SNF RRAM Standard Process Flow and Characterization of Lesker-2 TiN

ENGR241 Week 5 Updates

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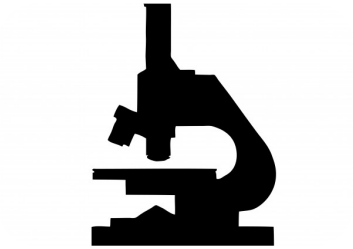
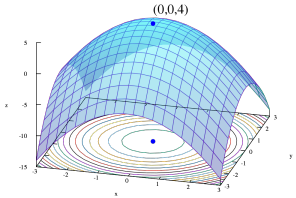
Aim & Goals

- Test and characterize ALD RRAM devices
- Develop TiN recipe on new Lesker with low oxygen contamination
- Compare TiN properties (composition, resistivity, topography)
- Make electrical/imaging data and test structure layouts available to SNF
- Make SOPs for RRAM stacks and report TiN findings



Process Flow Development



Parameter Optimization

Comprehensive Documentation

SNF Database

Diagnosis of Oxide Etch Problem Last Time

- Usha helped diagnose the issue
- We were using the wrong sample (oops!)
- It did not have the Pt + SiO_2, it was just a bare Si wafer

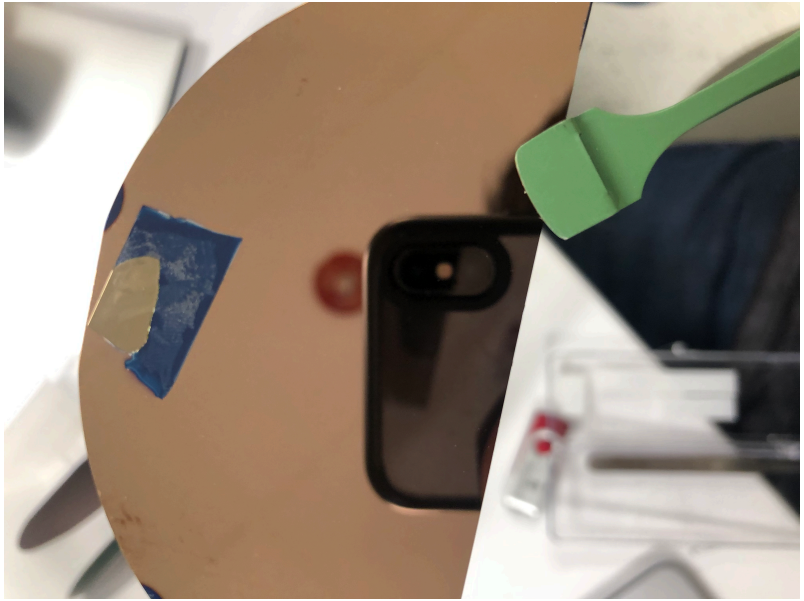
- We still have the Pt + SiO_2 wafers, which I am using to practice and get some working RRAM
- Also processing new batch of samples with better quality SiO_2 and Ti sticking layer under Pt

Progress Updates: Fabrication

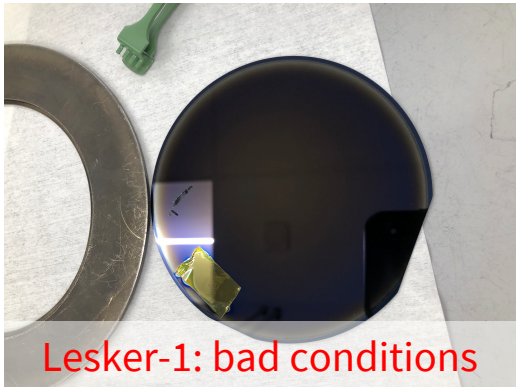
- ✓ Clean and grow SiO_2 for isolation
- ❑ Sputter 30nm TiN (Sharpie for step)
  - ✓ AJA (non-SNF)
  - ✓ Lesker-1 (SNF)
  - ❑ Lesker-2 (SNF)
- ❑ Characterization
  - ❑ XPS
  - ❑ Prometrix
  - ❑ AFM
  - ❑ Alphastep

