Parameter Investigation in solution combustion synthesis using electrospraying for actinide target preparation

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Motivation

- Research in nuclear science and stockpile stewardship rely on experiments on various projectile and target combinations to extract key nuclear cross-section and structure information.
- Current target preparation techniques are based on decades-old approaches that do not take advantage of recent developments in materials science.
- In this work we report on electrospray deposition of chemically reactive layers that can be converted to actinide oxides by simple heat treatments.
- Investigations were performed of the parameters for electrospraying in the production of actinide targets with desired properties.
- Overarching goal of this work is to produce robust, uniform and cost-efficient targets of actinides.

Steps of the Experimental Technique

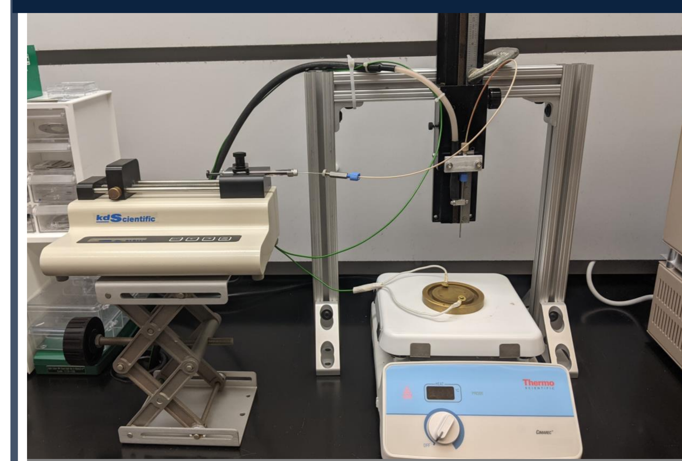

Fig 1: Electrospraying Setup

- Syringe pump
- Capillary Nozzle
- High Voltage source
- High voltage connector
- Brass base
- Hot plate

- Electrospray combustible solution onto Al or C substrate, followed by annealing of the targets.
- Alpha Spectroscopy helps determine the amount of U in the targets.
- TEM helps determine the uniformity in a microscopic level.
- XRF helps determine the uniformity in a macroscopic level.
- FIB/SEM measurements help determine the cross-section thickness as well as the surface morphology.

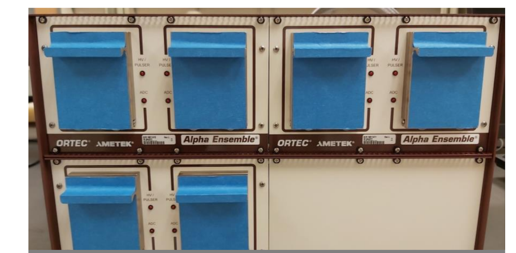

Fig 2: Alpha Spectrometer

Fig 4: XRF Spectrometer

Fig 5: FIB/SEM Microscope

Fig 3: TEM Microscope

Alpha Spectroscopy

Alpha spectroscopy is our main way of investigating the effect of different spraying parameters in the amount of uranium atoms/cm^2.

Spraying time, Uranium concentration in the spraying solution and hot plate temperature are the different parameters we investigated and present here.

