

NVM Technologies

Flash-backed DRAM



Phase-Change Memory

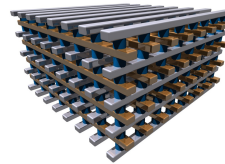
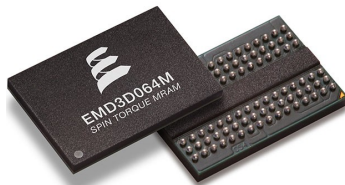


Latency



ns

μ s



Spin Torque MRAM

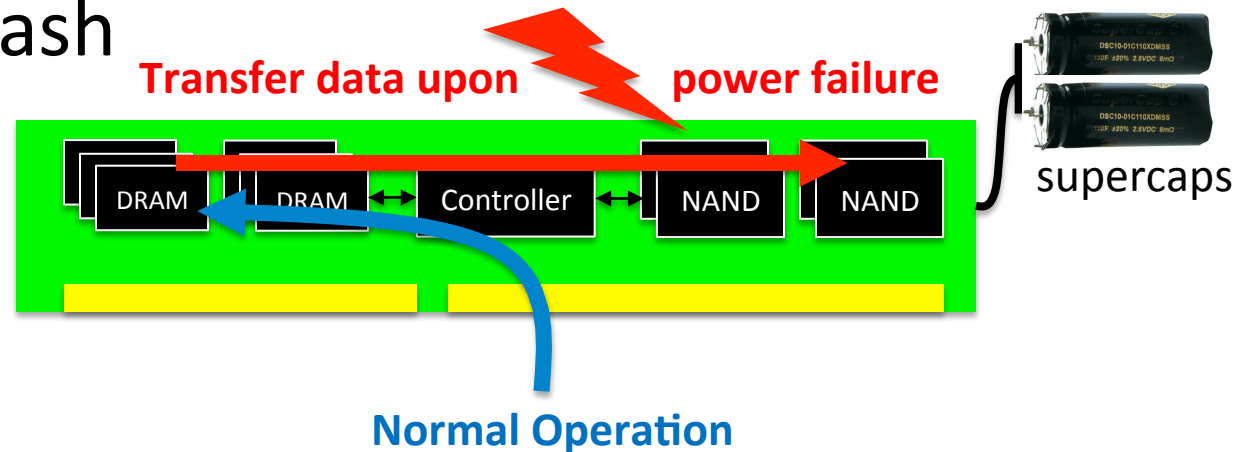
Resistive RAM

Flash

- Persistent
- Short access time
- Byte Addressable

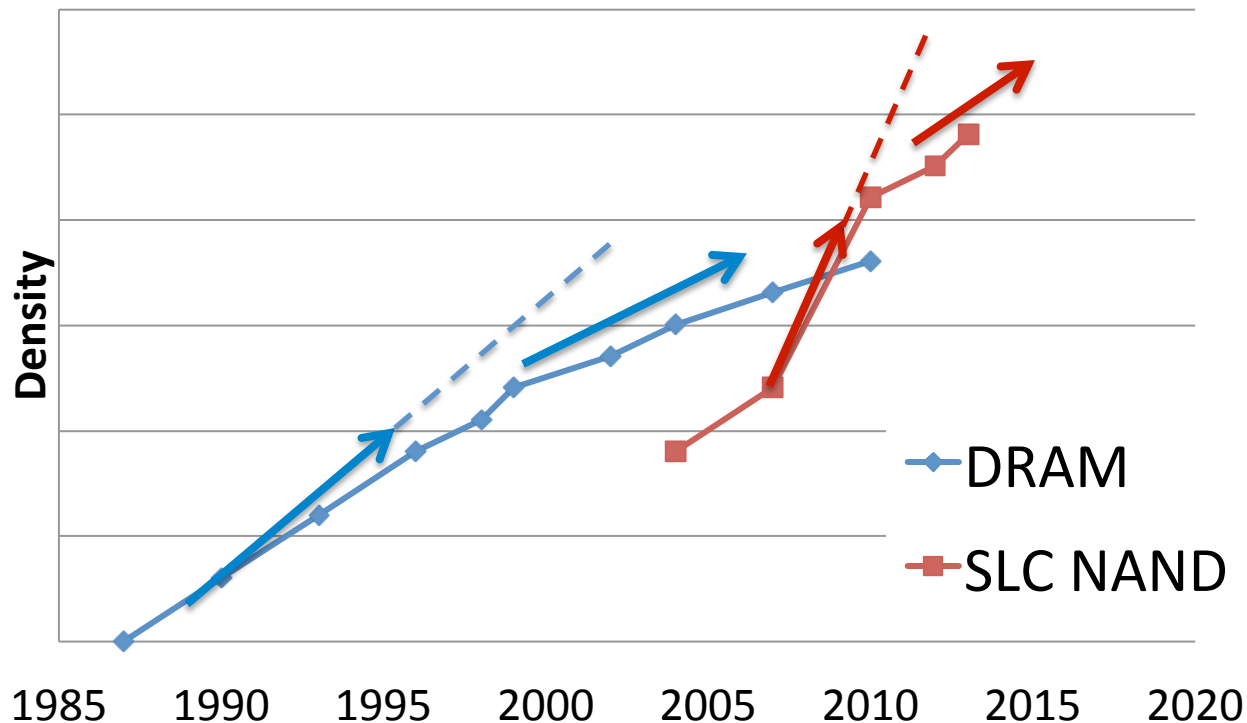
Flash-backed DRAM (NV-DIMM)

