Flash Memory Summit

Process Challenges for 1S-1R Crossbar Memory

W. Kim, M. Frei and M. Pakala

APPLIED MATERIALS

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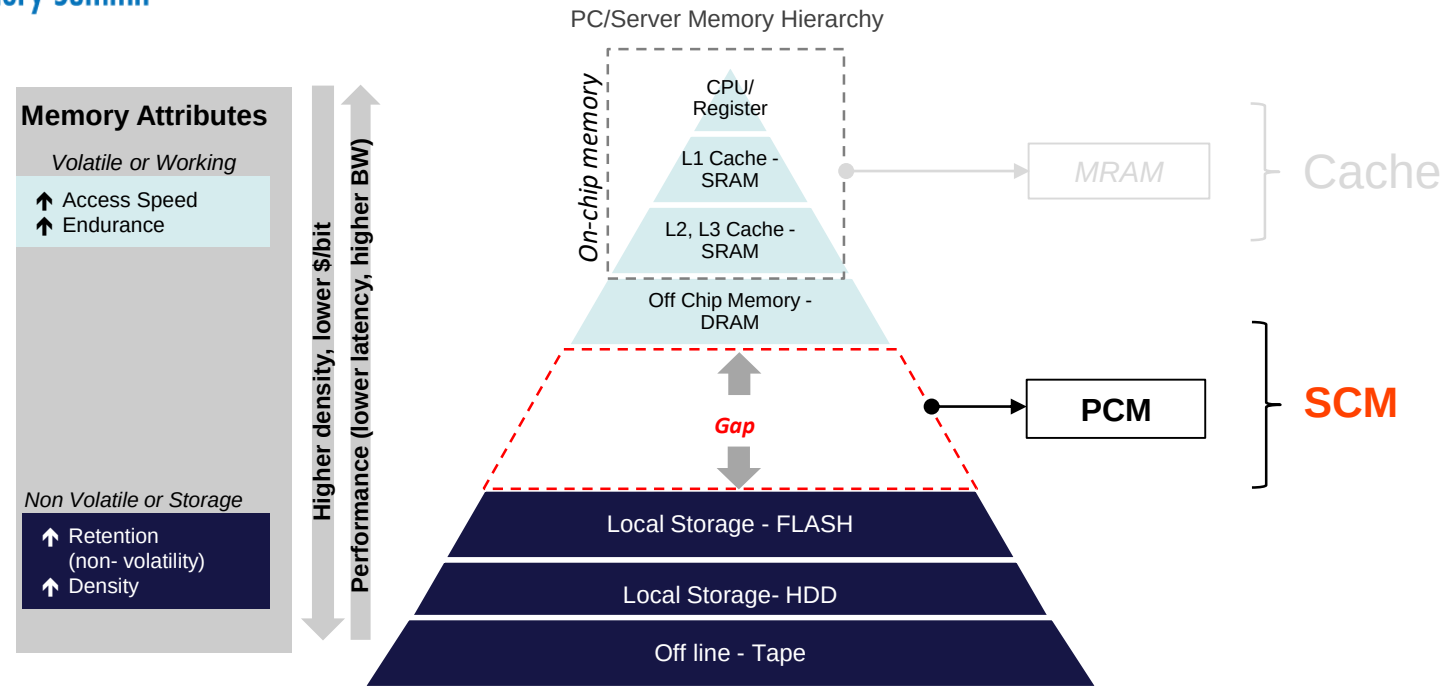
OUTLINE

- Background
- Crossbar Memory as Storage Class Memory (SCM)
  - Chalcogenide Materials: PCM, OTS Selector
  - Crossbar patterning status
- Summary and Outlook

New Memory Inflections Address Memory Gaps



PCRAM is non-volatile and faster than flash

Integration Schemes for New Memory

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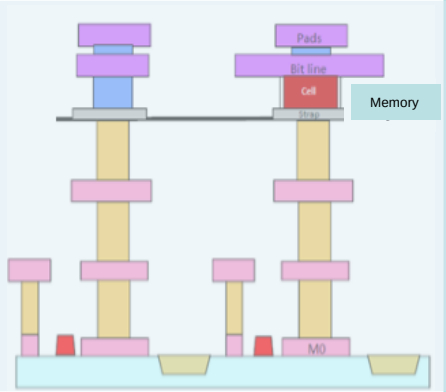
Embedded in BEOL