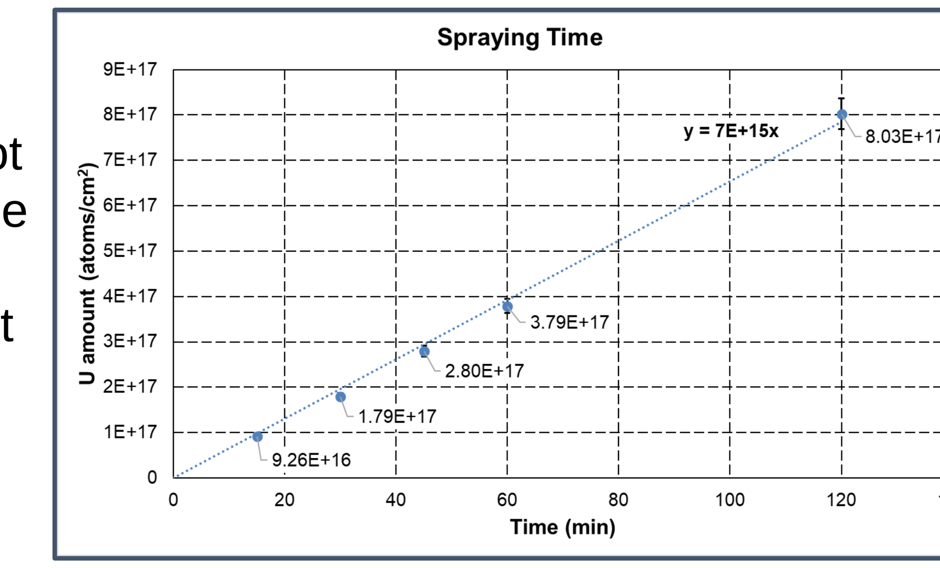

Fig 15: U amount on target vs. spraying time

The variation of the spraying time follows a linear trend.

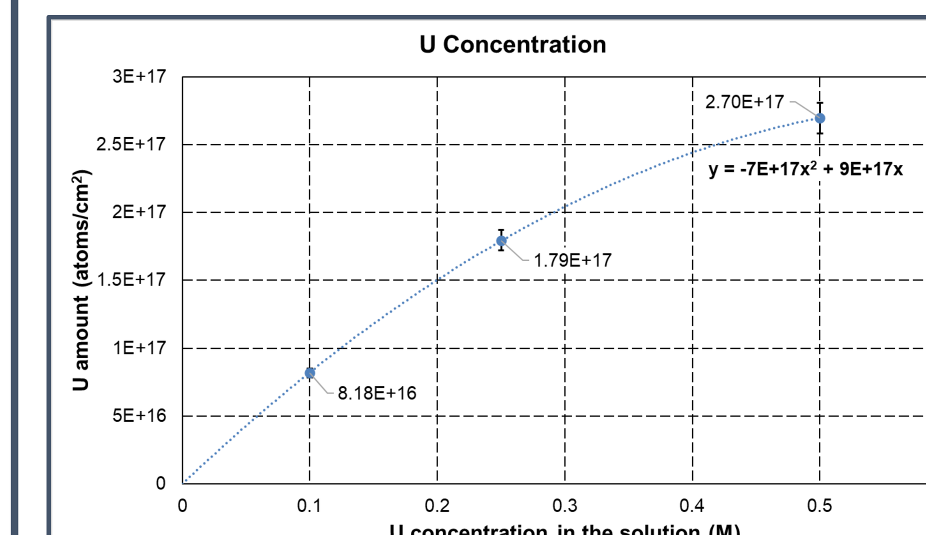

Fig 16: U amount on target vs. U concentration in the solution

The variation of the U concentration in the spraying solution follows a 2nd degree polynomial trend.

The variation of the hot plate's temperature during spraying does not yield significant changes in the amount of U in the targets.

