Using Chemical Vapor Deposition to Grow Thin Film UTe_2

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Outline

- Plans for NIST with Chemical Vapor Deposition (CVD)
- Introduction to CVD
- Applications of CVD
- History of Thin Film Uranium Compound Growth
- My Contribution to the Project

What does NIST hope to use CVD for?

The goal to is to grow UTe_2 (Uranium ditelluride) thin film crystals using the CVD technique.

Growing thin film UTe_2 is special because:

- It is a superconductor at low temperatures
- Could be used for future devices
- No one has done it before!

NIST
National Institute of Standards and Technology

What makes UTe_2 Unique?

UTe_2 has spin triplet superconductivity

This could be very useful for future quantum technology!

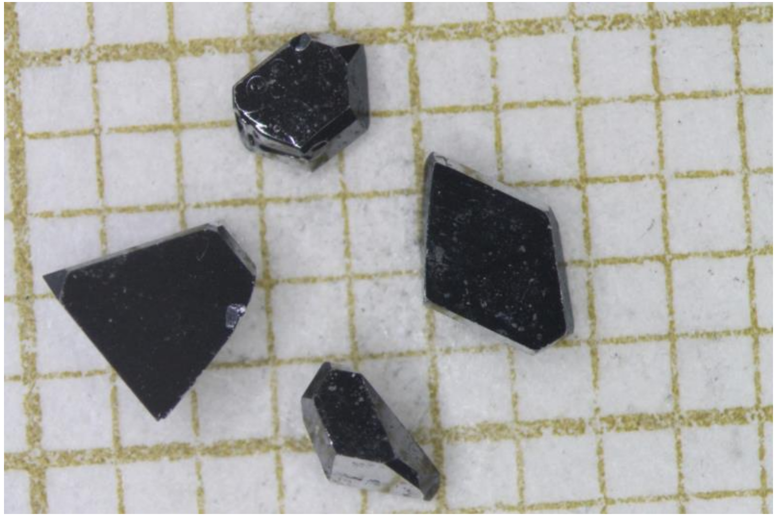


Image from NIST

What is CVD?

CVD (Chemical Vapor Deposition) is a technique used to grow thin film crystals on a substrate by heating up the reactant gases to create new chemical bonds.

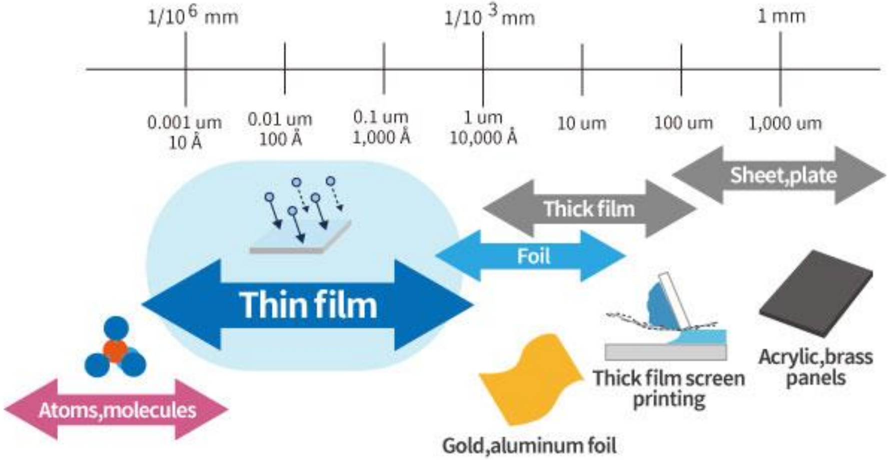


Image from Vac Coat

How does CVD work?

