LCM Modeling for SONOS 3D NAND

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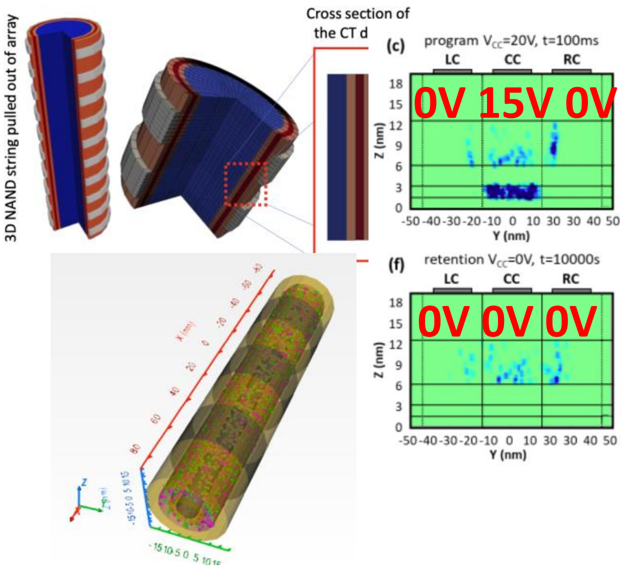
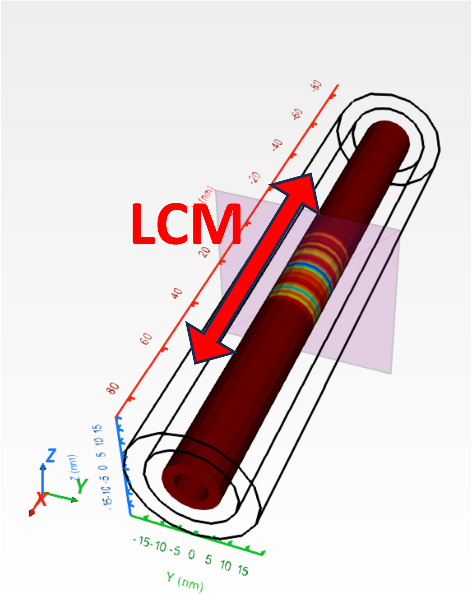
LCM Modeling

- **3D NAND model built on AMAT Ginestra (template from Prasanna*)** pravindran6@gatech.edu
  - Base Device: Cylindrical SONOS 3D CT-NAND
  - Added: LCM model (PGM 1e-2s → Retention 1e4s)

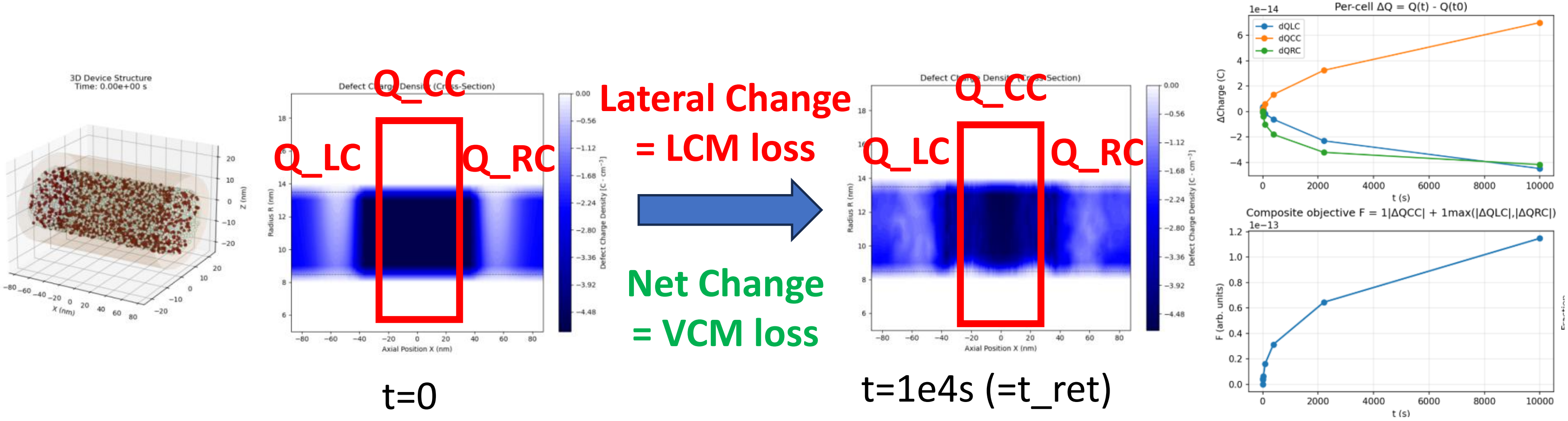




* Work based on IRPS 2019 (A. Padovani et al.) Understanding and Variability of Lateral Charge Migration in 3D CT-NAND Flash

