THE EFFECT OF DWELL ON SSD TESTING

Jim Fitzpatrick

SMART STORAGE™ SYSTEMS

Making NAND Better

MOTIVATIONS

- Dwell is known to play a role in flash wear
  - JEDEC 22-117, 218, etc
  - Papers by Mielke, Matsukawa, etc.
- Drive level testing to demonstrate endurance
  - SSD's spec'd for 5 years, so average dwell is long (e.g. 4000 sec)
  - Demonstrating endurance in a few weeks requires very short dwell (e.g. 40 sec)
    - How does short dwell impact results of drive testing?
- Component level testing needs to be relatively quick

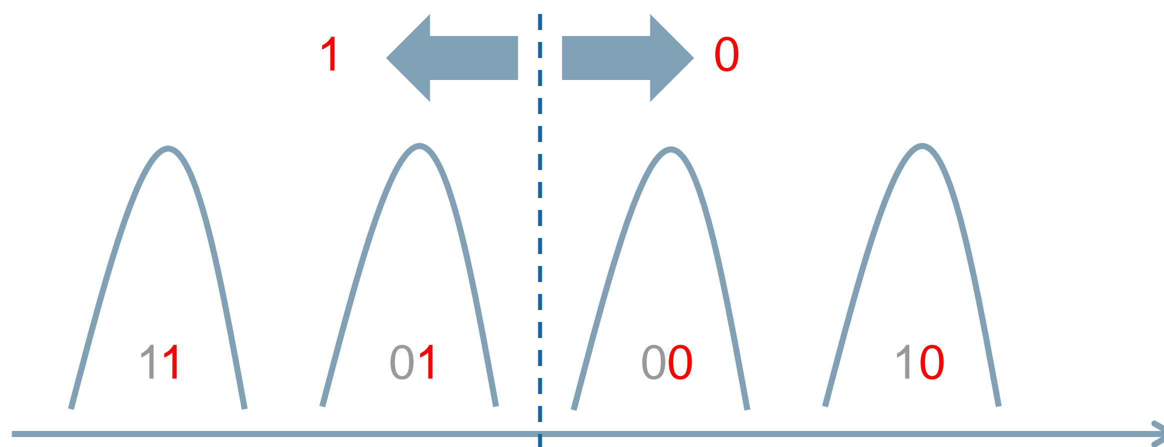
TRAPPING & DE-TRAPPING

- Gate oxide structure develops trap sites with repeated high voltage stresses
- During times that the cell is not being written or erased, the insulator heals, or de-traps.
  - Longer dwell provides more time for healing.
  - Higher temperatures can accelerate healing.

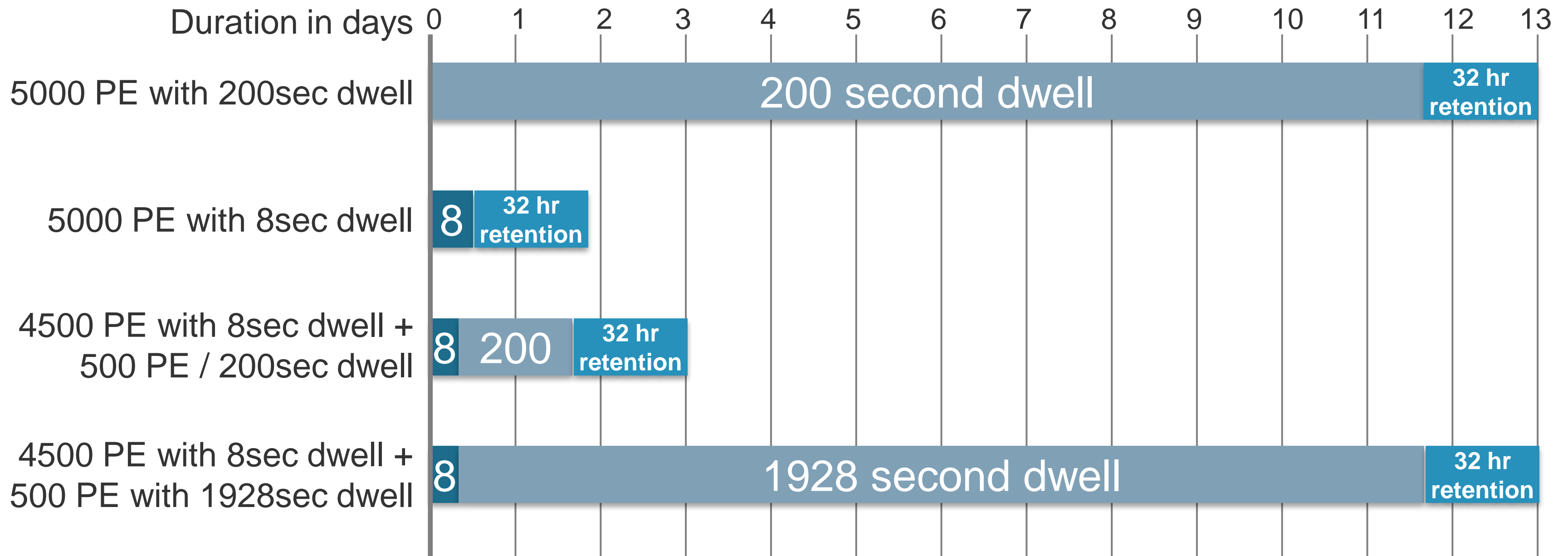
SMART STORAGE SYSTEMS
Making NAND Better

