GENERAL PROCESS AND OPERATION SPECIFICATION

Lesker PVD 75 DC Metal Sputter

I. SCOPE

a. The purpose of this document is to describe requirements and basic operating instructions for the Lesker PVD 75, DC sputter tool. This tool is intended for thin film deposition of metals by DC sputtering. Use of this tool is limited to only approved thin films and substrates.

II. SAFETY

a. Be sure that you are trained and signed off to use this equipment.
b. Be sure to keep all doors and protective shields in place before operating this equipment.
c. Use care when operating around high voltage or high current. **Ensure that all electrical power is removed from the power supply/generator before working on any sputter source.**
d. High pressure gas cylinders for this tool are stored in ventilated gas cabinets located in the service corridor. Be sure to ask a staff member for assistance to change out any gases.
e. If you are unsure about any procedure or indication while operating this equipment be sure to contact a staff member or trainer for assistance.

III. APPLICABLE DOCUMENTS, MATERIALS AND REQUIREMENTS

a. For more information about the detailed operation of this tool refer to the Lesker factory manual – "PVD 75 Thin Film Deposition System Operation Manual." File name: PVD 75 Manual.pdf.
b. Appendix A: Editing of Recipes in KJL Software
c. Appendix B: DC Sputter Example Recipe
d. Appendix C: Changing Targets
e. Appendix D: Increasing Deposition Rate
f. Appendix E: Maximum Power Density of Target Materials
g. Appendix F: Cosputter Process Example Recipe
h. Appendix G: Test for shorts in the DC sputter tool
i. This tool is intended to be used with a restricted selection of substrate and target materials.
j. Approved target materials: Ag, Al, Cr, Cu, Er, Fe, Ge, Mo, Nb, Ni, Pd, Pt, Rh, Ru, Ta, Ti, W, Zr.
k. Target materials provided by AggieFab as part of normal lab fees: Al, Cr, Cu, Ti, Ni.
l. Approved substrate materials: Glass, Si, PVDF (with no substrate heating), $LiNbO_3$, MACOR (ceramic).
m. Other substrate and target materials must be pre-approved by the Materials Review Board before running in this tool.

IV. OPERATION

a. Login using username and password.
b. Start the “PC Vent”.
c. Once PC is at atmosphere pressure, run the “Substrate load and unload” recipe to open the shutters.
d. Remove the substrate holder. Be careful not to move the shutters surrounding it.
e. Attach your substrate to the holder using Kapton tape or pins.
f. Place the substrate holder back into position.
g. Uncover and change targets as needed (see Appendix C).
h. Close the door, click “Run Recipe”, and run “PC Pump low turbo + Plasma Check #” (# corresponds to the source being used).
    i. When this recipe reaches the 60 second dwell step, open the window shutter and confirm the plasma is lit.
    ii. If the plasma does not light, abort the recipe, perform a short circuit test (see Appendix G), then rerun the plasma check. If the plasma still does not light, notify a staff member.
i. Start the “PC Pump”
j. While the chamber pumps down, find the recipe you need to use.
    i. If the recipe does not exist, copy a similar recipe and edit the copy (See Appendix A and B).
    ii. Rename the copy to identify it as your own and press “Update VB” to save it.
k. Once “PC Pump” is complete, click “Run Recipe”, choose your desired recipe, then click the green area.
l. Allow the recipe to run. Confirm that the plasma lights when the recipe reaches the ignition step.
    i. If the plasma does not light, try restarting the recipe.
m. When the process has completed, vent the system and run the “Substrate load and unload” recipe to remove your samples. Cover all the targets with aluminum foil and pump the chamber down again. Once the chamber is pumping, you can log out.

