ALD Oxide Nanolaminates Final Presentation

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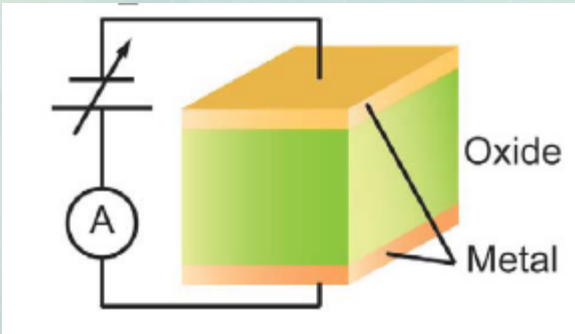
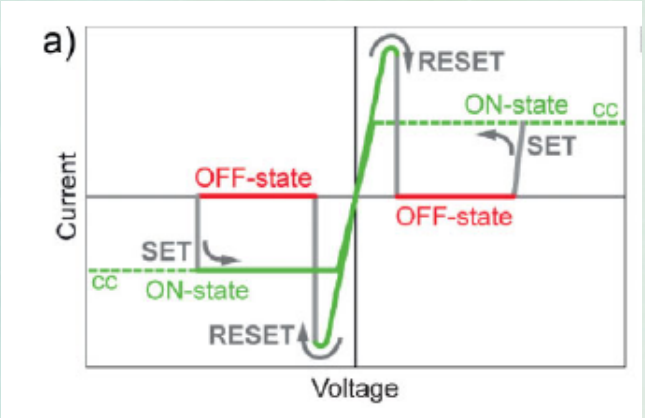
Outline

- Motivation
- Overall Schedule
- Device Fabrication
- Measurement & Discussion
  - Growth Thickness
  - Leakage Current
  - Breakdown Voltage
  - RRAM Characteristics
- Summary

Motivation (1)

- Resistance random access memory(ReRAM) application
  - A ReRAM memory cell is a capacitor-like structure composed of insulating or semiconducting transition metal oxides that exhibits reversible resistive switching on applying voltage pulses [1]
  - Plenty of transition metal oxides have such property: HfOx [2], AlOx [3], NiO, TiOx, WOx, CuOx, etc.



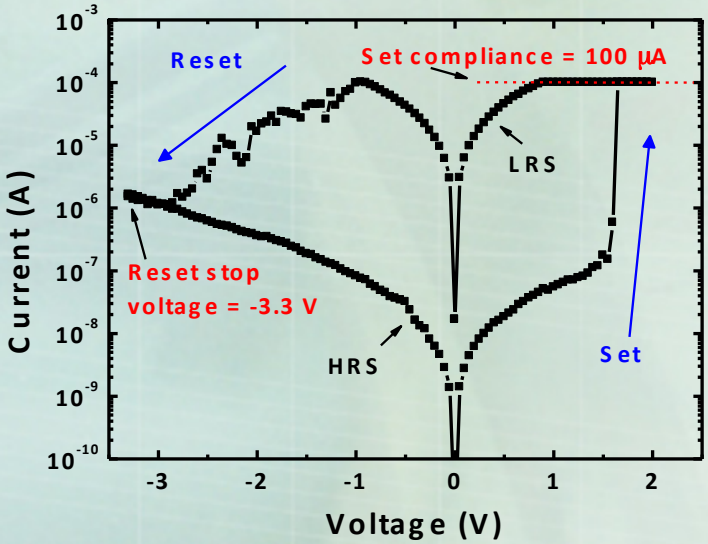


[1] R. Waser, R. Dittmann, G. Staikov, and K. Szot, "Redox-Based Resistive Switching Memories –Nanoionic Mechanisms, Prospects, and Challenges," *Adv. Mater., vol. 21, pp. 2632-2663, 2009.*
[2] H. Y. Lee, P. S. Chen, T. Y. Wu, Y. S. Chen, C. C. Wang, P. J. Tzeng, C. H. Lin, F. Chen, C. H. Lien, and M. J. Tsai, "Low Power and High Speed Bipolar Switching with A Thin Reactive Ti Buffer Layer in Robust HfO2 Based RRAM," in *IEDM Tech. Dig. , 2008, pp. 297-300.*
[3] Y. Wu, B. Lee, and H. S. P. Wong, "Al2O3-Based RRAM Using Atomic Layer Deposition (ALD) With 1-μA RESET Current," *IEEE Electron Device Letters, vol. 31, pp. 1449-1451, 2010.*