EXPERIMENTS

- Apply PE cycles with varying dwell
  - Study error rates and sensitivity to retention time.
- Conditions
  - 80C ambient (flash ~82C)
  - 5000 PE in all tests
  - 32 die tested at a time
- Results
  - Examine only those pages requiring a single threshold for detection.

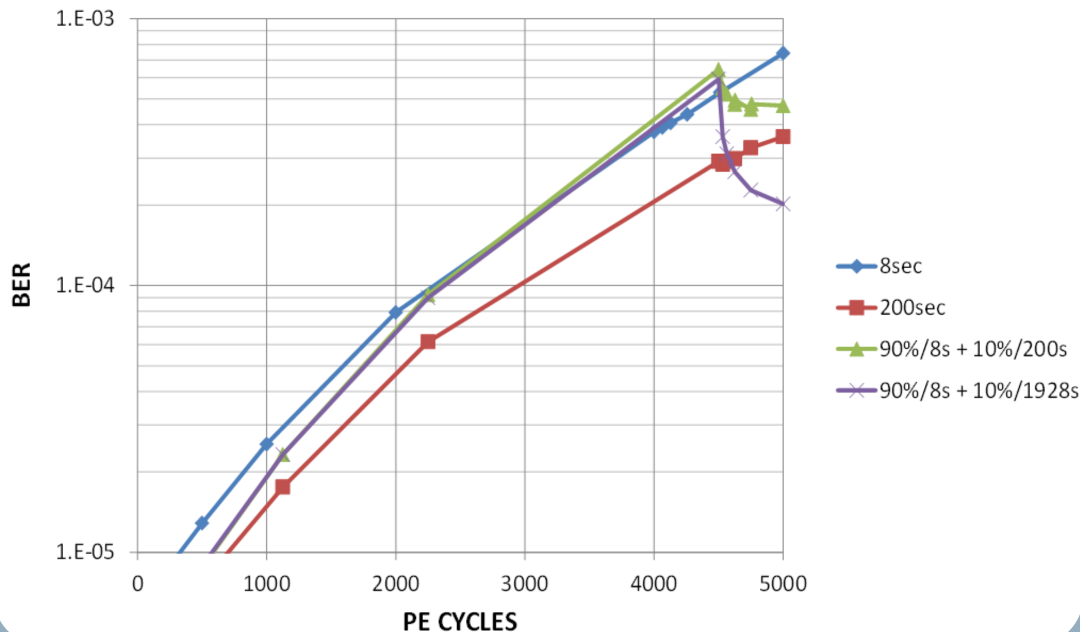


EXPERIMENTS



- First and last experiment have equal average dwell
- Middle experiments use short dwell to accelerate testing