LCM Modeling

- **Retention loss** is defined as **defect charge density** $Q = \int \rho_{def}(r,t)dr$
  - Direct Retention prediction available using the defect charge density ratio
  - Defined by:
    - **Q_VCM = |Q_total(0) - Q_total(t_ret)|**
    - **Q_LCM = |Q_LC(t_ret)+Q_RC(t_ret)| - |Q_LC(0)+Q_RC(0)|**
  - → **Minimize Q_Loss = α ∗|dQcc(t_ret)|+ β ∗ Q_LCM**



LCM Modeling

- **Data Synthesis Structure (5*3*3=45 sweeps, ~2hrs per each node)**
  - **Variables (according to IRPS 2019):**
    - **1. Tunnel layer Thickness**
      - t_TL = 2, 2.5, 3, 3.5, 4nm to
    - **2. PGM voltage**
      - V_PGM = 10, 15, 20V
    - **3. Cell Spacing**
      - L_sp = 20, 25, 30nm → **Observe change in neighboring cells**
  - **→ Accelerated Design Space Exploration & Retention Loss Optimization**

Loss = $\alpha *$|dQcc(t_ret)|+ β $*$ Q_LCM
w.r.t. {t_TL, V_pgm L_sp}

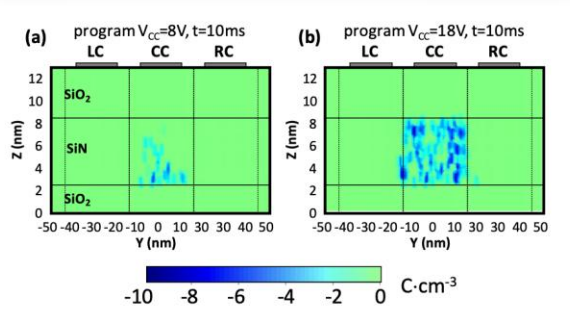
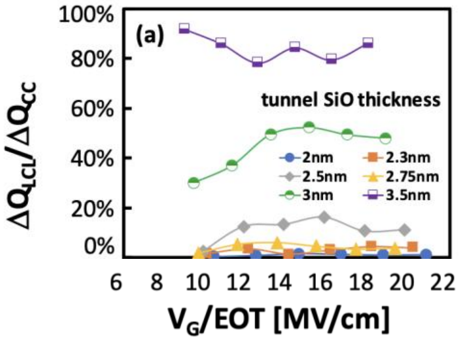


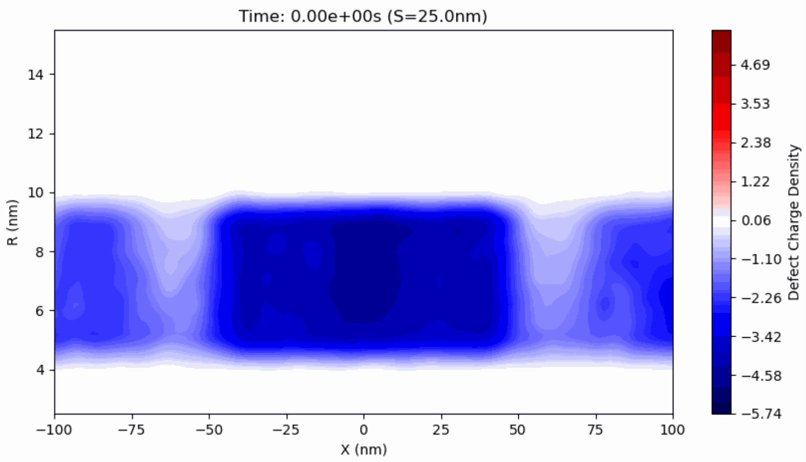
Fig. 8. Trapped charge distributions obtained from the simulation of a device with nominal stack after (a) 8V and (b) 18V program operation.

