A novel technique for the production of robust actinide targets

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The success of accelerator experiments is highly influenced by the availability of targets with specific and well-defined properties. Actinide targets in particular are in high demand due to the importance they hold for stockpile stewardship as well as basic nuclear science. The main goal of this project is the development of revolutionary new approaches in the preparation of actinide targets that are isotopically pure, cost efficient, reliable, robust, and highly uniform with controlled thicknesses and dimensions. The actinides will be provided by the center of excellence in Actinide Research in the Engineering College at the University of Notre Dame.

The method used to produce these targets is electrospray deposition of chemically reactive layers that can be converted to actinide oxides by simple heat treatments. The target production setup is pictured in Fig. 1 and consists of the following components:

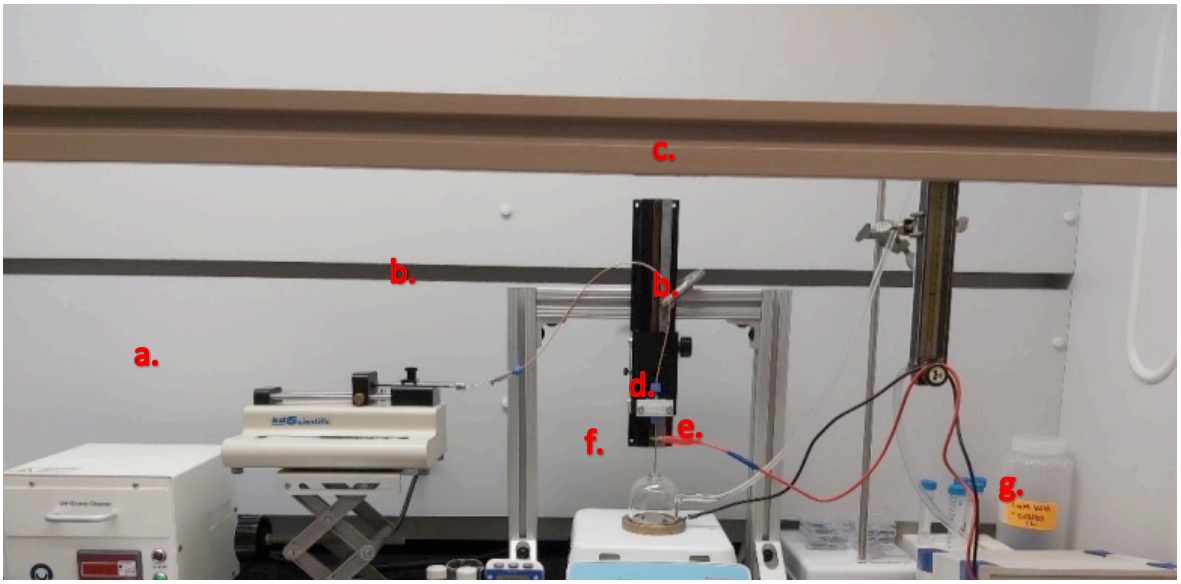

Fig. 1. The Electrospraying setup. The components are marked as follows; a) Ozone cleaner, for the preparation of my substrates before the spraying, b) Syringe pump – Syringe – Capillary nozzle, c) Distance regulator between the tip of the nozzle and the substrate, d) Pyrex dome, to control the environment of our electrospraying, e) Copper base, f) Hot plate, g) High voltage power supply, h) Nitrogen flow regulation

The project began by exploring the different combinations of parameters that will give the best possible targets. The first thing explored was the treatment of the aluminum substrates prior to the spraying. Here we discovered that nontreated substrates did not produce the desired result since instead of a uniform layer of material, droplets were forming on the substrate.

Using the same parameters for this set of targets (same distance between the nozzle and the substrate, flow rate of 25µl/h, voltage of 7.50 kV, nitrogen flow of 50 ml, spray time of 10 min and heat treatment time after spraying of 10 min), the substrate treatment was varied (parameters varied included plasma cleaning, ozone cleaning, sonication, ethanol cleaning, heat treatment and the combination of the above). Using microscope imaging, it was concluded that the best and most feasible treatment is a 30-minute heat treatment at 300ºC followed by a 20-minute ozone cleaning. Results from these substrate treating studies are shown in Figs 2.

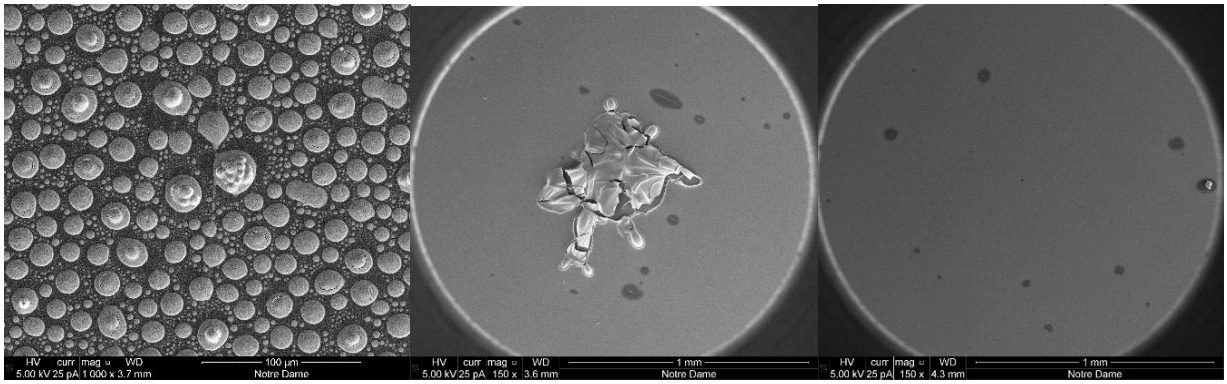

Fig. 2. (Left) Microscope image of a target produced after no substrate treatment. (Center) Microscope image of a target produced after 15 min plasma cleaning and 5 min ozone cleaning. (Right) Microscope image of a target produced after 30 min heat treatment and 20 min ozone cleaning.

