COST-EFFECTIVE ATOMIC LAYER DEPOSITION SYSTEM

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BACKGROUND

- Atomic Layer Deposition (ALD) - a subclass of chemical vapor deposition (CVD), is widely used to deposit metal oxide films for microelectronics fabrication
- The ALD process can precisely deposit films at a rate of one monolayer per cycle
- Commercial ALD systems are expensive ~$150,000, but work done at Central Michigan University outlines a system built for less than $10,000

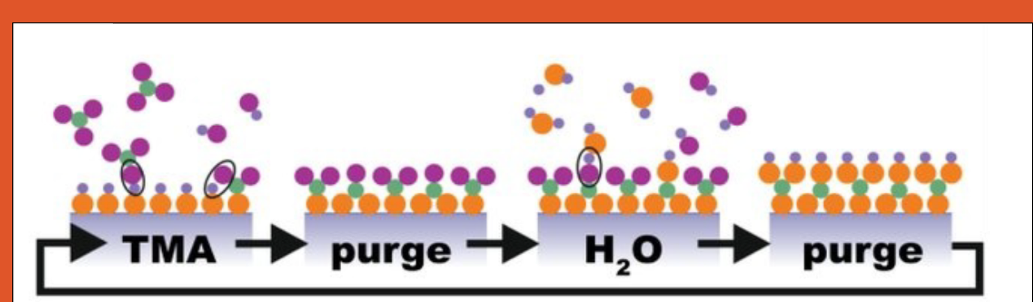

Figure 1. *Surface reaction of trimethylaluminum (TMA) and H_2O, with an inert gas purge, to create an Al_2O_3 monolayer after one cycle from Grillo et al.*

OBJECTIVES

- Design, build, and characterize a versatile bench-top ALD system for less than $10,000
- Create a standard operating procedure to safely handle and install the pyrophoric reactant, trimethylaluminum (TMA), and an operating procedure for the ALD system
- Achieve deposition of Al_2O_3, and evaluate the feasibility of implementing an ALD lab into the CHE 544/444 lab
- Expand deposition to other thin film materials for Dr. Feng's research

Build an economical ALD system with the capability of performing graduate research and possibly implemented into an undergraduate instructional lab.