Motivation (2)

- Savannah to deposit HfOx/AlOx nanolaminates for RRAM devices, aiming to achieve lower switching power and better switching uniformity and reliability.
- Oxide property extraction, e.g. leakage current, breakdown voltage from MIM structures

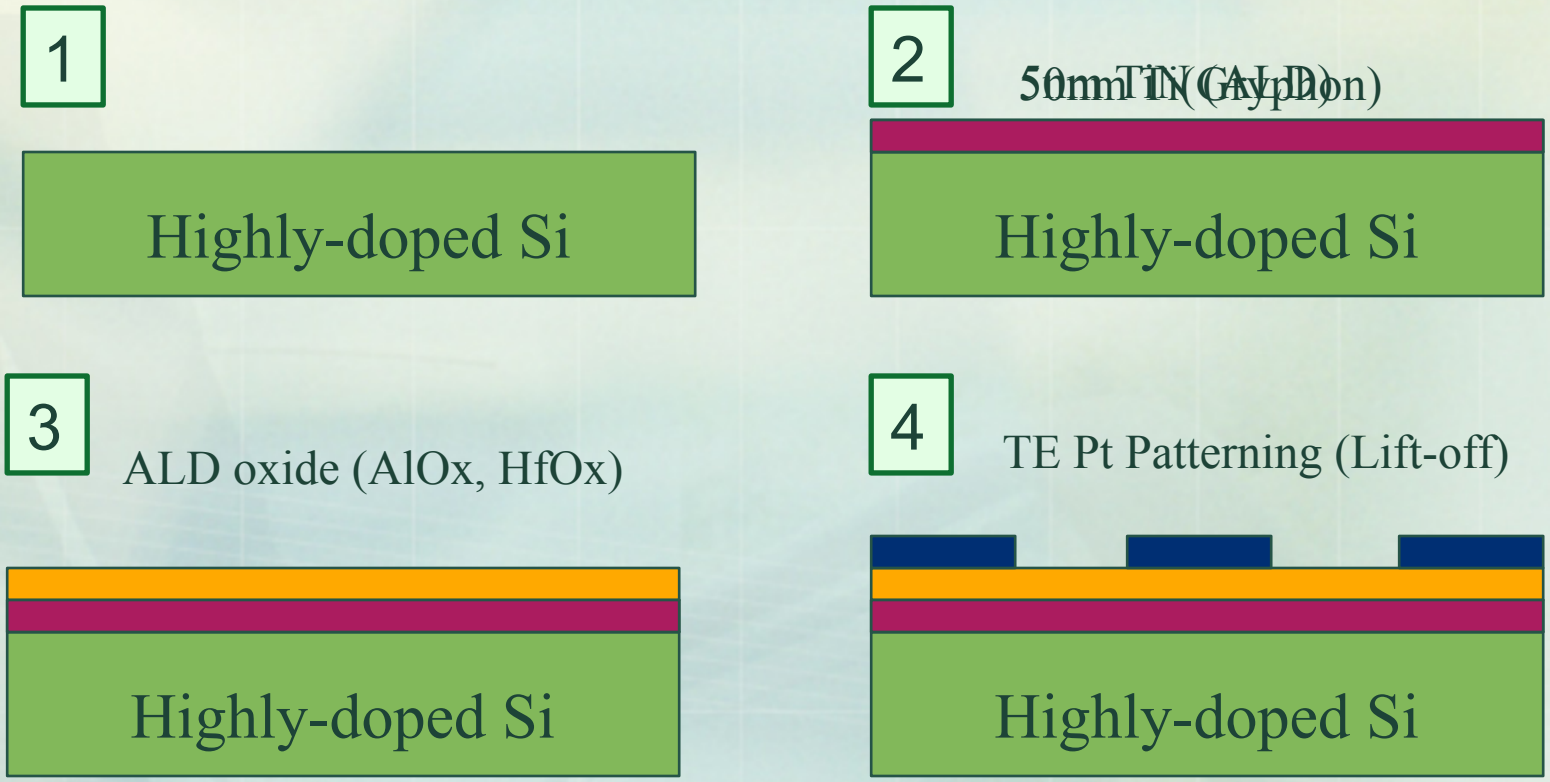
I-V curve from TiN/HfOx/AlOx/Pt RRAM devices
* The oxide laminate was deposited at Cambridge Nanotech using Fiji system



