Fabrication and Characterization of Ferroelectric Tunnel Junctions with Different Bottom Electrodes

Justin Zwick

Primary Advisor: Dr. Santosh Kurinec

Outline

- Introduction
  - Background
  - Previous Work at RIT
  - Project Objectives
- Fabrication Process
  - Fabrication of FTJs
  - Future Work

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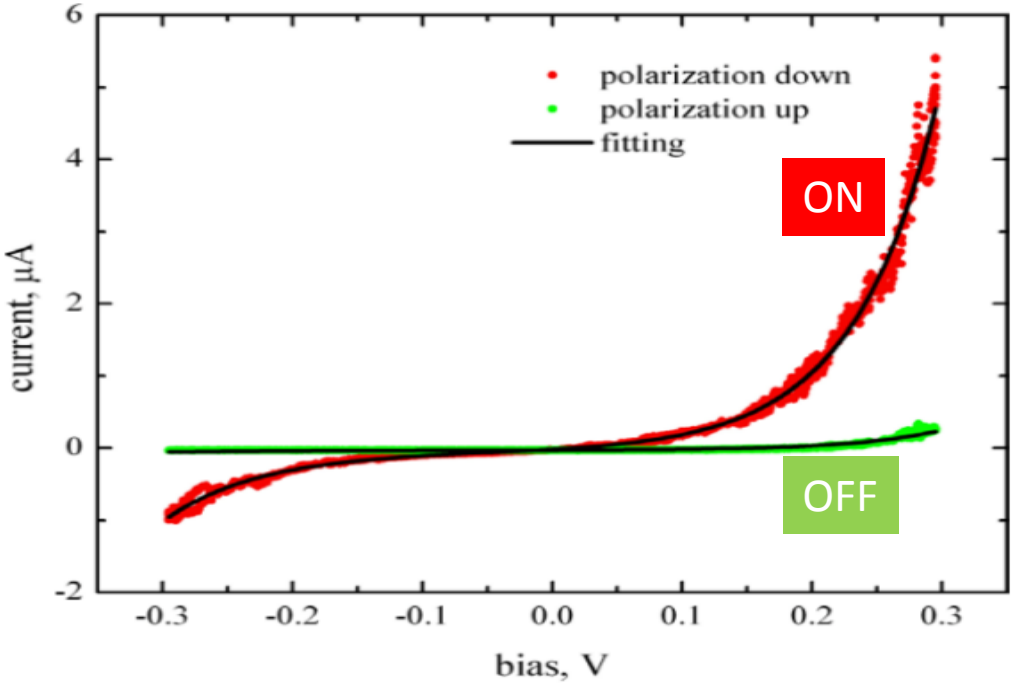
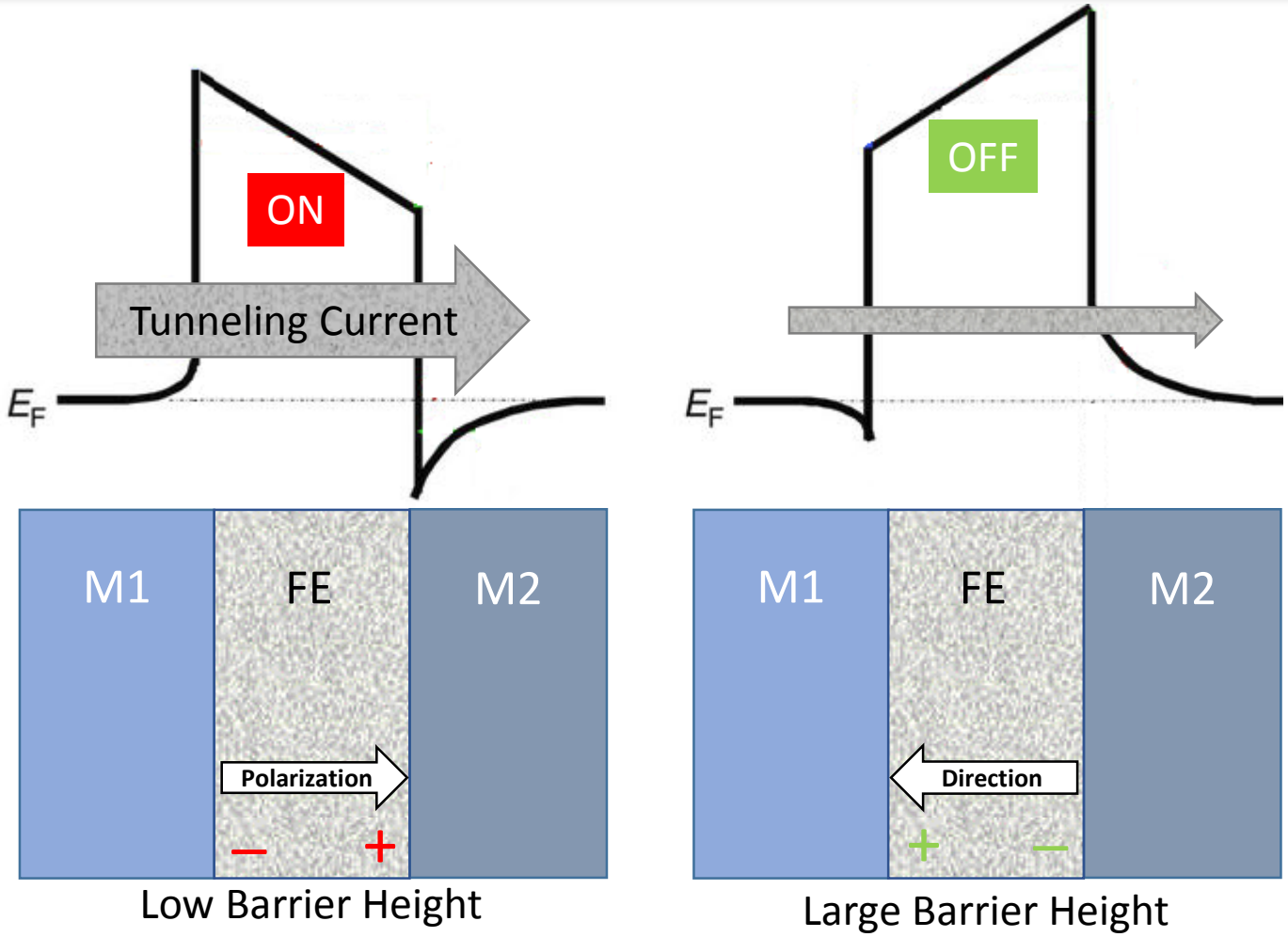
What is an FTJ?

An FTJ is a tunnel junction in which two metal electrodes are separated by a thin Ferroelectric Layer. Switching the ferroelectric polarization induces variations of the tunneling current.