Oregon State University

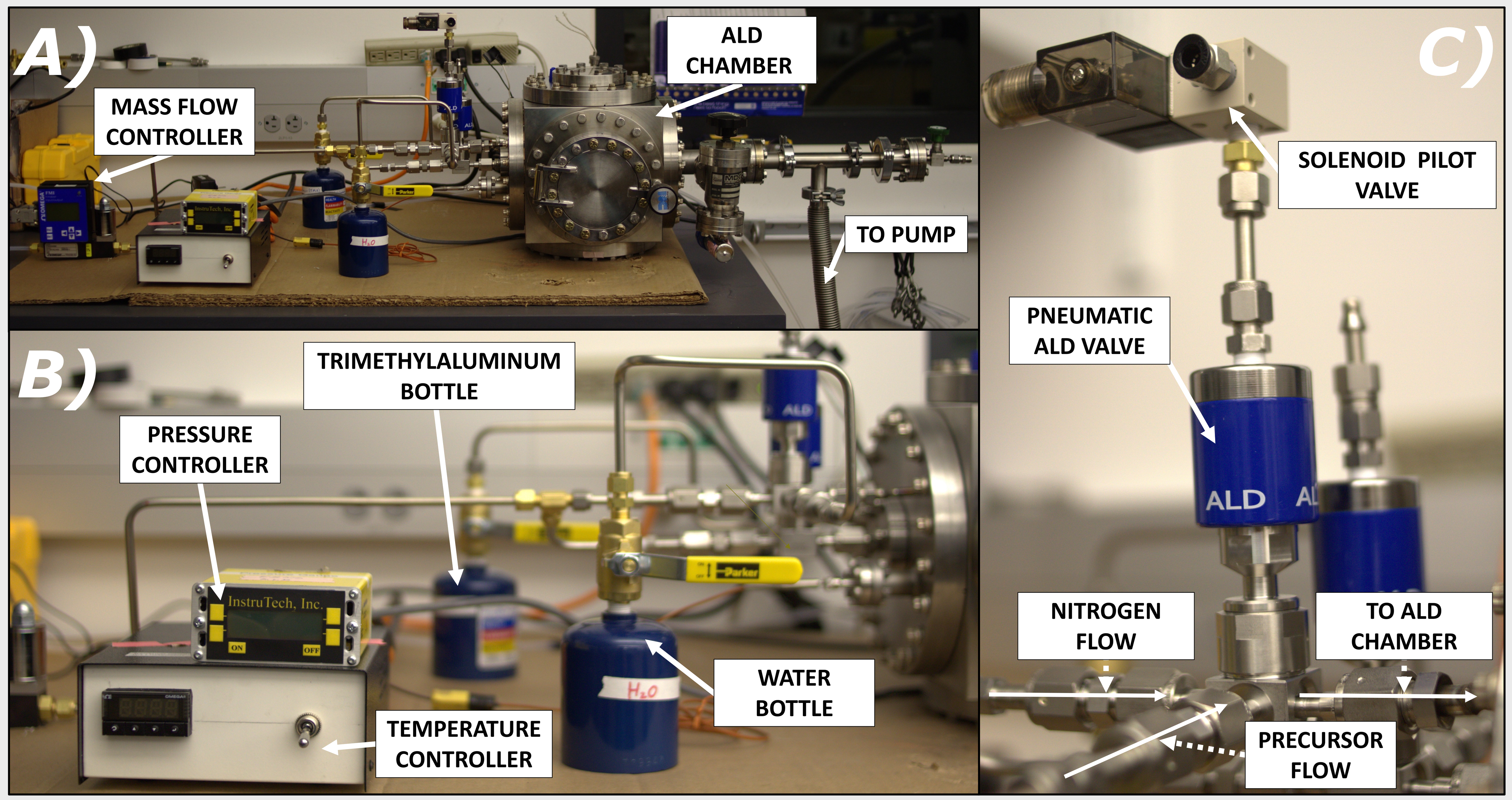

Figure 2. A) *The atomic layer deposition system located in Johnson 200.* ***B)*** *The temperature controller (Omega, CNi3244) and pressure gauge (InstruTech, VGC301A) located next to ALD chamber with the TMA and water carbon-steel bottles connected to pneumatic ALD valves (Swagelok, 6LVV-ALD3TC333P-C).* ***C)*** *A close up of the ALD valves connected to solenoid pilot valves (LDS, SVK-DC24-200) which allows the cycling of water and TMA.*

OUR SYSTEM

The gaseous reactants flow from left to right through the ALD chamber. The reaction takes place at the substrate surface as the reactants flow across horizontally.

The pneumatic ALD valves are controlled by solenoid pilot valves (SMC, NVZ5120-5LZ-01T) connected to an Arduino microcontroller. This allows for control of the precursor (TMA) and co-reactant (H_2O) addition in pulses of 0.015 seconds while constantly flowing nitrogen as a carrier gas at a rate of 20 sccm.

Only the substrate stage is heated during the deposition process. The system is described as cold-walled due to the lack of complete system heating. This allows for more precise temperature control during the deposition process.

KEY COMPONENTS

- Arduino Microcontroller – used to control the solenoid pilot valves at the microsecond scale to alternate which chemical is sent to the chamber
- Quartz Crystal Microbalance (QCM) - the QCM (Colnatec, Phoenix System PC®) will allow for *in situ* thickness measurements of the deposited film on a separate quartz sensor
- Temperature Controller – an Omega PID temperature controller (CNi3244) is utilized for precise substrate temperature control
- Argon Mass Flow Controller (MFC) – Argon flow into the system is controlled using an Omega MFC (FMA5408A), allowing for system pressure control during deposition experiments

RESULTS

- Successful deposition of Al_2O_3 on silicon, see figure 3 for XPS spectrum of material deposited.
- Temperature fluctuation of +/- 10 °C during deposition while holding pressure of 2 Torr.

