Fabrication and Characterization of Ferroelectric Tunnel Junctions with Different Bottom Electrodes

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Outline

- Introduction
  - Background
  - Previous Work at RIT
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- Fabrication Process
  - Fabrication of FTJs
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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.

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.
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.
• In-depth modeling of HfO$_2$-based FTJs and simulation of FTJ memory devices has been done by Spencer Pringle.
• 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

Si Wafer

Grow Oxide

Deposit Ta or NiSi

Litho & Etch

Deposit Doped HfO₂ Via ALD

Deposit TiN

Rapid Thermal Anneal

Litho & Etch

Deposit Al

Litho & Etch

Thickness ~ 3-5nm

Aluminum

TiN [Top Electrode]

FE HfO₂

Bottom Electrode

Bottom Oxide

Si Wafer

Thickness ~ 3-5nm
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
• In the next few weeks I plan on finishing the fabrication of the FTJs

• 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


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