Fabrication and Characterization of High-k, Al_2O_3 and HfO_2 Capacitors

R·I·T Kate Gleason College of Engineering

Jesse Judd, Advisor: Dr. Michael Jackson

Rochester Institute of Technology, Department of Electrical and Microelectronic Engineering, Rochester NY 14623

MicroE Microelectronic Engineering

I. Project Objectives

Goal: Use atomic layer deposition (ALD) to fabricate high-k capacitors and implement accelerated testing routines to derive dielectric strength.

- ALD to enable high uniformity processing
- C-V characteristic curves
- Quality of dielectric, ALD film (dielectric strength, permittivity)

II. Motivation

Fabrication

- ALD
  - High uniformity
  - High-k dielectrics
- Demonstrate fabrication process for capacitors with high quality, thin dielectrics to support IC (integrated circuit) scaling.

Characterization/testing

- Quality of thin, ALD films
  - CV testing
    - Permittivity
  - Break-down testing
    - Dielectric strength

[1]	Dielectric Constant	
	Alumina	Hafnia
Literature	9	25
Experimental	8.36	24.8

Figure 1: Dielectric constants of alumina and hafnia

III. Atomic Layer Deposition

ALD provides monolayer control on film thickness, enabling high uniformity dielectrics for scaled IC's.