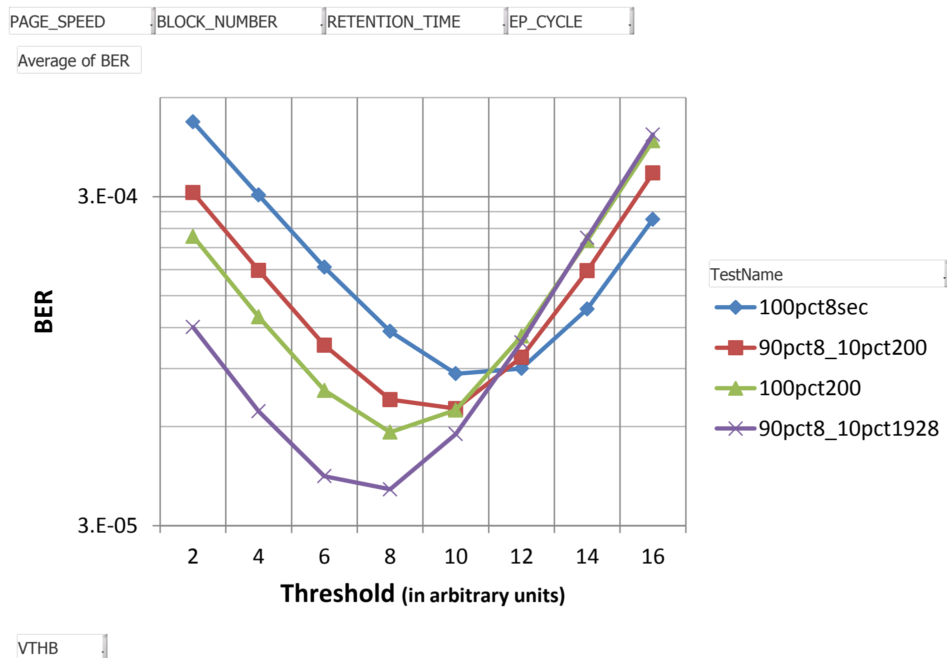
BER VS PE



- Worst BER with 8sec dwell
- BER improves and then stabilizes with last 10% of PE's with 200 sec dwell
- Last 10% with 200 sec dwell is nearly the same BER as all cycles with 200 sec dwell

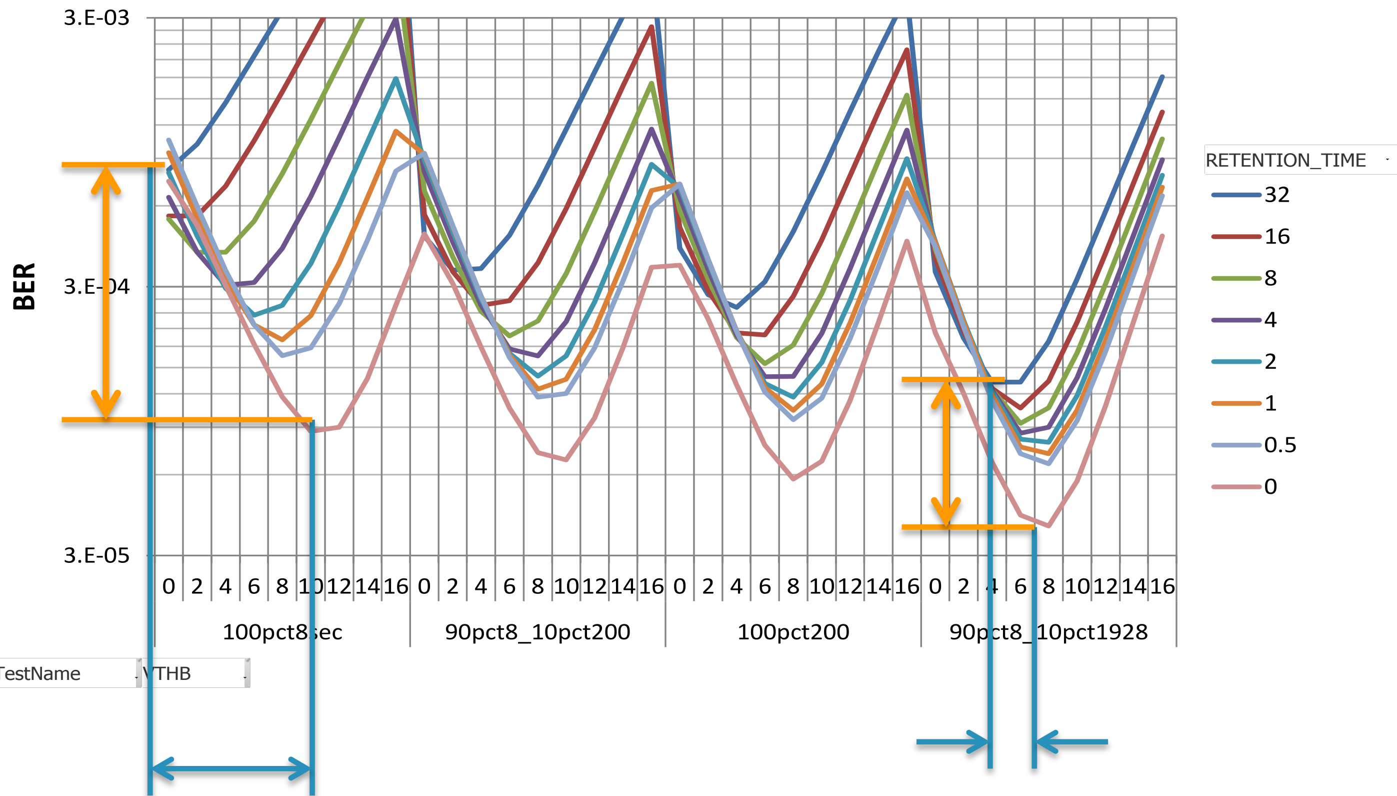
- **UNIFORM DWELL IS WORSE THAN THE MIXED DWELL WITH THE SAME AVERAGE**
- **NUMBER OF PE'S WITH LONG DWELL IS A FUNCTION OF DWELLS**
  - **MORE THAN 500 PE'S ARE REQUIRED TO STABILIZE HEALING FOR 1928S DWELL.**