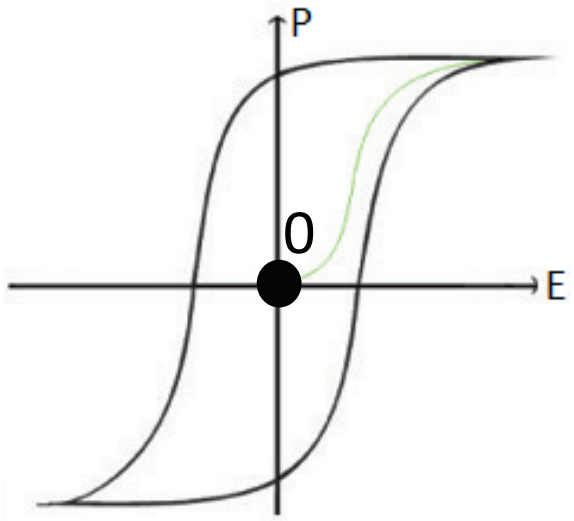


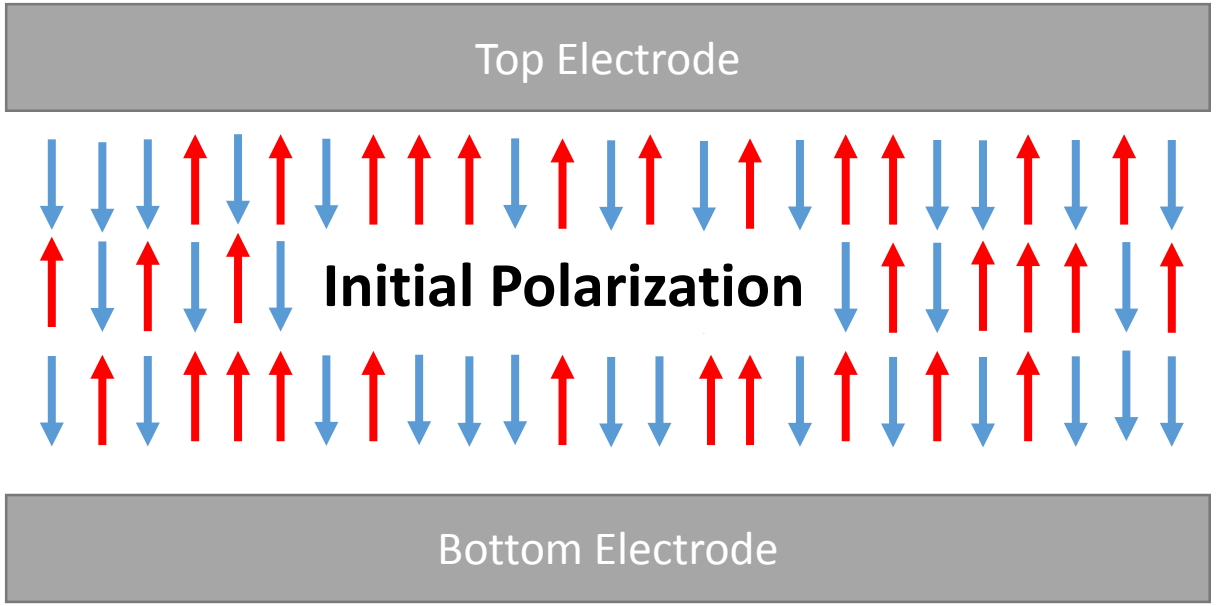
Florent, Karine, "Ferroelectric HfO2 for Emerging Ferroelectric Semiconductor Devices" (2015). Thesis. Rochester Institute of Technology.



What is Ferroelectricity?

- A material is defined as ferroelectric if it has a spontaneous remnant polarization (P_r) that can be reversed by an electric field (E)





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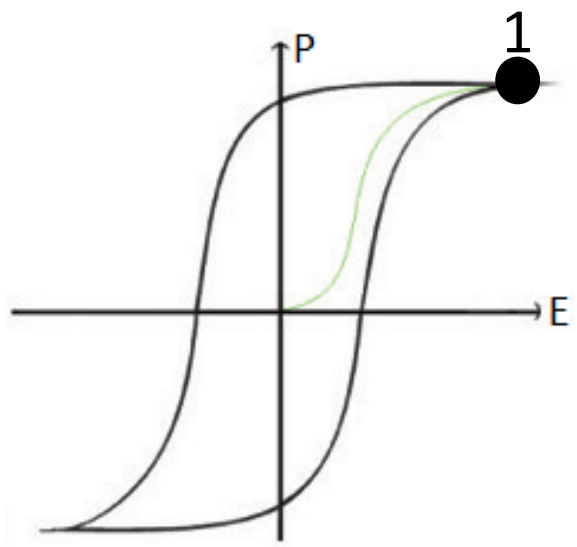
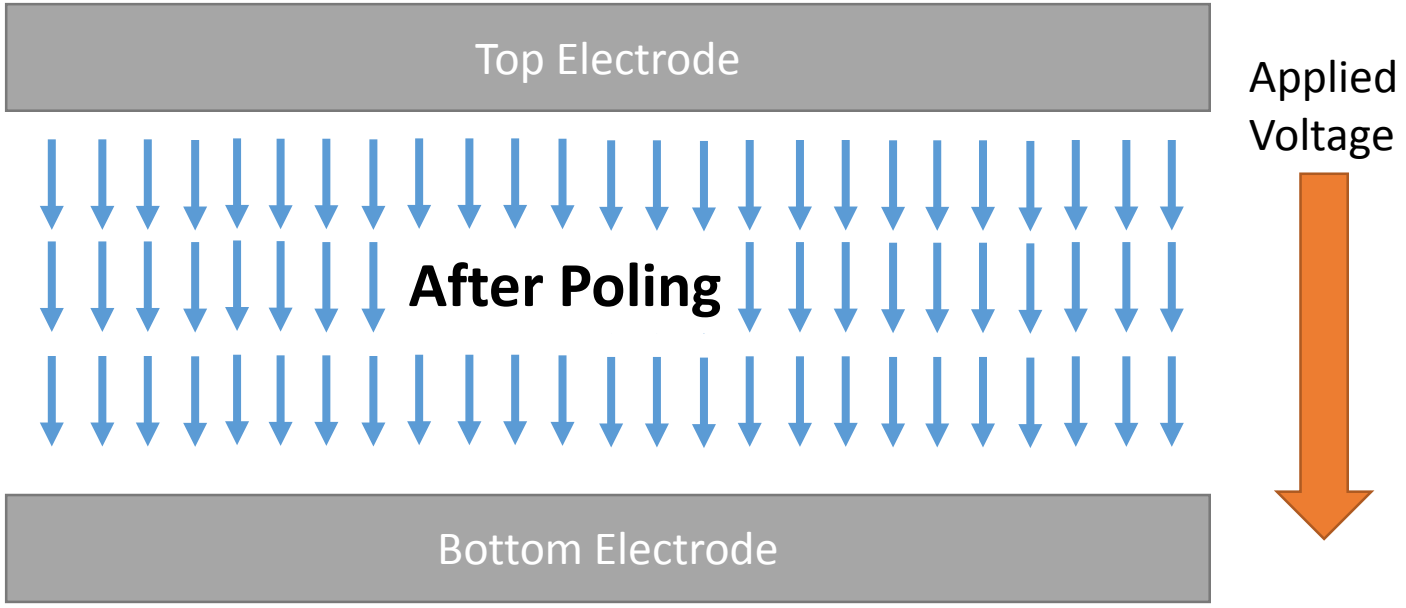
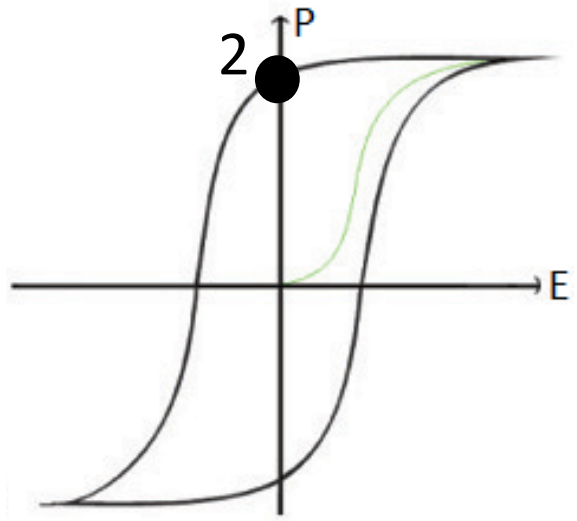
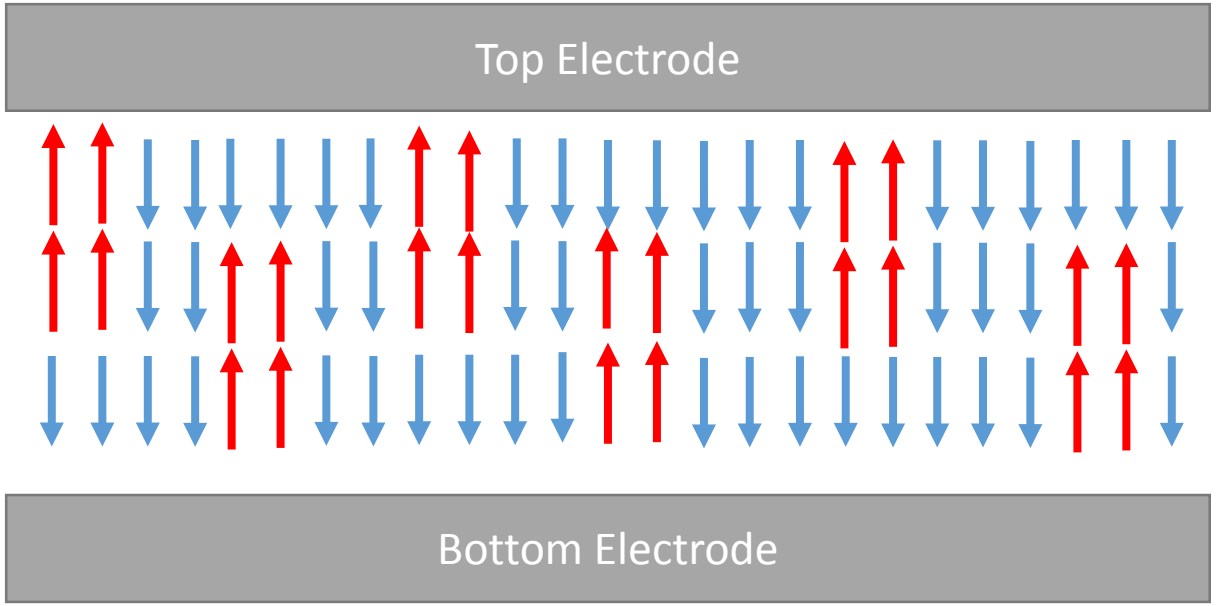




