Proposal & Plan:
ALD Precursor Delivery System

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Background

The Precursor Delivery System is responsible for delivering the precursors of I2O3 and SnO2 (TMIn and TDMASn respectively), H2O, and the N2 carrier gas to the ALD chamber.

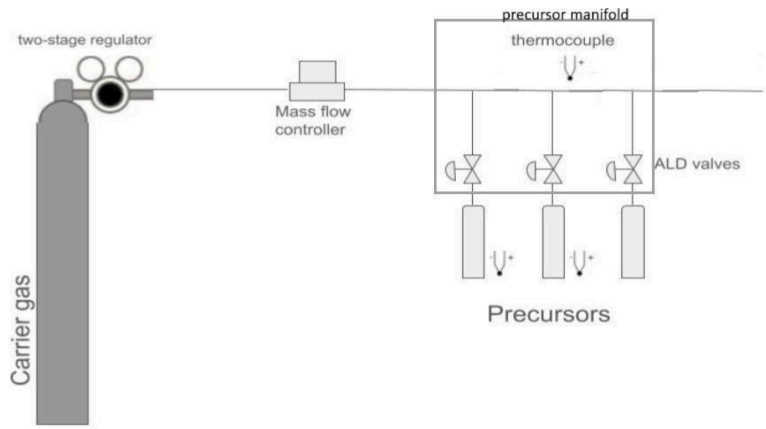
The delivery system is designed to pulse the precursor chemicals at specific pressures and time intervals to deliver the right chemical at each state of the deposition process. It is also designed to facilitate the flow of the carrier gas at a specific temperature and flow rate for both chemical delivery and purging on the wafer surface.

This is all done in order to facilitate the growth of high quality ITO thin films in the ALD chamber.

The delivery system must be rated and sealed for the overall vacuum requirement of the entire ALD system of 100 mTorr. In addition, due to the precursor chemicals being pyrophoric, materials that interact with the chemicals must also be considered in order to comply with lab safety requirements.

The overall ALD Delivery System will consist of two main parts:
- Delivery System
- Delivery Storage

Delivery System



Technical requirements

- Material Selection:
  - Compatible with pyrophoric chemicals and corrosion resistant
- Thermal:
  - TMIn and TDMASn bubblers heated to 60C
  - Needs possibility for 20C for TMIn and 45C for TDMASn
  - Delivery line capable of maintaining fluid temperature of 60C up to ALD chamber
- Fluid Delivery and Vacuum:
  - Delivery line rated for 100 mTorr vacuum
  - Carrier gas delivered at 10 - 40 sccm
  - Compatible with either N2 or Ar
  - ALD valves able to pulse for 3-0.625 s
- Measurement:
  - Thermocouple capable of accurate fluid temperature measurement
- Integration with DAQ and electronics
- Integration with the ALD chamber
- Minimize cost where possible

What has been completed/purchased

- Dual stage regulator (NOT ORDERED)
    - Steps down from cylinder pressure (~2000 psi) to operating pressure for Mass Flow Controller (<70 psi)
- 100 SCCM flow controller
- Chemical ampules
    - From CMU Nanofab
- Swagelok ALD3 valves and manifold
    - From CMU Nanofab
    - inlet = ¼” female VCR
    - outlet = ¼” male VCR
- Stainless steel tubing
- Male and female VCR to male fittings
- VC face seal metal gaskets
- KF25 to ¼” tube fitting
    - Interface with vacuum
- Heating tape (DOESN’T WORK)

Since most of the central components have already been procured and critical materials and fittings have been decided, further development would be focused on tube routing, possible thermal insulation, thermocouple integration, and construction.

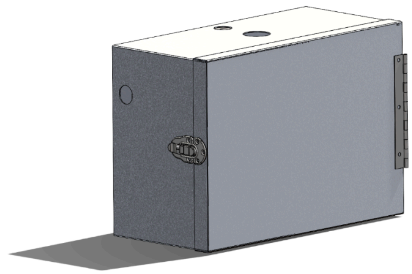
Major deliverables

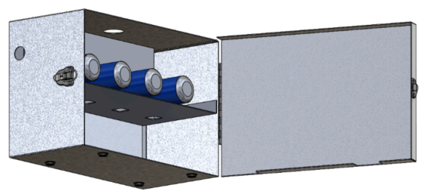
- Full CAD of delivery system
  - Fittings locations and tubing geometry accurate to real life setup
  - Communication with electronics for sensor placement and wiring plan
  - Check for assembly operations and integration with Delivery Storage
- Assembly of delivery system
  - Troubleshoot any potential problems with integrating electronics
- Testing for performance of assembly under vacuum
  - Ensure that the system complies with safety and technical requirements during use
- Testing heating element and sensors
  - Ensure temperature, flow rate, and pressure targets are met
  - Ensure that controls are able to read accurate data
- Documentation
  - Design process, analysis
  - Manufacturing and assembly instructions
  - BOM

Things to consider

- Overall dimensions of proposed locations of ALD station
- Heating should be maintained for all lines downstream of precursor
  - Must avoid condensation and precursor build up so line doesn't explode
- Thermocouple placement should be on tube surface as to not disrupt fluid flow
  - Research temperature values also measure at tube
  - ¼" tube should not have steady state and conduction loss problems
- Operations of assembly
  - We do not want to get tubings that don't fit
- Integration with delivery storage and electronic components
- Heating block vs heating tape
  - Heating block is made to fit manifold but very heavy
  - Heating tape would need some thinking to figure out how to wrap manifold