Overall Timetable

Week	Job Description
1-2	Start of the quarter; training of the equipment tool including Savannah/ woollam/ wetbench-diff/ innotec, etc.
3-4	ALD AlOx deposit with 3nm/5nm/10nm thickness on Si/TiN and Si control wafers at 200^{o}C using standard recipe
5	ALD HfOx deposit with 3nm/5nm/10nm thickness on Si/TiN and Si control wafers at 200^{o}C using standard recipe
6	ALD AlOx deposit with 100 cycles (target 10nm thickness) on Si/Ti and Si control wafers at 100/150/200/250^{o}C using standard recipe
7	ALD HfOx deposit with 100 cycles (target 10nm thickness) on Si/Ti and Si control wafers at 100/150/200/250^{o}C using standard recipe
8	(1) ALD HfOx at 100/150/200/250^{o}C targeted at same thickness (~10nm); (2) ALD AlOx/HfOx lamninate deposition: AlOx/HfOx bilayer
9	Summary

Device Fabrication



Measurement Method

1. Thickness (Woollam)

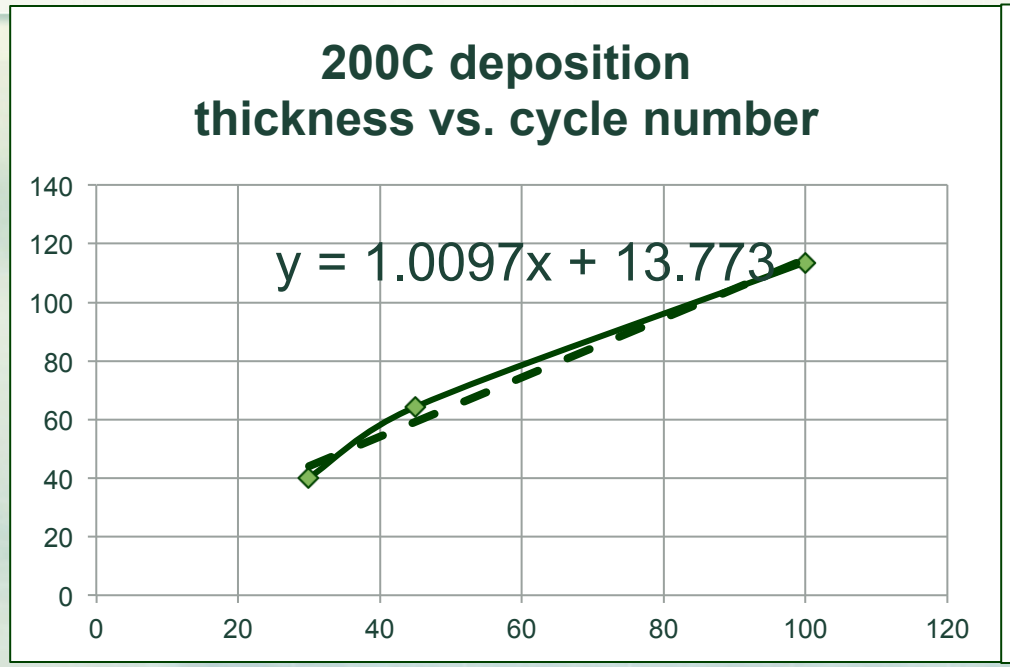
2. Breakdown Voltage

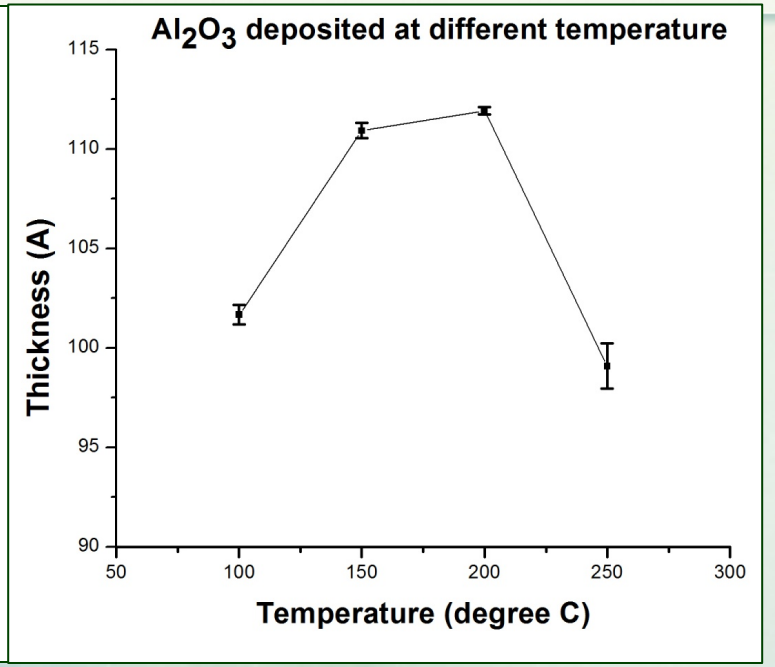
- Oxide immediate breakdown occurs when the current density through the oxide becomes high enough to cause thermal run-away.
- Ramp-up MIM two-terminal voltage up to 10V and extract voltage node at sudden substantial current jump.
- Average 25 points per wafer