Trained on Lesker-2! Will run test wafers as soon as it is fully set up ☺

TiN Film Comparison



AJA: gold standard



Lesker-1: bad conditions

Lesker-1: better conditions

Literature Review on TiN Sputtering

- TiN films absorb a high concentration of contaminants including hydrogen, carbon, and oxygen when they are exposed to air after deposition
- With the target–substrate distance set to 88 mm the **contaminant levels increase from ~0.1% to ~10% as the pressure is increased from 2 to 9 mTorr**
- The contaminant concentrations also correlate with in-plane distance from the center of the substrate and increase by roughly two orders of magnitude as the target–substrate distance is increased from 88 to 266 mm
- Contaminants strongly influence properties of TiN thin films
- **Resistivity of stoichiometric films increases by around a factor of 5 as the oxygen content increases from 0.1% to 11%**
- Energy of the sputtered TiN particles plays crucial role in determining the film properties
- Important to precisely control the energy of these particles to obtain high-quality TiN

Ohya, S., B. Chiaro, A. Megrant, C. Neill, R. Barends, Y. Chen, J. Kelly et al. "Room temperature deposition of sputtered TiN films for superconducting coplanar waveguide resonators." *Superconductor Science and Technology* 27, no. 1 (2013): 015009.

TiN Properties

	AJA: A1	Lesker-1: X1	Lesker-1: X2	Lesker-1: X3	Lesker-1: X4	Lesker-1: X5
Target	Ti	TiN	TiN	TiN	Ti	TiN
Base Pressure	~1e-7 Torr	~1e-6 Torr	~1e-6 Torr	~1e-7 Torr (?)	~1e-7 Torr (?)	~1e-7 Torr
RF Power	200W	150W	200W	200W	200W	200W
Gettering/Chamber Conditioning	2 min TiN	2 min TiN	5 min Ti, 5 min TiN	5 min Ti, 5 min TiN	5 min Ti, 5 min TiN	10 min Ti, 5 min TiN
Wafer Bias	100V	100V	100V	100V	100V	100V
Ar/N Flow	30/3 sccm	50/5 sccm	30/3 sccm	30/0 sccm	30/3 sccm	30/3 sccm
Pressure	2.15 mTorr	35->5 mTorr	30->3 mTorr	20->2 mTorr	20->2 mTorr	20->2 mTorr
Sheet Resistance	15.650 Ω/□	?	?			
Resistivity	?	?	?			
Uniformity/Color	Excellent	Bad	Good			
Thickness/Time	?nm/1800s	?nm/1800s	?nm/900s			?nm/1800s
Roughness	0.67nm	?	?			
Composition (Ti:N:O)	46:51:3	?	?			

Progress Updates: Old Samples

- ✓ RCA clean wafer
- ❖ Grow 50nm SiO_2 with thermco4 (20 min. of 900C wet growth, skipped)
- ❖ Deposit 10nm Ti with AJA (skipped)
- ✓ Deposit 30nm Pt with AJA
- ✓ Deposit 100nm SiO_2 with AJA
- ✓ Woollam to check oxide thickness (834Å)
- ❑ Photolithography (1)
  - ❑ YES Oven for 30 mins
  - ❑ SVG Coat 2 with 1µm Shipley 3612 resist, 2mm EBR, skip prime step
  - ❑ Expose with Heidelberg (use defoc: -2, dose: 70/80 for Heidelberg1/2, 350nm)
  - ❑ SVG Develop (1µm 3612 dev) w/post-exposure bake and inspect
- ❑ PT-Ox: Oxide_ER_Test, 1 min
- ❑ Resist ashing: Matrix default recipe (1)
- ❑ Metal cleaning on wbflexcorr (1)
  - ❑ SRS-100 for stripping photoresist from metal wafers, 60C
  - ❑ PRS-1000 for final metal clean before deposition or furnace step, 40C
- ❑ Alphastep to check etching
- ❑ Fiji1 thermal HfO_2: 100 cyc. std. recipe
- ❑ Woollam to check oxide thickness
- ❑ TiN deposition 30nm
- ❑ Photolithography (2)
- ❑ PT-MTL: still need details
- ❑ Resist ashing: Matrix default recipe (2)
- ❑ Metal cleaning on wbflexcorr (2)
- ❑ Initial electrical testing