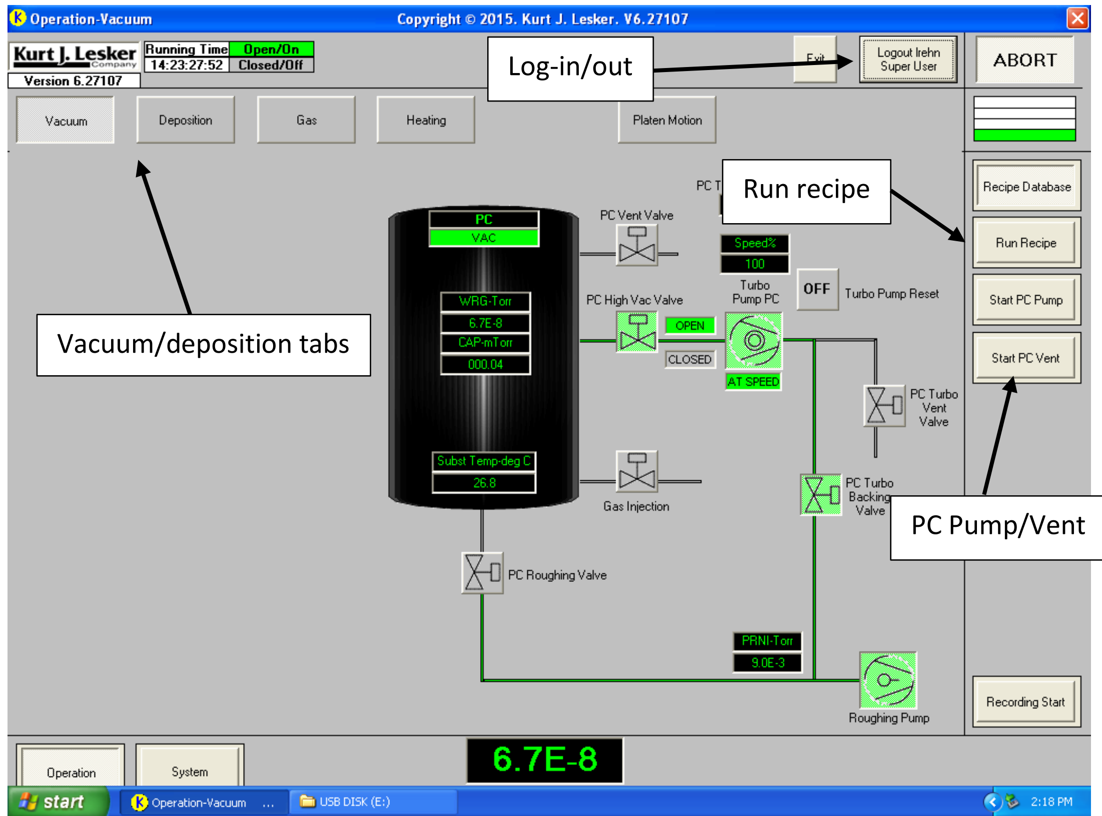


Fig. 1: Main vacuum screen showing pumps and valve positions during normal operation under high vacuum.

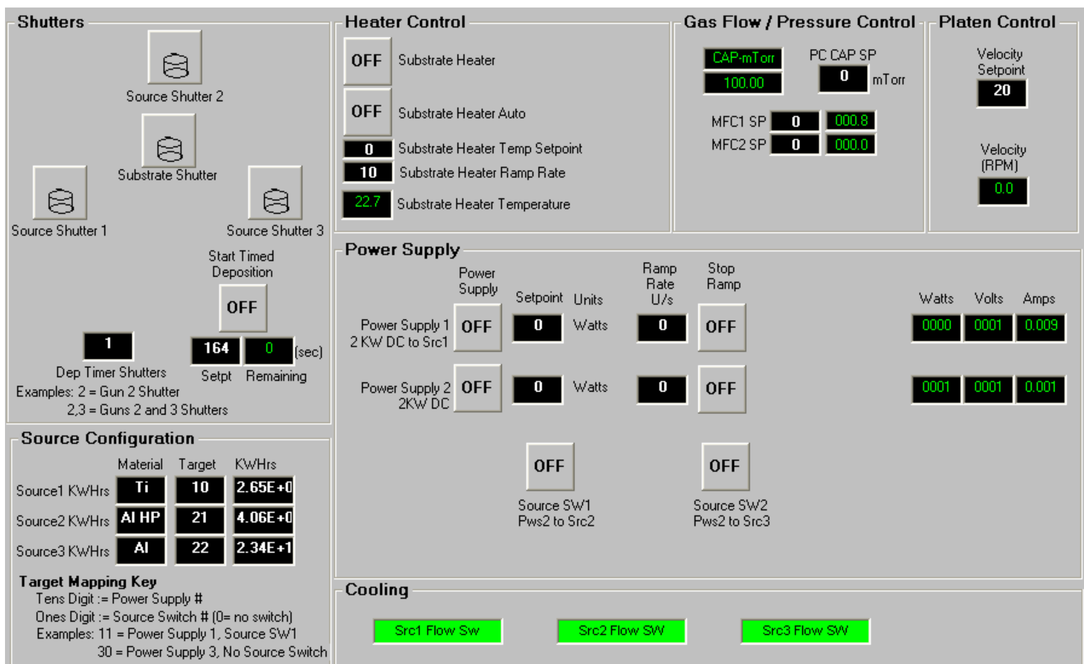


Fig. 2: The deposition screen showing shutters, source targets and configuration, heating, power supply status, gas flow, and platen (substrate holder) motion.

