# Coated Li Film Targets for TNSA Light-Ion Reaction Experiments with the MTW Laser


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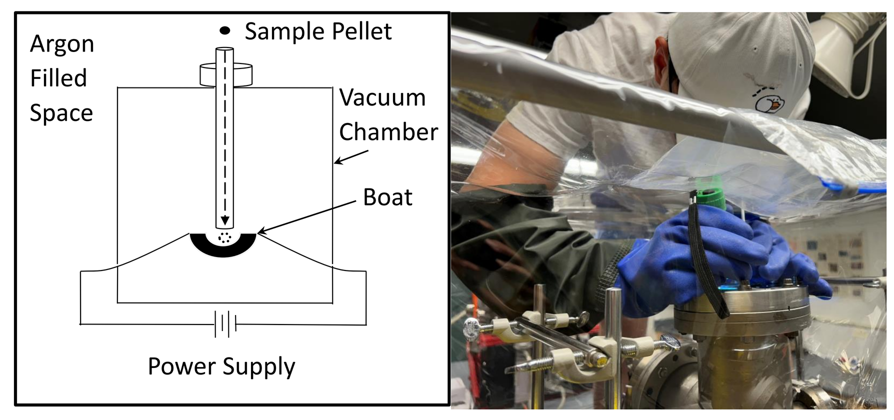
## I. Abstract

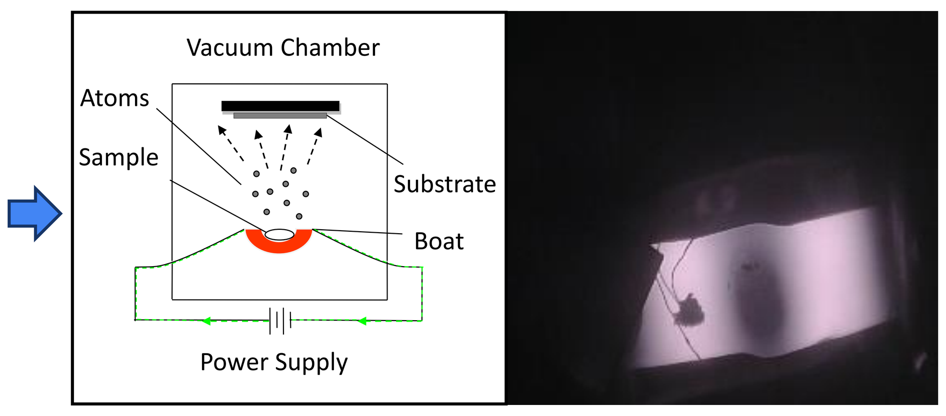

A system for creating Sn or Ag coated Li targets was developed for a Multi-Terra Watt (MTW) laser Target Normal Sheath Acceleration (TNSA) experiment to study the $^7$Li(d, p)$^8$Li reaction. The Li targets were designed to have a ~50 nm thick coating to prevent Li from interacting with air and water vapor and be ~2 μm thick to reduce energy loss. The films were produced in a ~$10^{-5}$ Torr evacuated deposition chamber in which about 15 A flowing one way through a diode circuit heated a stainless-steel boat holding a Li pellet to a thermocouple-measured temperature of nearly 400℃, evaporating the Li onto a 25 μm thick stainless-steel substrate. A current of up to 60 amps flowing the opposite direction through another diode heated a molybdenum boat holding a Sn or Ag pellet, evaporating the metal and forming the thin coating over the Li. The thicknesses were measured using a micrometer, magnetic adhesion, a home-made mechanical profilometer, and Rutherford backscattering. To allow Li metal to be weighed and inserted into the boat, an Air-filled glove box was constructed around the deposition chamber.

Funded in part by a grant from the DOE through the Laboratory for Laser Energetics, and by SUNY Geneseo and Houghton University.

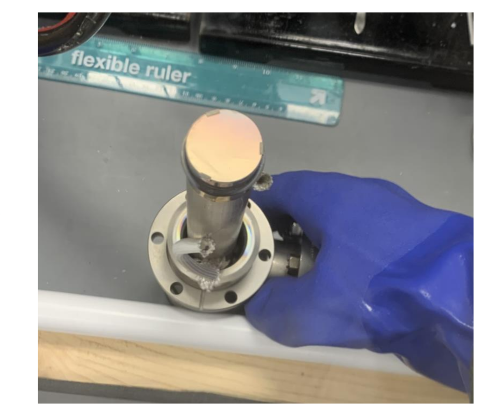
## III. Procedure and Sample Target Films




**Step 1:** In an argon atmosphere, 0.03g lithium pellets were loaded into the stainless steel boat and 0.05g tin pellets into the molybdenum boat through a tube inserted through the flange at the top of the chamber.