- Store data within regular DRAM backed by NAND Flash



- Industrial development
 - AgigA Tech: ships DDR3 NV-DIMMs up to 8GB
 - Diablo, Sandisk, Netlist: offer similar products

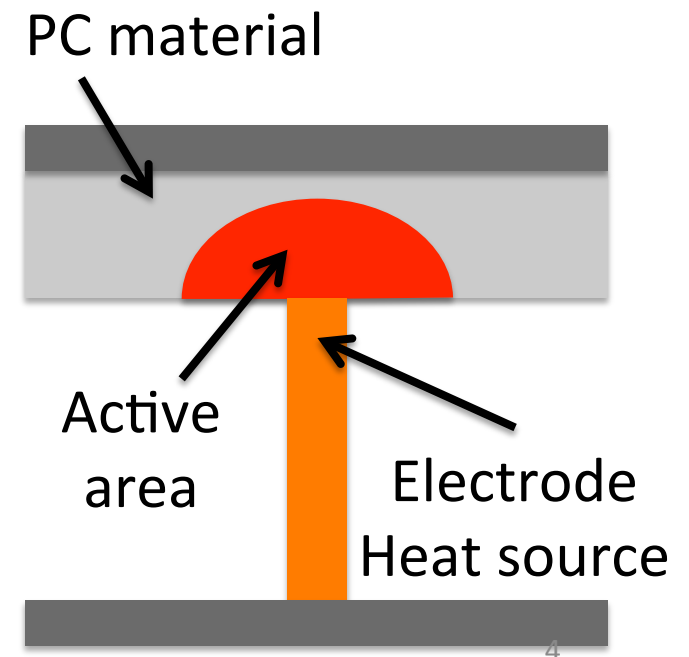
DRAM and Flash Scaling: “The End is Nigh”



- Engineering tricks fuel scaling: MLC, Vertical NAND
- Other NVM technologies emerge as replacements³

Phase-Change Memory (PCM)

- Store data within phase-change material
 - Amorphous phase: high resistivity (0)
 - Crystalline phase : low resistivity (1)
- Set phase via current pulse
 - Fast cooling → Amorphous
 - Slow cooling → Crystalline