V. SIGNATURES AND REVISION HISTORY

a. Author of this document: Larry Rehn
b. Rev 1: Update approved materials list, modify recipe explanation to reflect current procedures
c. Rev. 2: Added Appendix G
d. Rev. 3: Updated instructions and Appendix G to reflect current procedures

Approvals:

Technical Manager Signature:__Sandra G Malhotra____________

Date: __9/14/21____

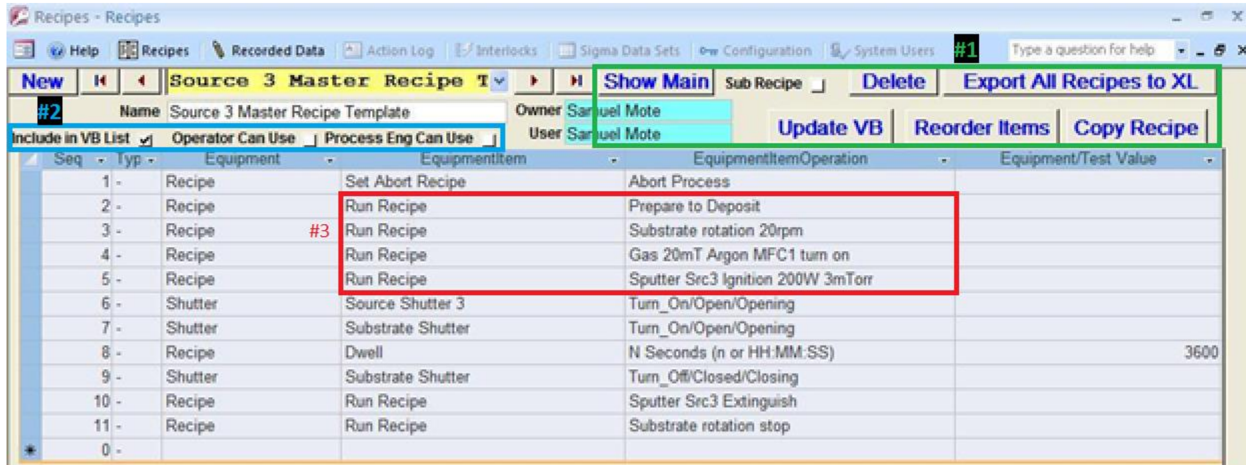
Revision History:

Revision	Author	Date
Original Issue	L. Rehn	11/6/2015
Rev 1	Ethan Morse	18 February 2020
Rev 2	Marcelo Pier	14 September 2021
Rev 3	John Slentz	7 June 2023
Rev 4		
Rev 5		

Appendix A: Editing of Recipes in KJL Software:

Editing Recipes

Note: You can only edit recipes if you are the owner or if the owner has opened access to you for editing. The owner of a file cannot be changed and only the owner or a system administrator can delete the file.



Seq	Typ	Equipment	EquipmentItem	EquipmentItemOperation	Equipment/Test Value
1	-	Recipe	Set Abort Recipe	Abort Process	
2	-	Recipe	Run Recipe	Prepare to Deposit	
3	-	Recipe	Run Recipe	Substrate rotation 20rpm	
4	-	Recipe	Run Recipe	Gas 20mT Argon MFC1 turn on	
5	-	Recipe	Run Recipe	Sputter Src3 Ignition 200W 3mTorr	
6	-	Shutter	Source Shutter 3	Turn_On/Open/Opening	
7	-	Shutter	Substrate Shutter	Turn_On/Open/Opening	
8	-	Recipe	Dwell	N Seconds (n or HH:MM:SS)	3600
9	-	Shutter	Substrate Shutter	Turn_Off/Closed/Closing	
10	-	Recipe	Run Recipe	Sputter Src3 Extinguish	
11	-	Recipe	Run Recipe	Substrate rotation stop	
0	-				

Fig. 3: Recipe editing using KJL's VB software.

#1:

Show Main/(Show All): Toggles the yellow recipe list between showing only Main Recipes or both Main and Sub Recipes. (The button displays the opposite of what is being used. For example, when the button reads "Show Main", the recipe list will be showing all.)

Sub Recipe Check Box: Defines Recipe as a Sub Recipe; Default as Main Recipe

Delete: Remove Recipe file

Export All Recipes to XL: Used only by system administrators

Update VB: Save all recipes that have been edited

Reorder Items: Move lines of the recipe

Copy Recipe: Create new recipe file with all of the same specifications currently selected. You will become the "Owner" of the new file.

#2:

Include in VB List Check Box: (Default checked.) If checked, and if the recipe is a main recipe, it will be made visible in the yellow recipe list when Show Main is selected. If not checked, it will only show when Show All is selected.