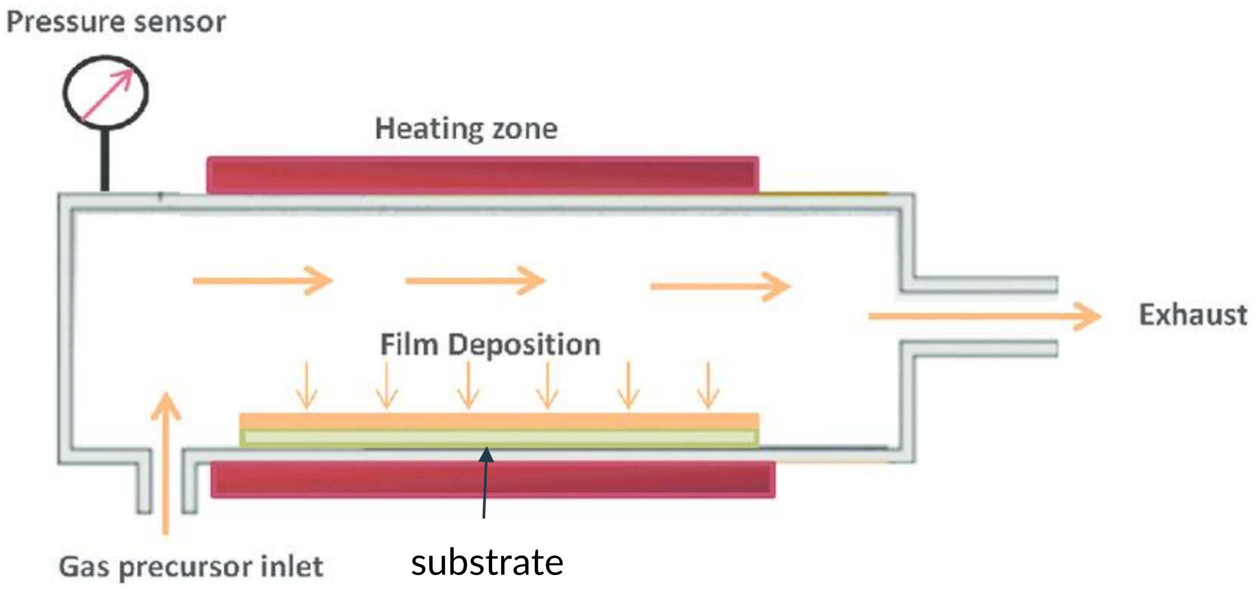


Image from Zhang et. al., 2016

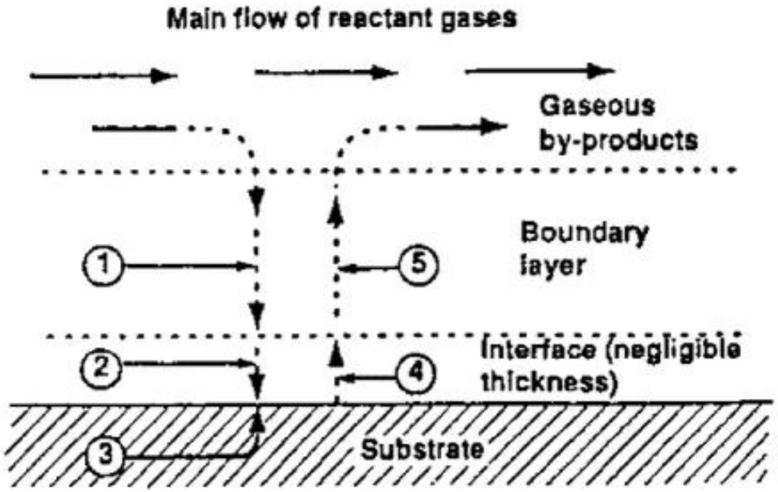
What increases the likelihood of the desired compound growing?

Gibbs Free energy Equation:

$$\Delta G_r = \sum \Delta G_{products} - \sum \Delta G_{reactants}$$

What other scientific considerations need to be considered?