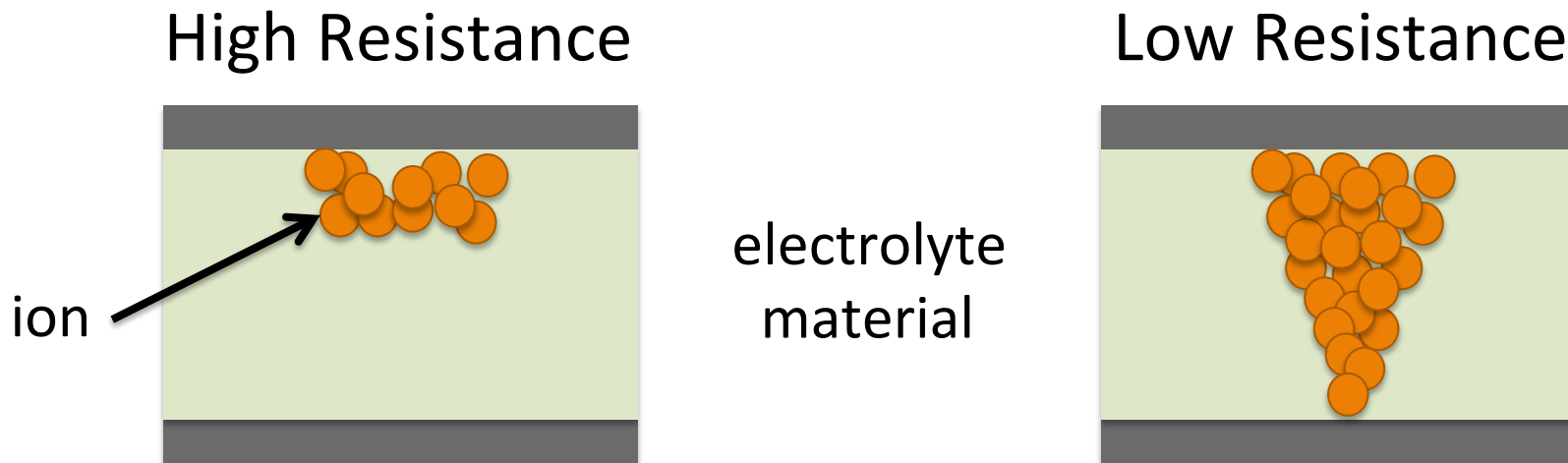


Phase-Change Memory

- Key properties
 - Reads: 100 – 300 ns
 - Writes: 10 – 150 us
 - Endurance: 10^8
 - Density (expected): Medium/High
 - Cost: Medium (few \$/Gb)
- Industrial development
 - IBM and WD: demoed SSDs based on Micron PCM
 - Micron: taking a strategic break from PCM

Resistive RAM (RRAM)

- Store data by dissolving ions within electrolyte memristive material (e.g., TiO_x)

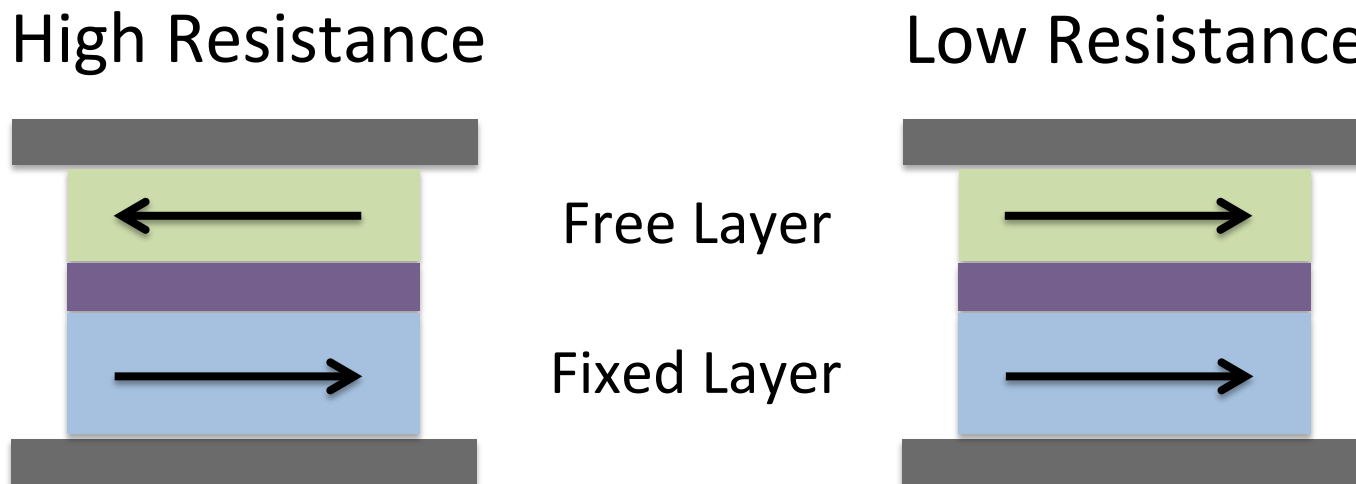


Resistive RAM (RRAM)

- Key properties
 - Reads: 30 ns – 2 us
 - Writes: 100 ns – 2 us
 - Endurance: 10^{10}
 - Density (expected): High
 - Cost: Very high (\$5,000/Gb)
- Industrial development
 - Adesto: offers Conductive Bridging RAM (CBRAM)
 - HP and SK Hynix: plan to deliver memristors
 - Crossbar: promises to deliver 3D-stacked RRAM

Spin-Transfer Torque RAM (STT-RAM)