Operator /Process Eng Can Use Check Boxes: (Default unchecked.) These boxes specify what groups are given access to editing the recipe file. If unchecked, only the owner and system administrators can edit it.

#3:

If the "Equipment/Item" column reads "Run Recipe", then the next column will specify what Sub Recipe is being called. Sub Recipes contain most editable parameters of a process. By clicking on the Sub Recipe name, a drop down box will appear that will allow you to select which specific Sub Recipe to run. Other "Equipment/Item" commands specify an action to be taken within the Main Recipe.

Editing Sub Recipes

Sub Recipes are where most parameters are defined.

Seq	Typ	Equipment	EquipmentItem	EquipmentItemOperation	Equipment/Test Value
1	-	Recipe	Set Abort Recipe	Abort Process	
2	-	Power Supply	Power Supply1 Output Setpoint	Set Value = n.nn	0
3	-	Source	Source SW3	Turn_On/Open/Opening	
4	-	Power Supply	Power Supply 1	Turn_On/Open/Opening	
5	-	Power Supply	Power Supply1 Output Setpoint	Set Value = n.nn	50
6	-	Power Supply	Power Supply1 Fwd Power	Check Value > n.nn	20
7	-	Recipe	Dwell	2 Seconds	
8	-	Shutter	Source Shutter 3	Turn_On/Open/Opening	
9	-	Recipe	Dwell	2 Seconds	
10	-	Shutter	Source Shutter 3	Turn_Off/Closed/Closing	
11	-	Power Supply	Power Supply1 DC Bias	Check Value > n.nn	3
12	-	Power Supply	Power Supply1 Ramp Rate	Set Value = n.nn	2
13	-	Power Supply	Power Supply1 Output Setpoint	Set Value = n.nn	100
14	-	Power Supply	Power Supply1 Fwd Power	Check Value > n.nn	95
15	-	Gauge	Capman Pressure SP	Set Value = n.nn	3
16	-	Gauge	Capman Pressure	Check Pressure <= n.nn	3.2
17	-	Power Supply	Power Supply1 DC Bias	Check Value > n.nn	1
0	-				

Fig. 4: Recipe editing with the equipment/test value parameter highlighted.

Equipment/Test Value: This is where the parameters of a Sub Recipe within a process are defined and edited. The same owner permissions are required as in a Main Recipe for editing. If there are a set value and a check value for the same parameter, make sure to change both values together to keep the logic true. For example, if the power is set to 200 W and the check is set to greater than 190 W originally, and you want to drop to only 100 W set point, make sure that the check point is reduced similarly to greater than 95 or something close.

The GRST column on the right-most side sets the timeout logic.

Appendix B: DC Sputter Process Example Recipe

Refer to the **PVD75 Operation Manual** (page 57-58) for an example and explanation of steps required for a typical DC Sputter recipe.

In general, a DC Sputter recipe will look like the following:

1. Set the abort recipe to ensure a safe abort process.
2. Rotate the substrate (optional)
3. Obtain desired sputter pressure and gas mixture, e.g. 20 mTorr with 95% Ar and 5% N2
4. Light the plasma and ramp to peak power
5. Decrease pressure
6. Clean the target surface (source shutter open, substrate shutter closed)
7. Deposit (source shutter open, substrate shutter open)
8. Turn everything off: source power, gas flows, and substrate rotation.

There are other optional steps you can add within the recipe to change the film, such as:

- Substrate heating
- Different deposition rates
- Different pressures
- Different gas environments

See the next page for detailed and explained steps of a common main recipe and its subrecipes.

Main Recipe: Source 2 TiN 5% N2 10mT

Table 1: Example of a main recipe using multiple sub-recipes

Seq	Type	Equipment	EquipmentItem	EquipmentItem Operation	Equipment/ TestValue	GRST
1	-	Recipe	Set Abort Recipe	Abort Process		
2	-	Recipe	Run Recipe	Prepare to Deposit		
3	-	Recipe	Run Recipe	Substrate rotation 20rpm		
4	-	Recipe	Run Recipe	Gas 20mT Ar /N2 MFC1/2 turn on 5% N2		
5	-	Recipe	Run Recipe	Sputter Src2 Ignition 400W SUB 10 mT		
6	-	Shutter	Source Shutter 1	Turn_On/Open/Opening		
7	-	Recipe	Dwell	N Seconds (n or HH:MM:SS)	00:05:00	
8	-	Shutter	Substrate Shutter	Turn_On/Open/Opening		
9	-	Recipe	Dwell	N Seconds (n or HH:MM:SS)	00:30:00	
10	-	Shutter	Substrate Shutter	Turn_Off/Closed/Closing		
11	-	Recipe	Run Recipe	Sputter Src2 Extinguish SUB		
12	-	Recipe	Run Recipe	Gas Supply turn off		
13	-	Recipe	Run Recipe	Substrate rotation stop		