BER VS THRESHOLD AT 5000 PE

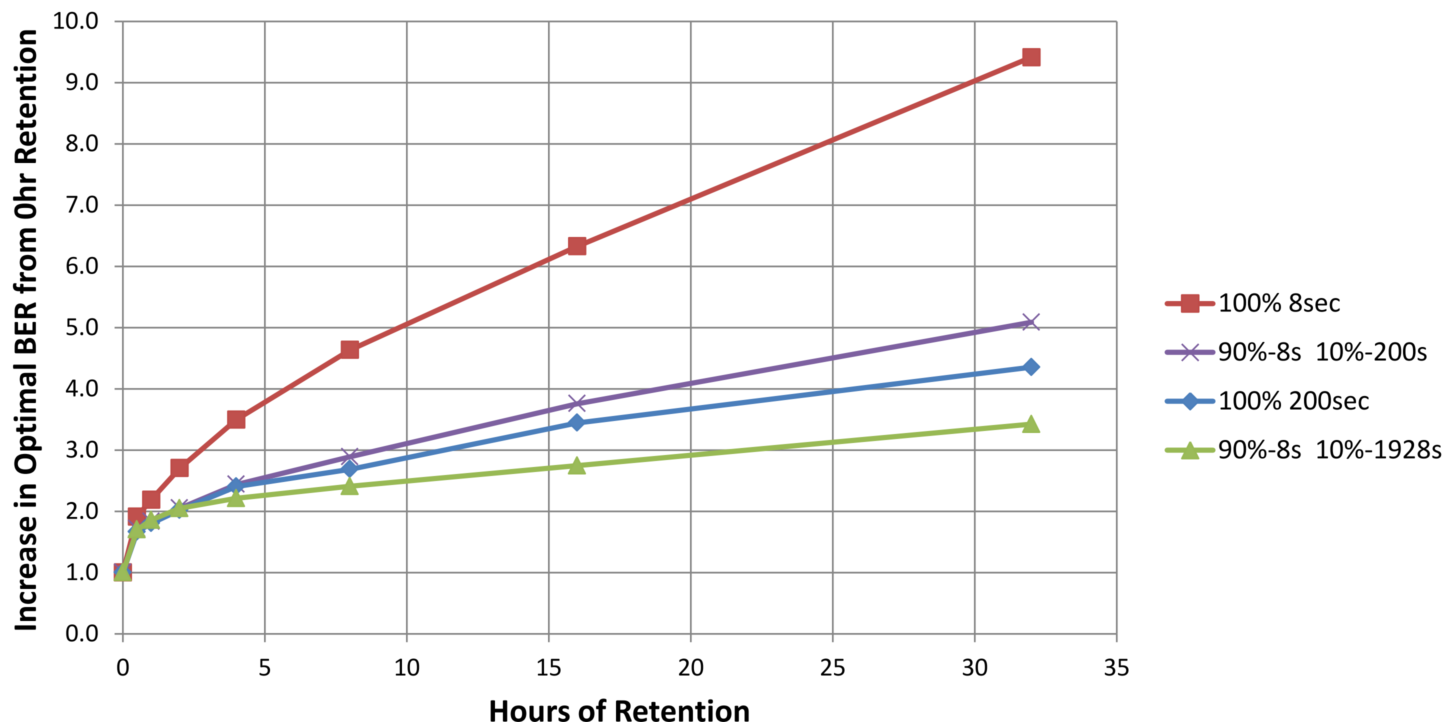


- Both absolute BER & threshold shift vary with dwell
  - The healing from long dwell after 4500 PE is significant.