Diagram that demonstrates flow of the gas in the process of CVD



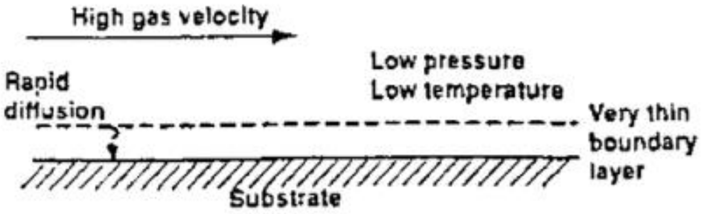
1. Diffusion in of reactants through boundary layer
2. Adsorption of reactants on substrate
3. Chemical reaction takes place
4. Desorption of adsorbed species
5. Diffusion out of by-products

Figure 2.3. Sequence of events during deposition.

Image from Pierson, 1999

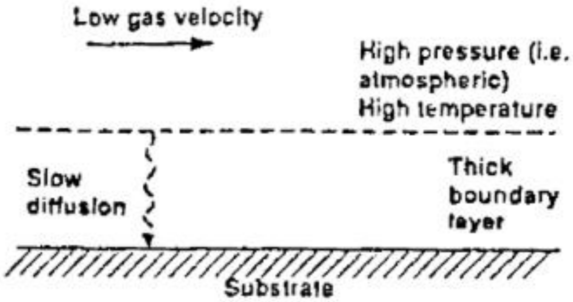
What controls the growth rate of the crystals?

Low Pressure
Low Temperature



High Velocity
Thin boundary layer

High Pressure
High Temperature

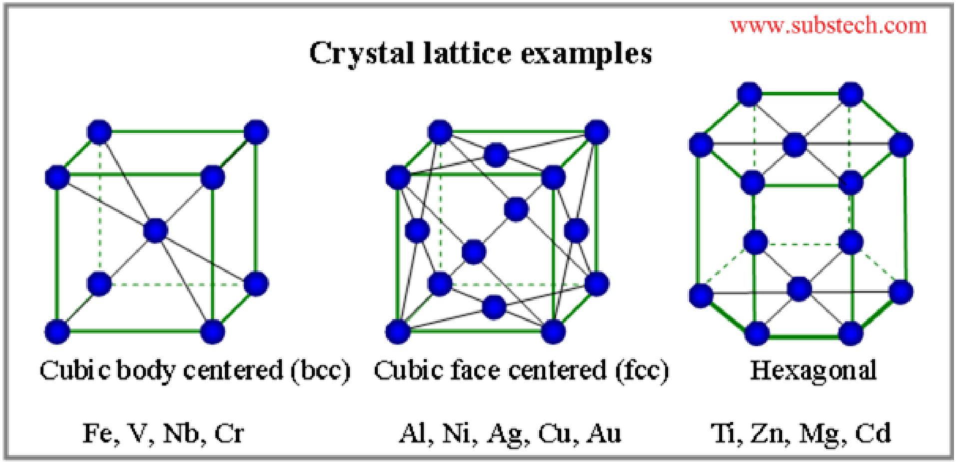


Low Velocity
Thicker boundary layer

The goal is to find a balance between these two extremes

Image from Pierson, 1999

How do you know what substrate to use?



The substrate should match the crystal on lattice structure and parameters

What are the applications of CVD?