1. Set the procedure the tool should follow if it needs to abort. This always needs to be the first item in a recipe.
2. Check chamber pressure to ensure it is low enough to begin deposition.
3. Rotate the substrate at 20 rpm. This improves film uniformity across the sample.
4. Increase chamber pressure to 20 mTorr with 95% Ar and 5% N2. [See subrecipe explanation below.]
5. Ignite the Source 2 plasma, increase power to 400 W, then decrease pressure to 10 mTorr. [See subrecipe explanation below.]
6. Open the Source 2 shutter to begin target cleaning.
7. Clean the target for 00:05:00 (5:00 min). This sputters off any contaminants on the target surface.
8. Open Substrate Shutter to begin deposition.
9. Deposit for 00:30:00 (30:00 min).
10. Close Substrate Shutter to prevent further deposition on substrate.
11. Slowly decrease Source 2 power until it turns off.
12. Turn off the gas flow and seal the chamber.
13. Stop rotating the substrate.

Sub Recipe: Gas 20mT Ar/N2 MFC1/2 turn on 5% N2

Table 2: Example of gas flow sub-recipe using 95% Ar and 5% N2 at 20 mTorr

Seq	Type	Equipment	EquipmentItem	EquipmentItem Operation	Equipment/ TestValue	GRST
1	-	Recipe	Set Abort Recipe	Abort Process		
2	-	Valve	PC High Vac Valve Opened	Check_On/Open/Opening		AT[1]
3	-	Pump	PC Turbo Speed Setpt	Set Value = n.nn	35	
4	-	MFC	MFC1 Ratio	Set Value = n.nn	95	
5	-	MFC	MFC2 Ratio	Set Value = n.nn	5	
6	-	Valve	Gas Injection	Turn_On/Open/Opening		
7	-	MFC	MFC1 SP	Set Value = n.nn	0	
8	-	MFC	MFC2 SP	Set Value = n.nn	0	
9	-	Recipe	Dwell	2 Seconds		
10	-	MFC	MFC1 Mode	Set Value = n.nn	4	
11	-	MFC	MFC2 Mode	Set Value = n.nn	11	
12	-	Gauge	Capman Pressure SP	Set Value = n.nn	20	
13	-	Gauge	Capman Pressure	Check Pressure > n.nn	19.5	AT[2]
14	-	Pump	PC Turbo Speed	Check Value <= n.nn	37	T[3]

[1] TimeOut for Wait = 1. TimeOut Message = Hi Vac Valve Not Open. Goto Sequence No if Timeout = 999.

[2] TimeOut for Wait = 300. TimeOut Message = Failed to Reach SP in Set Time. Goto Sequence No if Timeout = 999.

[3] TimeOut for Wait = 500.

1. Set the procedure the tool should follow if it needs to abort. This always needs to be the first item in a recipe.
2. Check if the High Vacuum Valve is opened.
3. Set the turbo pump speed to 35%.
4. Set MFC1 (Ar) ratio to 95%.
5. Set MFC2 (N2) ratio to 5% (of the 95% flow rate during flowing).
6. Open the gas injection valve to allow gas to flow into the chamber.
7. Reset MFC1 flow value to 0 standard cubic centimers per minute (SCCM).
8. Reset MFC2 flow value to 0 SCCM.
9. Hold (dwell) for 2 sec.
10. Set MFC1 to Mode 4. Mode 4 will flow the required amount of gas to match the capman pressure setpoint. Since the capman setpoint is 0, the flow is 0.
11. Set MFC2 to Mode 11 (one-one). Mode 11 on MFC2 will slave MFC2 to MFC1, so MFC2's flow will be 5% of MFC1's.
12. Set the capman pressure to 20 mTorr. MFC1 will begin flowing Ar and MFC2 will begin flowing N2.
13. Check if the capman pressure is >19.5 mTorr. If yes, it is essentially 20 mTorr and will continue.
14. Check if turbo pump speed is low enough to begin plasma ignition.