**Step 2**: Roughly 15A through the lithium boat heated it to about 470°C for about 15 min. The current was reversed and about 54A heated the tin boat to approximately 1160°C forming a protective tin layer over the lithium.



**Step 3:** Once deposition was complete, the target was removed in an argon atmosphere.

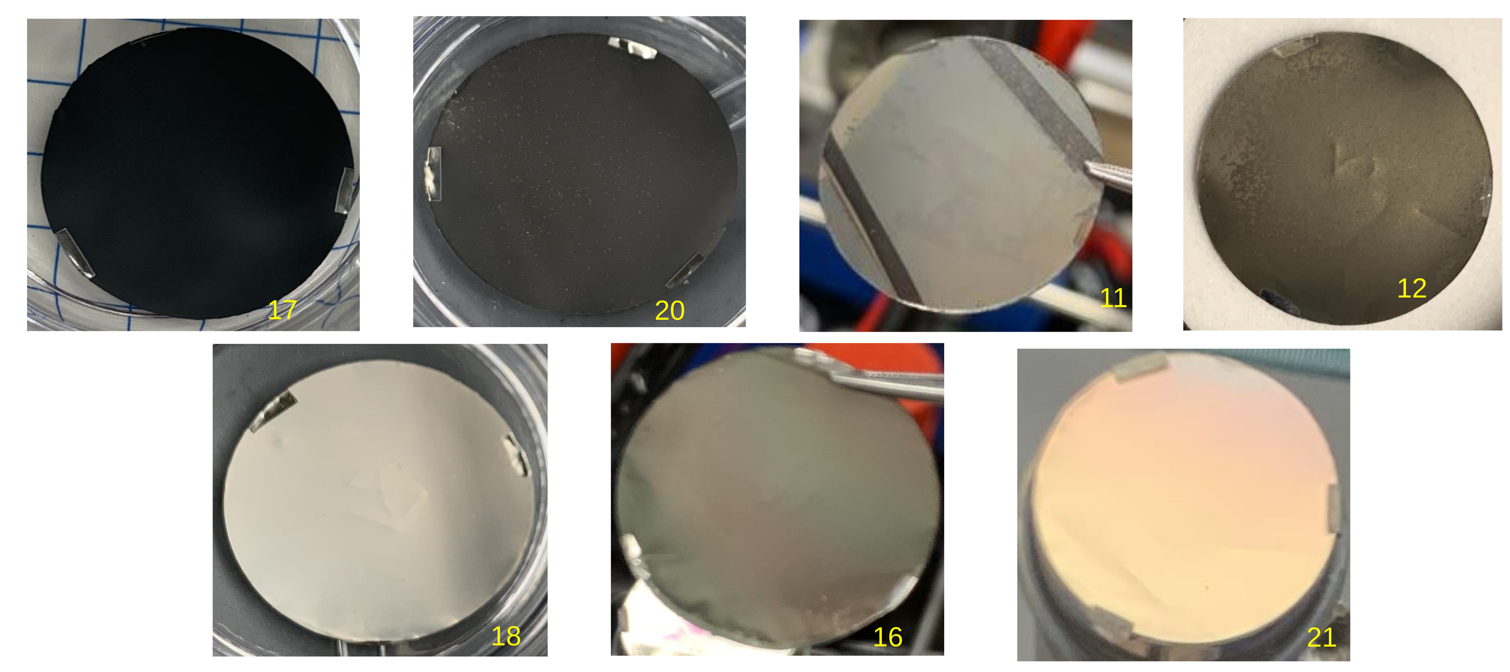
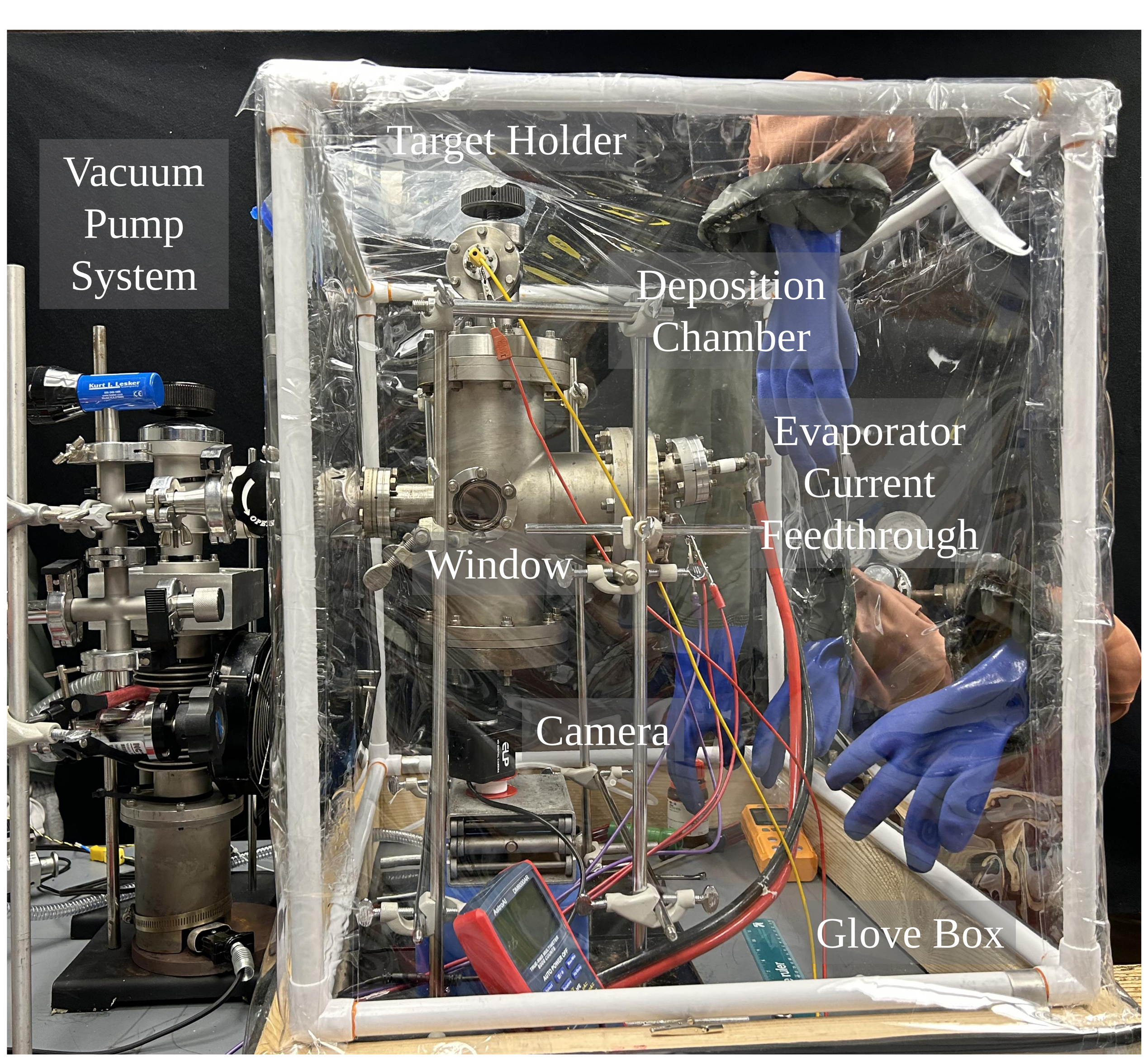
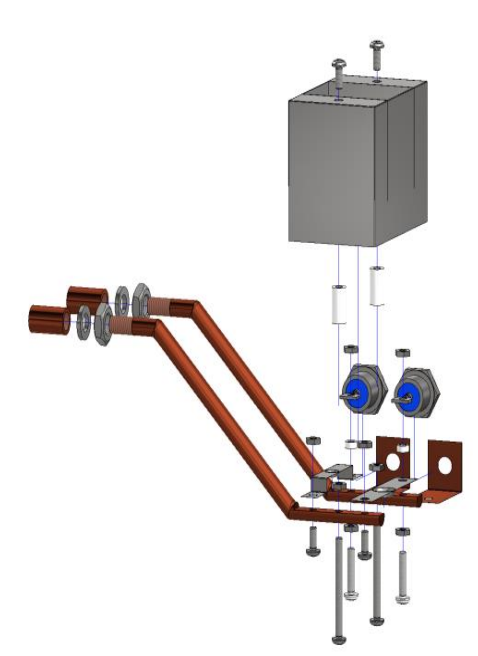


