What a Year It Was - and Where We Need To Go in Emerging Memory

Live Webcast
14 January 2020, 11:00 am PT/ 2:00 pm ET
Today’s Presenters

Moderator: Alex McDonald, Co-Chair

Presenter: Tom Coughlin, President

Presenter: Jim Handy, General Director
Technologies We Cover:

- Solid State Storage
- Persistent Memory
- Computational Storage

Join Us in January and February 2020 for these exciting events:

**SNIA 2020 Persistent Memory Hackathon**

www.snia.org/pmhackathon

- **January 22, 2020**
  - 1:00 pm – 5:00 pm
  - Santa Clara, CA

  *Complimentary registration*

- **February 4, 2020**
  - 9:30 am – 5:00 pm
  - Tel Aviv, Israel

  As part of SDC 20

  SNIA EMEA

**SNIA Persistent Memory Summit**

www.snia.org/pm-summit

- **January 23, 2020**
  - 8:30 am – 6:30 pm
  - Hyatt Regency Santa Clara

Keynote by Andy Bechtolsheim of Arista Networks

*Complimentary registration*
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Many Emerging Memory Types

MRAM

ReRAM

PCM

FRAM

They’re All Persistent!

AND THEY’RE ALL IN OUR EMERGING MEMORIES REPORT
Agenda

- SNIA Support Moves Ahead
- Optane DIMMs Arrive
- New MRAM types Emerge
- Business Conditions in Flux
- More Work is Needed
PM Needs Support

- **Hardware (JEDEC, Others)**
  - Supporting early development
  - Ongoing requirements
  - Form factors, interfaces

- **Software support (SNIA, Others)**
  - O/S support
  - Application program support
Hardware: Early Development

- Early groundwork has been helpful
  - NVDIMM-N
    - DRAM with flash backup
    - Deeply investigated in Objective Analysis NVDIMM Report
  - BIOS changes
    - How/when to boot without reloading memory?
  - New power fail signal brought to DIMM

- 3D XPoint Memory/Optane is driving HW changes
- Cadence now supports DDR4 MRAM for ASICs & FPGAs

Ongoing Hardware Requirements

- Nonuniform Memory Architecture: “NUMA”
- MMU redesign
- Faster CPU context switches needed
  - Use polling for now
- Updated DDR4 bus
  - Intel has developed proprietary DDR-T
    - “Transactiona”l
  - Support for non-deterministic access times
Software: Operating System Support

SNIA’s Persistent Memory Programming Model

- https://www.SNIA.org/PM
SNIA’s Persistent Memory Progress

2019
- PM Programing Hackathon and Workshops launched
- Work on PM software interface specifications
  - Developed PMDK
- Persistent Memory Summit
- White papers

Future
- Define Remote PM Programming Model (i.e. RDMA)
- Updates to current PM Programming Model
Application Program Support

- PM is useless if its advantage is untapped
  - Persistence is unknown in most software
- This change will take some time
  - Closed systems can use it now
    - Hyperscale Data Centers, SANs
  - Open systems will evolve
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3D XPoint Must Be Priced Below DRAM
Otherwise People will Just Buy DRAM

- 1.E+00
- 1.E+01
- 1.E+02
- 1.E+03
- 1.E+04
- 1.E+05
- 1.E+06
- 1.E-01
- 1.E+00
- 1.E+01
- 1.E+02
- 1.E+03
- 1.E+04
- 1.E+05
- 1.E+06

Bandwidth (MB/s)

Price per Gigabyte

Tape
HDD
SSD
DRAM
L3
L2
L1

3D XPoint

Optane Status

- Optane DIMMs are a key selling point for next-generation server “Cascade Lake” CPUs
  - Big performance benefit from Optane + CPU enhancements
- Optane SSDs gaining modest acceptance
  - NAND makers countering with fast SLC SSDs
- Covered in depth by Objective Analysis XPoint report
  - Details at end of slideshow
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Existing MRAM Types: Toggle & STT

**Toggle Mode**

"Reset"

```
S  N
S  N
```

Magnets aligned = Low resistance: “0”

"Set"

```
N  S
S  N
```

Magnets unaligned = High resistance. “1”

**Spin Transfer Torque (STT)**

"Free" magnetic layer

Tunnel barrier

"Fixed" magnetic layer

Low Resistance or “0”

```
Free Layer
Tunnel Barrier
Reference Layer
```

Parallel Magnetic Polarization

High Resistance or “1”

```
Free Layer
Tunnel Barrier
Reference Layer
```

Anti-Parallel Magnetic Polarization
New: Spin-Orbit Torque MRAM (SOT)

- Higher reliability in-plane current
- Faster than STT – As fast as SRAM
MRAM Status

- MRAM cache is in certain new IBM SSDs as well as some RAID controllers
- Spin Memory introductions:
  - Precessional Spin Current
  - Endurance Engine Technologies
- Everspin still sole supplier of stand-alone MRAMs
  - Over 123 million units shipped
  - Avalanche is sampling
- Today’s markets: Space, high-uptime systems, caches and buffers
Embedded MRAM on SoCs

- Support from all major semiconductor foundries for embedded MRAM:
  - Samsung
  - Intel
  - TSMC
  - GLOBALFOUNDRIES
  - UMC
- This will increase the volume to lower costs
- New tools are needed for MRAM, driving capital equipment spending
MRAM Capital Spending Up

MRAM Production Equipment Spending, 2018-2029

2019 Emerging Memories Ramp Up, Coughlin Associates and Objective Analysis, 2019

>$800 Million!
Agenda

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Who Wants Persistent Memory?