Sub Recipe: Sputter Src2 Ignition 400W SUB 10 mT

Table 3: Example of plasma ignition sub-recipe with 400 W peak power and 10 mTorr pressure

Seq	Type	Equipment	EquipmentItem	EquipmentItem Operation	Equipment/ TestValue	GRST
1	-	Recipe	Set Abort Recipe	Abort Process		
2	-	Power Supply	Power Supply2 Output Setpoint	Set Value = n.nn	0	
3	-	Source	SW1	Turn_On/Open/Opening		
4	-	Power Supply	Power Supply 2	Turn_On/Open/Opening		
5	-	Power Supply	Power Supply2 Output Setpoint	Set Value = n.nn	50	
6	-	Power Supply	Power Supply2 Output Voltage	Check Value > n.nn	20	AT[1]
7	-	Power Supply	Power Supply2 Ramp Rate	Set Value = n.nn	2	
8	-	Power Supply	Power Supply2 Output Setpoint	Set Value = n.nn	400	
9	-	Power Supply	Power Supply2 Output Power	Check Value > n.nn	380	AT[2]
10	-	Gauge	Capman Pressure SP	Set Value = n.nn	10	
11	-	Gauge	Capman Pressure	Check Pressure < n.nn	10.5	

[1] TimeOut for Wait = 5. TimeOutMessage = PWS2 Plasma Not On. Possible short circuit, pressure too low, etc. Goto Sequence No if Timeout = 999.

[2] TimeOut for Wait = 200. TimeOutMessage = PWS2 Power < 400 W. Goto Sequence No if Timeout = 999.

1. Set the procedure the tool should follow if it needs to abort. This always needs to be the first item in a recipe.
2. Set power supply power to 0 W, in case it was non-zero before.
3. Turn on Switch 1 (SW1). Because both Source 2 and Source 3 are connected to PWS2, a switch needs to be on to designate which source to power. SW2 will allow Source 3 to be turned on.
4. Turn on Power Supply 2 (PWS2). No power is being applied yet.
5. Set PWS2 output to 50 W. This will ignite the plasma.
6. Check output voltage. If less than 20 V, there is probably no plasma. Lack of plasma can be due to a short circuit or the pressure being too low.
7. Set the PWS2 ramp rate to 2 W/s. See suggested ramp rates in Appendix E.
8. Set final PWS2 power to 400 W. It should take (P_{final} - $P_{initial}$)/(ramp rate) = (400-50)/2 = 175 sec to reach the peak value.
9. Check if PWS2 power is greater than 380 W. If yes, it is close enough to 400 W that the pressure can be lowered.
10. Set capman pressure to 10 mTorr. The pressure will immediately begin to decrease.
11. Check if capman pressure is less than 10.5 mTorr. If yes, continue to next step (this will bring us back to the main recipe).

Appendix C: Changing Targets (pp 63-64 from the PVD75 Operation Manual):

TARGET CHANGING

Installing/changing targets:

1. Loosen the 3 screws using a hex wrench supporting the dark space shield (DSS) and remove the shield (see Figure 7).
2. Remove the 4 screws using a flathead screwdriver and remove the rings. Be careful not to drop the screws or rings.
3. Remove the target and place it back in its box.
    a. When removing a target of magnetic material, carefully slide the target to one side and pick it up (do not attempt to pry magnetic targets from the cooling well. This may result in permanent damage to the cooling well).
4. Place a new target on to the source, ensuring all parts are perfectly clean.
    a. If installing a magnetic target, take extra care that fingers or parts of a glove do not get pinched between target and source as the magnets are very powerful.
5. Tighten the 4 hold-down ring screws evenly. Do NOT overtighten – this can break the target.
6. Place the DSS back on. The DSS has three machined slots, which ensure .080" dark space on top of the 1/8", 3/16", and 1/4" targets. Position the DSS on the smallest slot for thick targets and one of the larger slots for thin targets.
7. Tighten the screws evenly and enough to prevent the DSS from moving.
8. After installing a target, you can check for a short. Refer to Appendix G to check for a short.