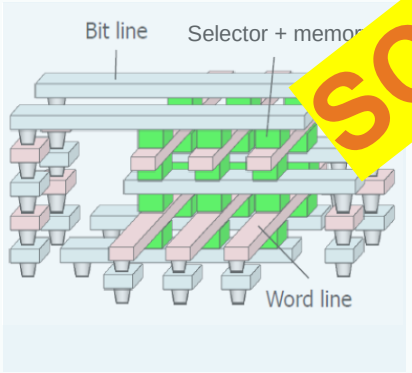
1T-1R



Bottom Electrode Contact, 400°C BEOL thermal budget, Etching & LT Encapsulation

Crossbar Memory

1S-1R

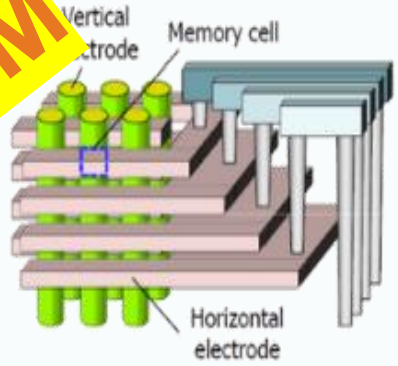


SCM

Damage free etching at < 60nm pitch

3D Strings

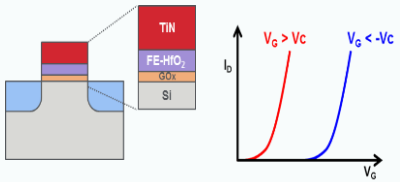
1S-1R, 1T



ALD of complex compounds/alloys

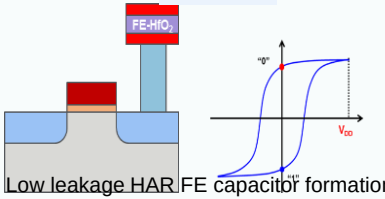
Others

1T



Thermal budget (FEOL integration)

1T-1C

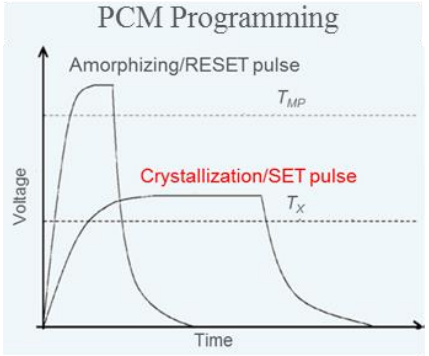


Low leakage HAR FE capacitor formation

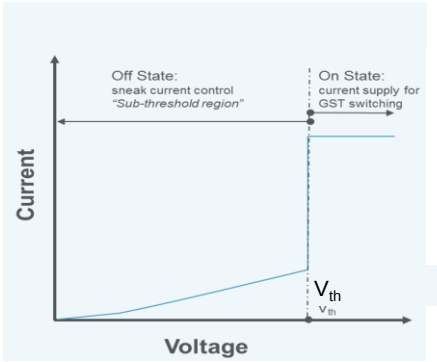
New materials and integration schemes – have new process & equipment requirements

Materials Optimization For Performance

- PCM (example)
  - Reduce **SET time** for crystallization
  - Lower RESET/SET **energy**
  - Increase **Memory Window**



- OTS Selector
  - Increase I_{ON}/I_{OFF} ratio
  - Lower I_{OFF} current
  - Increase cycling **endurance**
  - Reduce amorphous chalcogenide V_{th} **drift**
  - Improve high temperature **stability**



Composition Screening by Multi-Cathode PVD

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Desired Composition Matrix

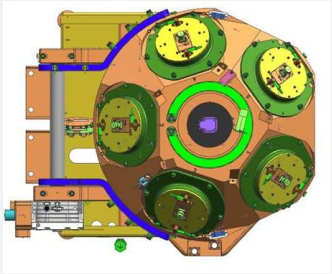
13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07
31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96
49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6