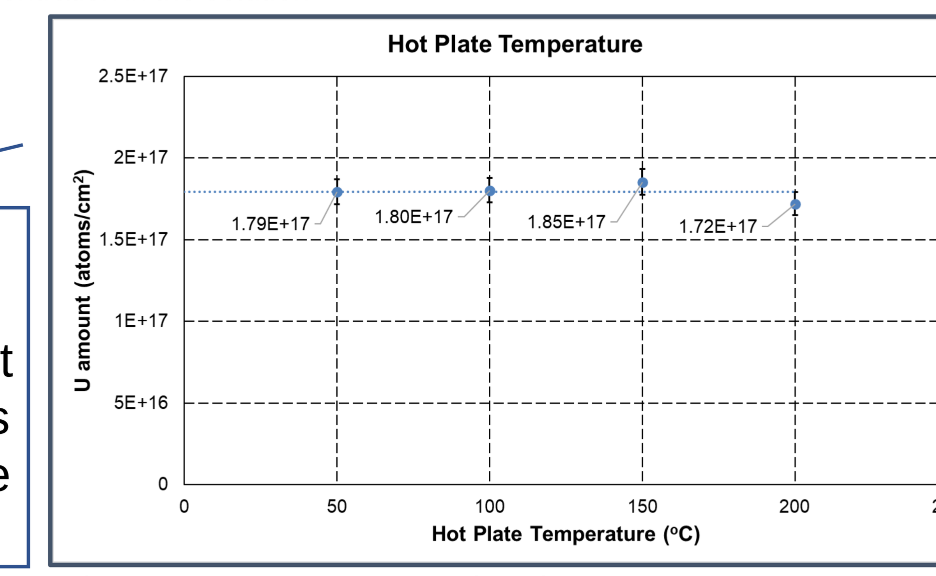

Fig 17: U amount on target vs. hot plate temperature

Deposition on C backing with and without treatment before the spraying

With plasma cleaning treatment before the deposition

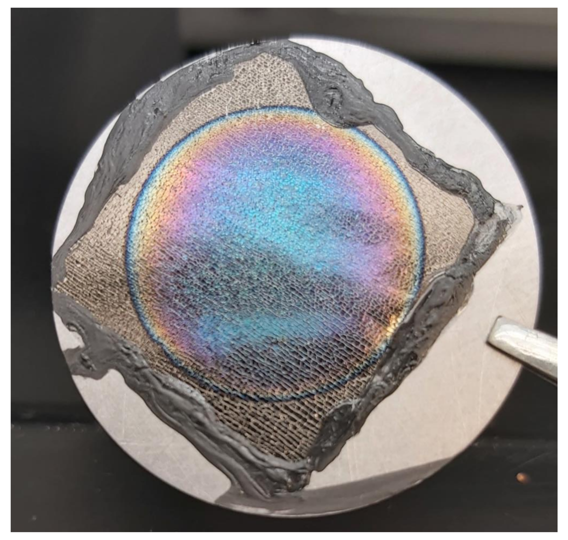

Fig 6: UO_2 on thin Carbon backing

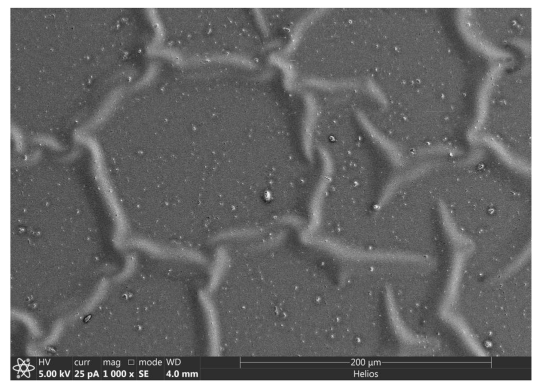

Fig 7: Surface image of the UO_2 layer

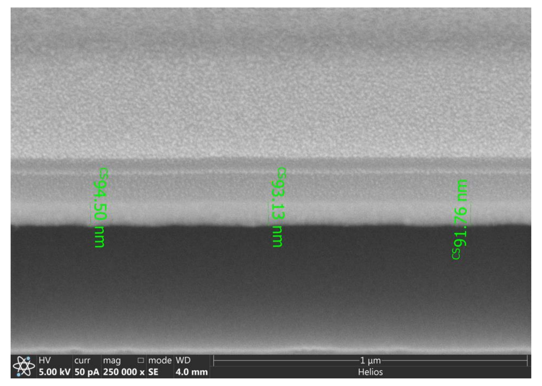

Fig 8: Cross section measurement of the UO_2 layer

Without treatment before the deposition

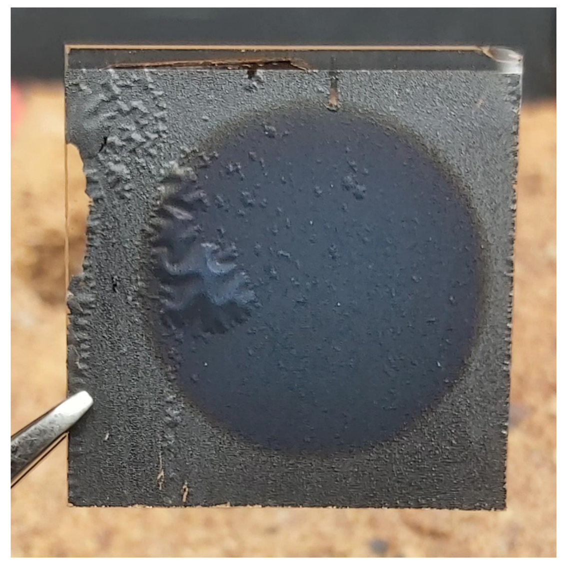