What is Ferroelectricity?

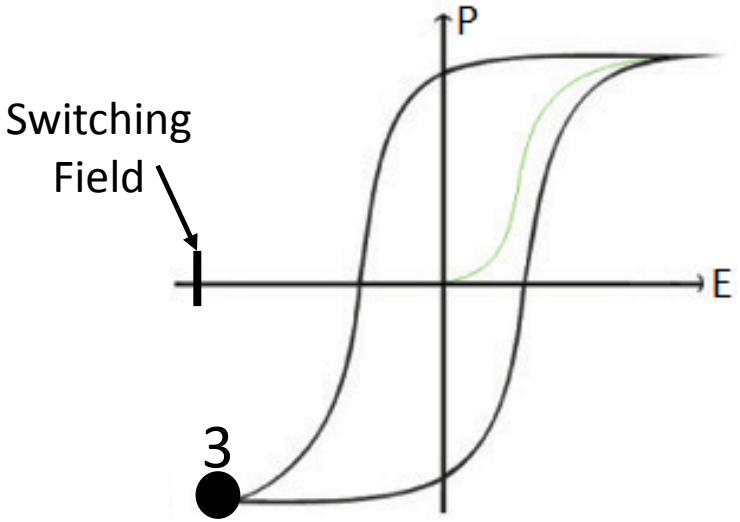
- As you decrease the applied voltage, the polarization begins to flip
- When the electric field is zero, there is a net remnant polarization

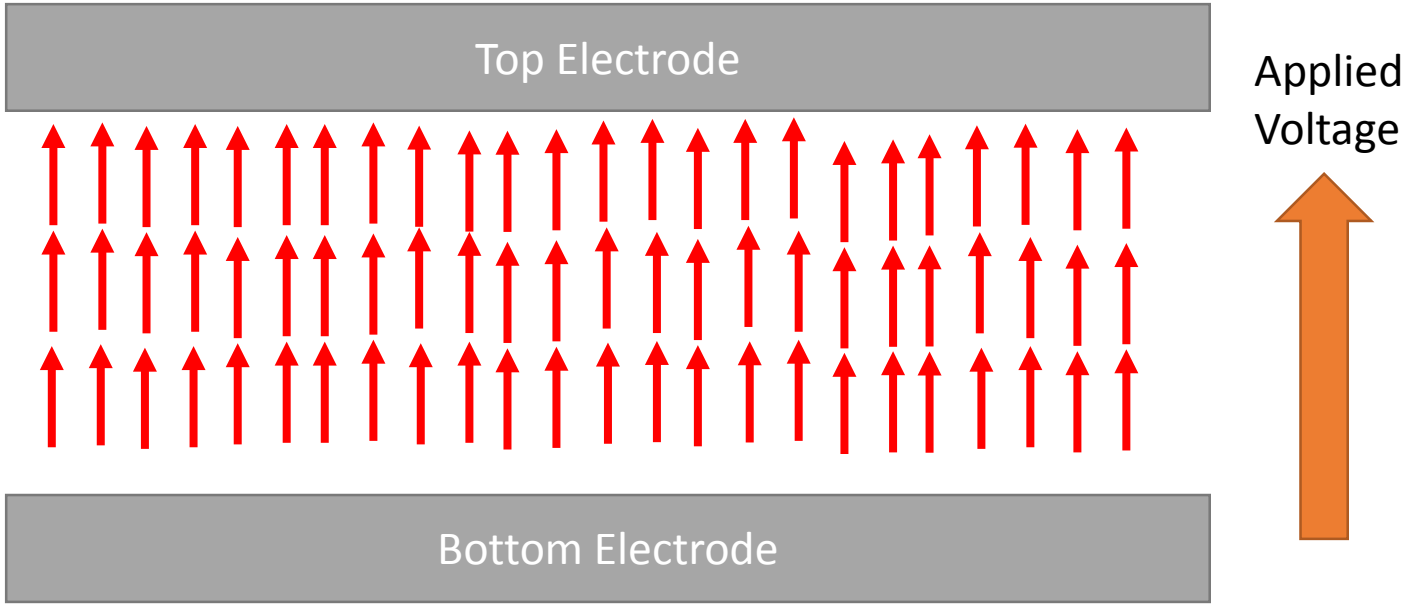




What is Ferroelectricity?