3. Leakage Current

- Leakage current suggests the oxide quality, dense degree, etc.
- Extract the initial leakage current before the dielectric breakdown at 1V
- Average 25 points per wafer

Thickness-ALD AlOx

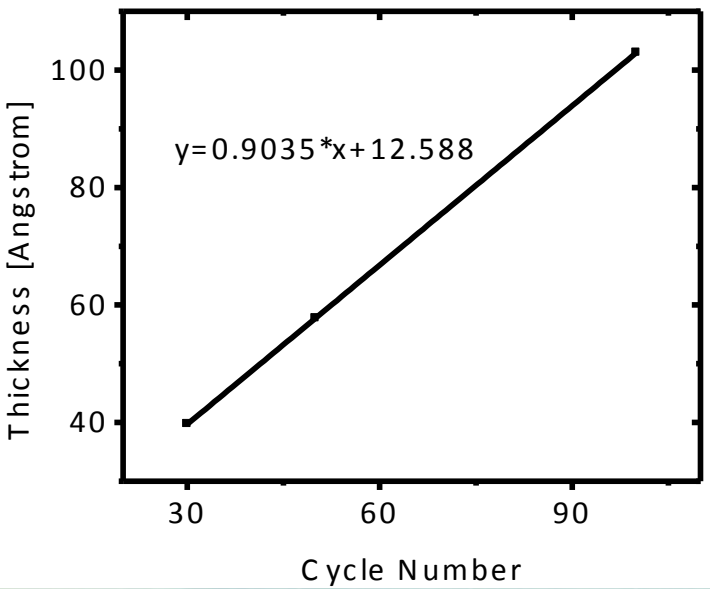


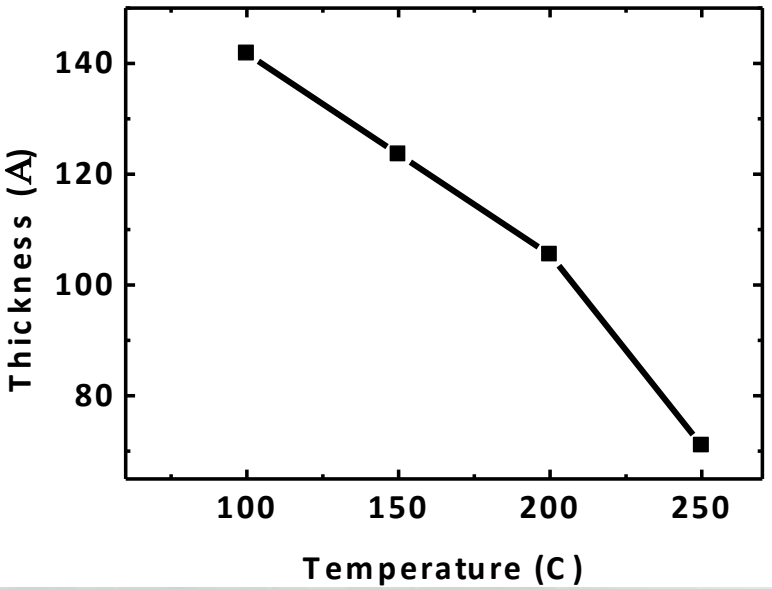


cycles	Thickness(A)
30	40.057
45	64.309
100	113.65

	Mean (A)	STD (A)
100 C	101.67	0.48576
150 C	110.92	0.38361
200 C	111.93	0.18846
250 C	99.085	1.1394