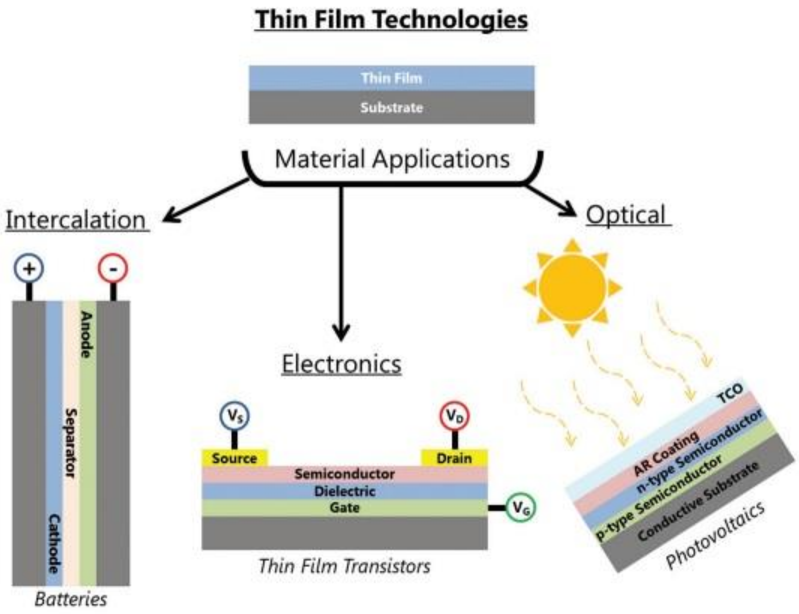


Image from Vac Coat

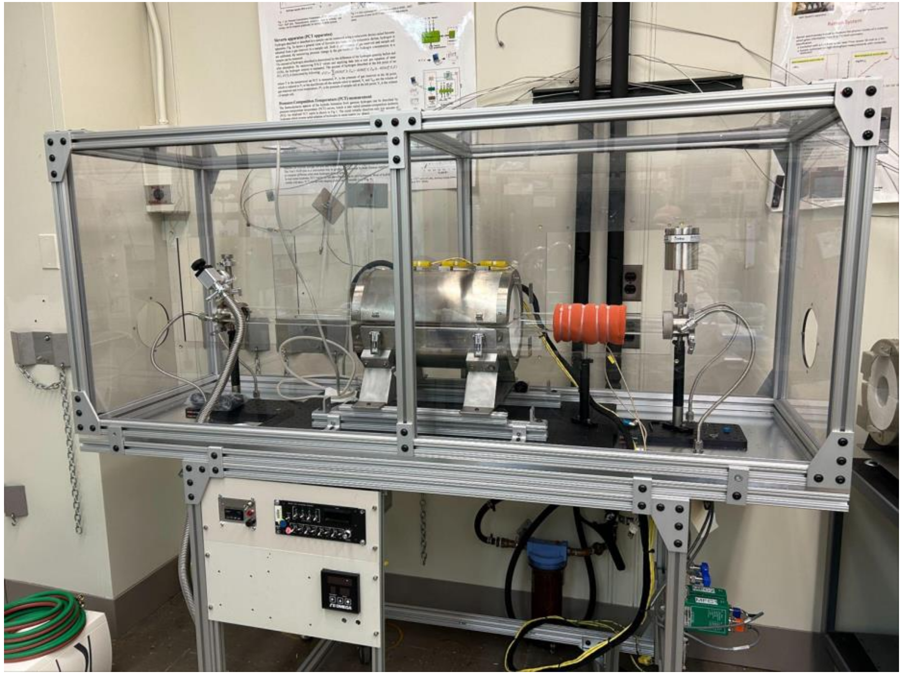
History of Thin Film Uranium Compound Growths

- Only dates back to the 1960s
- Not very common for labs to grow thin film uranium compounds
- UO_2 is the most common Uranium compound grown
- Biggest challenges in growing Uranium compounds has been:
  - Lattice matching
  - Surface oxidation