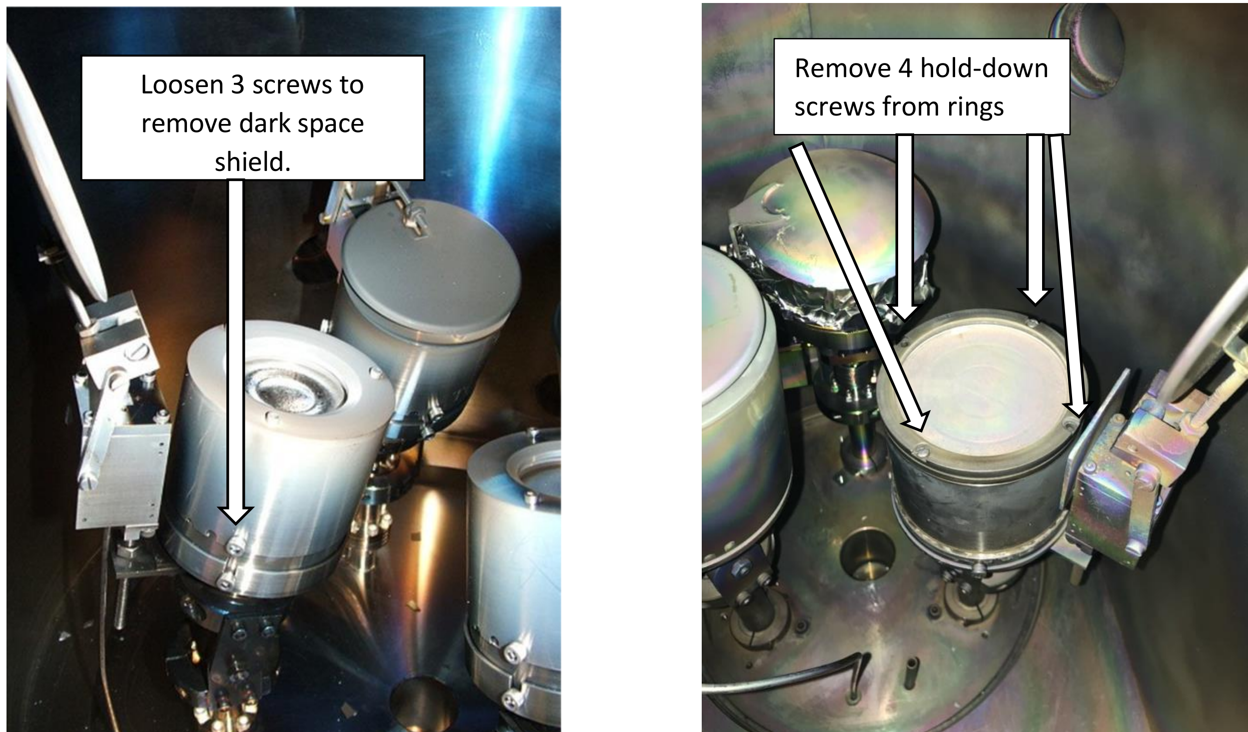


Fig. 5: Sputter gun with DSS on (left) and DSS off (right).

Appendix D: Increasing Deposition Rate

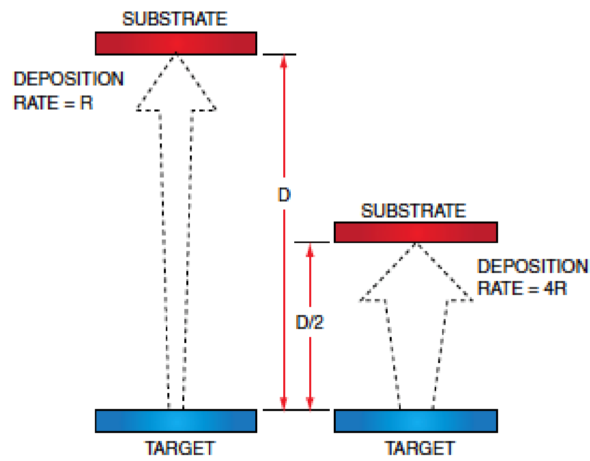
There are three ways to increase the sputter deposition rate: decreasing throw distance (distance from target to substrate), increasing power, and decreasing chamber pressure.

Decreasing Throw Distance

The deposition rate and throw distance are related by the inverse square law: Rate = 1/(distance^2). While the substrate position cannot be changed, the target position can be moved up. Ask a staff member to help you with this. There are a few advantages and disadvantages of shorter throw distance.

Advantages:

- Reduction in tensile stress of growing film
- Improved film adhesion
- Higher density films



Disadvantages:

- Worse film thickness uniformity
- Substrate melting due to higher heat (caused by target proximity)
- Increase in compressive stress of growing film
- Substrate outgassing
- Underlying film damage due to electron bombardment

Increasing Power

Increasing power increases the accelerating voltage of ions, which increases the number of atoms “knocked off” of the target for each incoming ion (called sputter yield).

Maximum power density must be considered, or else damage to the target, sputter gun, and possibly substrate may occur. You can find maximum power density of DC-sputtered materials in Appendix E. It is important to not go near the maximum power, but rather 10-20% below it to prevent possible damage.

Decreasing Chamber Pressure

Decreasing chamber pressure will cause an increase in deposition rate for two reason:

1. The mean free path within the chamber is less, so more sputtered atoms will reach the substrate surface.
2. Ion accelerating voltage will increase as pressure decreases, causing a larger sputter yield.