Thickness-ALD HfOx

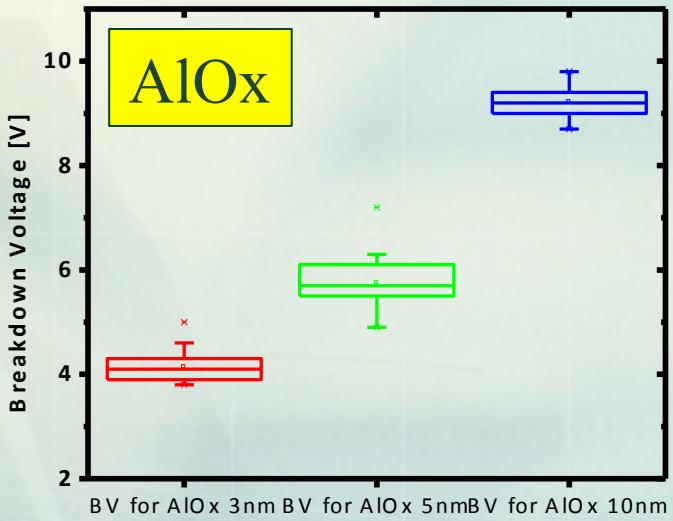


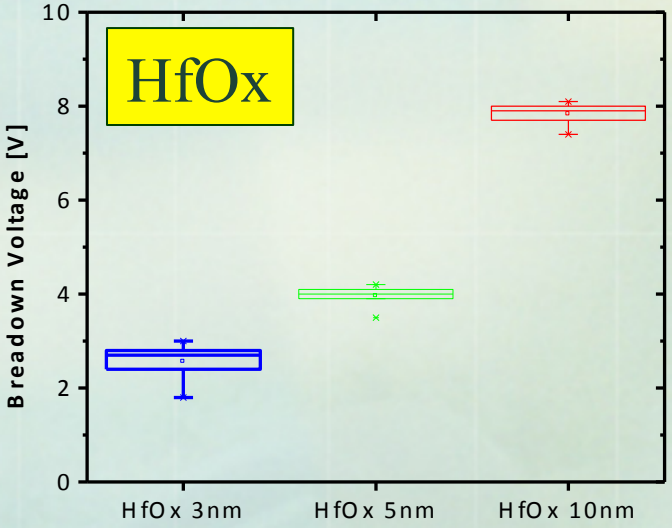


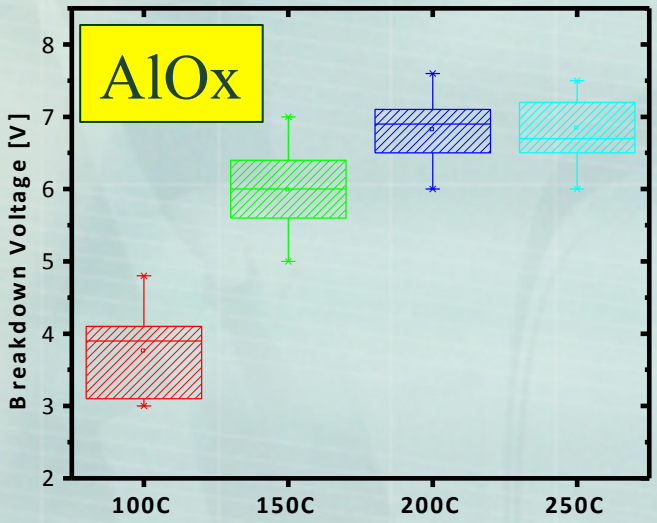
Cycles	Mean (A)	STD (A)
30	141.8	0.49
50	123.6	0.23
100	105.5	0.46

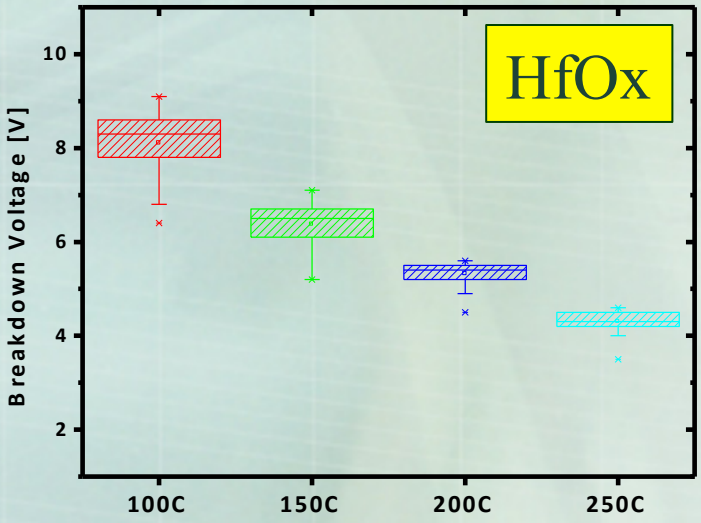
Temp	Mean (A)	STD (A)
100 °C	141.8	0.49
150 °C	123.6	0.23
200 °C	105.5	0.46
250 °C	71.0	0.33

