Depositing Lithium Films to Simulate ICF Reaction Products

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I. Abstract

A possible future experiment using Inertial Confinement Fusion (ICF) to measure low-energy light-ion nuclear cross sections has been simulated using the SUNY Geneseo Pelletron to activate a thin lithium target which was then rapidly evaporated, trapped, and detected. This experiment required a lithium film to be deposited in a vacuum of approximately 10^{-5} Torr onto the surface of a thin tungsten foil. The films were produced by heating natural lithium pellets to 400 °C in a stainless-steel boat through which 20 A of current was passed. The evaporated lithium was contained inside a stainless-steel "house" inside the vacuum chamber, with a small opening on the top that allowed the lithium to reach the tungsten foil. The vacuum chamber was in an argon-filled glove bag which allowed the films to be briefly removed and handled since lithium reacts vigorously with oxygen and water vapor.

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

II. Deposition Chamber

A deposition chamber was used to make thin lithium films, which were activated using the SUNY Geneseo Pelletron accelerator. These films were used to simulate using an ICF shot to measure light ion nuclear cross sections at low energy. One nuclear reaction product of interest is ^{8}Li, which has a half-life of 839 ms. The goal of this experiment is to measure the efficiency of the system for collecting the ^{8}Li and counting the beta decays. The efficiency is needed to determine the cross section from an actual ICF laser shot.