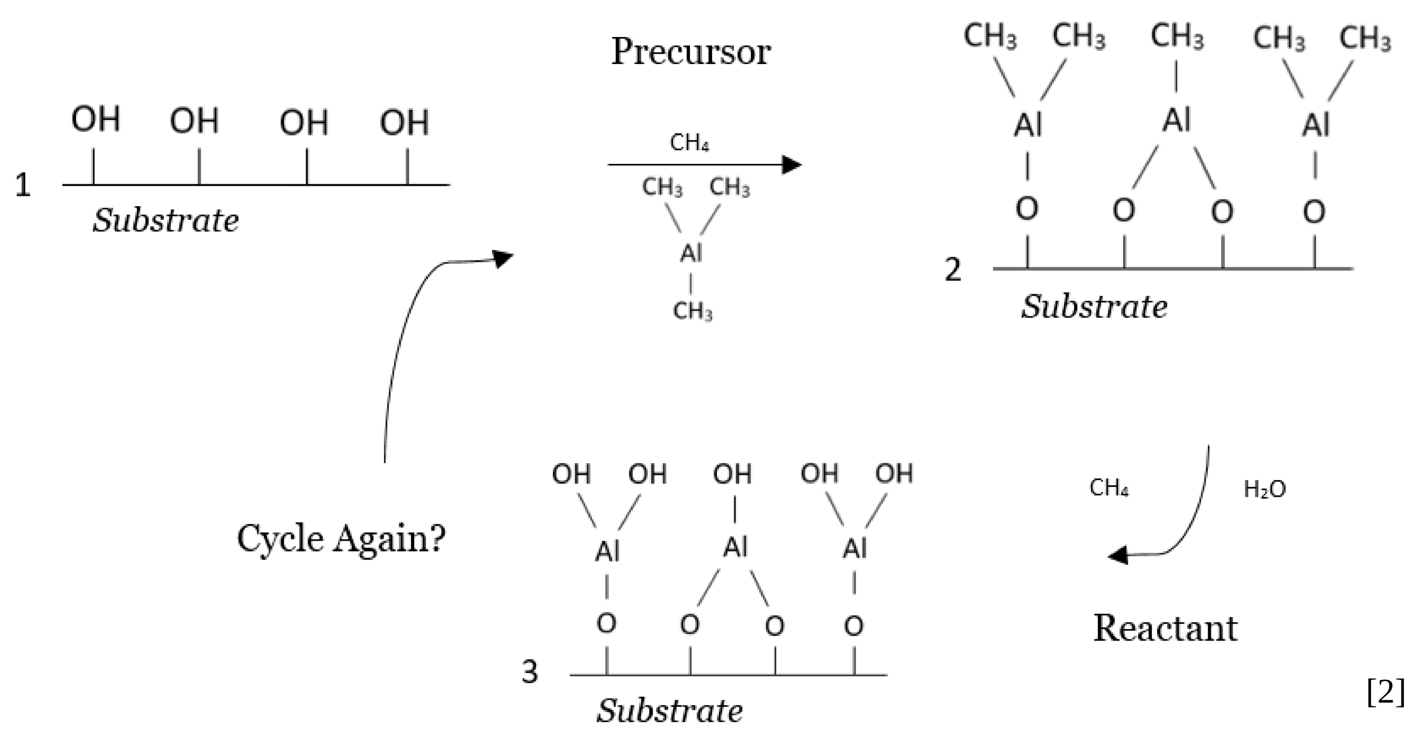

Figure 2: ALD reaction for the CVD (chemical vapor deposition) of Al_2O_3 on the surface of a silicon wafer by reacting trimethylaluminum with dangling hydroxyl groups

IV. Experimental Results

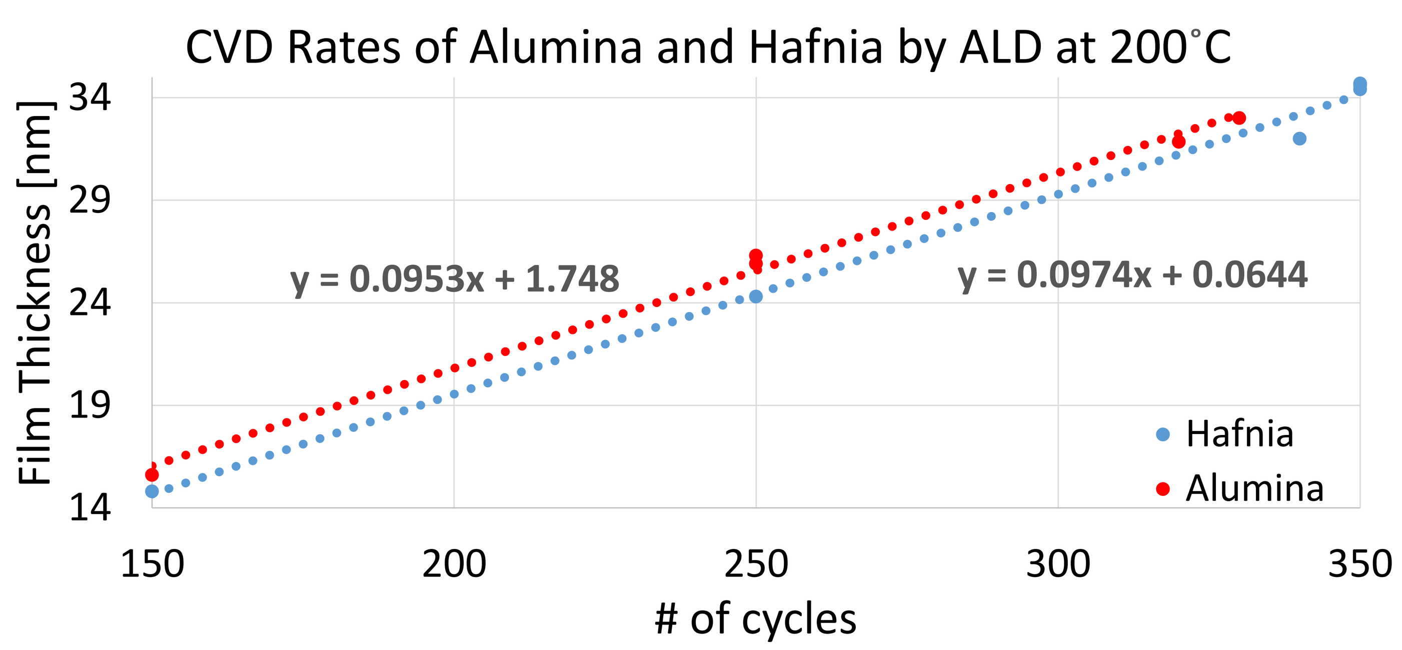

Figure 3: Validation of deposition rates of each dielectric in order to target specific capacitance values

- Al_2O_3 - (~.97 Å/s @ 200˚C) t_{ox}=31.8 nm n=1.69
- HfO_2 - (~0.95 Å/s @ 200˚C) t_{ox}=34.7 nm n=2.07