- At the ‘switching field’ the polarization has become entirely reversed
- This ‘ON/OFF’ property is particularly attractive for non-volatile memory and logic applications

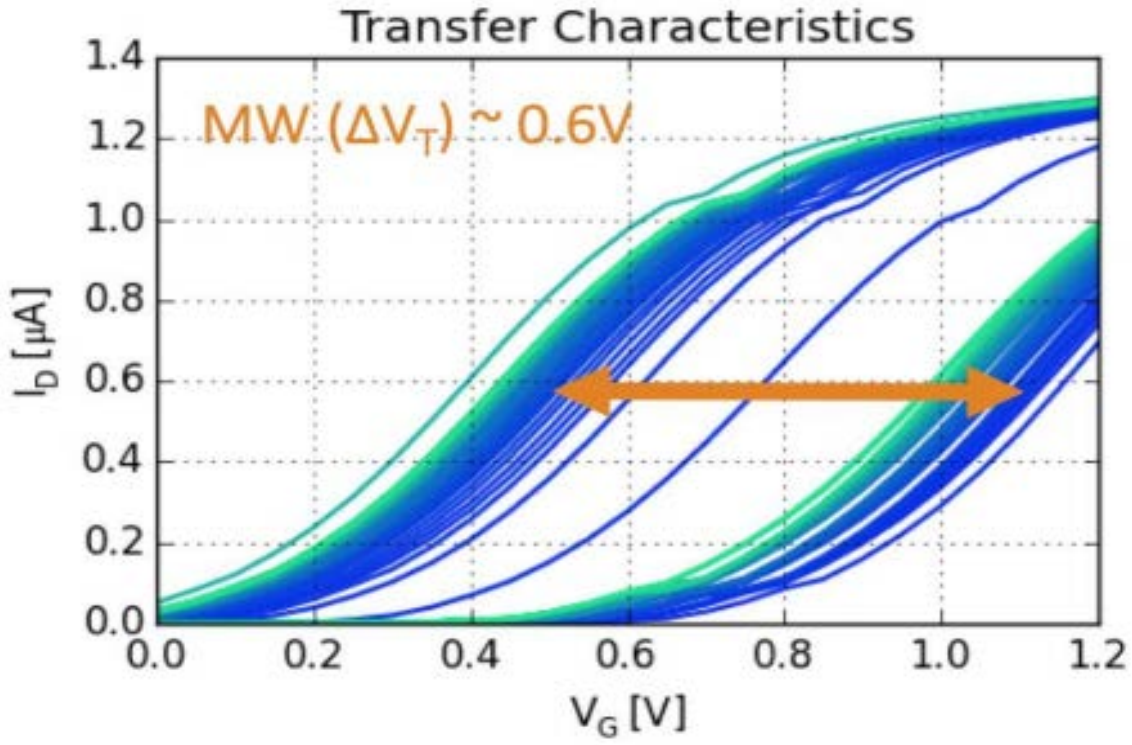




Why Hafnium Oxide?

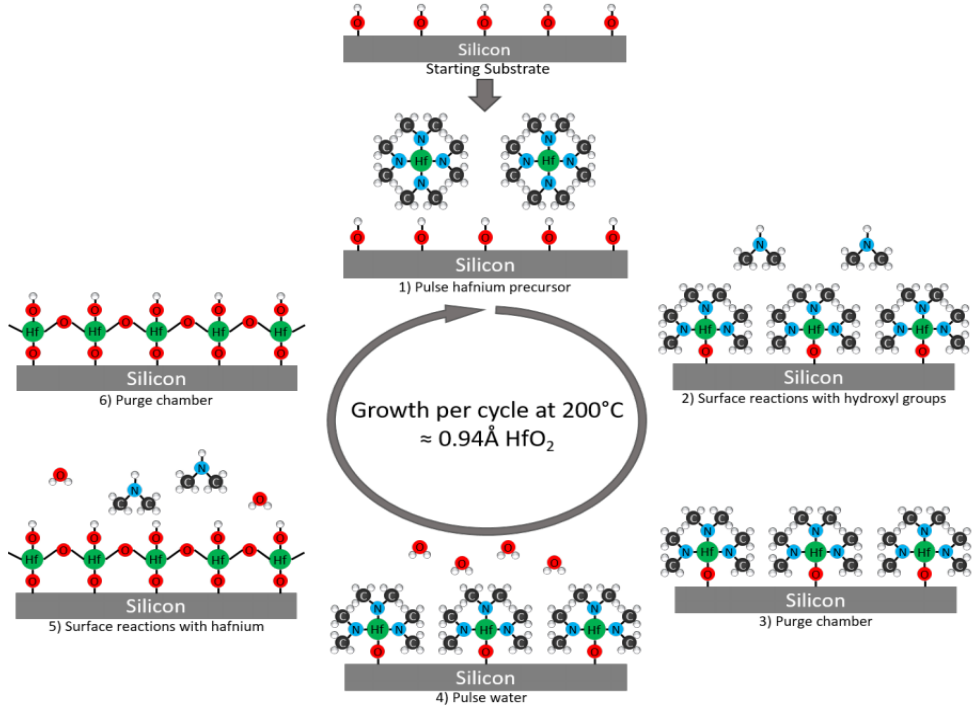
- Hafnium oxide (HfO_2) is a high permittivity dielectric material
- HfO_2 has replaced SiO_2 as the gate dielectric in silicon CMOS
- Its advantages over PZT(Lead Zirconate Titanate) and SBT(Strontium Bismuth Tantalite) include:
  - thin layers, high annealing temperatures, high coercive fields, ALD(Atomic Layer Deposition) capability, and CMOS compatibility
- Doped HfO_2 has been shown to be ferroelectric

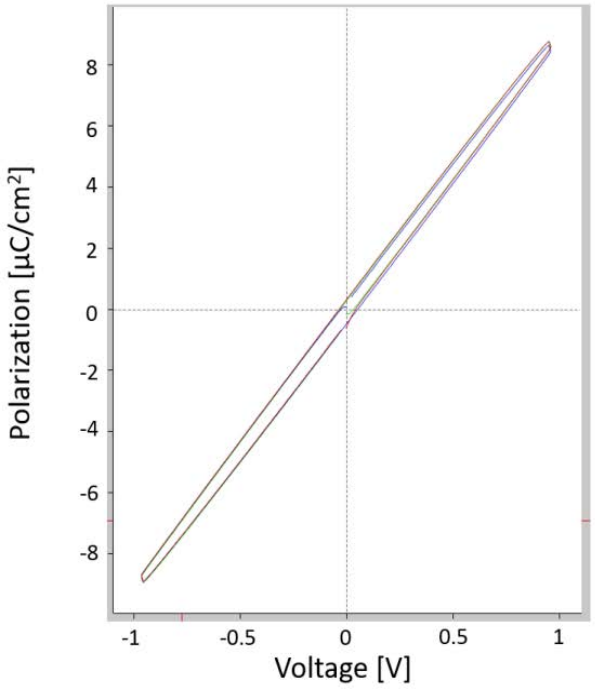
Previous Work at RIT

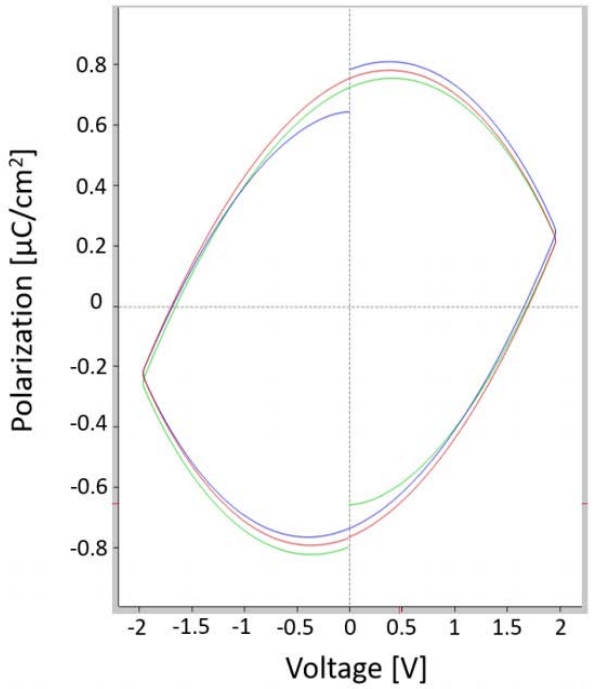


- Ferroelectric silicon doped hafnium oxide (Si:HfO_2) transistors have been fabricated at RIT by Joe McGlone. With the ALD done in Germany.