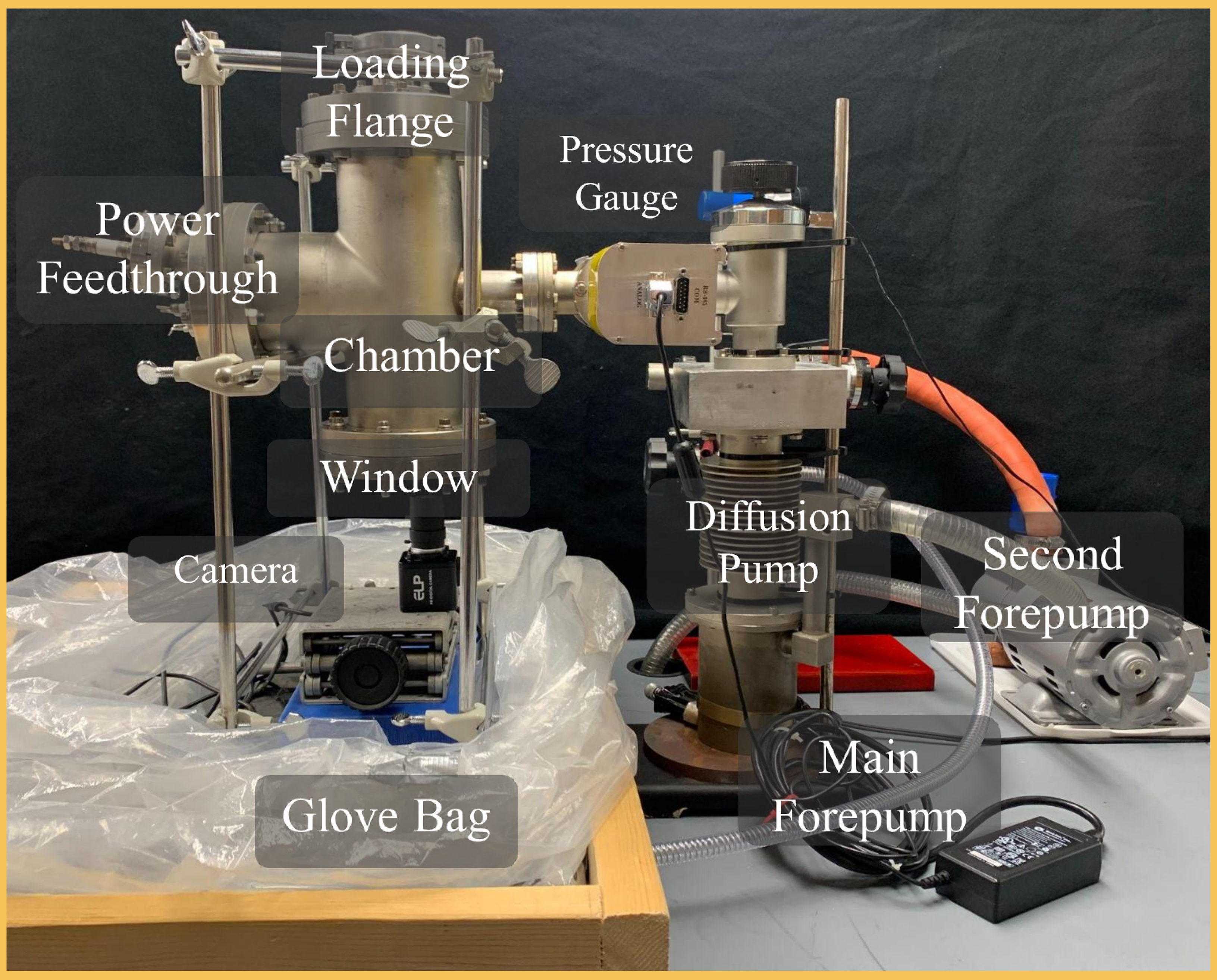

Figure 1. Setup of the deposition chamber. The Power Feedthrough allows electrical current to flow through the "boat" (Fig. 3) that contains natural lithium pellets. The pellets are melted, and the lithium evaporates through a hole in the stainless steel "house" onto a tungsten foil substrate that is kept cool by a copper heat sink. The loading flange allows the lithium and foil to be inserted and removed. The chamber is evacuated using a diffusion pump and forepump to pressures around 10^{-5} torr. The window port on the bottom of the chamber allows the lithium pellets to be monitored using a camera (Fig. 4). The glove bag filled with argon to prevents oxidation when handling the lithium pellets and target foil.