Fig 9: UO_2 on thin Carbon backing

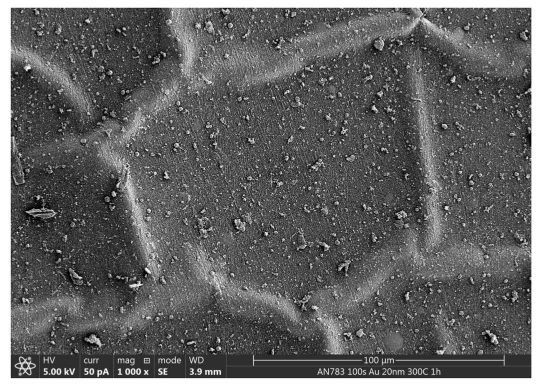

Fig 10: Surface image of the UO_2 layer

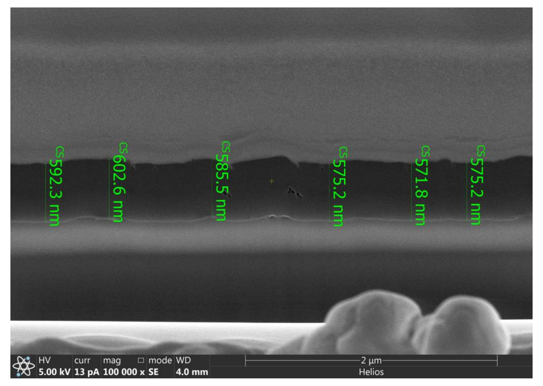

Fig 11: Cross section measurement of the Carbon backing (no UO_2 layer)

TEM Microscopy Measurements

TEM measurements are an integral way to help us understand the uniformity and structural features of the UO_2 layer at a microscopic level.

It also provides insights about the internal morphology, grain size and crystallinity of the UO_2 layer for different annealing temperatures.