Delivery Storage



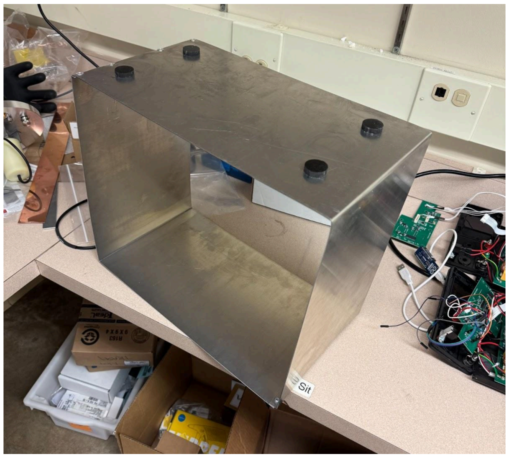
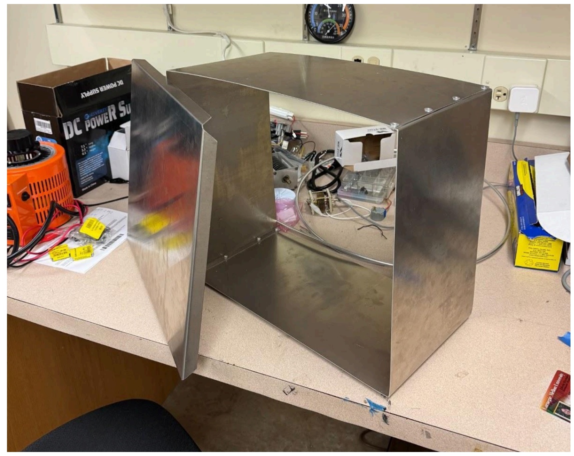


Technical Requirements

- Storage Capacity:
    - Holds the precursor manifold with three ALD valves and three gas ampules
    - Potentially has room for mass flow controller in the future
- Packaging:
    - Contains holes to attach proper fittings for an exhaust connection, carrier gas inlet, and a gas outlet
    - Potentially need pass throughs to account for wiring
    - Leave room for either heating block or heating tape/alternative heating options
- Materials:
    - Made out of aluminum for precursor compatibility
- Ergonomics:
    - Ampoules should be easy to access in order for simpler replacement when necessary
- Manufacturing:
    - Minimize time to manufacture and assemble
    - Design needs to be easily replicable
    - Allow design to be manufactured with precision
- Minimize cost

What has been completed/purchased

- Prototype enclosure partially made with bent sheet metal and riveted

- Draw latches
- Adhesive bumpers
- Excess of 0.050” thick 5052 AL
- Rivet tool and blind rivets (3/16”)

Certain decisions like materials have already been made. The prototype is not yet completed, and several recommendations for improvements have been made regarding the design from F24. Therefore I will be focused on both possible redesign/modifications of components as well as aiming to finish the assembly of the Delivery Storage.

Major Deliverables

- Examine results from F24 and decide on necessary changes
    - Decide on the scope of redesigning components
    - Take into consideration the manufacturing lessons learned
    - Communicate with team to include capacity for future use
- Full updated CAD of Delivery Storage
    - Check for compliance with available space in the lab
    - Implement any design changes to better meet technical requirements
    - Designing for manufacturing
    - Integration with Delivery System CAD
- Manufacturing plan
    - Consider ease of manufacturing and assembly
    - Review outsourcing decision based on timeline and cost
- Fully assembled storage prototype
    - Aim to reduce effort and time for manufacturing
    - Prior experience with machining and access to shops should help with making components
- Testing for interferences and manufacturing issues
    - Working with electronics and ALD chamber for integration
- Documentation
    - Design process, analysis
    - Manufacturing and assembly instructions
    - BOM

Things to consider

- Hardware choice
    - Is the cost-benefit of rivets outweighed by nuts and bolts being easier to install?
    - Adhesive could also be an option, but may have issues with chemical compatibility
- Structural considerations
    - Noticed the prototype is a bit floppy, also the AL is relatively thin
    - Thicker AL can improve rigidity, but costs more
    - Structural support both internally and externally can be considered
        - External support doesn't need to meet chemical compatibility requirements due to AL walls as barriers
            - Potential for low cost materials like PLA 3D prints
- Shelf redesign
    - How to best fixture ampules and make them easy to replace?
- Replication and outsourcing
    - Can we find a cheaper alternative for outsourcing sheet metal manufacturing?
    - Can we expect others reading our documentation to easily construct the enclosure?
- Sheet metal manufacturing
    - Potential design changes that can reduce manufacturing time by reducing number of sheet metal bent parts
- Packaging
    - Heater choice:
        - Can we make a decision early on between heater block and heater tape?
    - MFC is probably not going in the enclosure
    - Do not need to plan for more than three ampules
    - Clear communication about wire routing and hole placements

Timeline

Deadline	Delivery System	Delivery Storage
1/28/25	Document and understand physical design space in the lab + Order new heating tape, regulator, and KF25 fitting	Look at heating block and get mass & CAD
2/2/25	Finalize design decisions	
2/9/25	CAD rev 1	
2/15/25	Full BOM + ordering	
2/16/25	Presentation 1	
2/18/25	Manufacturing and Assembly Plan	
2/23/25	Tubes cutting	Sheet metal bending
2/26/25		Machining + other manufacturing
2/28/25	Assembly	
3/1/25	Testing for vacuum and thermals	Testing for reliability and ergonomics
TBD	Make changes as necessary	
3/23/24	Presentation 2	
4/25/24	Documentation	
4/27/24	Final Presentation	