BER VS RETENTION TIME & THRESHOLD

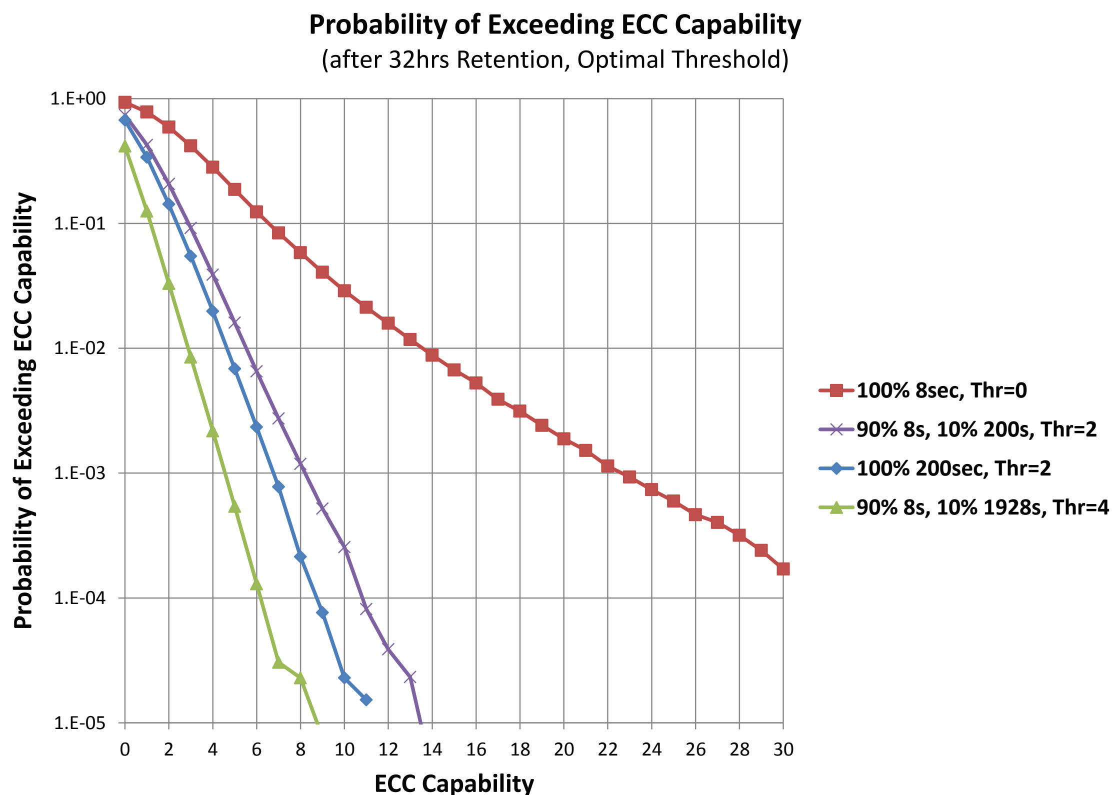


ERROR RATE INCREASE VS RETENTION TIME



- Sensitivity to retention time is a strong function of the dwell
  - Demonstrating retention after short dwell is pessimistic.

PROBABILITY OF EXCEEDING ECC



- Short dwell leads to high probability of long error events that are healed with longer dwell.

SMART STORAGE SYSTEMS
Making NAND Better

CONCLUSIONS

- Short dwell accelerates degrading effects of PE cycling
  - BER margin is diminished by overly broad Vth distributions.
  - Sensitivity to retention is dramatically exaggerated by short dwell
- Maintaining average dwell is not sufficient
  - 90% of the PE's with 8sec dwell followed by 10% with 1928sec dwell was superior to constant 200sec dwell, even though the average dwell was the same
- Drive level endurance demonstrations with short dwell are vulnerable to being overly pessimistic
  - Supporting component data needed to explain the effects of short dwell on the results

SMART STORAGE™
SYSTEMS
Making NAND Better