FUTURE WORK

- Expand the system capabilities to additional thin film materials
- Modify system to reach a lower absolute pressure

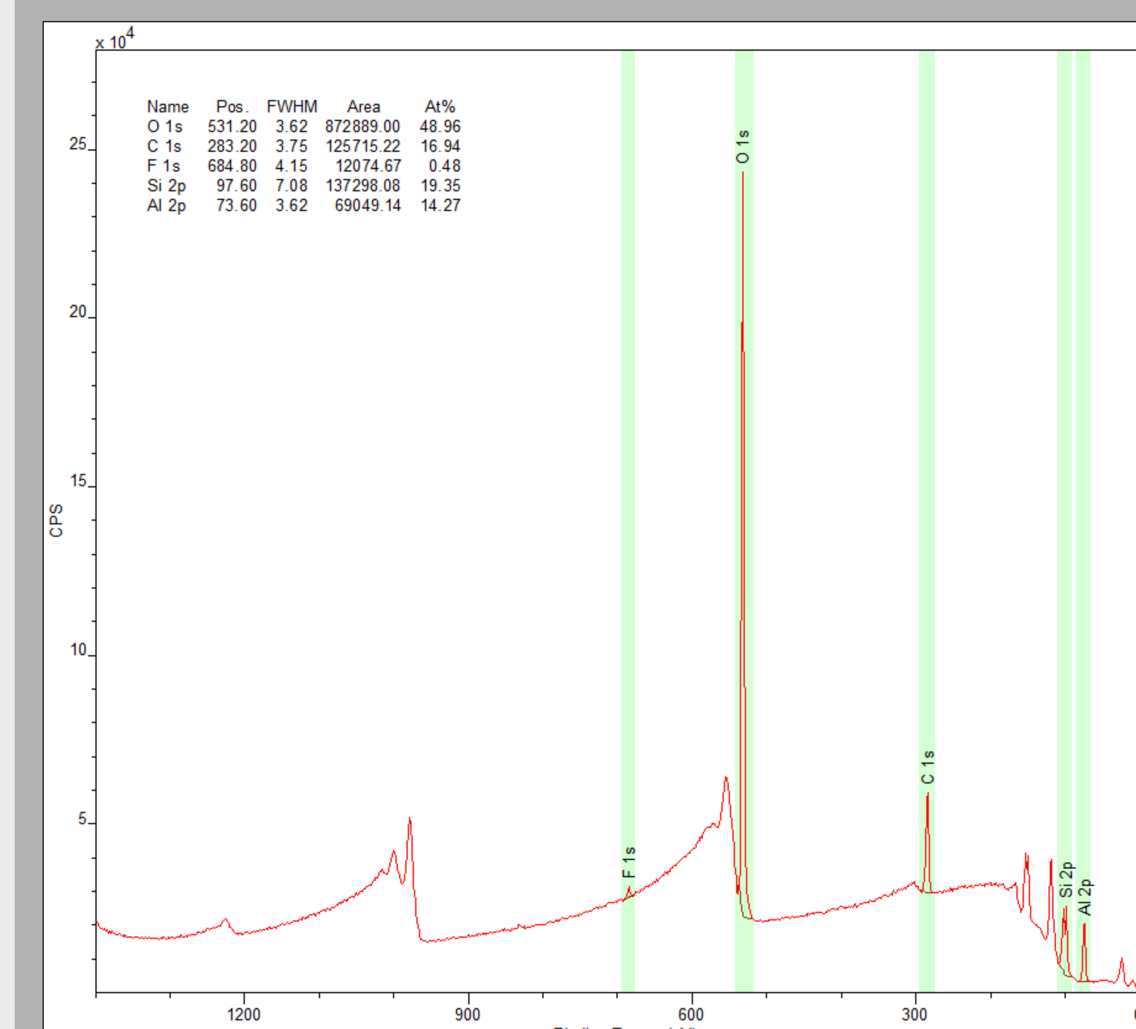

Figure 3. *X-ray spectroscopy (XPS) spectrum for Al_2O_3 on Silicon from a PHI 5600 X-ray photoelectron spectroscopy and Auger electron microscopy system. The aluminum and silicon peaks prove the deposition of an aluminum oxide film on a silicon substrate.*

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