CV Characteristics

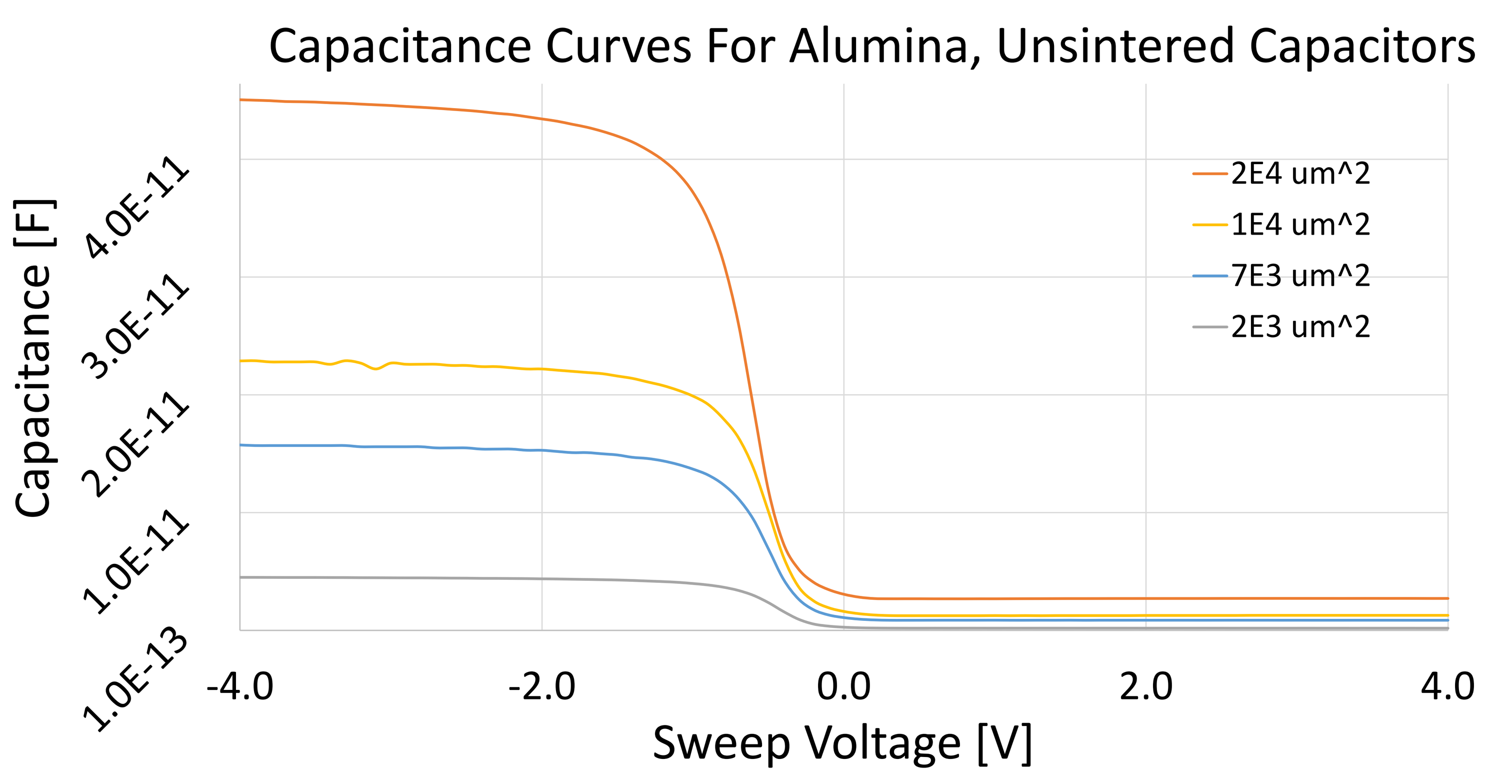

Figure 4: CV curves for capacitors with varying area exhibit expected behavior

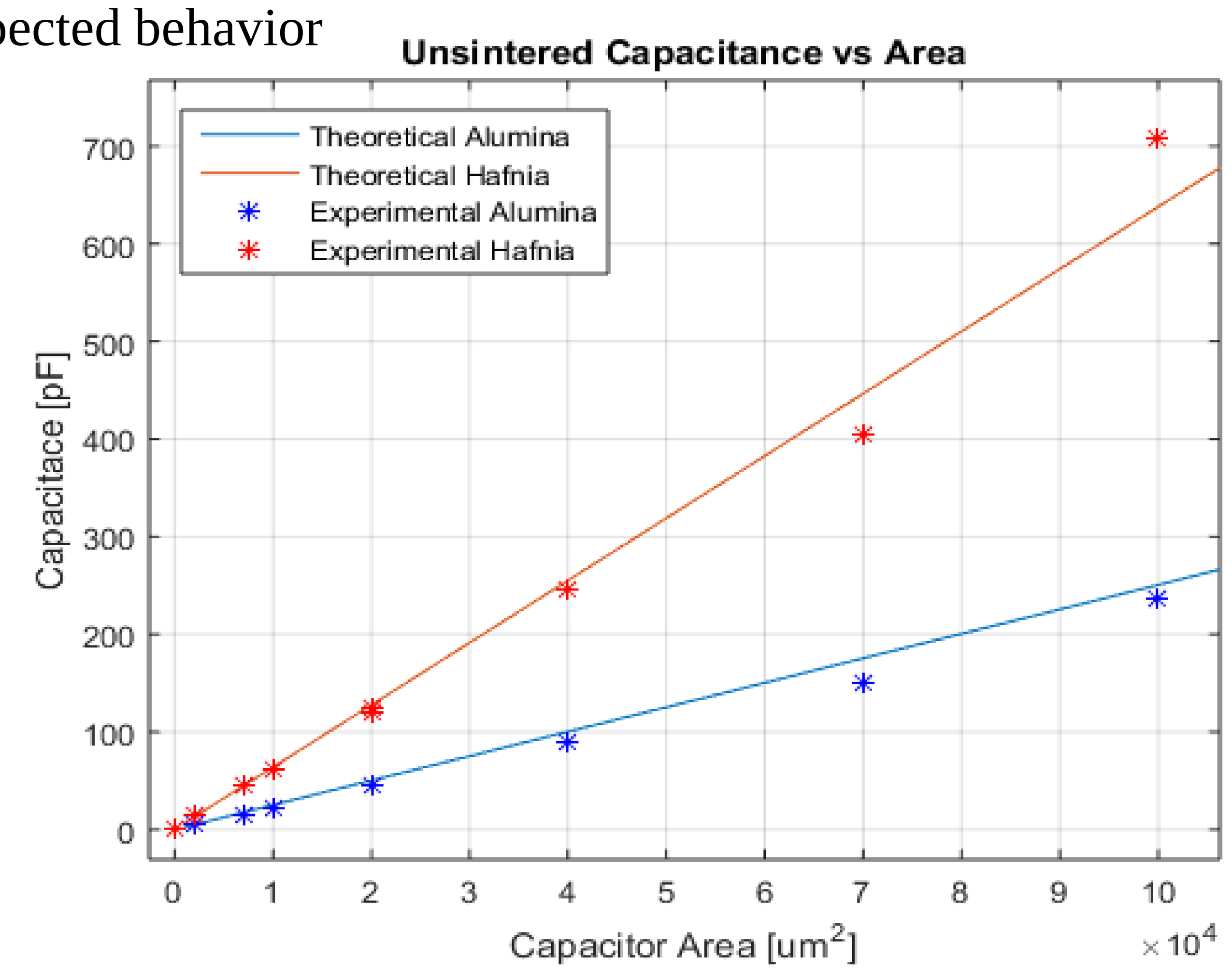

Figure 5: Experimental capacitor values match closely with theory for both alumina and hafnia

Accelerated Breakdown Results

Experimentally, both alumina and hafnia exhibited larger dielectric strengths than were expected from literature.