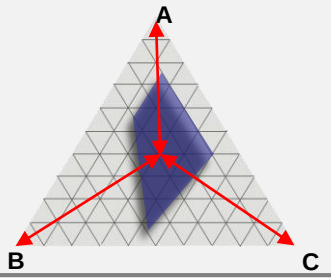
Chalcogen atoms

Control thermal and electrical properties by additives:

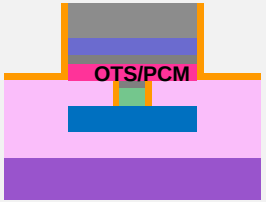
Ge, Si: Cross linking
As: Stabilize amorphous state

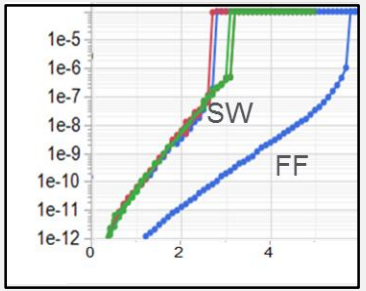
Multi-cathode PVD Co-sputtering





Short Loop eTest



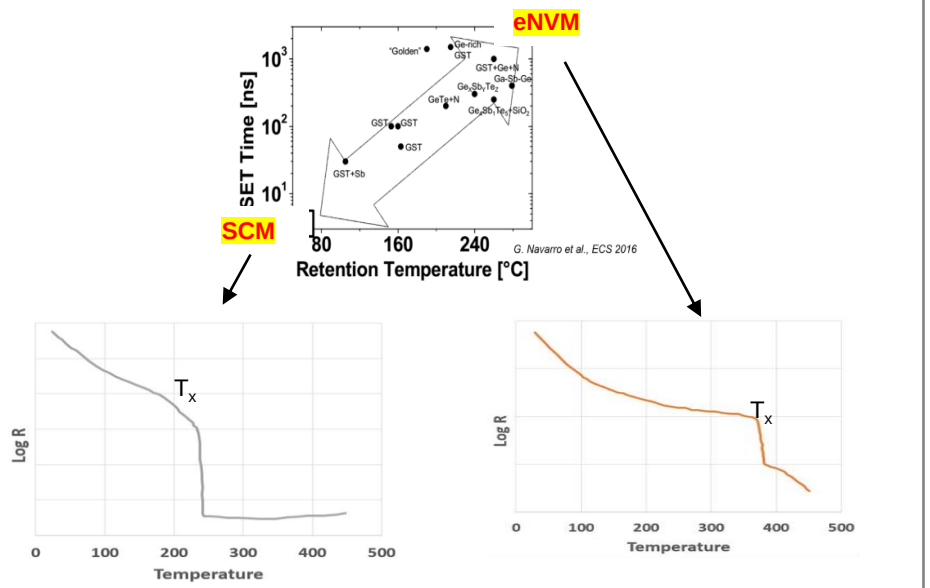


Multi-cathode for fast composition screening of multi-elemental chalcogenides

APPLIED MATERIALS

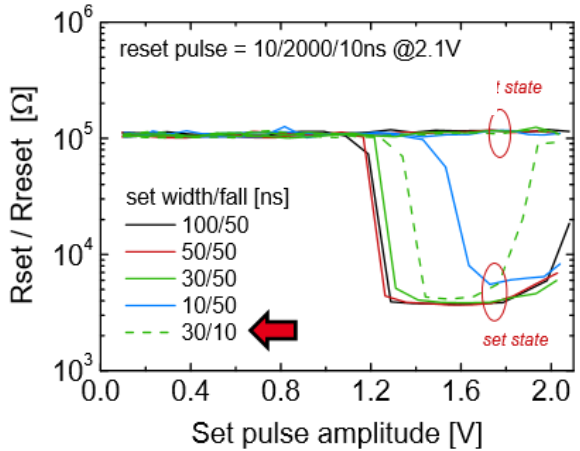
PCM Composition Optimization

Composition study by co-sputtering for different device targets