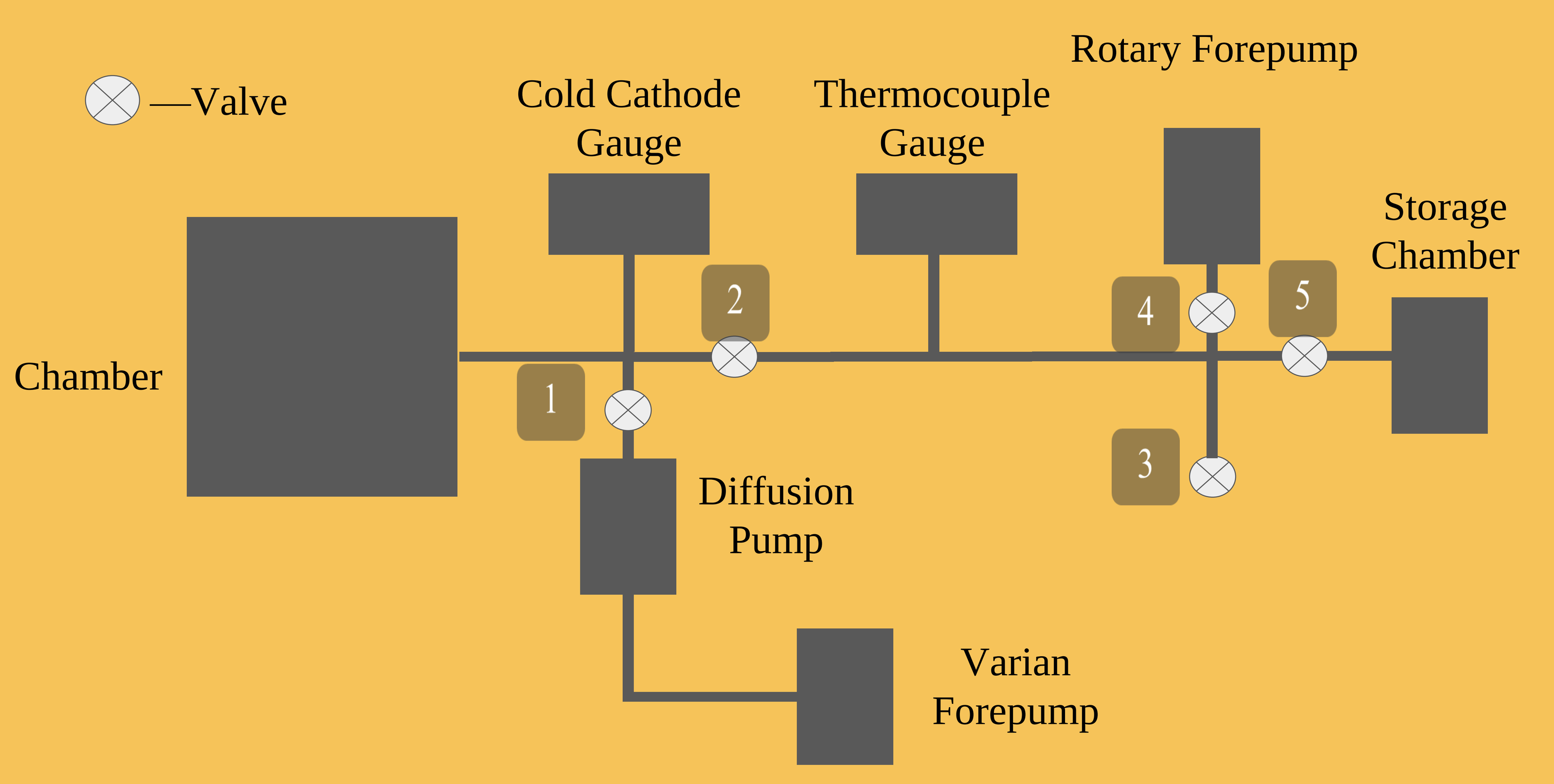

Figure 2. Schematic diagram for the vacuum system. Valves allow the diffusion pump to remain on when the chamber pressure is raised for loading. The chamber is first evacuated with valve 3, 4 and 5 closed. When the lithium pellets or tungsten foils need to be inserted or removed, argon is allowed into the chamber by closing valves 1 and 2 and opening the loading flange. When the chamber is ready to be re-evacuated, valves 2 and 4 are opened with the Rotary Forepump running. Once the chamber pressure reaches about 10^2 torr valve 4 is closed and valves 1 and 2 are re-opened.