Previous Work at RIT

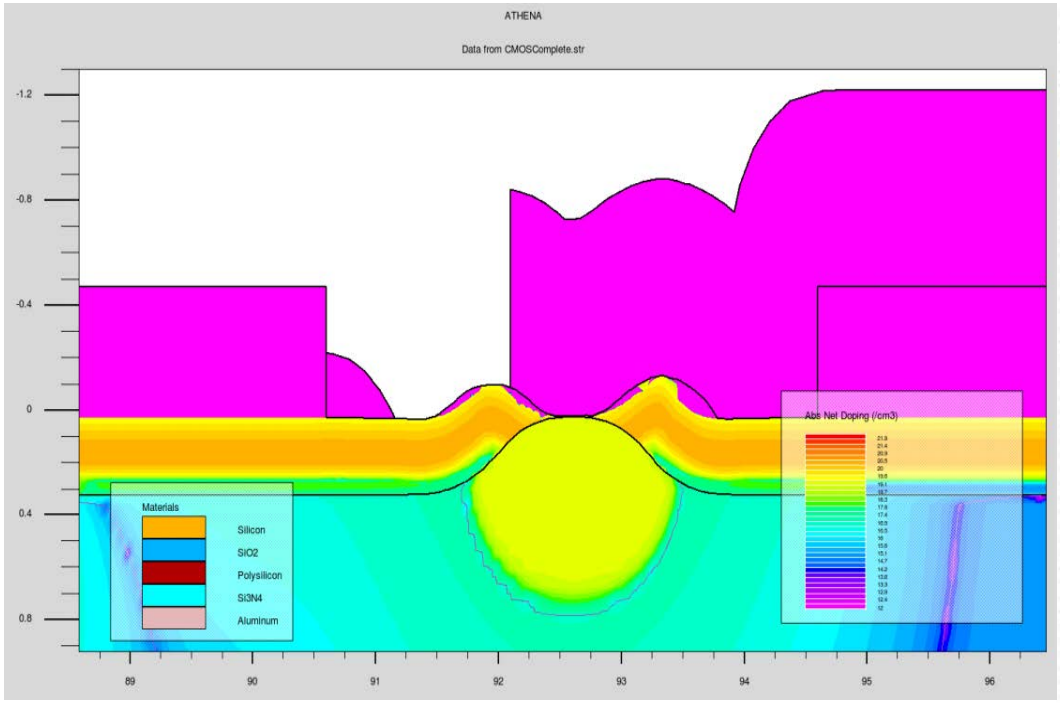


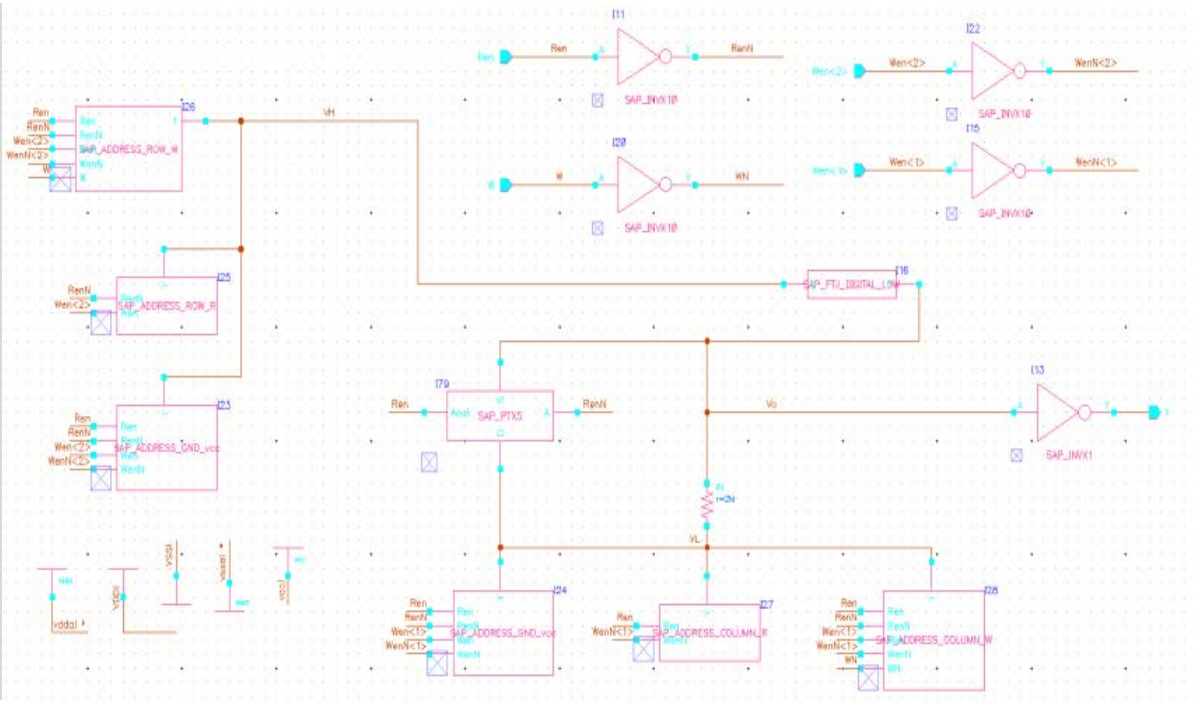




- Casey Gonta developed initial ALD recipes for aluminum doped hafnium oxide (Al:HfO_2) at RIT and characterized their performance. Unfortunately no ferroelectric behavior was found.

