Investigation of ALD Dielectrics in Silicon and Non-Silicon Capacitors

Enri Marini, Advisors: Dr. Ewbank, Dr. Pearson, Dr. Rommel
Rochester Institute of Technology, Department of Electrical and Microelectronic Engineering, Rochester NY 14623

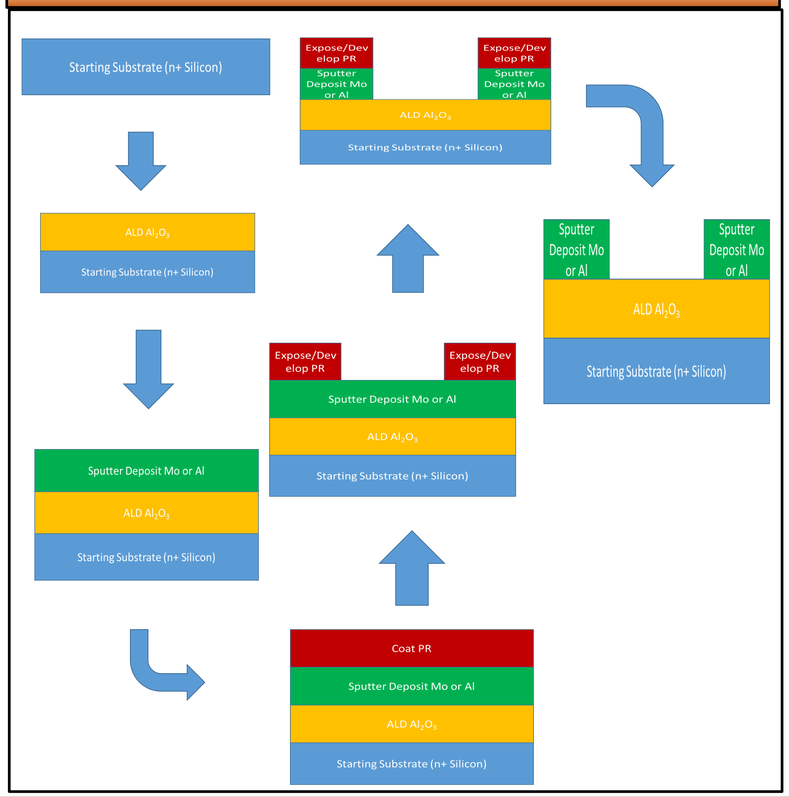
I. Project Objectives

Goal: Investigate the material properties of aluminum oxide as a dielectric material as well as two metals, molybdenum and aluminum, for MOS capacitors. The goal of this analysis is to scale aluminum oxide films deposited by ALD for use in transistor fabrication with silicon and silicon-germanium substrates and the two metals offer varying work functions for gate control on the transistor level.

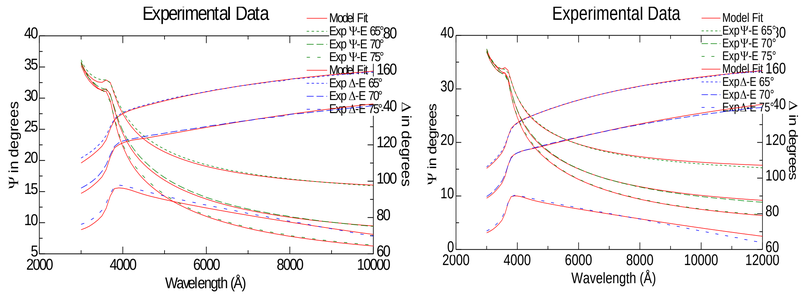
II. Motivation

- Silicon-based CMOS technology currently dominates the semiconductor industry given its great scaling capability and incorporation of silicon dioxide as the dielectric interface.
- Planar scaling of traditional CMOS technology is becoming more difficult as higher operating speeds and lower power consumption are sought after.
- Compound substrates and stoichiometric channel MOSFET devices have been of great interest as they can achieve similar operating frequencies and current densities without many of the processing issues as traditional planar CMOS devices.

