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KATE GLEASON College of ENGINEERING

Fabrication and Characterization of Ferroelectric Tunnel Junctions with Different Bottom Electrodes

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Project Objectives

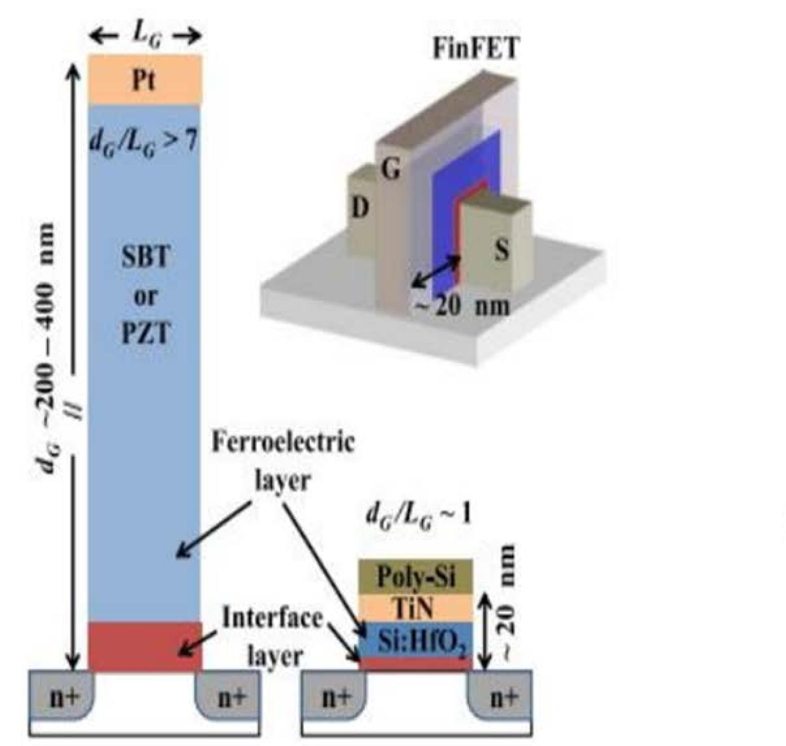
Goal: To further ferroelectric device research at RIT through:

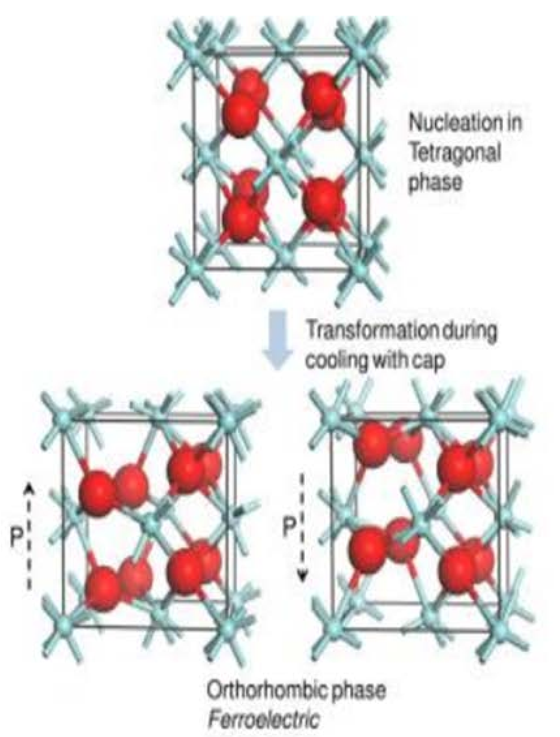
- Developing an RIT process for fabrication of HfO_2 ferroelectric tunnel junctions
- Characterization of these devices with differing bottom electrode material

Background

Ferroelectricity – electricity induced polarization in the crystal lattice:

- Ferroelectricity in HfO_2 is stronger than ceramic films (1MV/cm vs 50 kV/cm), enabling reduction in gate height. [1]





- Doping of HfO_2 makes the ferroelectric phase more favorable. Ferroelectricity reported in ALD HfO_2 with Al, Y, or Si dopants. Results also seen with Y and Hf reactive co sputtering. [3, 4]
- TiN or SiOxNy used as an interfacial layer between ferroelectric capacitor and substrate [1]
- TiN layer used above ferroelectric gate to help coerce the HfO_2 layer into a ferroelectric (FE) phase [2]