Appendix E: Maximum Power Density of Target Materials

This is a guideline only. These are initial maximum power levels and power densities. This is not to replace common sense. If you see a target overheating or the results of a target overheating do NOT increase the power further. Also, if the target survives a max power limit the max power can be increased over these values. This chart Serves ONLY to get you started. It is always a BAD idea to work at the maximum rated power.

Maximum power densities will be determined by the target material and how it is made into the target shape, the melting point for that material, the thermal conductivity of that material, the efficiency of the cooling circuit in the sputtering gun, how the target is fixed into the sputtering gun, and structural strength of the target.

Target Material	Max Power (DC) 3 in. gun	Max Power (DC) 4 in. gun	Suggested Ramp Rate
Aluminum	883 Watts	1570 Watts	5 W/s
Silver	1060 Watts	1884 Watts	5 W/s
Gold	1060 Watts	1884 Watts	5 W/s
Chromium	706 Watts	1256 Watts	5 W/s
Copper	1060 Watts	1884 Watts	5 W/s
Magnesium	706 Watts	1256 Watts	5 W/s
Molybdenum	706 Watts	1256 Watts	5 W/s
Nickel*	706 Watts	1256 Watts	5 W/s
Platinum	706 Watts	1256 Watts	5 W/s
Tungsten	706 Watts	1256 Watts	5 W/s
Iron*	353 Watts	628 Watts	2 W/s
Germanium	565 Watts	1005 Watts	3 W/s
Niobium	353 Watts	628 Watts	3 W/s
Silicon	353 Watts	628 Watts	3 W/s
Tantalum	565 Watts	1005 Watts	3 W/s
Titanium	565 Watts	1005 Watts	2 W/s
Zirconium	353 Watts	628 Watts	2 W/s

Appendix F: Co-Sputtering Two Materials

Two materials can be sputtered at the same time with the combination of: (Source 1 and Source 2) OR (Source 1 and Source 3). (Source 2 and Source 3) CANNOT be run at the same time.

In order to create a cosputter recipe, simply put two sputter ignition recipes together in a main recipe (Table 4). The example given is the same as in Table 1 in Appendix B.

Table 4: Example of a main cosputter recipe using multiple sub-recipes

Seq	Type	Equipment	EquipmentItem	EquipmentItem Operation	Equipment/ TestValue	GRST
1	-	Recipe	Set Abort Recipe	Abort Process		
2	-	Recipe	Run Recipe	Prepare to Deposit		
3	-	Recipe	Run Recipe	Substrate rotation 20rpm		
4	-	Recipe	Run Recipe	Gas 20mT Ar /N2 MFC1/2 turn on 5% N2		
5	-	Recipe	Run Recipe	Sputter Src2 Ignition 300W SUB		
6	-	Recipe	Run Recipe	Sputter Src1 Ignition 250W SUB 10 mT		
7	-	Shutter	Source Shutter 1	Turn_On/Open/Opening		
8	-	Recipe	Dwell	N Seconds (n or HH:MM:SS)	00:05:00	
9	-	Shutter	Substrate Shutter	Turn_On/Open/Opening		
10	-	Recipe	Dwell	N Seconds (n or HH:MM:SS)	00:30:00	
11	-	Shutter	Substrate Shutter	Turn_Off/Closed/Closing		
12	-	Recipe	Run Recipe	Sputter Src2 Extinguish SUB		
13	-	Recipe	Run Recipe	Gas Supply turn off		
14	-	Recipe	Run Recipe	Substrate rotation stop		

All of the steps remain the same, with a few minor differences:

- The final chamber pressure during deposition (10 mTorr) is not reached until AFTER both sources achieve peak power (S2 first at 300 W, then S1 at 250 W).
- The original power of S2 is decreased. Because two sources will be running at a total of 550 W, the chamber is likely to heat up more than it would if S2 was running at 400 W. This should be especially considered when using materials with low thermal conductivity, as too much heat can cause it to break.

Appendix G: Test for shorts in the DC Sputter tool

A short between the dark space shield (DSS) and the target could prevent ignition of the plasma. To test for a short:

1. Vent the chamber.
2. Grab the multimeter from the Lesker supplies shelf and set it to measure continuity.
3. Run “00 Source short check SW1 SW2” and perform the following steps on the source that will be used:
    a. Touch one lead to the target and the other to the DSS.
    b. The multimeter should read 0L. If not, there is a short.
    c. If there is a short, remove the DSS, adjust the rings holding the target and the target itself (see Fig. 5).
    d. Reassemble the source and check for a short again.
4. If the short persists no matter what adjustments are made, rerun the plasma check. If the plasma still does not ignite, notify a staff member.