III. Process Flow



IV. Experimental Results



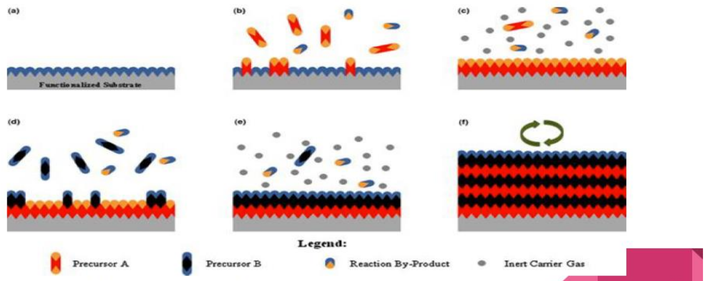
15nm Al_2O_3 experimental fitting from WVASE Ellipsometer

Thickness	15.642nm ± 0.105nm
Refractive Index (An)	1.744 ± 0.010

20nm Al_2O_3 experimental fitting from WVASE Ellipsometer

Thickness	20.391nm ± 0.115nm
Refractive Index (An)	1.613 ± 0.010

Schematic of ALD Film Growth Process



[Richard W. Johnson, Adam Hultqvist, Stacey F. Bent, A brief review of atomic layer deposition: from fundamentals to applications]

I-V Characteristics

Measurement	Value	Units
Avg. Thickness	3785	[Å]
Thickness Non-Uniformity	18.438	[%]
Sheet resistance (ρs)	563.16	[mΩ/square]
Sheet resistance Non-Uniformity (NU)	8.011	[%]
Resistivity (ρ)	2.223E-07	[Ω·m]
Good sites : Bad Sites	49:52	None

Sheet resistance and non-uniformity measurements of Molybdenum

Measurement	Value	Units
Avg. Thickness	1635	[Å]
Thickness Non-Uniformity	10.326	[%]
Sheet resistance (ρs)	347.52	[mΩ/square]
Sheet resistance Non-Uniformity (NU)	9.546	[%]
Resistivity (ρ)	5.771E-07	[Ω·m]
Good sites : Bad Sites	51:52	None

Sheet resistance and non-uniformity measurements of Aluminum

Results (con't)

	Hand-calculated Capacitance	Ideal ϵ_r (no units)	Experimental Capacitance	Experimental ϵ_r (no units)
15nm oxide with Area = 0.001cm^2	531 pF	9.00	489 pF ± 58 pF	8.64 ± 3.23
20nm oxide with Area = 0.001cm^2	395 pF	9.00	367 pF ± 34 pF	8.45 ± 2.56
15nm oxide with Area = 0.002cm^2	1063 pF	9.00	1001 pF ± 105 pF	8.84 ± 3.04
20nm oxide with Area = 0.002cm^2	797 pF	9.00	767 pF ± 48 pF	8.83 ± 2.15

Hand calculations and experimental observations of capacitance and relative permittivity of Silicon substrate MOS capacitors with Aluminum as the gate metal

$$C = \frac{\epsilon_r \epsilon_0 A}{t_{ox}} \rightarrow \epsilon_r = \frac{C t_{ox}}{A \epsilon_0}$$

MOS capacitance was modeled using parallel-plate capacitor system. Once the experimental capacitance was measured, the relative permittivity can be back-calculated.

V. Summary

Conclusions

-Atomic layer deposition of high dielectric constant material has been characterized in capacitors for future use in field effect devices.

Future Work

-Test different gate metals and dielectric materials for CV test

References

-Ye, P.D., et al. "GaAs MOSFET with Oxide Gate Dielectric Grown by ALD." IEEE Electron Device Letters 24.4 (2003): 209-211
- Lin, Jianqiang, Tae-Woo Kim, and Dimitri A. Antoniadis. "A Self-Aligned InGaAs Quantum-Well MOSFET Fabricated through Lift-off-free front-end process." Applied Physics 5.6 (2012)

Acknowledgements

- SMFL Staff (special thanks to Patricia!)