Previous Work at RIT

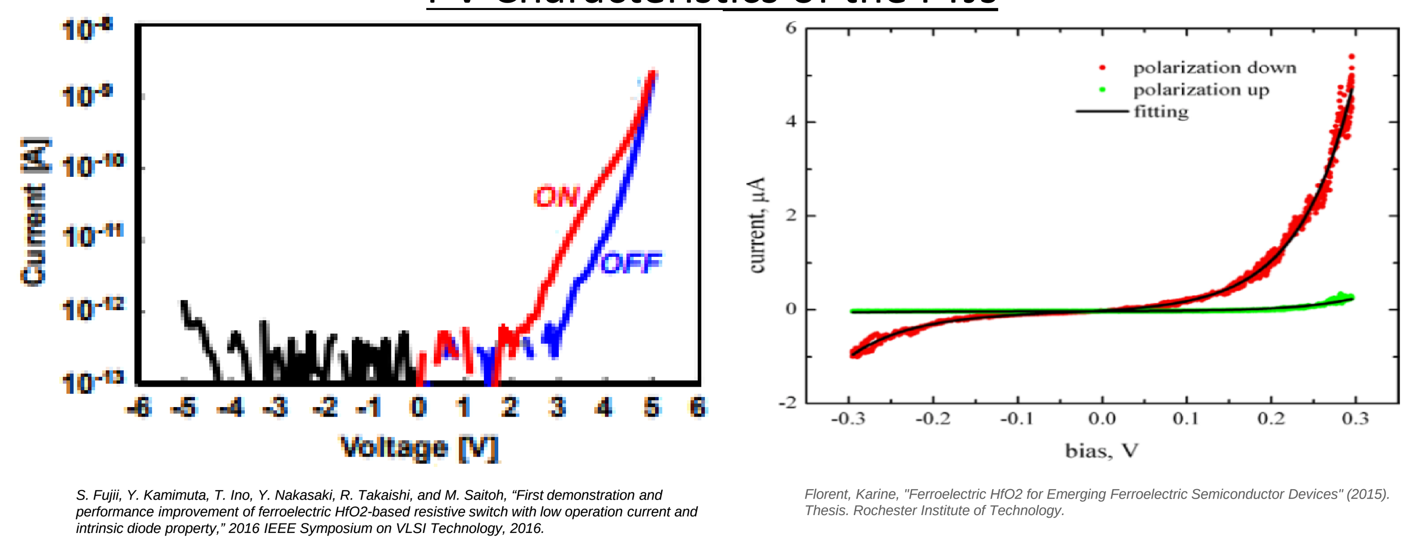
- Ferroelectric silicon doped hafnium oxide ($Si{:}HfO_2$) transistors have been fabricated at RIT by **Joe McGlone**. ALD done in Germany.
- **Casey Gonta** developed ALD recipes at RIT for aluminum doped hafnium oxide ($Al{:}HfO_2$) transistors and characterized their performance.
- In-depth modeling of HfO_2-based FTJs and simulation of FTJ memory devices has been done by **Spencer Pringle**.
- Characterization of n & k values as well as further ALD work of ferroelectric aluminum doped hafnium oxide ($Al{:}HfO_2$) by **Josh Eschle**.

Expected Device Characteristics

- The fabrication should give FTJs that have characteristics similar to those shown below:

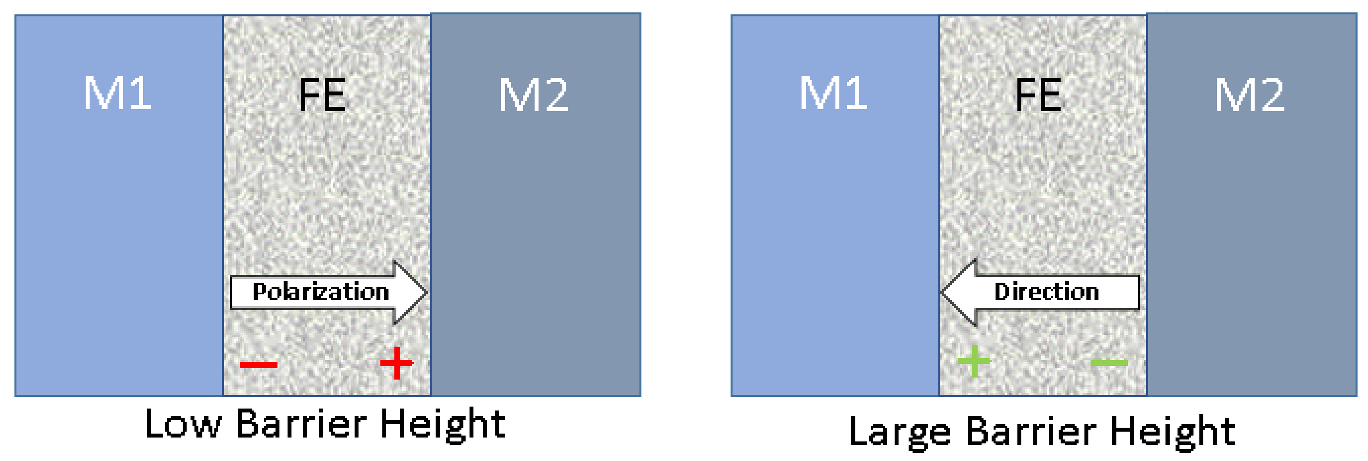
Low current dependent on polarization direction