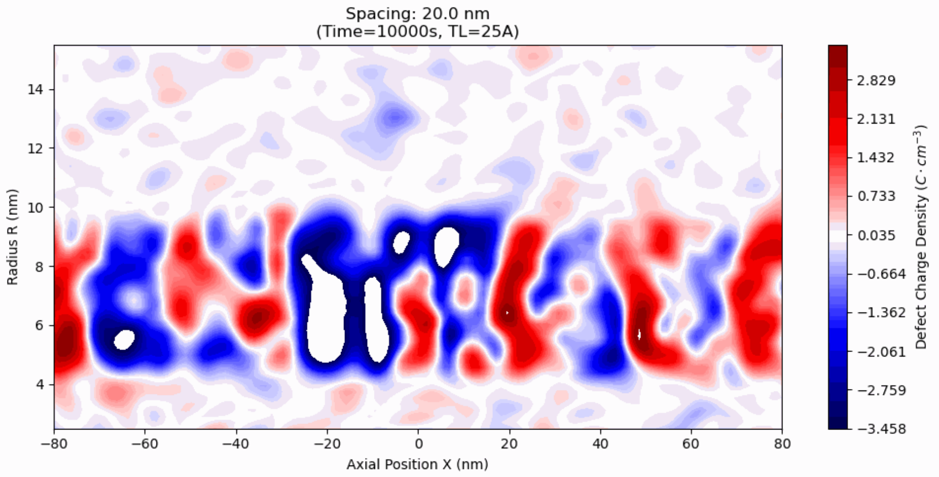
Thick t_TL suppresses VCM → LCM dominant



LCM Modeling

- **Accelerated Design Space Exploration**
  - **Interpolation visualization available**
  - **Time advantage: 2hrs per sweep vs. inference less than milliseconds**

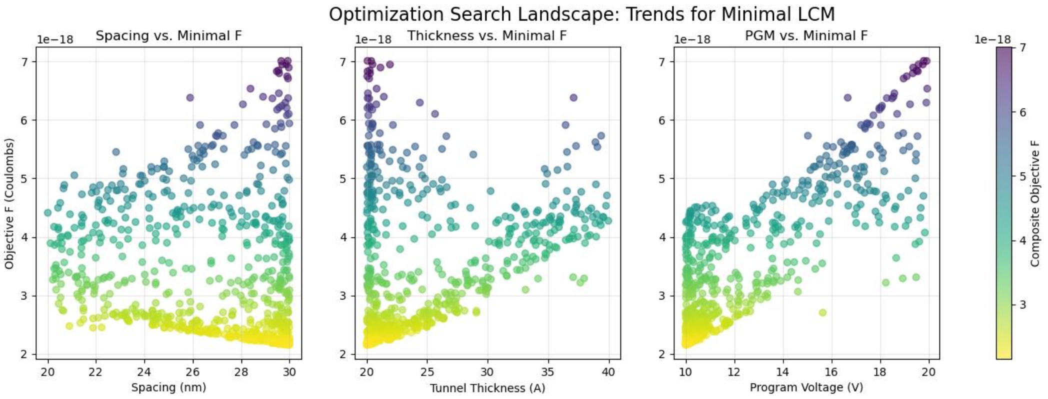


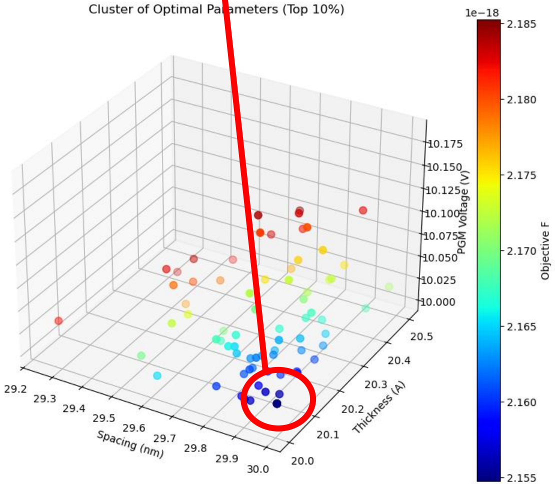


LCM Modeling

- **Retention Loss Optimization**
  - Interpolation visualization available
  - Can use this framework for Non-linear variables optimization

Spacing	TL	PGM	Loss
29.986683nm	20.020785am	10.018136V	2.154765e-18





Variables (according to IRPS 2019):

1. Cell Spacing → Wide Spacing: Prevent LCM
2. Tunnel layer Thickness → Thick t_TL: LCM ratio (dQlcl/dQcc) increases
3. PGM voltage → High PGM: LCM dominant