1) If it Costs MORE than DRAM

- That’s NVDIMMs!
  - Early adopters:
    - High-availability systems
    - Financial databases
    - Some hyperscale applications

- MRAM DIMMs are also interesting (faster but more expensive)
New Memory Prices Will Move Past Established Technologies

Price per Gigabyte

<table>
<thead>
<tr>
<th>Year</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>10^6</td>
</tr>
<tr>
<td>2015</td>
<td>10^5</td>
</tr>
<tr>
<td>2020</td>
<td>10^4</td>
</tr>
<tr>
<td>2025</td>
<td>10^3</td>
</tr>
<tr>
<td>2030</td>
<td>10^2</td>
</tr>
</tbody>
</table>

Source: Objective Analysis, 2018
Who Wants Persistent Memory?

2) If it Costs LESS than DRAM

✦ That’s 3D XPoint!
 ✦ Everybody will want it!
 ✦ It improves cost/performance
    › Persistence is of secondary importance
 ✦ This will drive its success
    › Persistent apps come later

Meanwhile, DRAM Prices Collapse

![Graph showing the price of DRAM over time with a significant drop of 55% between Jan-18 and Jan-20.](image)
Commodity Price Cycle at Work!

- Shortage
- Prices Stabilize
- Manufacturers Under Invest
- Manufacturers Over Invest
- Oversupply
- Prices Collapse

How Does This Impact PM?

- Persistent memory competes against established technologies
  - E.g. 3D XPoint must be cheaper than DRAM
  - MRAM takes up less space on die than SRAM
- A DRAM collapse undermines XPoint pricing
  - Even though XPoint is sole-sourced!
Big XPoint/Optane Losses For Intel

-60%
-40%
-20%
0%
20%
40%
60%

1Q16 2Q16 3Q16 4Q16 1Q17 2Q17 3Q17 4Q17 1Q18 2Q18 3Q18 4Q18 1Q19 2Q19 3Q19

Net Profit

New Memory Shipment Growth

Memory Petabyte Shipments 2018-2029

2019 Emerging Memories Ramp Up, Coughlin Associates & Objective Analysis, 2019

Over $37B by 2029!

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Taking PM to the Max

▷ Application support for PM
▷ Additional open-source libraries to support PM (PMDK)
▷ PM hardware support outside of Intel
▷ Drive cost reductions by ramping production volume
▷ Standardize Remote PM protocol
▷ Buy our reports!
QUESTIONS?

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Coughlin Associates  
Data Storage Consulting

OBJECTIVE ANALYSIS  
Semiconductor Market Research
Emerging Memory Report

- Coughlin Associates/Objective Analysis
- Examines Emerging Memory Ecosystem
  - Technologies (PCM, ReRAM, MRAM, FRAM…)
  - Companies
  - Markets
  - Support requirements
- Forecasts Emerging Memory consumption
  - Embedded Emerging Memories
  - Discrete Emerging Memories
- 172 pages, 30 tables, 125 figures

http://www.tomcoughlin.com/techpapers.htm
https://Objective-Analysis.com/reports/#Emerging
And check out these additional resource links:

- SNIA Persistent Memory Summit videos and presentation slides
- SNIA Educational Library resources on Persistent Memory
- SNIA SSSI blog
- SNIA Persistent Memory activities
  - NVM Programming Technical Work Group
  - SNIA Persistent Memory and NVDIMM Special Interest Group
  - SNIA Persistent Memory Programming Tutorial and Hackathon Program
Additional Materials
Coughlin Associates

- Technical and Market Analysis
- Consulting
- Events
- Reports and Newsletter
  - Emerging Memories Ramp Up: Emerging Memory Report
  - Digital Storage in Media and Entertainment Report
  - Digital Storage Technology Newsletter

Tom Coughlin
President
OBVIOUS ANALYSIS

Profound Analysts

Reports & Services

Custom Consulting
# Objective Analysis

## Semiconductor Forecast Accuracy

<table>
<thead>
<tr>
<th>Year</th>
<th>Forecast</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Zero growth at best.</td>
<td>-3%</td>
</tr>
<tr>
<td>2009</td>
<td>Growth in the mid teens</td>
<td>-9%</td>
</tr>
<tr>
<td>2010</td>
<td>Should approach 30%</td>
<td>32%</td>
</tr>
<tr>
<td>2011</td>
<td>Muted revenue growth: 5%</td>
<td>0%</td>
</tr>
<tr>
<td>2012</td>
<td>Revenues drop as much as -5%</td>
<td>-2.7%</td>
</tr>
<tr>
<td>2013</td>
<td>Revenues increase nearly 10%</td>
<td>4.9%</td>
</tr>
<tr>
<td>2014</td>
<td>Revenues up 20%+</td>
<td>9.9%</td>
</tr>
<tr>
<td>2015</td>
<td>Revenues up ~10%</td>
<td>-0.2%</td>
</tr>
<tr>
<td>2016</td>
<td>Revenues up ~10%</td>
<td>1.1%</td>
</tr>
<tr>
<td>2017</td>
<td>Revenues up ~20%</td>
<td>22%</td>
</tr>
<tr>
<td>2018</td>
<td>Strong start supports 10+% growth</td>
<td>14%</td>
</tr>
<tr>
<td>2019</td>
<td>Semiconductors down -5%</td>
<td>TBD</td>
</tr>
</tbody>
</table>
NVDIMM Report

- Objective Analysis
- Explains the NVDIMM markets
  - NVDIMM-N
  - NVDIMM-P
- Vendor profiles
- Support requirements
- Market forecast

https://Objective-Analysis.com/reports/#NVDIMM

Now Available!
2019 Update from Objective Analysis

The Why, How, and When of 3D XPoint Memory

- Why Intel wants it
- How it fits into the memory hierarchy
  - Impact on DRAM
- When will it sell in volume

Detailed Forecasts

https://Objective-Analysis.com/reports/#XPoint