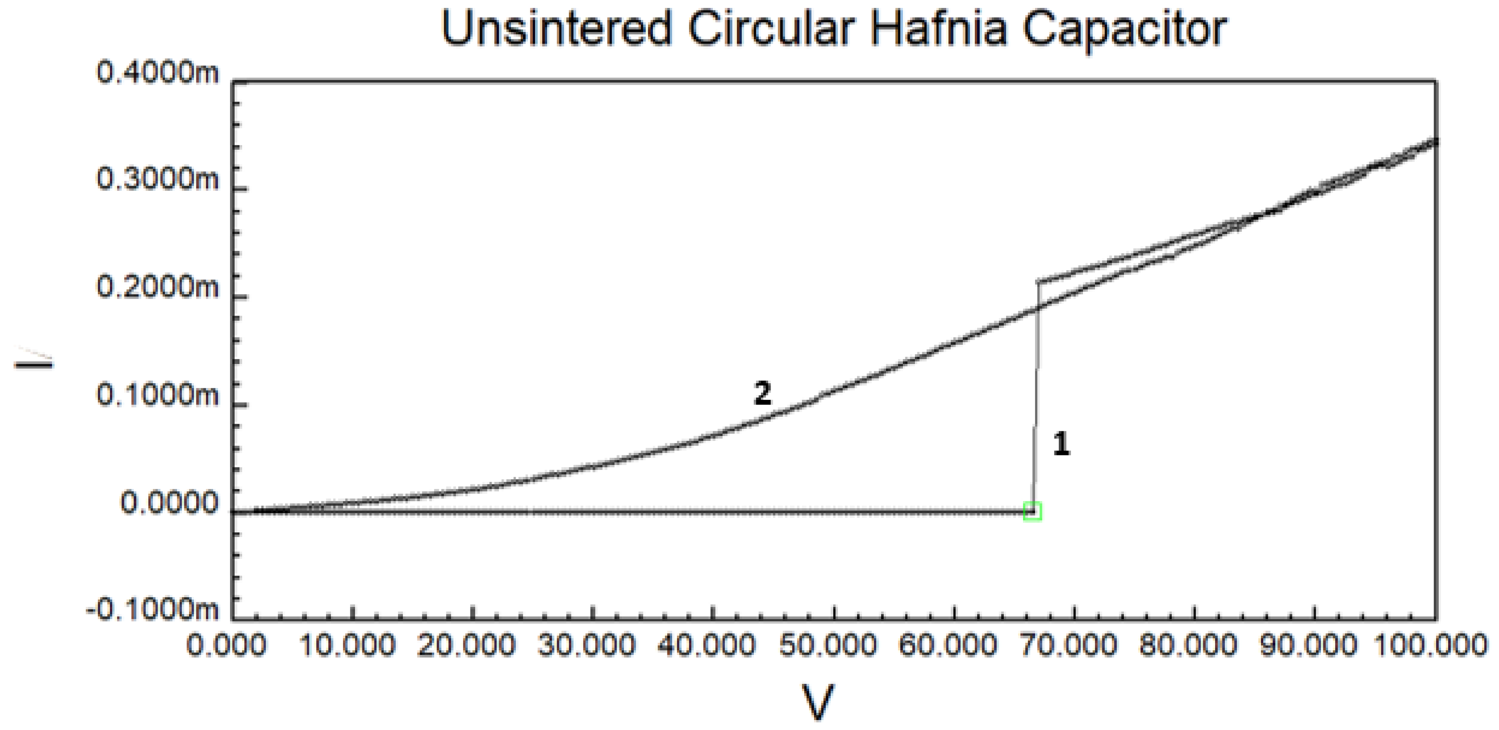

Figure 6: On the first sweep, no initial current flows until the dielectric breaks down. On the second sweep, the broken device behaves more like a capacitor

	Dielectric Strength [MV/cm]	
	Alumina	Hafnia
Literature	.08-.43	-
Experimental	17.0-24.5	16.8-27.0

[2]

Figure 7: Experimentally found dielectric strengths

V. Conclusions

ALD was used to deposit thin alumina and hafnia films on capacitors which exhibited expected capacitance, refractive index, and permittivity. Dielectric strength for alumina was found to be ~100x higher than dictated by literature.

Future Work

- Implement ALD into advanced CMOS process
- Scaled transistors with ALD high-k, gate dielectrics
- Temperature dependence with ALD

References

[1] J. Robertson. "High dielectric constant oxides." Cambridge University, Department of Engineering. Journal of Applied Physics

[2] D. N. Goldstein, J. A. McCormick, S. M. George. "Al_2O_3 Atomic Layer Deposition With Trimethylaluminum and Ozone studied by in Situ Transmission FTIR Spectroscopy and Quadrupole Mass Spectrometry." University of Colorado, Boulder, Dept. of Chemical and Biological Engineering

Acknowledgements

- Dr. Michael Jackson
- Dr. Robert Pearson
- Dr. Dale Ewbank
- Dr. Sean Rommel
- Dr. Karl Hirschman
- SMFL Staff

RIT Semiconductor & Microsystems Fabrication Laboratory