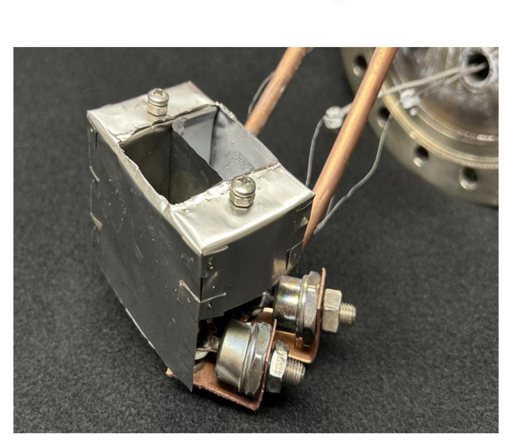

**Figure 3:** One-inch diameter lithium nuclear targets on 0.002 inch thick stainless steel substrates. (Target 17) An uncoated Li target shortly after removal from the vacuum. (Target 20) An uncoated Li target after a longer exposure to air, lithium hydroxide is starting to form. (Target 11) A tin coated Li target having to uncoated strips used to test thickness measurements. (Target 12) Thick tin coating on the lithium film. (Target 18) White lithium oxide formed under a waxy polyethylene coating after prolonged air exposure. (Target 16) Another polyethylene coated Li target. Lithium oxide is forming neat the edge where air is getting under the coating. (Target 21) Silver coated lithium film.

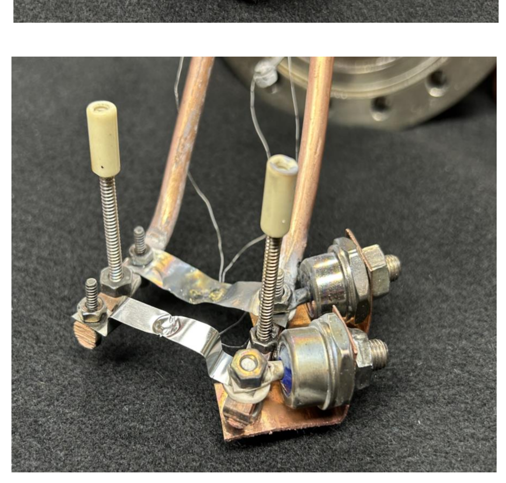
## II. Deposition System

An experiment was performed to determine the feasibility of using Target Normal Sheath Acceleration (TNSA) to measure light ion cross-sections in the 0.2 – 10 MeV range. A physical vapor deposition system produced lithium nuclear targets which were then activated by the $^7$Li(d, p)$^8$Li reaction using TNSA deuterons from the Multi-Terra Watt (MTW) laser at the Laboratory for Laser Energetics (LLE). The deposition system was designed to deposit a thin protective coating over the Li film to prevent oxidation. The evaporator, used for heating and evaporating materials, consisted of two evaporation boats surrounded by a "house" with a central divider to prevent material cross-contamination between boats and deposition on the chamber walls and viewports. A stainless steel boat was used for Li deposition, while molybdenum was used for other materials. A diode circuit allowed selection of the boat to be heated by using the direction of current flow. Tin, polyethylene, and silver protective coatings were tested.







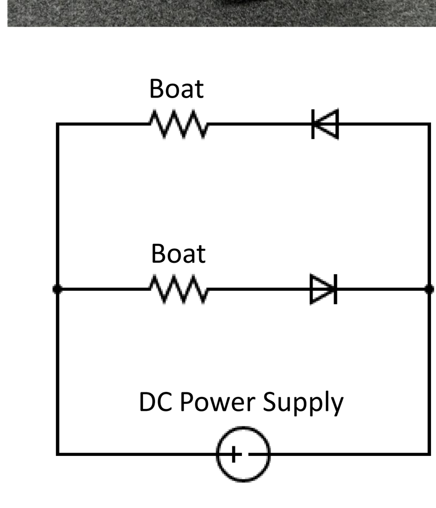



**Figure 1 (above):** The deposition vacuum chamber is evacuated to ~$10^{-5}$ Torr by an oil diffusion pump backed by a rotary forepump. Several valves allow the chamber to be brought up to air pressure for inserting and removing substrates while keeping the diffusion pump at low pressure. The air in the deposition chamber can then be removed by a different forepump before reconnecting to diffusion pump system. Pressure is monitored by thermocouple and cold-cathode ion gauges. The evaporator boats are heated by current flowing through a high-current feedthrough, and their temperatures are monitored with thermocouples. A motion feedthrough on the top of the chamber allows distance from the evaporator boats and the substrate to be adjusted. Viewports allow the deposition process to be monitored. Inserting lithium pellets and removing uncoated lithium films must be carried out in an argon atmosphere, which is created by transparent polyethene glove box.