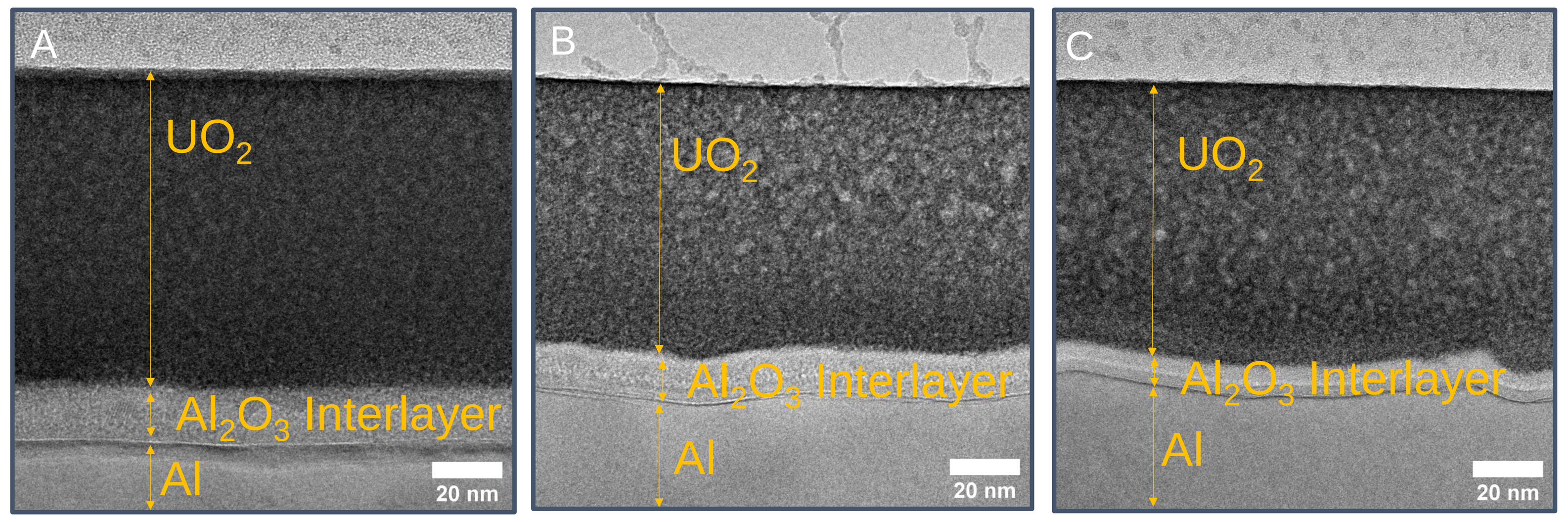

Fig 12: Low magnification TEM images of the UO_2 layer annealed at 350°C (A), 450°C (B) and 550°C (C)

At the low magnification we can observe that the 350°C heat treatment produces a little bit thicker targets with a lot of little porous, while higher heat treatment temperatures produce less but larger porous.