Breakdown Voltage

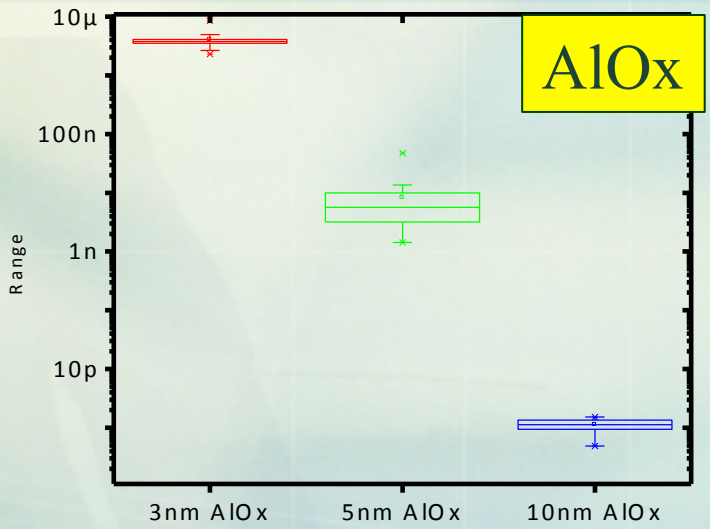


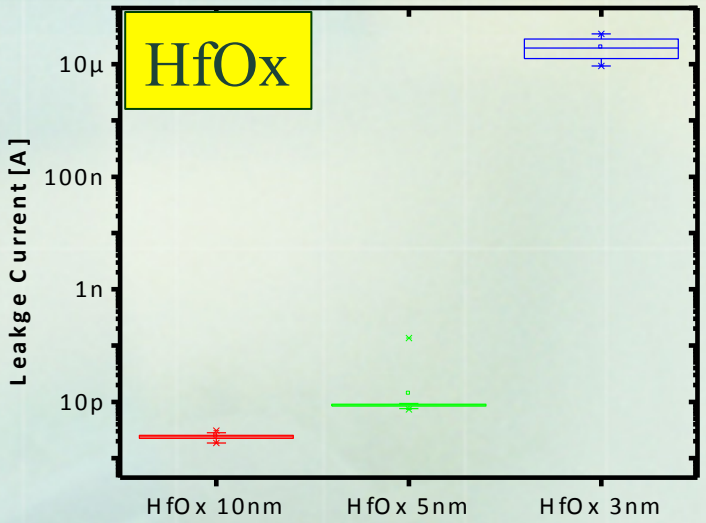


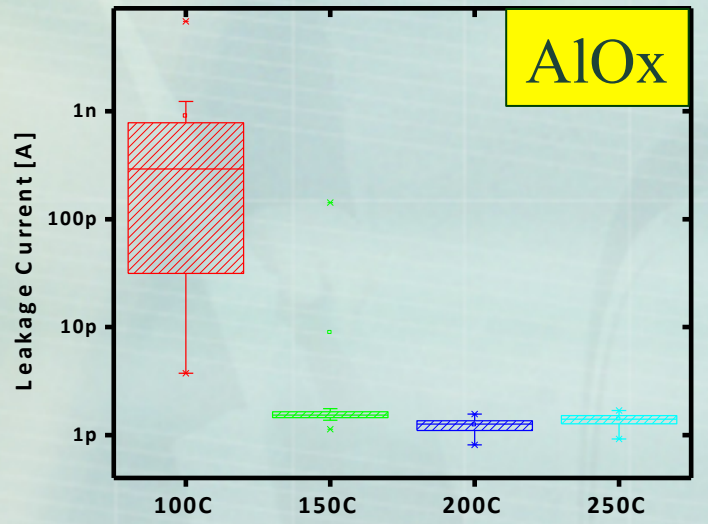


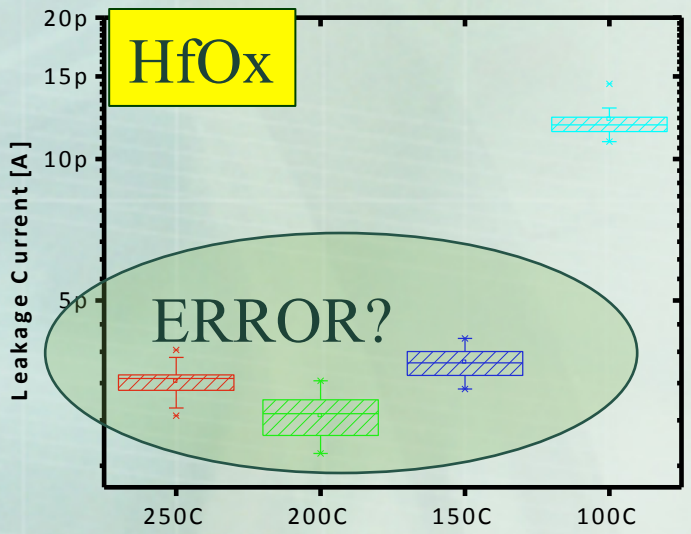


Leakage Current

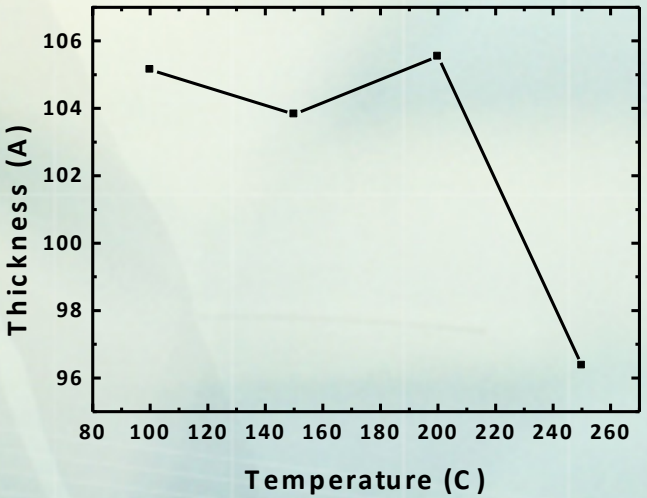




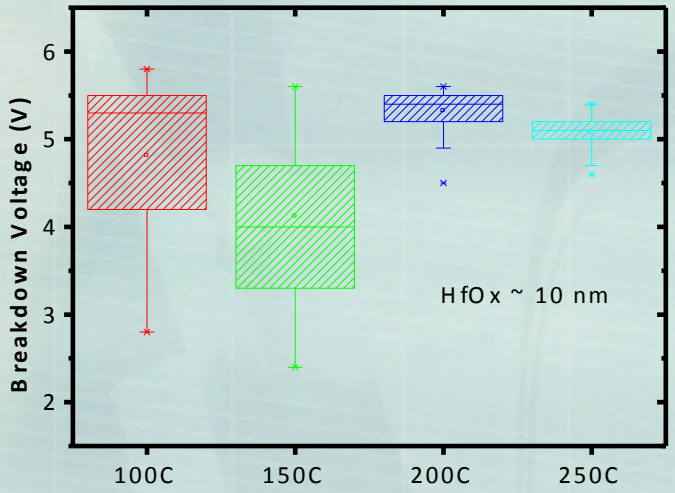


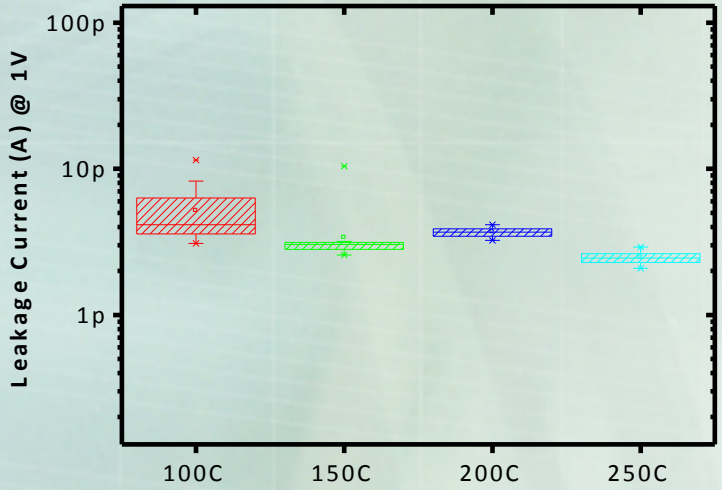


HfOx Quality vs. Temp



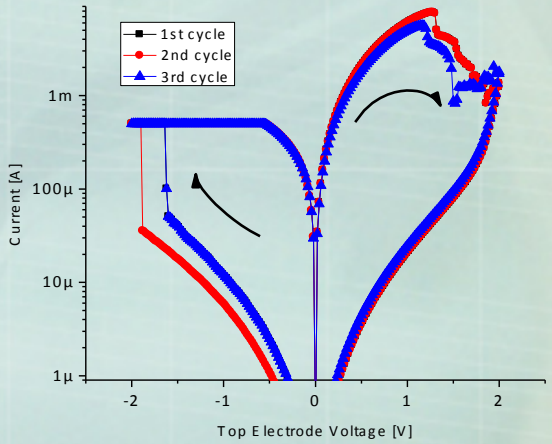
Temp (C)	Cycle	Thickness (A)
100	70	105.1472
150	80	103.8288
200	100	105.5418
250	140	96.3694