**Figure 2 (right, top to bottom) :** CAD exploded view of the evaporator and photographs with and without the house. Current passed through the copper rods heats up boats attached to them using ceramic screws. In the circuit diagram, high-current diodes in the vacuum chamber allow only one boat to heat up at a time depending on the direction of the flowing current.

## VI. Target Thickness Measurement

Many common techniques that are used to characterize the thickness of thin films will not work well for our targets, which are non-reflective conducting films on conducting non-magnetitic substrates.

**1. Micrometer** – a Mitutoyo IP54 micrometer measured the thickness with 1 μm resolution by subtracting the substrate.

**2. Magnetic Adhesion** – a Neoteck NTK103 magnetic adhesion tester with nominal 1 μm accuracy tended to scratch the film making measurement difficult.

**3. Rutherford Backscattering (RBS)** – carried out at SUNY Geneseo using the Pelletron accelerator successfully measured both surface coating and lithium film thickness.

**4. Mechanical Profilometer** – a homemade profilometer used a picomotor to move a rounded electrode in steps of about 10 nm until it made electrical contact with the film. A linear positioner moved the substrate to map out the surface. One problem was the probe sometimes punctured the surface.

| Method |
|---|
| Eddy Current |
| Micrometer |
| Magnetic adhesion |
| Weighing |
| Deposition rate meter |
| Alpha or beta transmission |
| Rutherford backscattering |
| Fluorescence |
| Mechanical profilometer |
| Microscopy |
| Interferometry |
| Ellipsometry |

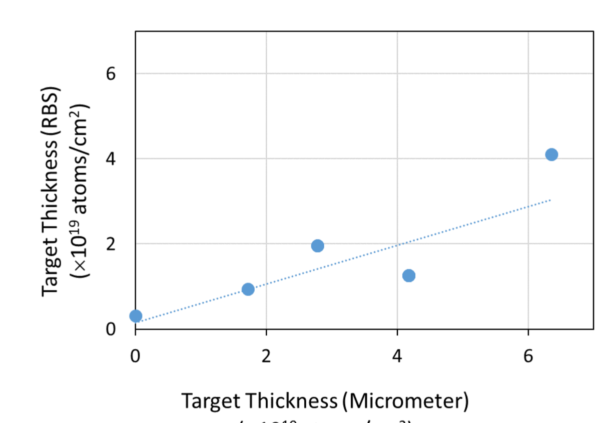
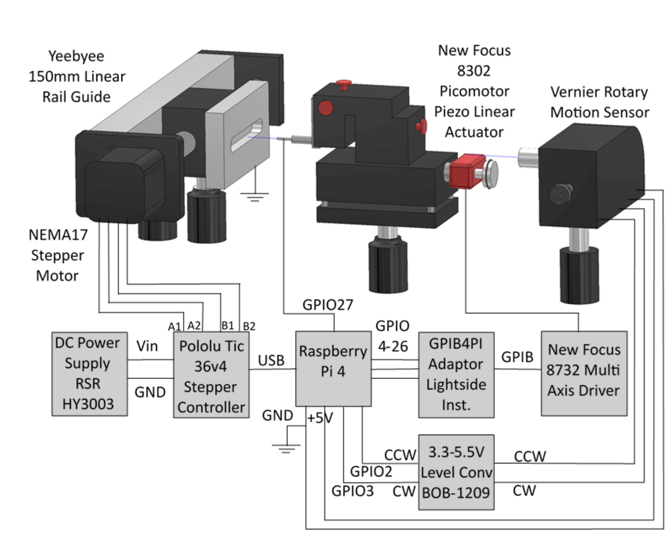
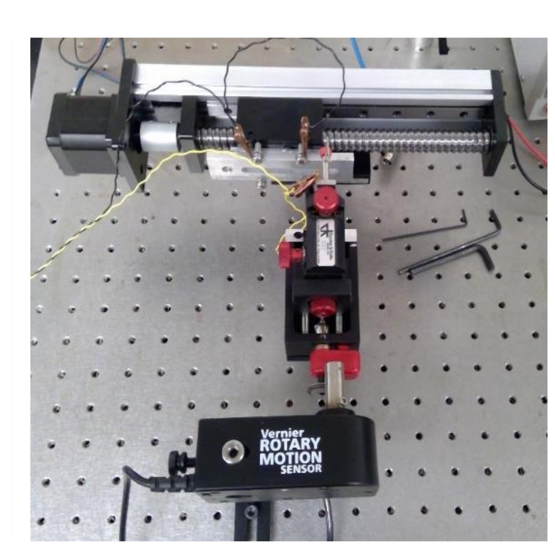