I-V Characteristics of the FTJs

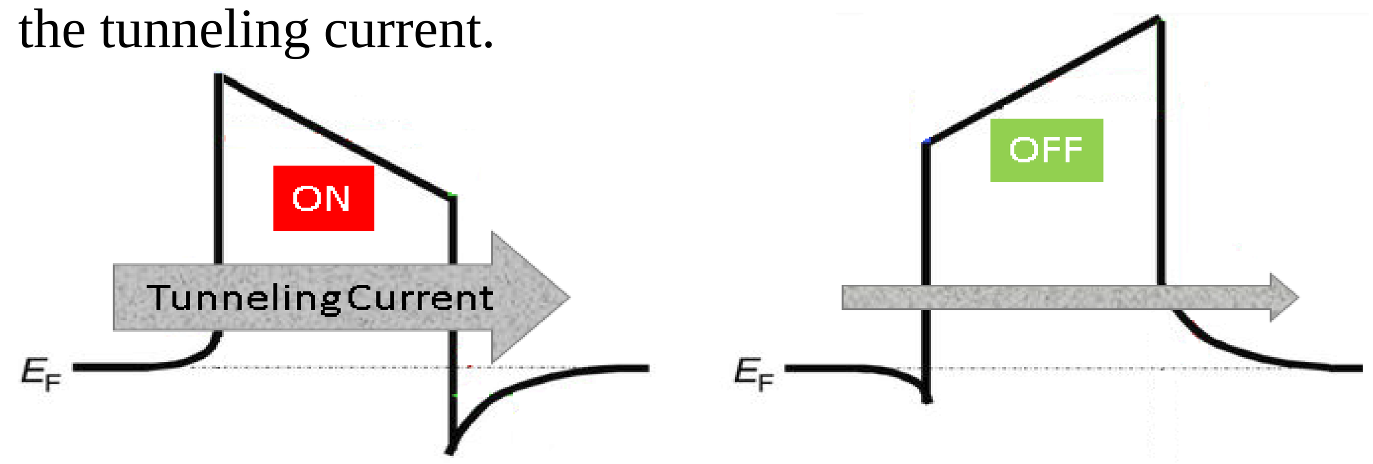


Ferroelectric Tunnel Junction

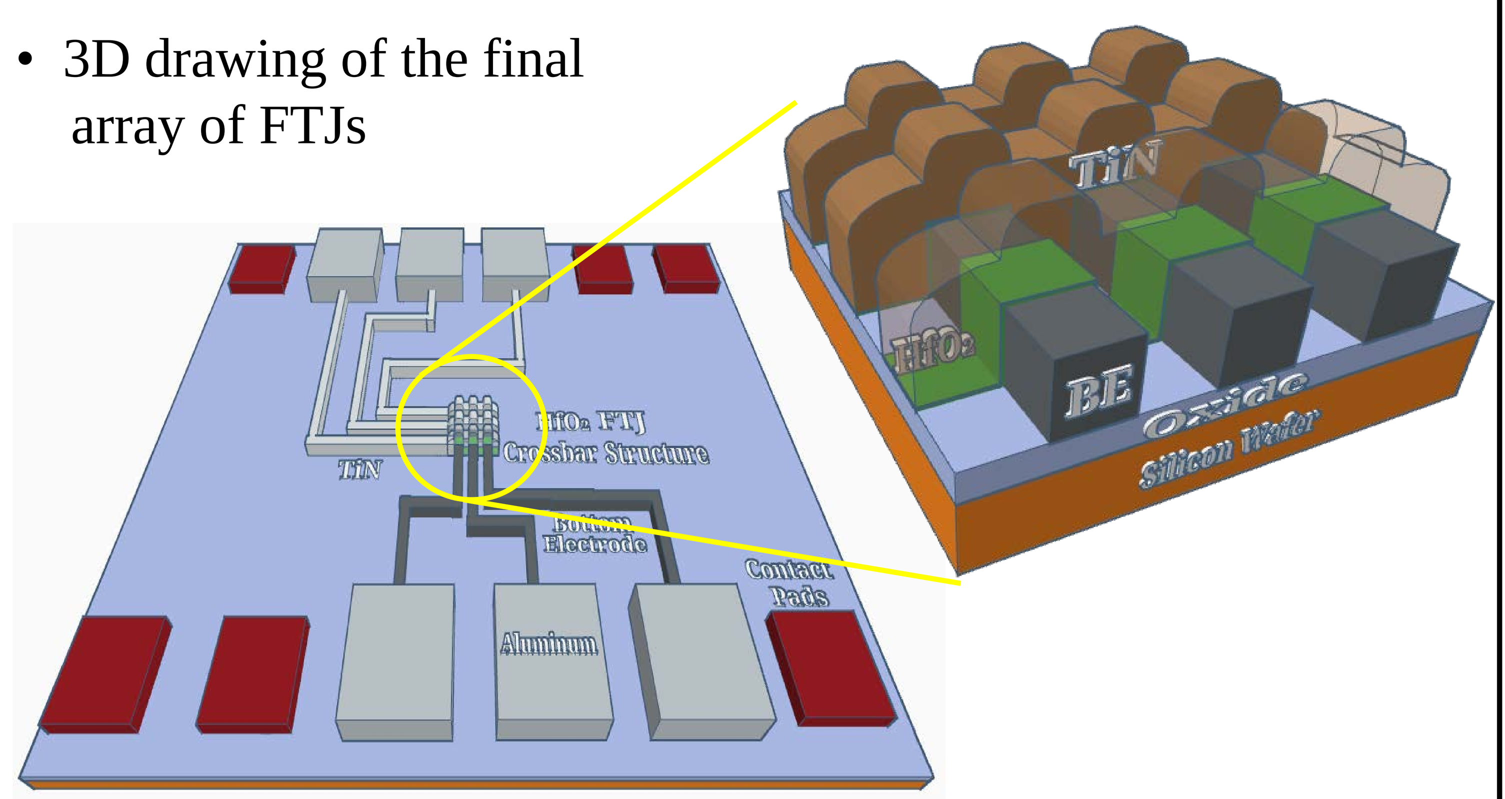
- An FTJ is a tunnel junction in which two metal electrodes are separated by a thin Ferroelectric Layer.



- Switching the ferroelectric polarization induces variations of the tunneling current.