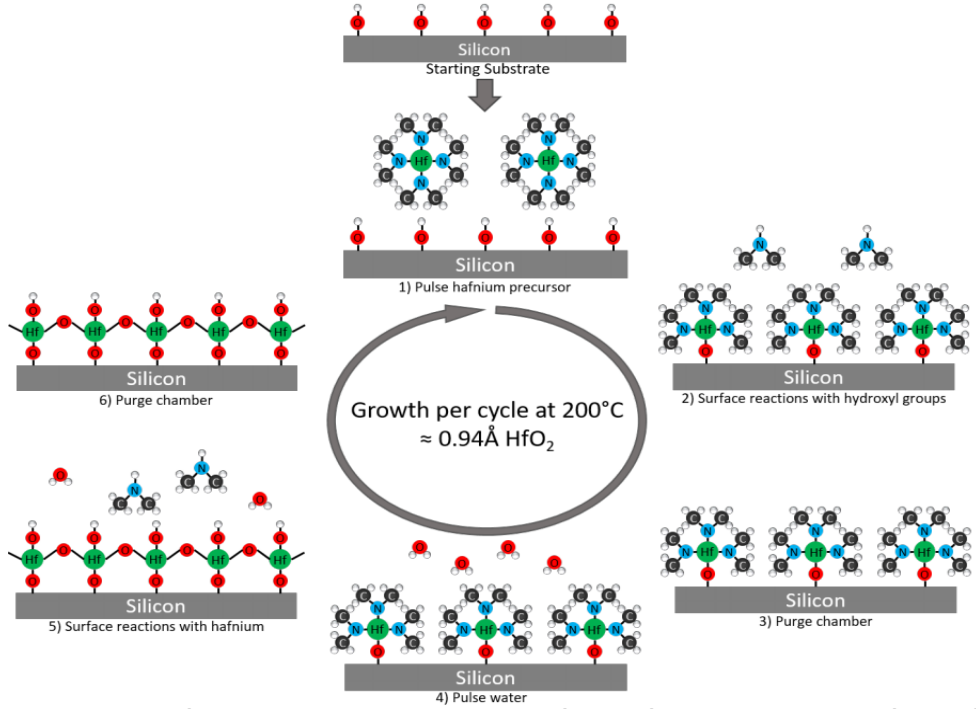
Previous Work at RIT

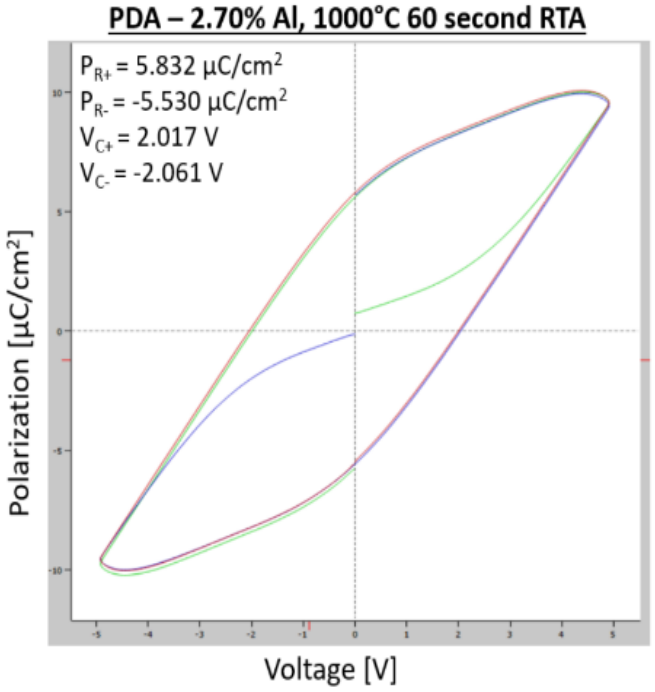


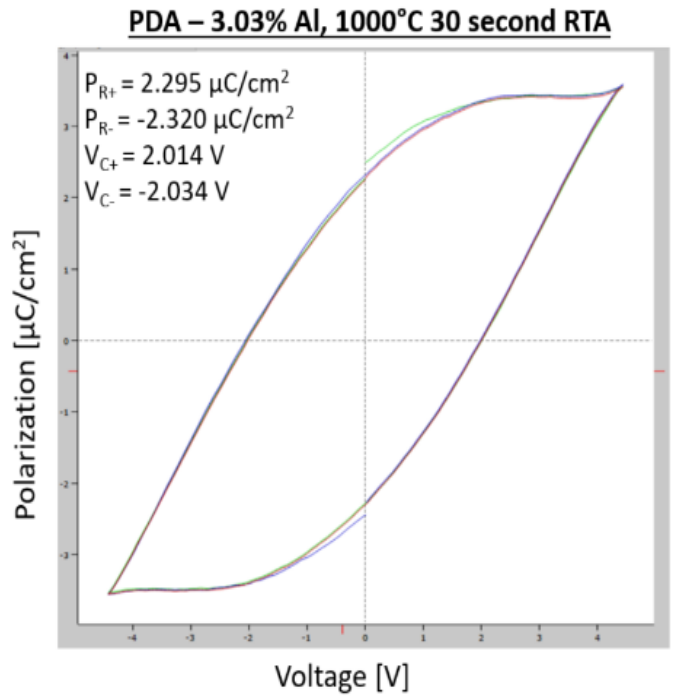


- In-depth modeling of HfO_2-based FTJs and simulation of FTJ memory devices has been done by Spencer Pringle.

Previous Work at RIT





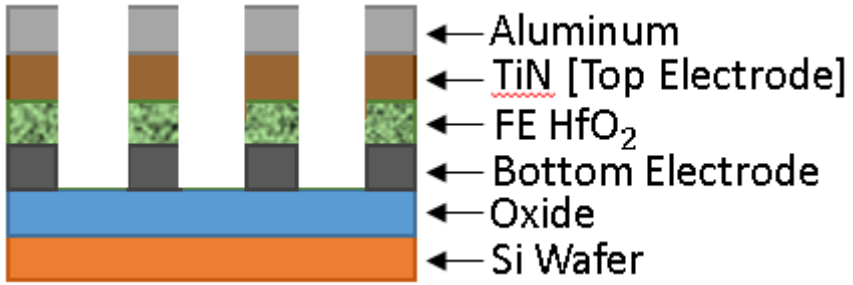


- Further ALD work along with the first demonstration of ferroelectric behavior in aluminum doped hafnium oxide (Al:HfO_2) at RIT by Josh Eschle last week.

Very Exciting!

Project Objectives

Goal: To observe the effects of bottom electrode(BE) material on HfO_2-based FTJ performance by:



- Developing a process flow
- Fabricating the FTJs with different BE material
- Conducting polarization and current testing to see the difference