**Figure 4**: Comparison of RBS and micrometer for lithium targets.





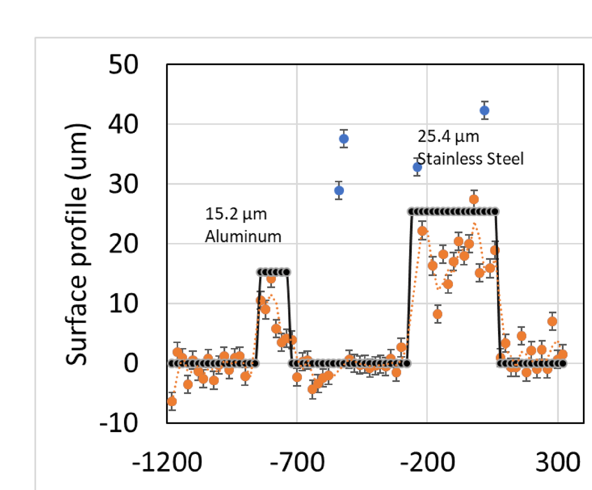



**Figure 5**: Block diagram (left) and photograph (center) of picomotor profilometer. The New Focus picometer uses piezo crystals to turn a finely threaded rod in tiny increments to move the probe in steps of about 10 nm. The rotary encoder captures the absolute motion. Test measurements (right) using thin foils show the foils were not laying flat.

## VII. Future Plans

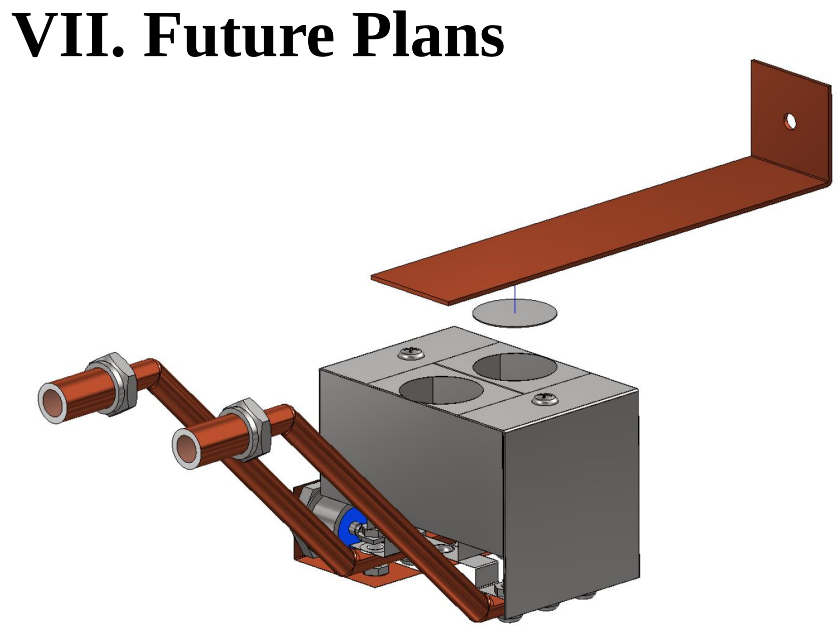


**Figure 6:** The evaporator "house" will be divided into separate lithium and tin chambers. The target substrate can be positioned directly over each boat with a slightly larger top hole on the tin side to overlap the edge of the lithium film. The slider provides increased heat transfer to cool the substrate, and blocks mixing.

The future plan is to modify the evaporator to solve the following problems:

1. Prevent lithium from evaporating and mixing with the tin when the tin boat is heated.
   - Isolate the tin and lithium sides of the evaporator.
   - Improve target heat sink to prevent lithium on target from re-evaporating.
2. Prevent air from penetrating under the edges of the coating to reach the lithium by making the tin coating extend past the lithium.
3. Create a uniform film and coating thickness by centering the substrate over the boat.