by TSMC, Samsung, Tokyo Electron

Michael Ofstedahl, Avalanche Tech, EE Times, 8/2014
Ferroelectric RAM (FRAM)

- Long history of niche products (caches, buffers), but has been difficult to scale
- IMEC’s work with HfO$_2$ ferroelectric has put new life into FRAM
- Possible NAND-like devices possible
Resistive RAM (RRAM or ReRAM)

Many varieties of ReRAM

- Fujitsu and Panasonic offer chip solutions
- Crossbar sampling 40nm ReRAM, made by China’s SMIC
- TSMC and UMC put ReRAM on their roadmaps
- ReRAM still touted for storage class memories—e.g. HPE’s “The Machine” although solutions still elusive
- Neuromorphic computing is touted as ReRAM application

Shahar Kvatinsky, DevelopEx2015, 11/2015

https://nicsefc.ee.tsinghua.edu.cn/projects/emerging/neural/
## Technology Comparison

<table>
<thead>
<tr>
<th>Technology</th>
<th>FeRAM</th>
<th>MRAM</th>
<th>ReRAM</th>
<th>PCM</th>
<th>DRAM</th>
<th>NAND Flash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonvolatile</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Endurance</td>
<td>$10^{12}$</td>
<td>$10^{12}$</td>
<td>$10^6$</td>
<td>$10^8$</td>
<td>$10^{15}$</td>
<td>$10^3$</td>
</tr>
<tr>
<td>Write Time</td>
<td>100ns</td>
<td>~10ns</td>
<td>~50ns</td>
<td>~75ns</td>
<td>10ns</td>
<td>10µs</td>
</tr>
<tr>
<td>Read Time</td>
<td>70ns</td>
<td>10ns</td>
<td>10ns</td>
<td>20ns</td>
<td>10ns</td>
<td>25µs</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>Low</td>
<td>Medium/Low</td>
<td>Low</td>
<td>Medium</td>
<td>Very High</td>
<td>Very High</td>
</tr>
<tr>
<td>Cell Size ($f^2$)</td>
<td>15-20</td>
<td>6-12</td>
<td>6-12</td>
<td>1-4</td>
<td>6-10</td>
<td>4</td>
</tr>
<tr>
<td>Cost ($/Gb$)</td>
<td>$10/Gb$</td>
<td>$30-70/Gb$</td>
<td>Currently High</td>
<td>$0.16/Gb$</td>
<td>$0.6/Gb$</td>
<td>$0.03/Gb$</td>
</tr>
</tbody>
</table>
Upcoming Emerging Memory Report

- Covers all major solid state memory/storage technologies and companies
- Describes major solid-state memory driving applications and formats
- Projections for volatile and persistent memory (embedded and discrete)
- Projections for capital investments
- Finish target date is May 2018
Summary

- PM needs to fit the storage/memory hierarchy
- It won’t all be used for its persistence
- There are many types of PM
- Different PM technologies will fill different market niches
THANK YOU

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Coughlin Associates
Data Storage Consulting

Objective Analysis
Semiconductor Market Research
Analyst Perspective – IT Clients

Randy Kerns, Evaluator Group
Persistent Memory

Enterprise customers perception in general
- Part of transition away from electro-mechanical primary storage
- Transformational for storing information
  - Performance
  - Longevity
    - Change in technology updating
    - Change in plans for migrating data
    - Amortization schedules
Enterprise customers biggest issue

- Quantification of value – has not been expressed well
  - Vendor and reseller sales and marketing still using a measure of data at rest - $/GB
  - Real value is how much work can get done
  - How to express to enterprise customers?
  - How to help them justify purchases?

- Not a simple answer
Persistent Memory

- **Data at rest economics – if $/GB is your measure**
  - Just use tape
  - Lowest cost of media acquisition
Persistent Memory

- Enterprise customer perception of use of PM beyond Flash in storage systems
  - Expect as cache in storage – rather than large DRAM
  - Economics discussion – what is the value – cost vs performance
  - Usage beyond that – beyond majority of customer's horizons
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Persistent Memory Dynamics

GIL RUSSELL & ALAN NIEBEL - WEBFEET RESEARCH, INC.
Technology is “thought” to be most relevant to the In-Memory Computing and Cognitive Computing Market Segments (Fat Memory Segment)

Storage Class Memory (SCM) 2008
- SCM fiction based on cost per bit;
  “..., ultimately such a storage-class memory (SCM) device could potentially replace magnetic hard-disk drives (HDDs) in enterprise storage server systems.” – G.W. Burr et al, IBM 2008