Then next step of the project involved trying different flow rates, voltages, size of nozzles, distances between the nozzle and the substrate, temperature for the heat treatment of the target, time of

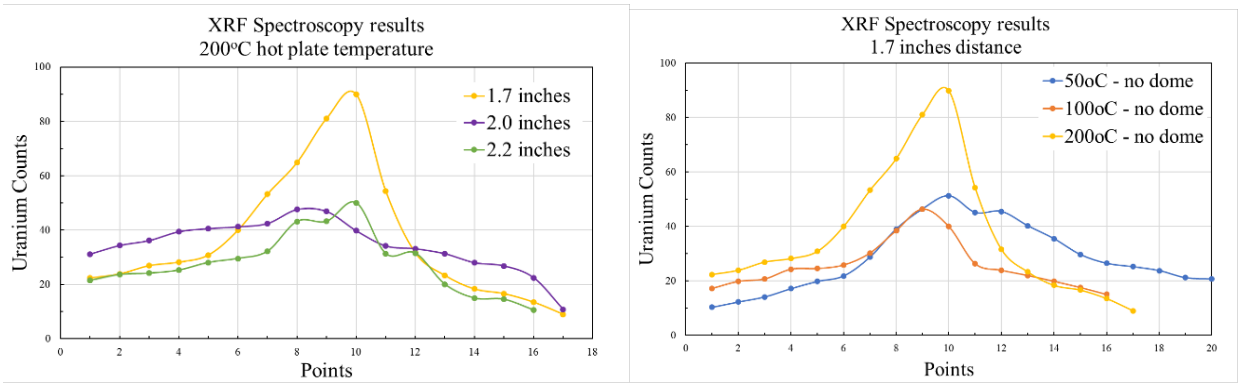

Fig. 3. (a) XRF results for targets with different distances between the nozzle and the substrate. (b) XRF results for targets with different temperatures on the hot plate.

spraying, time of the heat treatment of the target, as well as different temperatures on the hot plate. The preliminary results of these variations are shown in Figs. 3-4.

Ideally, the curves in Figs. 3-4 would consist of straight lines, indicating that the amount of uranium is evenly distributed throughout the target. Instead, we have a higher concentration of uranium in the middle of the target. This means that the thickness variation across these targets is far greater than 15%, which is a high maximum for this kind of targets. Further conclusions that can be drawn from these tests are:

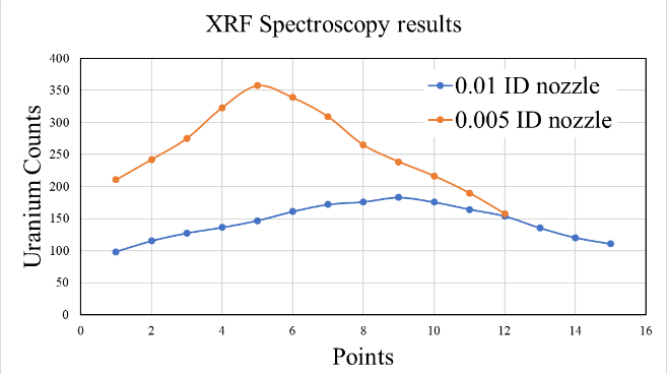

Fig. 4. XRF results for targets with different inner diameter (ID) nozzles.

a. Using the Pyrex dome while heat is applied by the hot plate creates a problem with the spraying. The solution is being evaporated at the tip of the nozzle, leading to clogging and non-uniform spraying.
b. The uniformity of the target improves with the increase of the distance between the tip of the nozzle and the substrate. The voltage applied has to increase as well in order for the electric field to remain unaffected by the change in distance.
c. The uniformity also improves when a nozzle with a smaller inner diameter is used.

Future work

More tests are essential in order to achieve the desired uniformity. Some of them being: using a new high voltage power supply which will allow applied voltage up to 20 kV, further increase of the distance between the tip of nozzle and the substrate, further increase of the temperature applied by the hot plate, as well as varying the flow rate and the time of spraying. Furthermore, we plan to investigate the deposition of different reactive solutions on self-supporting carbon substrates as well as the use of uranium oxide clusters in electro spraying deposition.

After the desired uniformity is accomplished, we plan to perform tests to determine the target's thickness and activity. These tests will be performed using a couple of different methods and microscopes like alpha spectroscopy, Rutherford Back Scattering (RBS) and X-Ray Fluorescence (XRF) measurements as well as a Focused Ion Beam (FIB) microscope and a Transmission Electron Microscope (TEM). Irradiation tests will also be performed in order to study our target's damage under a beam.

Finally, we have submitted a proposal at the Los Alamos National Lab (LANL), that requests for beam time to investigate the stability of the targets developed at Notre Dame. One aspect of the tests is to explore the interaction of neutrons with the various targets. This would involve the insertion of targets of varying thicknesses on both carbon and aluminum backings separately to understand the resulting γ-ray background in relation to the lines of interest from the uranium. Neutron beam time is requested in association with the DANCE detector (DANCE) [1],

The second aspect would ideally follow the first type of the test. The idea is to measure the average total kinetic energy (TKE) of correlated fission fragments of ^{238}U as a function of incident neutron energy with a twin Frisch-gridded ionization chamber (FGIC) at WNR [2].

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