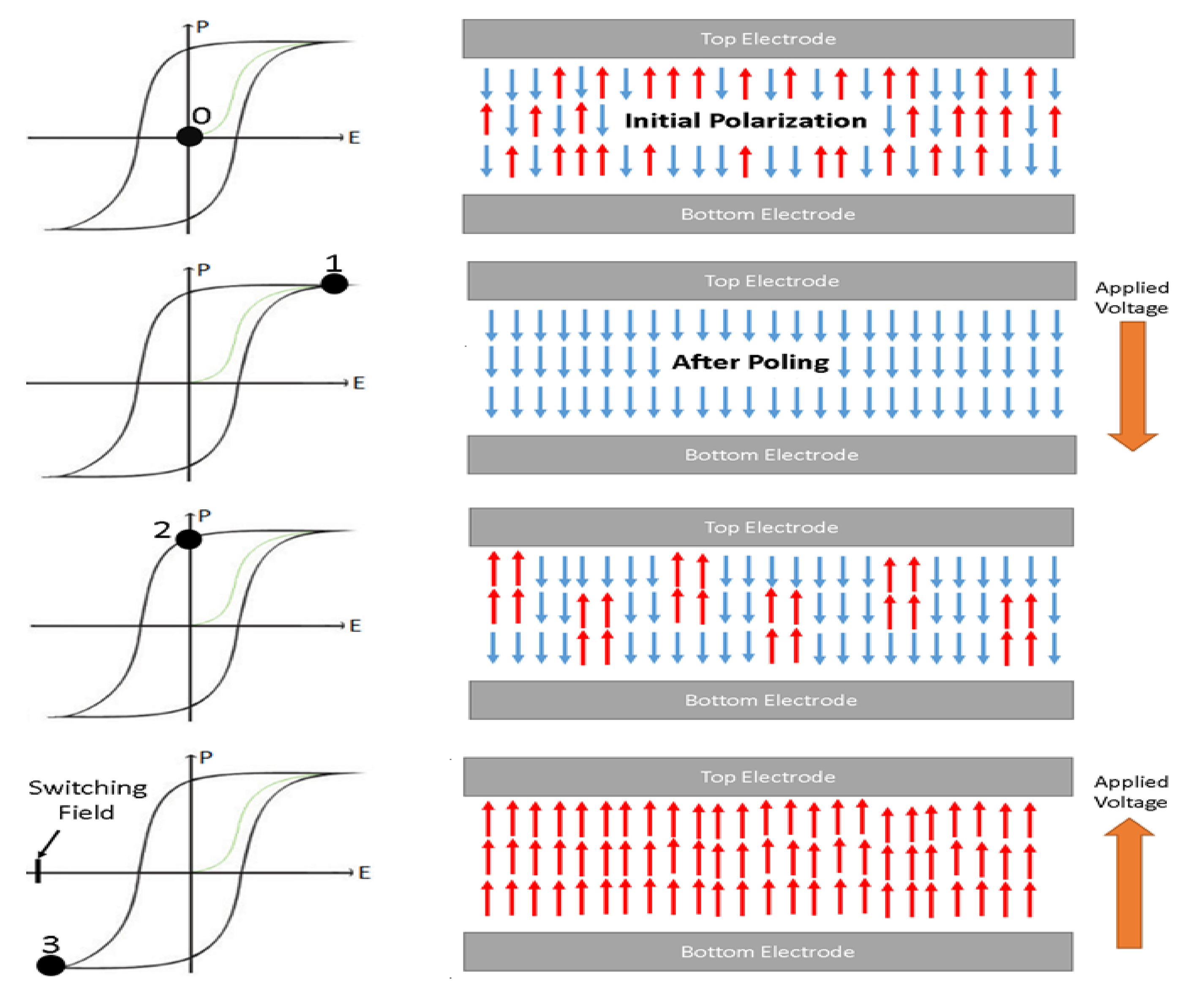


- 3D drawing of the final array of FTJs



Ferroelectric Polarization

- A material is defined as ferroelectric if it has a spontaneous remnant polarization that can be reversed by an electric field.
- As you decrease the applied voltage, the polarization begins to flip. When the electric field is zero, there is a net remnant polarization.
- At the 'switching field' the polarization has become entirely reversed. This 'ON/OFF' property is particularly attractive for non-volatile memory and logic applications



Future Work

Near Future:

- Finish processing the wafers
- Test the devices' I-V characteristics, comparing the effects of Ta vs. NiSi bottom electrode

Distant Future:

- A study of annealing conditions to achieve the proper orthorhombic crystal structure required for ferroelectricity in HfO_2
- Fabrication and characterization of working FTJ devices
- Simulate digital memory capabilities of FTJ devices for possible Ferroelectric Memristor research

References

[1] E. Yurchuk, J. Muller, J. Paul, T. Schlosser, D. Martin, R. Hoffmann, et al., "Impact of Scaling on the Performance of HfO2-Based Ferroelectric Field Effect Transistors," Ieee Transactions on Electron Devices, vol. 61, pp. 3699-3706, Nov 2014.
[2] T. S. Boescke, J. Muller, D. Brauhaus, U. Schroder, and U. Bottger, "Ferroelectricity in hafnium oxide thin films," Applied Physics Letters, vol. 99, p. 3, Sep 2011.
[3]T. Olsen, U. Schroder, S. Muller, A. Krause, D. Martin, A. Singh, et al., "Co-sputtering yttrium into hafnium oxide thin films to produce ferroelectric properties," Applied Physics Letters, vol. 101, p. 4, Aug 2012.
[4]U. Schroeder, S. Mueller, J. Mueller, E. Yurchuk, D. Martin, C. Adelmann, et al., "Hafnium Oxide Based CMOS Compatible Ferroelectric Materials," Ecs Journal of Solid State Science and Technology, vol. 2, pp. N69-N72, 2013

Acknowledgements

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