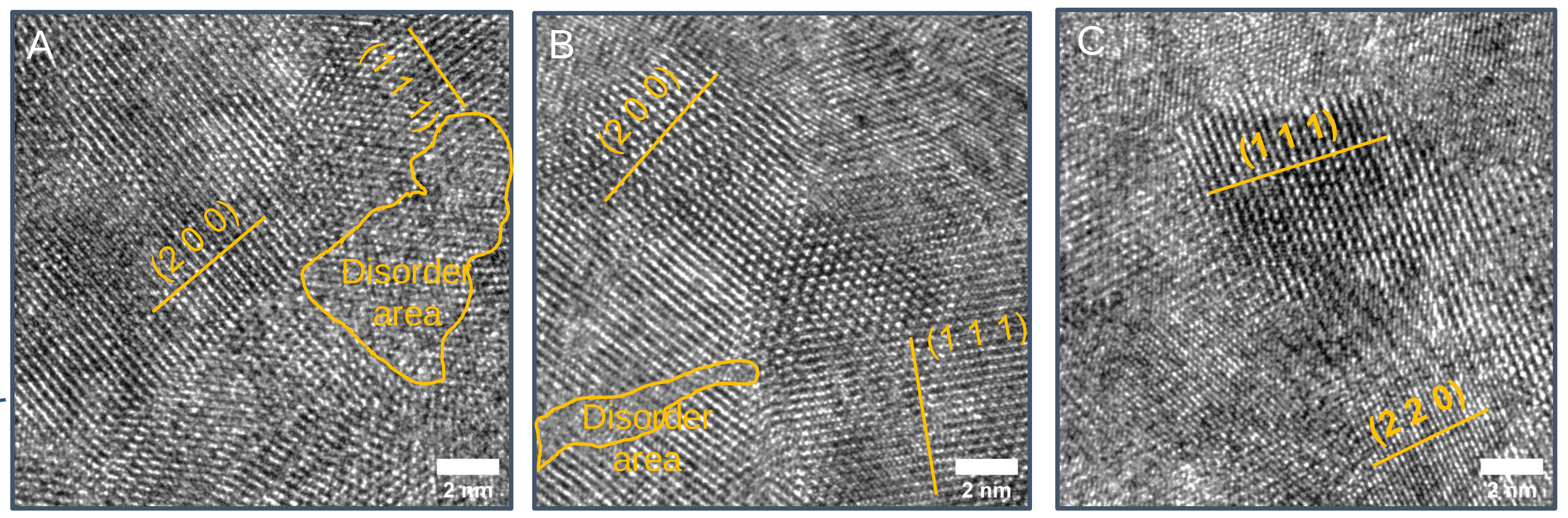

Fig 13: High magnification TEM images of the UO_2 layer annealed at 350°C (A), 450°C (B) and 550°C (C)

At the higher magnification we can observe large disorder areas that tend to get smaller and disappear with the increase of the heat treatment temperature. We also observe an increase of the grain size and better crystallinity.

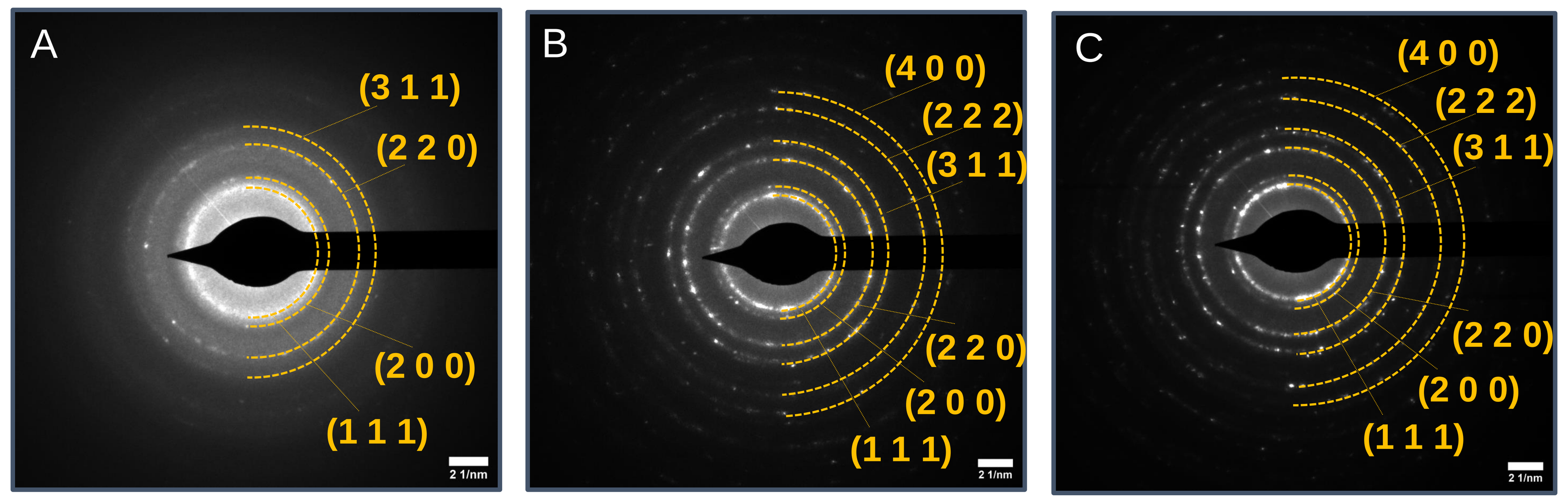

Fig 14: Diffraction patterns of the UO_2 layer annealed at 350°C (A), 450°C (B) and 550°C (C)

At the diffraction measurements we confirm our previous observations with respect to the better crystallinity we get as we increase the heat treatment temperature.

Conclusions – Future Work

- We can deposit thin UO2 layers on both Al and C backings.
- We can regulate the amount of Uranium on each target.
- We can regulate the target's crystallinity.

- Irradiation of the targets using an Ar+2 beam.
- Investigate the deposition of different actinide solutions.
- Use uranium oxide clusters in electrospyaing deposition.

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