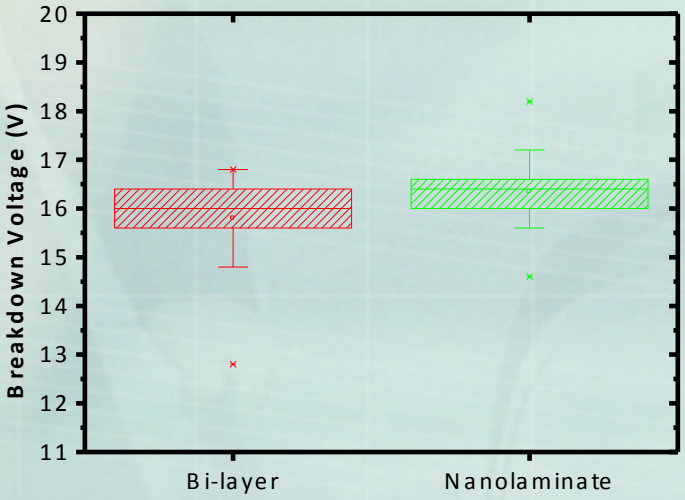
Resistance Switching Characteristics

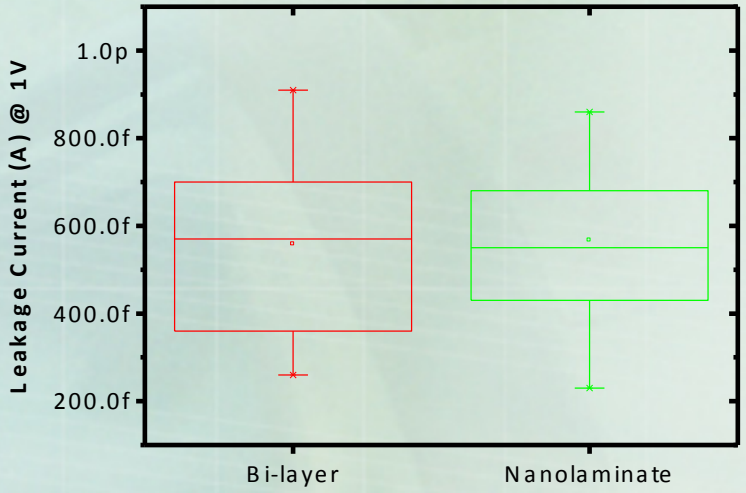
- Few of the devices show the resistance switching behavior but the devices failed after a few cycles
- Reasons: 1) Electrode material; 2)Large dimensions; 3)Oxide deposition method, etc.
- Solutions: 1) Nanolaminate or bi-layer; 2) Migrate to Fiji system



Bi-layer and Nanolaminate

- Bi-layer: Ti/AlOx(5nm)/HfOx(5nm)/Pt stack
- Nanolaminate: Ti/HfAlOx/Pt stack
- None of the resistance switching phenomenon





Summary

- Fabricate 100μm^2 MIM structures for RRAM application
- Investigate ALD AlOx and HfOx deposition rate, breakdown voltage and leakage current of oxide films at different temperatures
  - The oxide quality degrades with the temperature decreases
  - The deposition rate of HfOx decreases with temperature increases
  - The breakdown voltage are generally much higher than thinner films
- Bi-layer AlOx/HfOx and Nanolaminate HfAlOx were deposited