Rapid growth of NAND-Flash SSDs delayed market demand for Persistent Memory

Then came IMC and Cognitive Computing
- Byte addressability added to SCM
- Presto! “Persistent Memory!”
- Now called NVRAM when applied as a DRAM replacement
Non-Volatile RAM - NVRAM

- DDR4 Functionality
- Low latency
  CL ≤ 13.5
- Higher Density
  Roadmaps
  8 – 32 Layers
- Persistence
  ≤ 10 years
- Endurance
  $10^{11} - 10^{12}$ PE
- Zero Refresh
  (or very low overhead)
DRAM has had a good run (Toshiba 1966)

CPU performance gains limited by memory size (and cost)

- DRAM density has not improved fast enough to fill the need
- NVRAM fulfills density improvements (long term roadmap)
  - XY Square Geometry shrink density improvements
  - Multi Layer introductions provide linear improvements
  - Substantial power reduction
  - Opens market for MLC, TLC, and QLC type devices
NVRAM – Market Synopsis

- **NVRAM competitive product positioning**
  - Dependent on System Level Context
  - Price competitive with XPoint in a $71B Market?
  - Competitive performance comparisons?
  - Secondary supply suggests an open standard

- **3D XPoint will dominate market beginning in the 2H ’18**
  - Introduction of competing NVRAM products expected to begin ramp in 2H ’19

- **NVRAM replacing DRAM & NAND in mobile space in 2020**
Persistent Memory Trends

- Persistent Memory coupled with Cognitive Computing Architectures enables:
  - Very Large Persistent Memory Arrays
  - AI Algorithms to reduce compute times (hours to minutes)
- Processor In Memory – PIM (or Bottleneck Be Gone)
  - Beginning of Data Execution in Memory
  - Data motion progresses from inches to microns and data rates from 1TB/s to 10’s of PB/s
- Heteroassociative memory
  - The human brain is fully associative
  - One item is able to recall a totally different item
## NVRAM Revenue

### Smartphone

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<tr>
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<tbody>
<tr>
<td>Apple iOS Munits</td>
<td>234</td>
<td>252</td>
<td>269</td>
<td>277</td>
<td>290</td>
<td>306</td>
<td>322</td>
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<tr>
<td>NVRAM Attachment Rate</td>
<td>5%</td>
<td>35%</td>
<td>75%</td>
<td>85%</td>
<td></td>
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<tr>
<td>Apple iOS NVRAM units</td>
<td>14</td>
<td>101</td>
<td>229</td>
<td>274</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Smart Phone DRAM $M</td>
<td>4,524</td>
<td>12,707</td>
<td>15,986</td>
<td>19,321</td>
<td>21,142</td>
<td>21,867</td>
<td>22,509</td>
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<tr>
<td>Smart Phone NAND</td>
<td>12,524</td>
<td>17,651</td>
<td>16,277</td>
<td>18,786</td>
<td>21,202</td>
<td>22,156</td>
<td>25,817</td>
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<tr>
<td>iPhone DRAM</td>
<td>733</td>
<td>2,033</td>
<td>2,446</td>
<td>2,879</td>
<td>3,044</td>
<td>3,171</td>
<td>3,331</td>
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<tr>
<td>iPhone NAND</td>
<td>2,029</td>
<td>2,824</td>
<td>2,490</td>
<td>2,799</td>
<td>3,053</td>
<td>3,213</td>
<td>3,821</td>
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<tr>
<td>iPhone DRAM savings NVRAM $M</td>
<td>144</td>
<td>1,066</td>
<td>2,378</td>
<td>2,832</td>
<td></td>
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### NVDIMM

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<th></th>
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</thead>
<tbody>
<tr>
<td>Total - MLC NAND</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total - 3D NAND</td>
<td>1</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>11</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Total - NVRAM</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>79</td>
<td>750</td>
<td>2,029</td>
<td></td>
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<tr>
<td>Total - XPoint</td>
<td>0</td>
<td>171</td>
<td>1,369</td>
<td>3,596</td>
<td>4,301</td>
<td>3,127</td>
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<tr>
<td>Total RAM $M</td>
<td>2</td>
<td>175</td>
<td>1,377</td>
<td>3,688</td>
<td>5,061</td>
<td>5,168</td>
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<tr>
<td>Total - NVRAM $M</td>
<td>0</td>
<td>0</td>
<td>144</td>
<td>1,145</td>
<td>3,128</td>
<td>4,860</td>
<td></td>
</tr>
</tbody>
</table>
Thank You

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