SAND2012-4992C

Resistive Switching In Aluminum Nitride

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Acknowledgements: Funded in part by Sandia's Laboratory Directed Research and Development (LDRD) program. The authors acknowledge helpful discussions with Patrick Mickel, Robert Kaplar, and Robert Fleming of Sandia National Laboratories.

Introduction

- The Resistive or Redox RAM (ReRAM) is one of the most promising replacements for Flash, DRAM, and even SRAM memories [1]
- Many transition metal oxides exhibit bipolar resistance switching based on two reduction/oxdiation mechanisms [2]
  - Valence change mechanism (VCM) – anion motion
  - Electrochemical change mechanism (ECM) – cation motion
- Search for idea resistance switching material is still underway
- Desire fab compatible, high endurance (>10^{15}), long retention (10 y), high speed (<10 ns W/E) nonvolatile memory
- Resistance switching in aluminum nitride recently discovered [3]-[5]

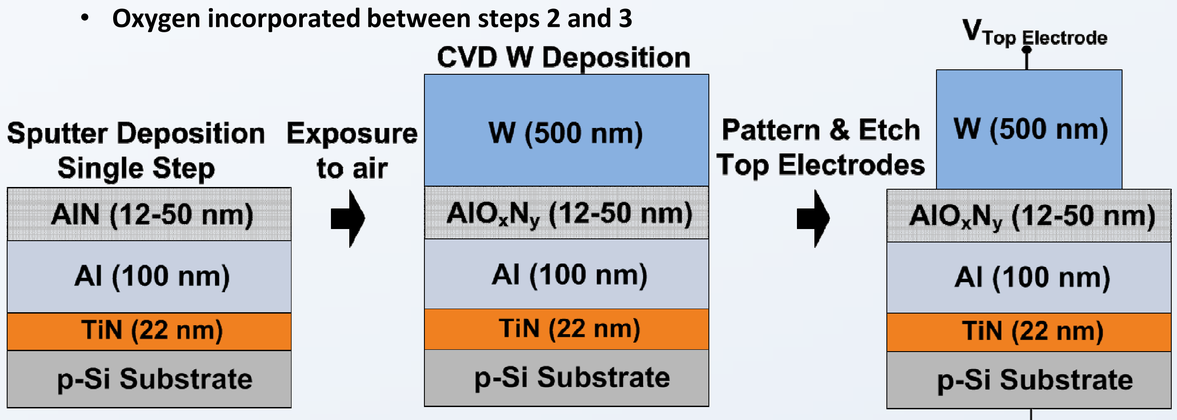
Experimental Details

Fabrication proceedure (illustrated below)

- Fabricated in Sandia's MESA Microelectronics Development Lab on 6 inch silicon wafers:
  1. Deposit blanket TiN with reactive PVD
  2. Deposit Al with PVD @ 350˚C
  3. Deposit AlN with reactive PVD @ 350˚C
  4. Deposit W top electrode
  5. Pattern ReRAM devices
  6. Wet etch W to define device area
  7. Deposit backside Al
- Oxygen incorporated between steps 2 and 3

Electrical Characterization

- Cascade low noise probe station
- Current-voltage (I-V) and pulsing with Agilent 4156C
- Pulsing expander box capable of 1 µs pulse width
- Two terminal connection to $V_{TopElectrode}$ and substrate



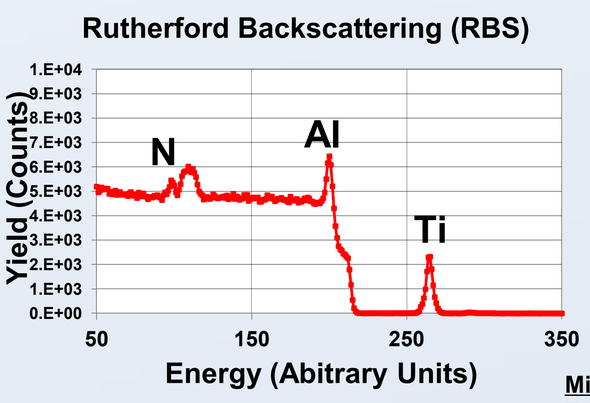
Results – Physical Characterization

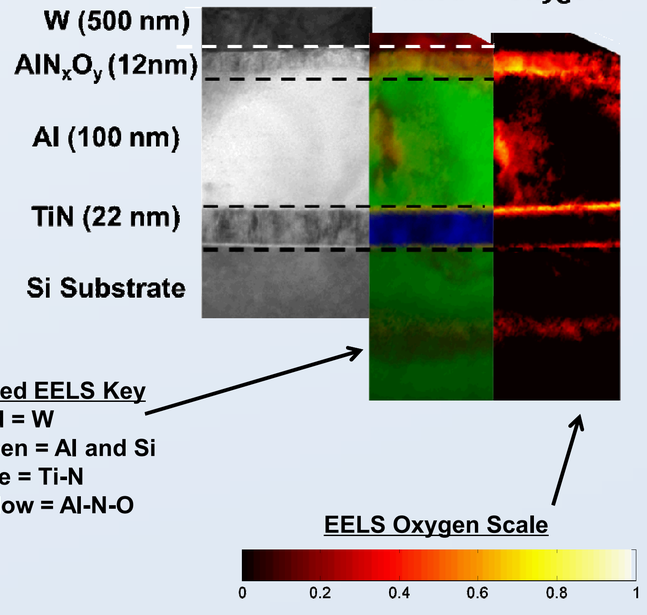
Rutherford Backscattering (RBS)