LETI-AMAT JDP 2015, 2017

SET at < 50ns pulse width achieved



LETI-AMAT JDP 2017

PCM composition optimization to address fast SET required for SCM application

OTS Composition Optimization

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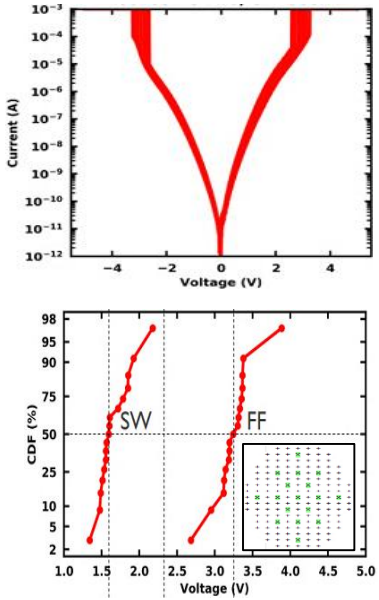
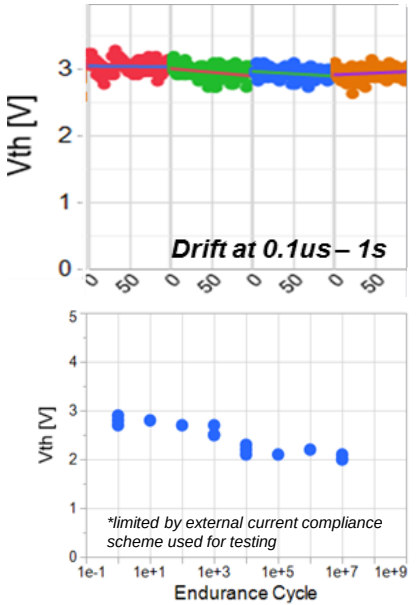
V_{th} distribution across 300mm wafer



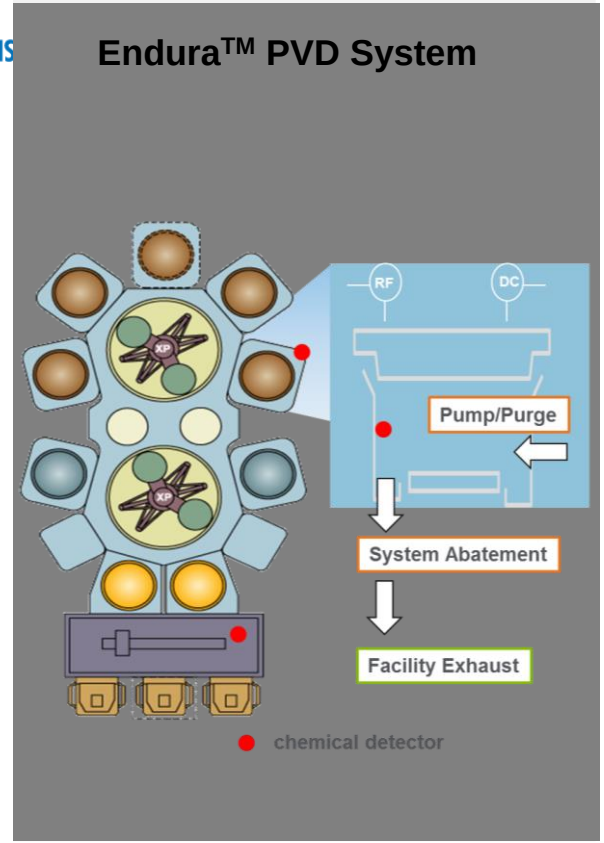
V_{th} drift / cycling endurance*



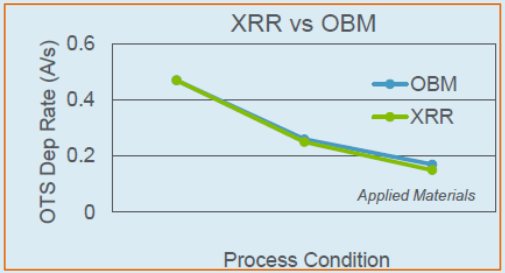
OTS composition optimization for low V_{th} drift

