



# Emerging Memory Technologies and their Quirks

Karin Strauss

a.k.a.

If Life Gives You Lemons...

# There is Something Brewing...



DRAM scaling is running out of steam



Other technologies gaining momentum

Phase-change memory, STT-MRAM, memristors, etc.

Most are non-volatile and byte-addressable: storage class memory



New opportunities and challenges

More fun for the ASPLOS community!

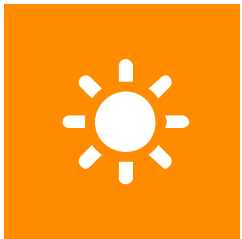
# Quirks of Emerging Memories



Non-volatile, byte-addressable



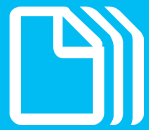
Read/write latencies higher than DRAM



Write energy higher than DRAM



Endurance issues (wear out)



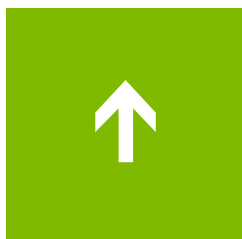
# Opportunities and Challenges

# Opportunities



## New system designs

Where in memory hierarchy should new memories go?



## Expose persistence to applications

May reduce overheads and indirections

Does it make sense to go through drivers? Swap memory?



## Non-volatile: no refreshes

Save power and performance?



## Read-mostly large footprint applications

Data center (e.g., search index?)

Mobile (e.g., Pocket Cloudlets<sup>[ASPLOS 2011]</sup>)

# Challenges – A Can of... Lemons



## Wear out issues

Lots of work in AS, not so much in PLOS

ECP<sup>[ISCA 2010]</sup>: ECC is not best for memory that wears out

Strategies to deal with wearout:

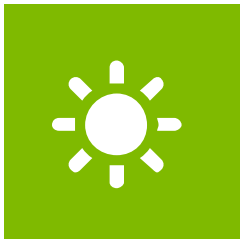
- Reduce number of writes to main memory
- Uniformly distribute wear
- Add redundancy for error detection and correction
- Use good cells in failed pages to fix pages still in use
- Beyond correction: tolerate “holes” in main memory

# Challenges – A Can of... Lemons



## Wear out issues

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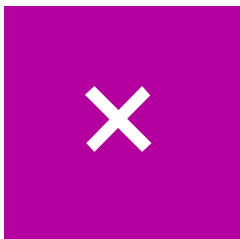
## High write energy and read/write latencies

DRAM-compatible naïve PCM: max one cache line write at a time  
Power tokens<sup>[MICRO 2011]</sup> is first step, but more room for improvement



## Security issues

Memory is not erased when turned off  
Encryption wears memory



## New types of bugs

Two types of memory: volatile and non-volatile, and pointers...  
State (including buggy state) may persist across program invocations

# Summary



Emerging memories are coming



They will very likely impact ASPLOS



Opportunities for interesting research



Get to work!





Thanks!