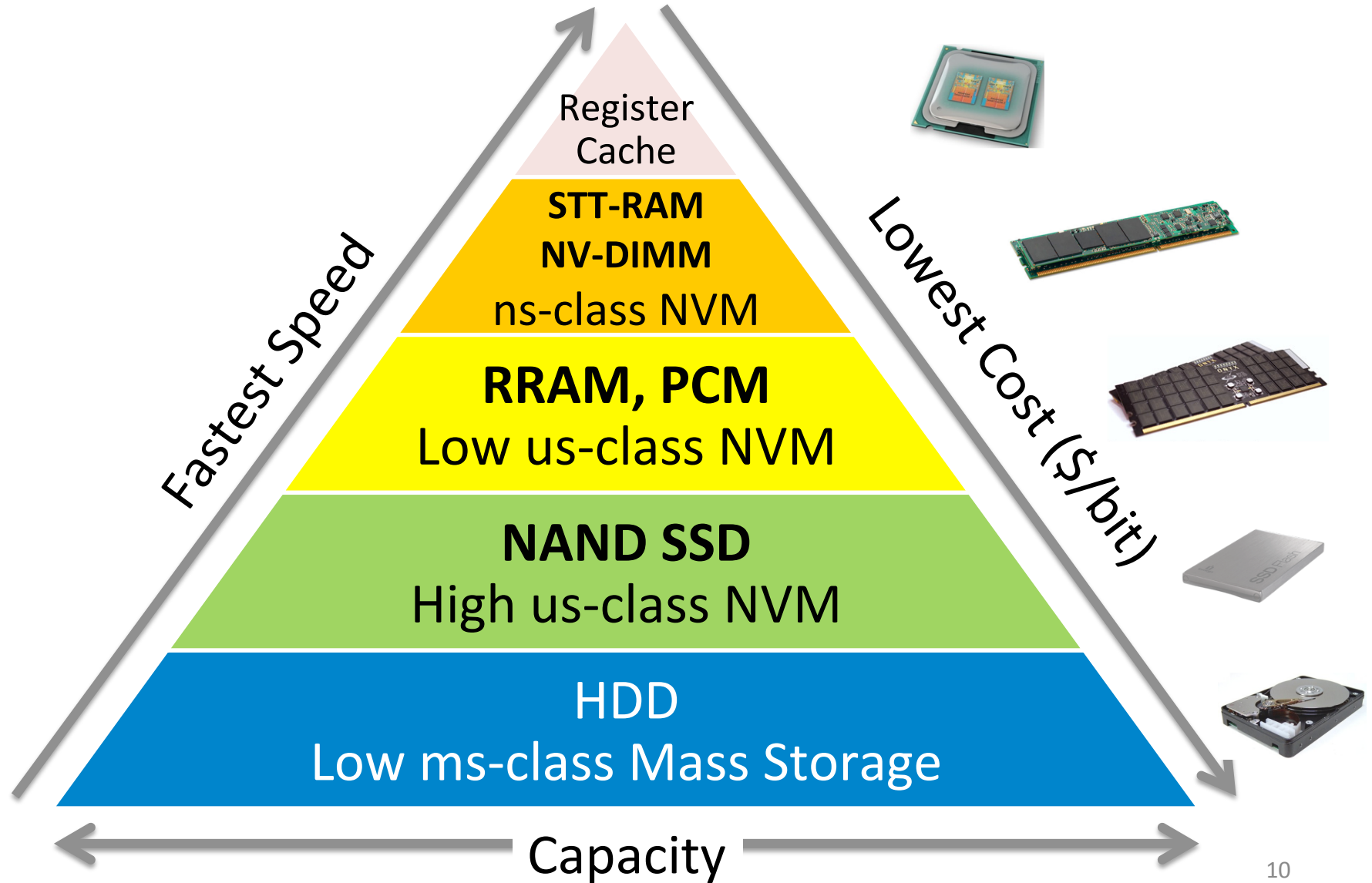
- Store data within magnetic-tunnel junction
 - Anti-parallel orientation: high resistance (0)
 - Parallel orientation: low resistance (1)



Spin-Transfer Torque RAM (STT-RAM)

- Key properties
 - Reads: 2 – 20 ns
 - Writes: 2 – 20 ns
 - Endurance: 10^{15}
 - Density (expected): Low
 - Cost: High (50\$-100\$/Gb)
- Industrial development
 - Everspin: ships 64Mbit modules used for caching

Summary



Summary - Implications to Software

- Persistent
- Short access time **Software overhead matters**
- Byte Addressable **Accessible via loads/stores**

References

- AgigA Tech NV-DIMM
 - <http://www.agigatech.com/agigaram.php>
- Everspin STT-MRAM
 - <http://www.everspin.com/products/second-generation-st-mram.html>
- HP and SK Hynix Memristor
 - <http://www.hpl.hp.com/research/systems-research/themachine/>
- CrossBar RRAM
 - <https://www.crossbar-inc.com/>
- Adesto CBRAM
 - www.adeptotech.com

Backup Slides

Qualitative Comparison

Technology	Read	Write	Density	Endurance	Power	Cost (2014)
DRAM	Green	Green	Red	Green	Green	Green
NAND Flash	Red	Red	Green	Yellow	Yellow	Green
NV-DIMMs	Green	Green	Red	Green	Yellow	Yellow
PCM	Yellow	Red	Yellow	Yellow	Yellow	Yellow
RRAM	Green	Yellow	Green	Green	Green	Red
STT-RAM	Green	Green	Red	Green	Green	Red