III. Power Feedthrough:

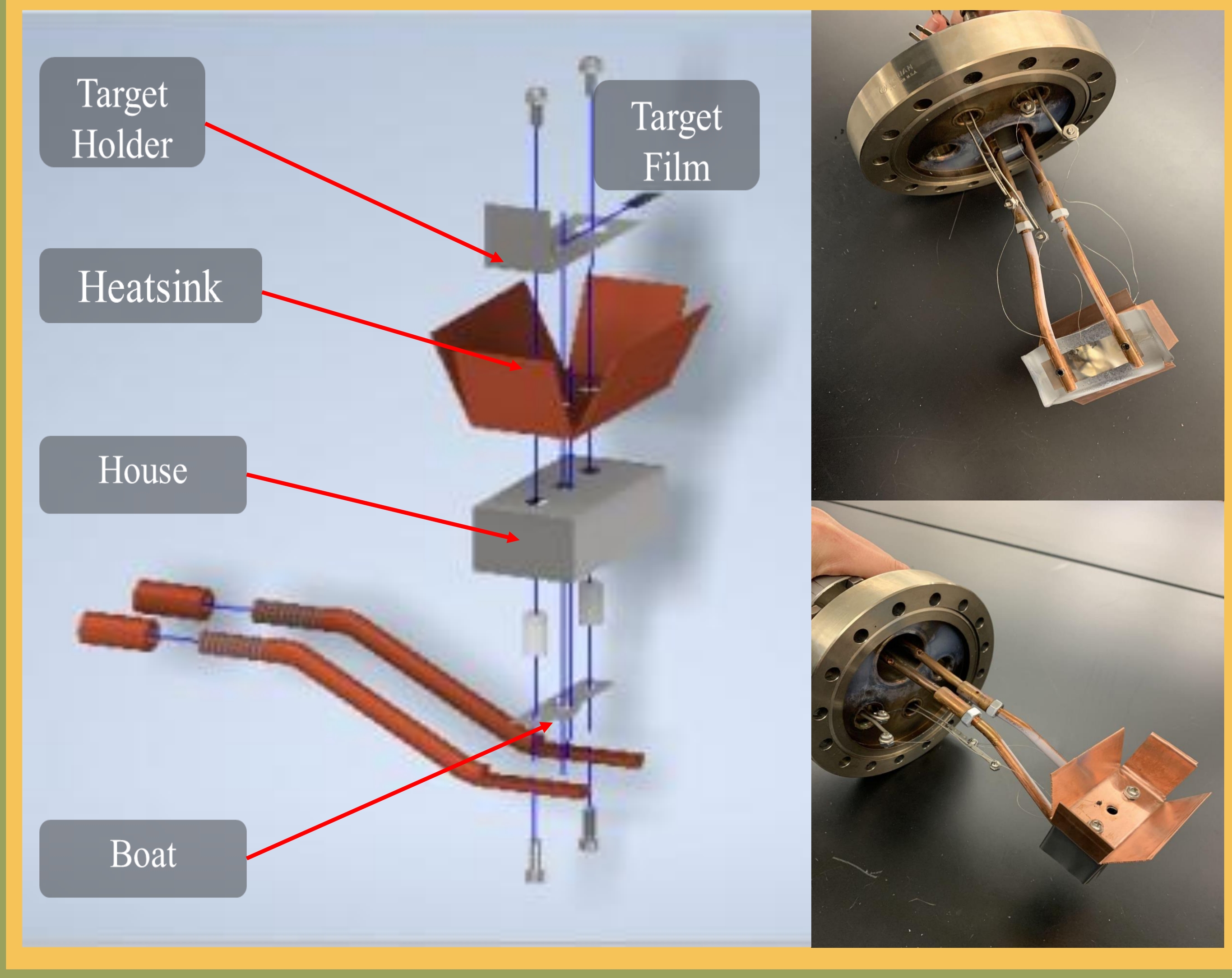

Figure 3. (Left) CAD drawing of the power feedthrough assembly. The copper heatsink and stainless steel "house" have holes in the middle to feed a tube onto the boat. Small lithium pellets are then dropped through the tube. The target holder with target are then placed onto the heatsink. Electrical current is passed through the boat to melt and evaporate lithium which is then deposited onto the tungsten target film though the holes. **(Top right)** Bottom view of the completed power feedthrough. **(Bottom right)** Top view of the completed power feedthrough.

IV. Procedure:

1. Lithium pellets are placed onto the boat (Fig. 3) by being dropped through a long tube fed through the loading flange (Fig.1).
2. Around 20A of current runs across the lithium boat (Fig. 3) to heat up the boat to 400°C to melt and eventually evaporate the lithium.
3. The evaporated lithium flies up from the boat and sticks to the tungsten target film that's placed on top of the house (Fig. 3).
4. The chamber is brought up to atmospheric pressure using argon. Then films can be removed, measured, and stored.

V. Results:

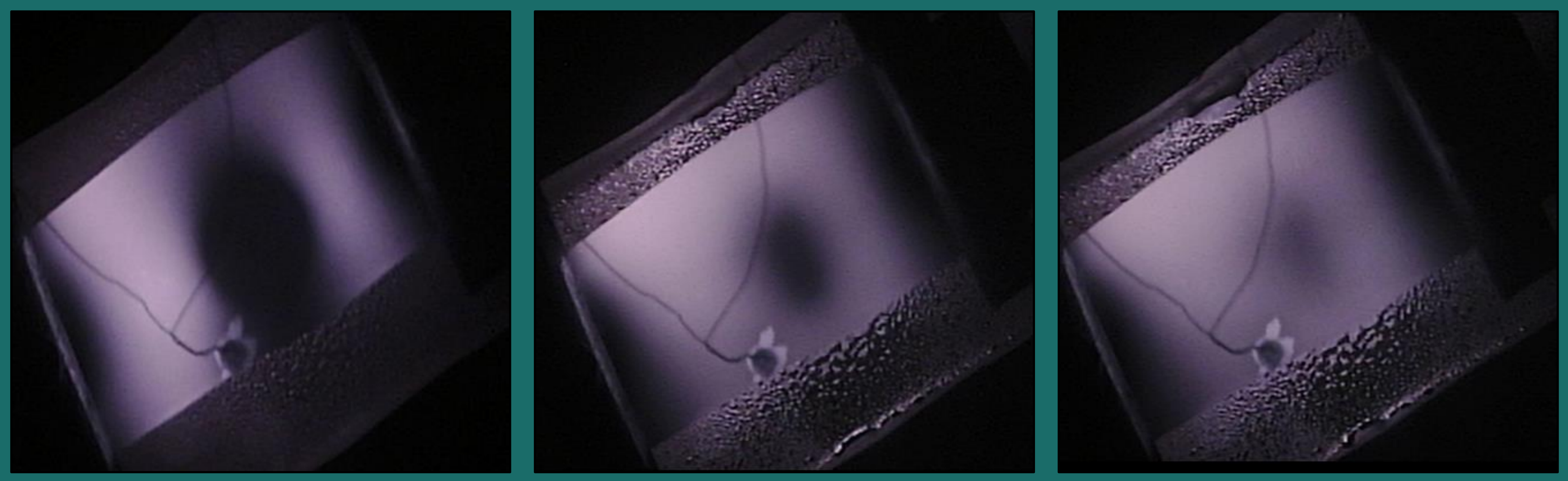

Figure 4. A phenomenon was observed through the bottom window (Fig. 1) while the lithium pellets were heating up in the boat (Fig. 3). As the lithium melted, it formed a cool dark spot on the boat **(left).** As the boat temperature stayed near 400 °C this dark spot slowly disappeared **(center and right).** This recurring process shows the evaporation of lithium over time. As the area of the dark spot is fades completely, the lithium is all evaporated.

