

Advanced Characterization of Memristors

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New AC-STEM At Sandia (~\$4M)

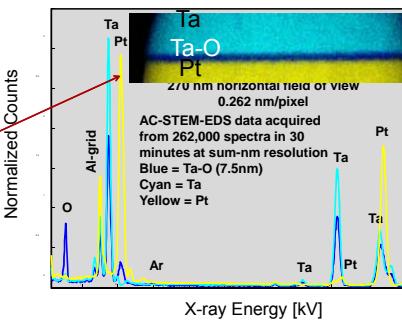
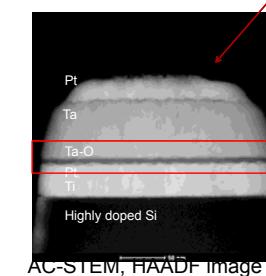
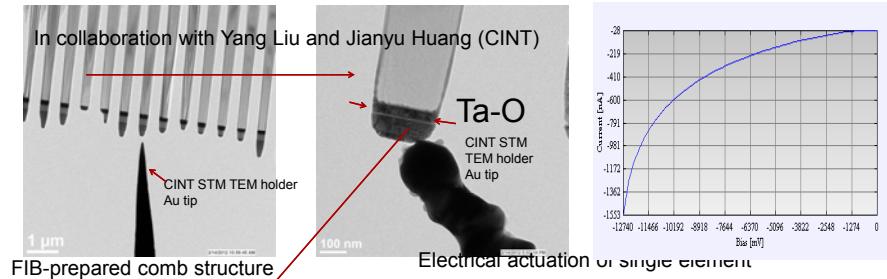


Room modifications (~\$700k)

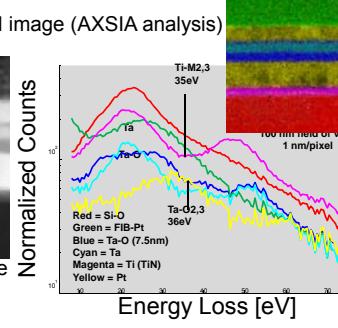
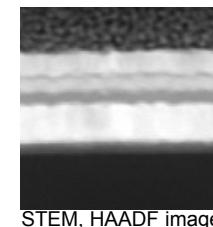
- Temperature stability of $0.1^{\circ}\text{C}/30$ min with low airflow
- Low EM fields, low floor vibrations, quiet

Microscope (~\$3.2M)

- Funded by Readiness in Technical Base and Facilities RTBF Program Office (MS&T ERC recommendation helped)
- Resource for both NW and S&T
- Super analytical tool, 50-100x better than other systems at Sandia
 - High-brightness Shottky emitter
 - Three condenser lenses
 - CEOS D-COR Cs probe corrector. Corrects:
 - Out to fourth-order aberrations
 - Fifth-order spherical aberration
 - Six-fold astigmatism
 - Array of four windowless silicon-drift energy-dispersive x-ray spectrometers (0.7sr)
 - 0.8Å STEM resolution at 200kV
 - 1.2Å STEM resolution at 80kV
 - Other detectors, STEM (4), CCD (3), EFTEM/EELS

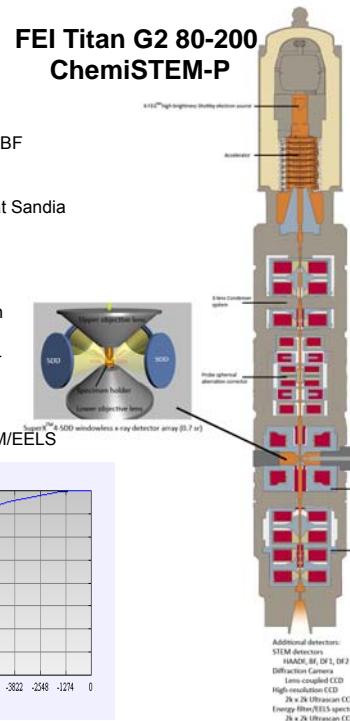


EELS Low-loss spectral image (AXSIA analysis)



Preliminary EELS measurements demonstrate unbiased characterization of the memristor structure

Memristor NTM LDRD FY 12-14

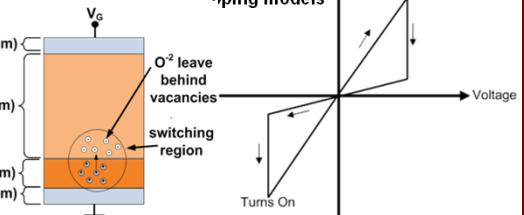


- The Memristor or Resistive/Redox RAM (RRAM) is one of the most promising replacements for Flash, DRAM, and even SRAM memories

- Poor physical understanding of switching action has limited the use of this technology
- Problem: Insufficient understanding of switching mechanism**

- Current working theories:**

- Conductivity modulated by O^2 anion migration
- Filament formation
- Donor or electron hopping models



Characterization Plan

- Initially HP fabricated materials
- First SNL materials currently being fabricated
- AC-STEM ex situ and CINT in situ observations
- HAADF, BF, EDS, and EELS spectral imaging, multivariate statistical analysis

Current development:

- EELS stoichiometry measurements
- Structural/chemical imaging
- In situ actuation followed by high-resolution microanalysis

Conclusions

- Preliminary experiments are promising.
 - In situ measurements
 - Next step better current limiting and demonstrating switching
- Microanalysis development
 - New AC-STEM online for 1.5 mo.
 - Already high-resolution x-ray microanalysis and EELS measurements, structural imaging
 - EELS core-loss spectroscopy
 - O-K and Ta-M stoichiometry
 - Valence state
 - Localized to the sub-nm scale