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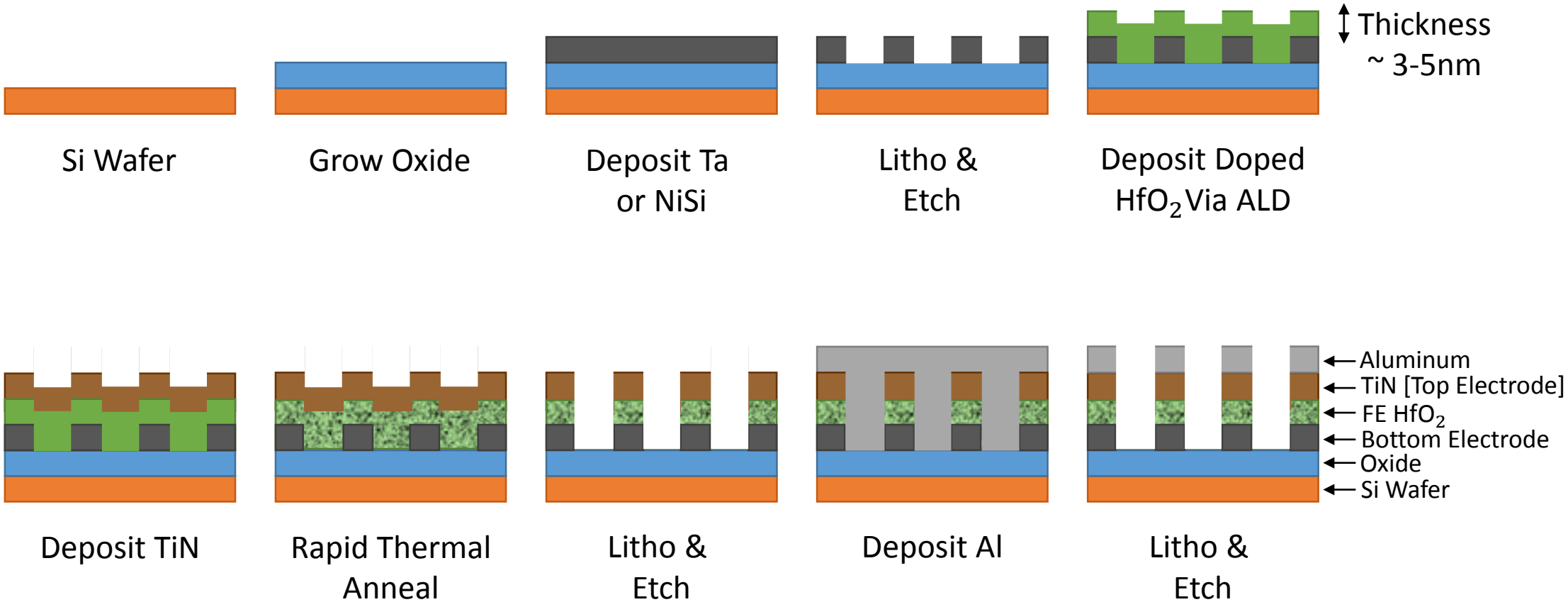
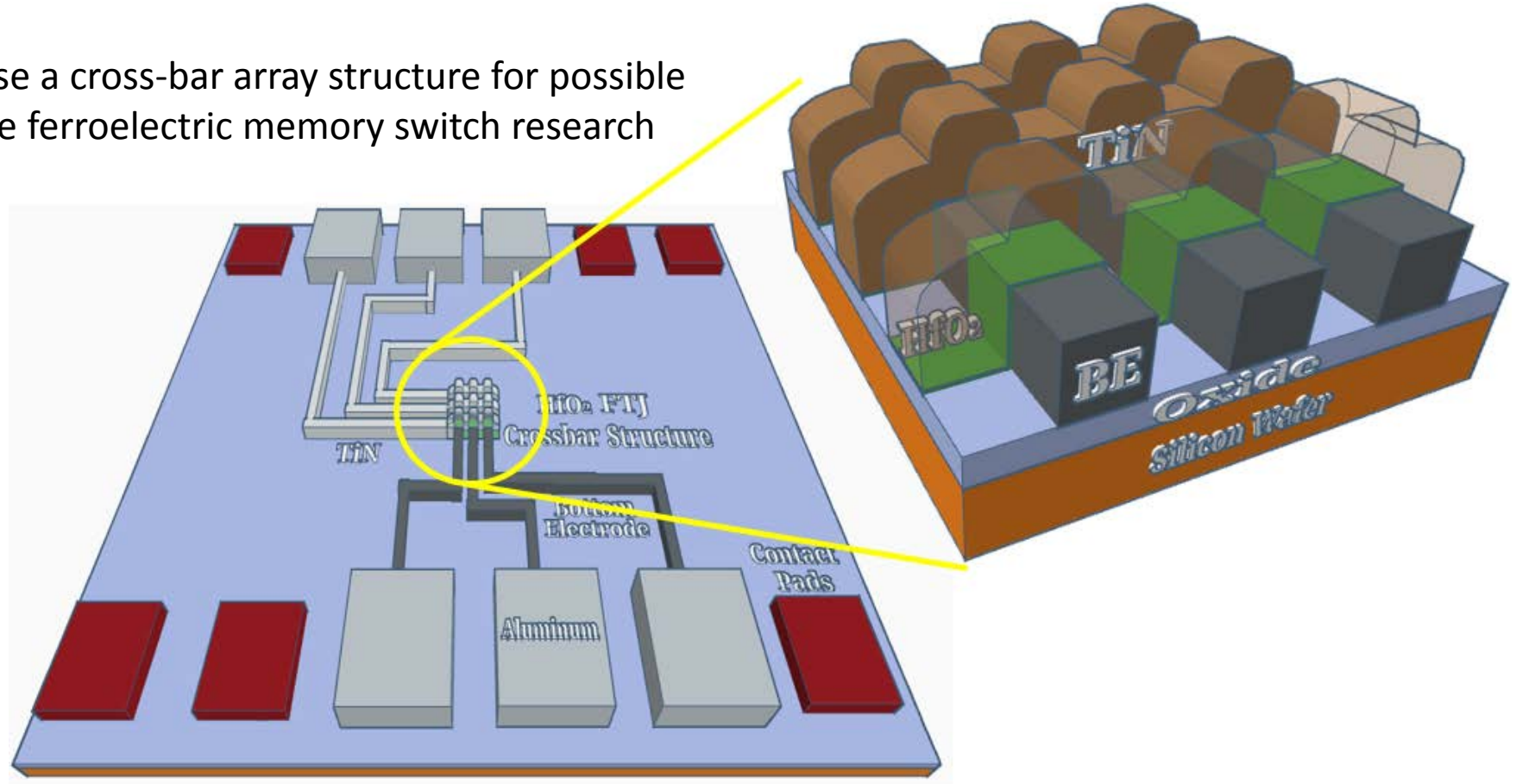
Fabrication of Devices

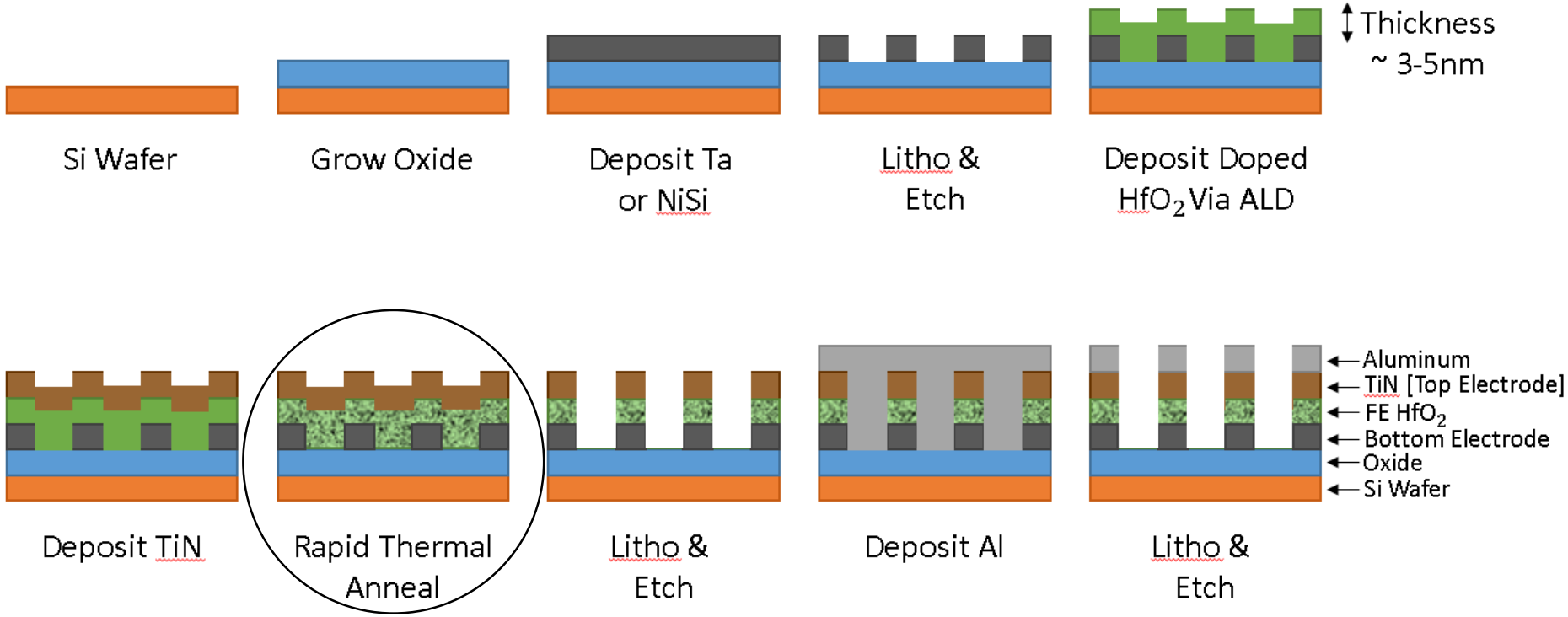


Design Layout

I chose a cross-bar array structure for possible future ferroelectric memory switch research