Progress Updates: New Samples

- ✓ RCA clean wafer
- ✓ Grow 50nm SiO_2 with thermco4 (20 min. of 900C wet growth)
- ❑ Deposit 10nm Ti with AJA
- ❑ Deposit 30nm Pt with AJA
- ❑ Deposit 100nm SiO_2 with ccp-dep
- ❑ Woollam to check oxide thickness (834Å)
- ❑ Photolithography (1)
  - ❑ YES Oven for 30 mins
  - ❑ SVG Coat 2 with 1µm Shipley 3612 resist, 2mm EBR, skip prime step
  - ❑ Expose with Heidelberg (use defoc: -2, dose: 70/80 for Heidelberg1/2, 350nm)
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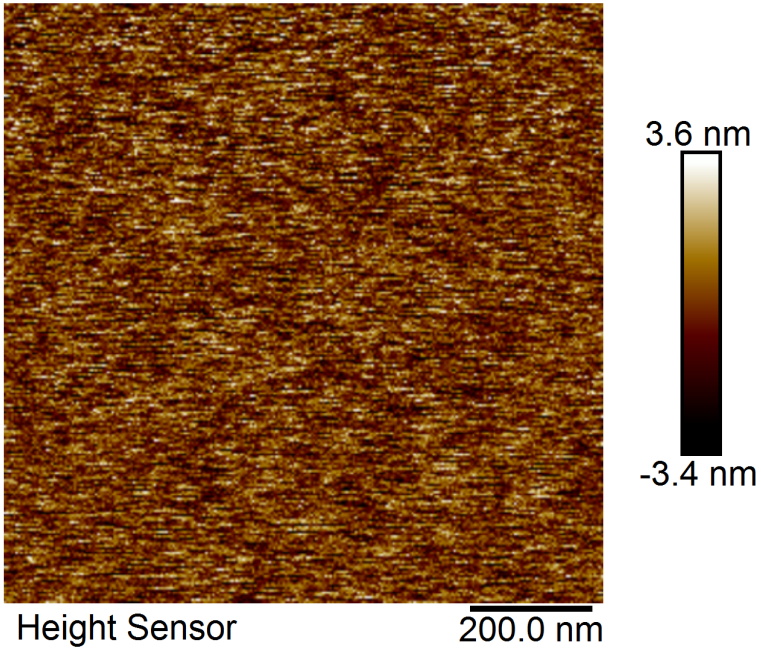
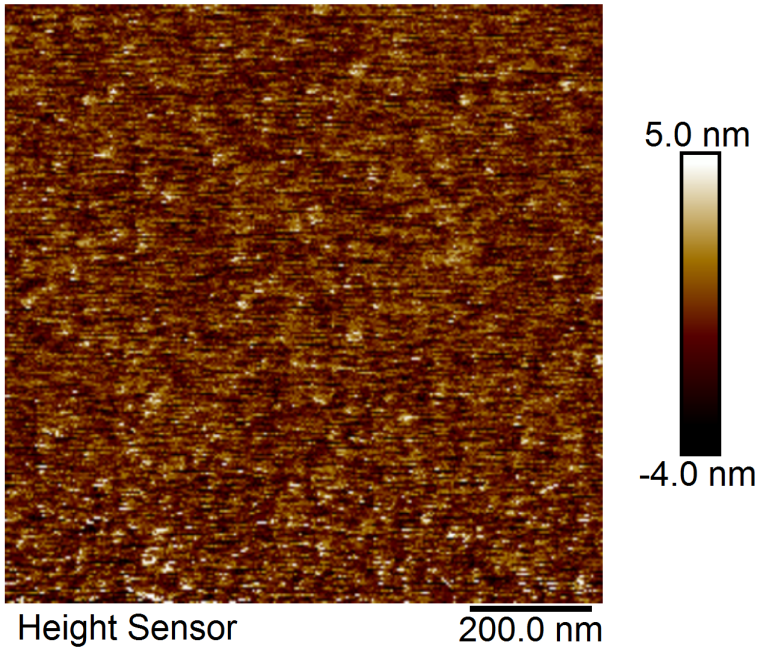
Thank you!

QUESTIONS?

AFM Roughness Measurements: AJA



Roughness: 1.02nm SiO_2



Roughness: 1.22nm TiN
0.67nm independent

AJA TiN Sputter Recipe: Reactive Sputtering

- **Target:** Ti
- **RF Power:** 200W
  - 150W also ok; different dep rates
- **Wafer Bias:** 100V
  - DC bias 92-94V on AJA in practice
- **Ar Flow:** 30 sccm
- **N Flow:** 3 sccm
  - Unit conversion means that this is written as 30 on AJA somehow
- **Set Pressure:** 2.15 mTorr
  - 1.8-1.9 mTorr on AJA in practice

Recipe:

- Load sample and wait for 1e-7 base chamber pressure
- Plasma on another target (conductive) e.g. Al, GeTe
  - Eases plasma ignition for TiN target
- Plasma on Ti target
  - Bias on other target off
- 20s ramp-up of Ti target RF power
- 2 minutes pre-sputtering of Ti target (shutter closed, no wafer bias)
- 20s ramp-up of wafer bias
- Open shutter and deposit for X seconds
- Close shutter
- 20s ramp-down of Ti target RF power