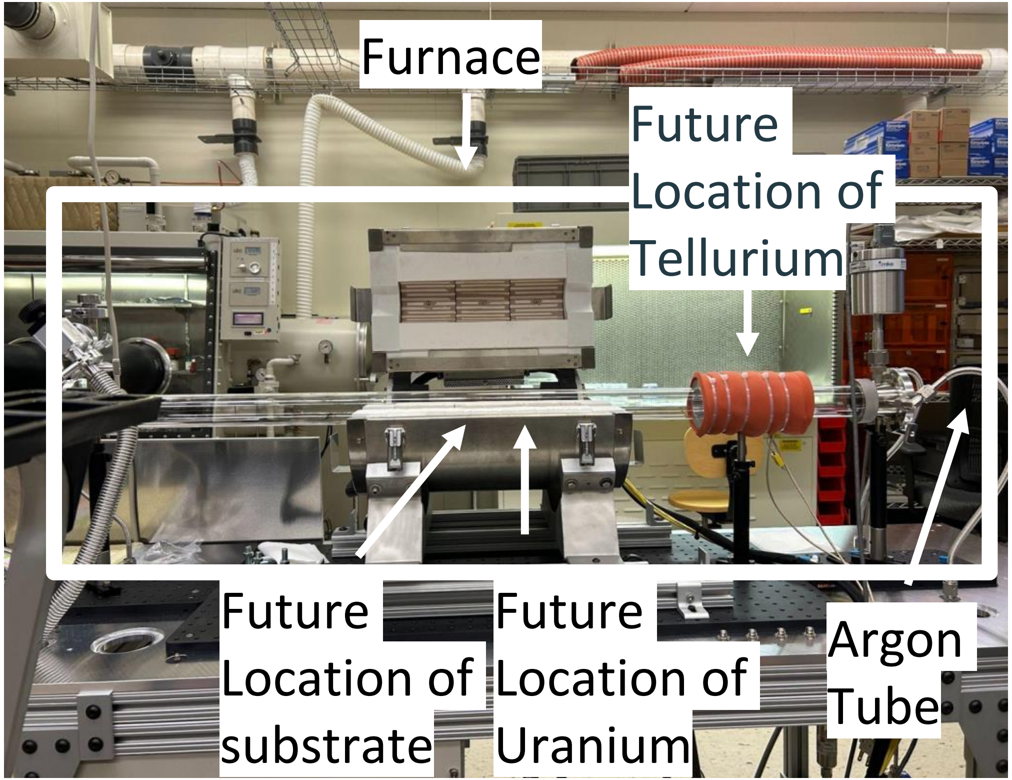
History of Thin Film Uranium Compound Growths Continued

- Scientists have been experimenting over the years with different:
    - Growth techniques (such as CVD and sputtering)
    - Uranium Compound growths (such as UO_2 and UN)
    - Substrates to deposit on (such as MgO and Sapphire)
    - Starting materials (such as Uranium Oxide and Uranium Iodine)
    - Amounts of starting material

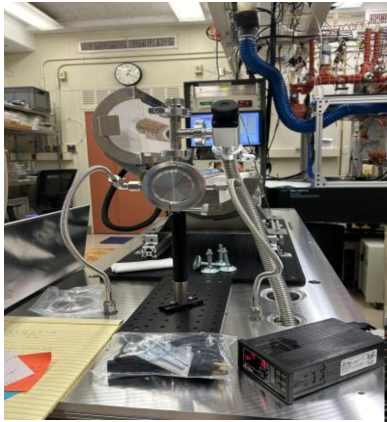
The Furnace



Description of Furnace

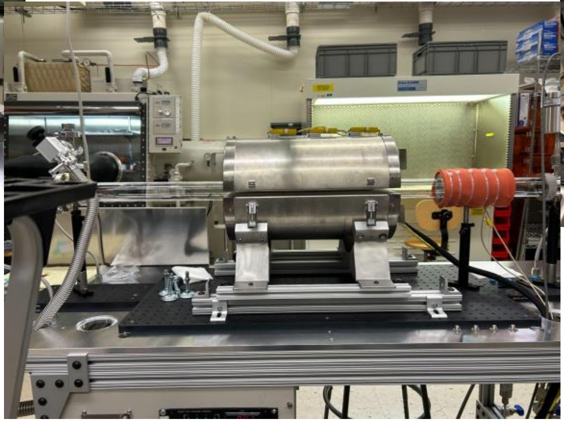


More Pictures!