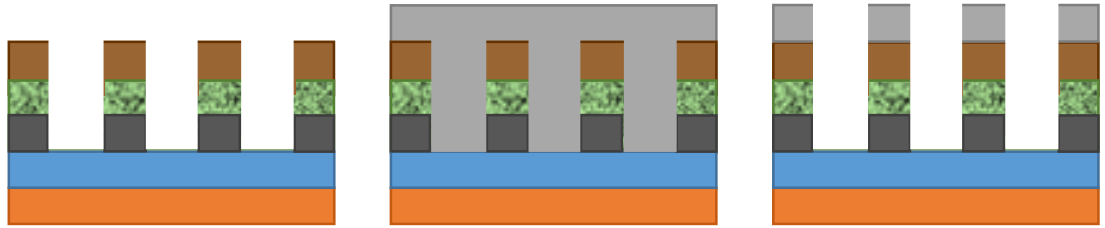
Steps Completed



- Ferroelectric behavior in hafnium oxide was demonstrated at RIT just last week, so I have only processed as far as the RTA

Moving Forward

- In the next few weeks I plan on finishing the fabrication of the FTJs



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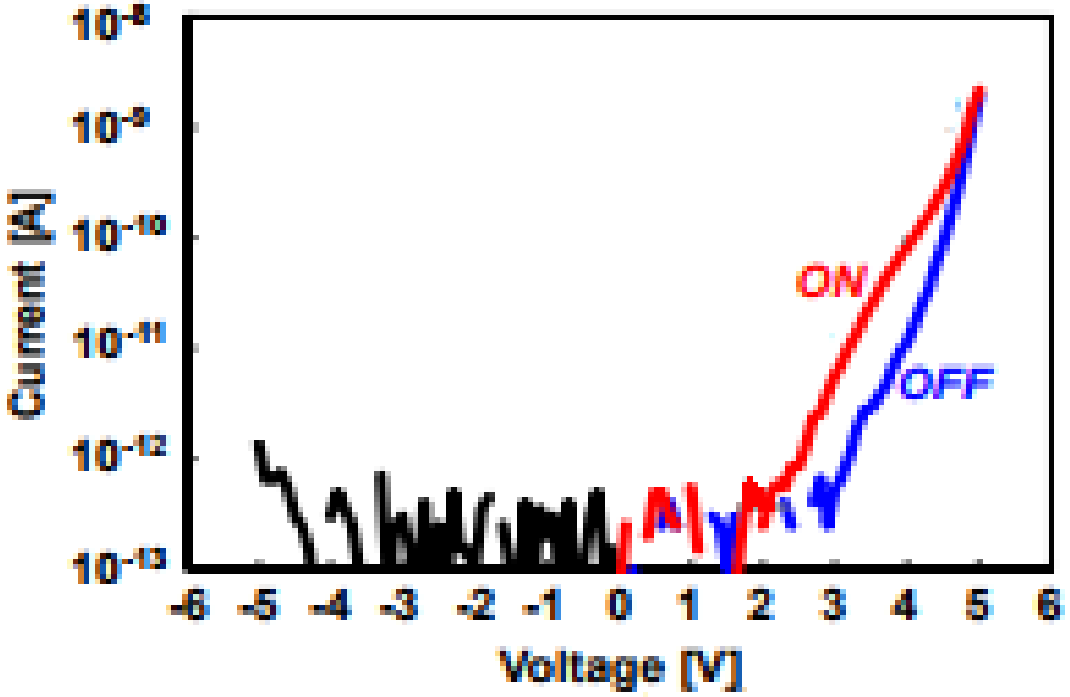
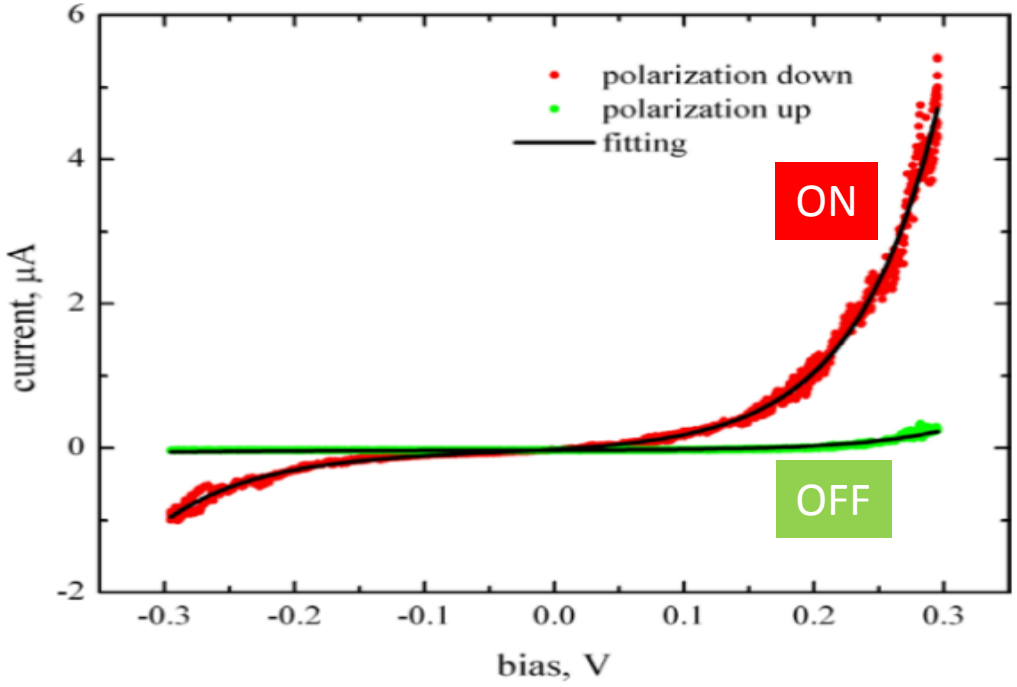
- As well as electrically testing the devices for their P-E, C-V and I-V characteristics.

Expected Device Characteristics

I-V Characteristics of FTJs



S. Fujii, Y. Kamimuta, T. Ino, Y. Nakasaki, R. Takaishi, and M. Saitoh, "First demonstration and performance improvement of ferroelectric HfO2-based resistive switch with low operation current and intrinsic diode property," 2016 IEEE Symposium on VLSI Technology, 2016.



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Acknowledgements

- Dr. Kurinec
- Dr. Ewbank
- Dr. Pearson
- SMFL Staff
- MicroE Classmates

Thank You!