- Very common elemental analysis technique using an ion beam
- Does not accurately show the incorporation of oxygen in the AlN film
- Secondary ion mass spectrometry (SIMS) (not shown) also gives inaccurate oxygen quantification due to preferential sputtering of light elements

Electron Energy Loss Spectroscopy (EELS)

- Analysis technique used in conjunction with a TEM microscope to analyze chemical composition of a sample
- Excellent spatial resolution
- Used Sandia's FEI Titan Aberration-Corrected TEM
- Shows that our AlN film incorporates oxygen

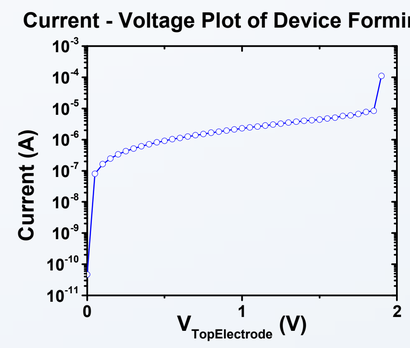


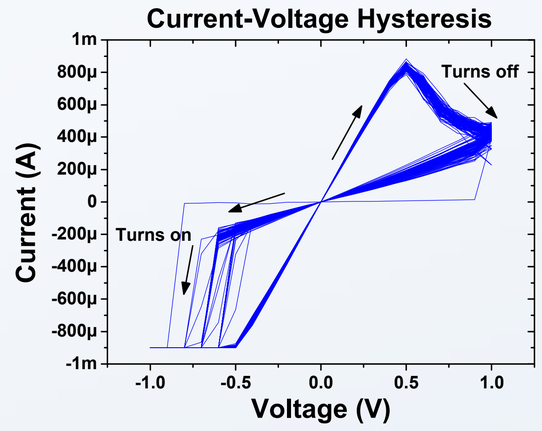


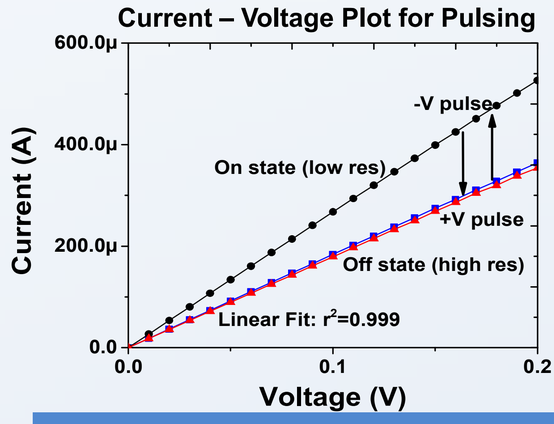
Results – Electrical

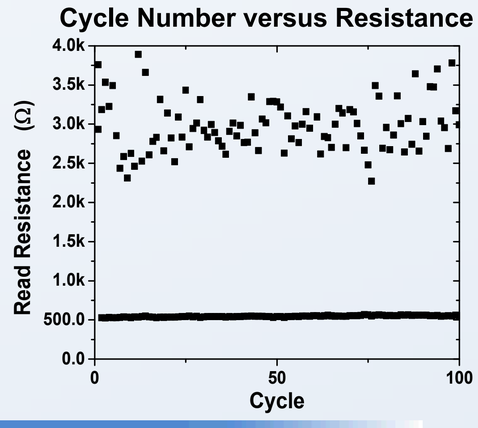
Electrical Characterization

- Positive electroforming at 100 uA
- Highly linear high resistance and low resistance states (HRS, LRS)
- Ohmic conduction
- R_{on}/R_{off} ≈ 6-7





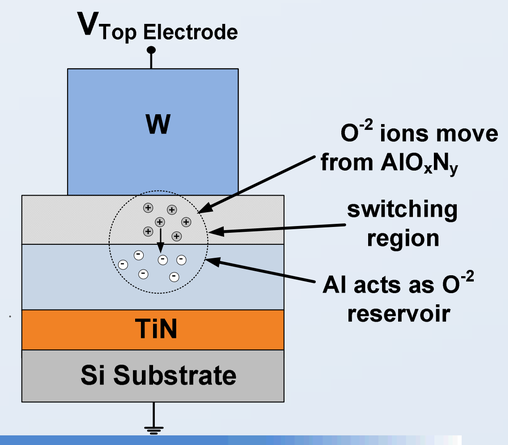




Possible Mechanism

Redox Reaction

- HRS and LRS are highly linear:
  - Ohmic conduction in both
- Electroforming required – fits with redox model
- Nitrogen not mobile in AlN [6]
  - Al is the mobile species
- Oxygen often substitutes for nitrogen in AlN (on the octahedral site)
- Oxygen is highly reactive with AlN
- Oxygen is deep donor in AlN [7]-[8]



Summary

- Resistive switching observed in oxygen doped AlN (AlO_xN_y) films
- Oxygen is most often incorporated into AlN films – this is difficult to prevent
- Oxygen-AlN redox reaction is a strong possibility as a mechanism
  - Oxygen substitution of octahedral N in AlN
- Future work includes investigating temperature dependence, endurance, and effect of oxygen concentration

References

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