Figure 5. (Top Left) This was a good film that did not get oxidized and was used for the ICF stimulation. The pinkish color may be due to lithium nitride formation. **(Top Right)** A sample that had a light grey appearance right out of the chamber. **(Lower Left)** A sample that was exposed to air right out of the chamber. It quickly turned from the color shown in top left to this dark color as it reacted with the moist air to form black coating of lithium hydroxide. **(Lower Right)** This was an sample that got exposed to air for a much longer period of time. It turned from black shown in lower left to white may indicate lithium oxide.

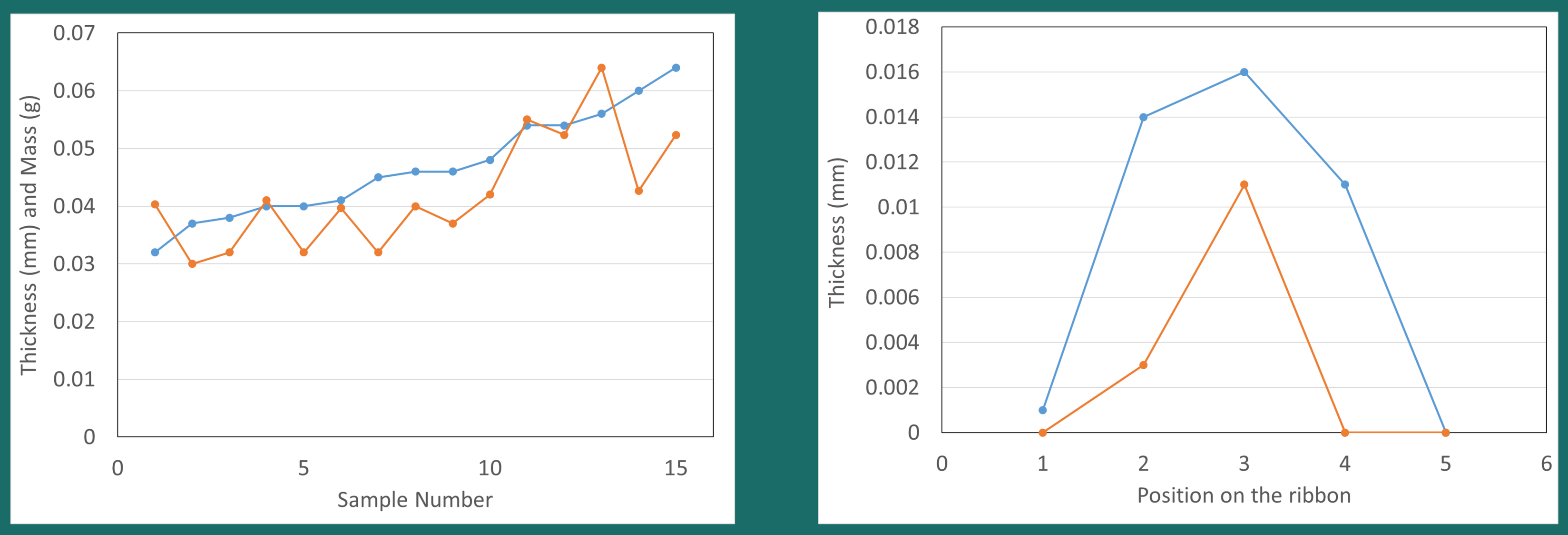

Figure 6. (Left) Plot showing the linear relationship between the mass of natural lithium (blue) and the thickness of deposited lithium (orange) on the film measured by a micrometer. This is expected since the evaporation process continues until all the lithium is evaporated. **(Right)** Plot comparing the thickness at various location of the lithium film measured using a small (orange) and wide (blue) tip on the micrometer. The x-axis values are simply five equally spaced locations across the surface of the film.