View of open furnace from the side

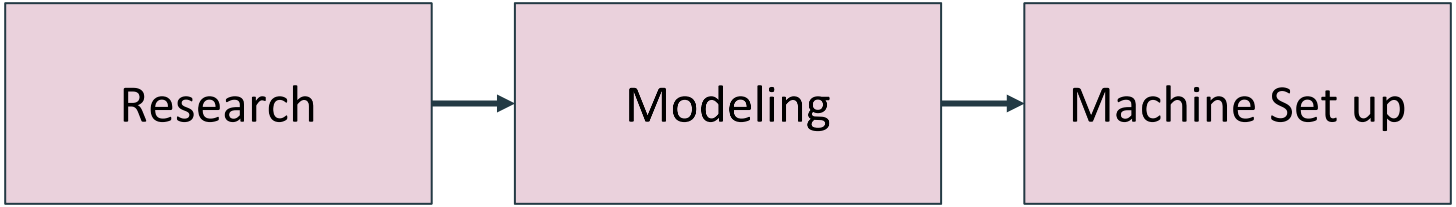
View of closed Furnace



Picture of the controls for the furnace

Picture of the canister to hold Uranium exhaust

My part in the project



Research → Modeling → Machine Set up

CVD Modeling Equation

$$M = \frac{DA}{LRT} \Delta P$$

M = Mass Transport (kg/s)

D = Diffusion Coefficient = 1.64E-05 cm^2/s

A = Cross Area of CVD Pipe = 17.35 cm^2

L = Distance between source and substrate (cm) = Adjusted between .5 and 5 cm

R = Ideal Gas Constant = 82 cm^3 atm/deg

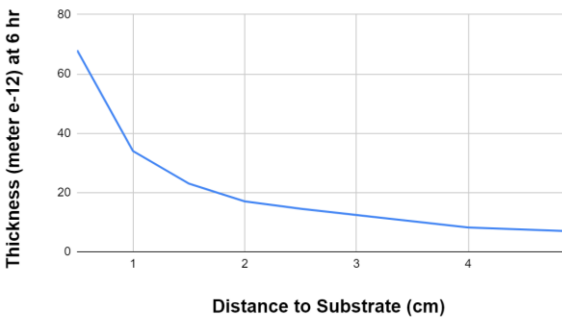
T = Initial Temperature (C) = Adjusted between 650 and 850 °C

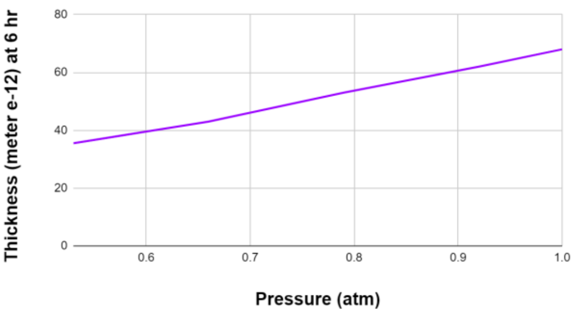
ΔP = change in pressure (atm) = Adjusted between .53 and 1 atm

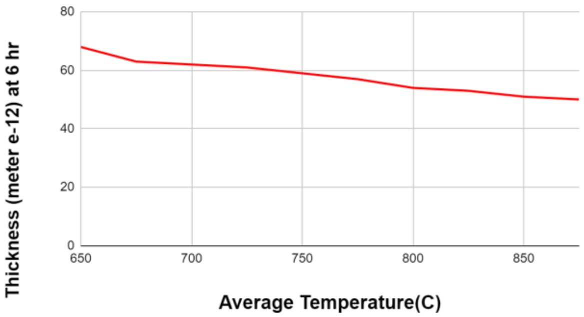
Experimented with different:

- Distance to Substrate (L)
- Temperature (T)
- Pressure (ΔP)

CVD Modeling Graphs and Conclusions


Thickness at 6 hr vs. Distance to Substrate


Thickness at 6 hr vs. Pressure


Thickness at 6 hr vs. Temperature

It is best to have:

- Shortest Distance to Substrate
- Highest Pressure Possible
- Lowest Average Temperature

Acknowledgements

Butch Lab (Left to Right):

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Thank you!