APPLIED MATERIALS

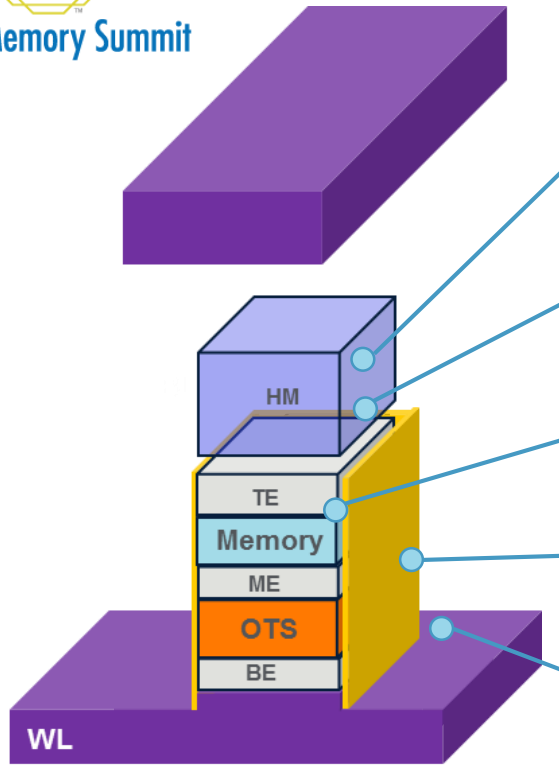
Equipment Challenges for PCM



- Safe handling of Arsenic containing composite deposition, wafer handling and maintenance
- Composite Sputter – Pulse DC PVD or RF DC PVD
  - Deposition of materials with high resistance and poor thermal conductivity, fragile/easily thermally mechanically fractured
  - Compositional uniformity within wafer and within kit life
  - Targeted film properties – low roughness, high density, low stress,
  - Minimal plasma damage and intermixing of materials
  - Low resistance / smooth barrier layers
  - Low defectivity
- Integrated processes
  - Surface Preparation
  - Bottom, Middle and Top Electrodes
  - Switch and Memory Layers
  - On-Board Metrology
- Performance and Productivity expected for HVM PVD

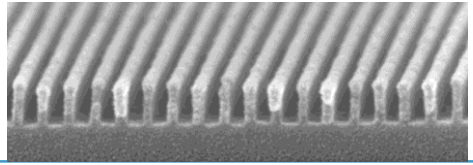


Crossbar Integration Flow and Process Equipment



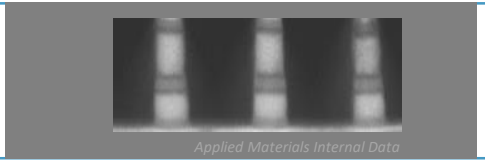
1 level schematic

- Precision In-situ Oxide / Poly

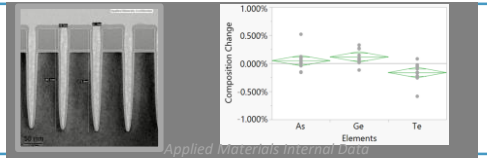


- Producer High Density SiN

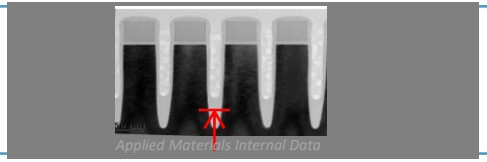
- Non-volatile Etch



- Celera SiN



- Low temp gap fill FCVD



Low damage processes key focus for integrating chalcogenide materials

Summary

- 1S-1R crossbar architecture and, 3D string architecture with PCM suitable for SCM application
- Etching and encapsulation of chalcogenide materials, without inducing damage (chemical, plasma and thermal), is key challenge for 1S-1R crossbar scaling
- Applied Materials focusing on High Volume Manufacturing Equipment that enables 1S-1R crossbar device performance, yield and cost. Multiple tools shipped