IIT Bombay Nanofabrication Facility

Tool Name: Sputter (ATC 2200)

Standard Operating System (SOP)

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Tool's Overview

Fig. Sputter (ATC 2200)

Video links:

https://www.youtube.com/watch?v=lUf5r9WyjFo
https://www.youtube.com/watch?v=6V8pGRzN534

It is a sputtering tool with the capability to co-sputter multiple materials to obtain film with composition gradient on the depositing substrate.

Location - Nano Lab

Capabilities

- Co- sputter 4 materials at a time.
- Deposition at elevated temperatures (upto 800C)
- Substrate to target distance variation possible.
- Angle of the gun can be varied.

Specifications

- No. of guns (targets) in the chamber – 7
- No. of RF sources – 3 (Max. 300 W)
- No. of DC sources – 1 (Max 750 W)
- No. of guns that can be used at the same time – 4 (3 RF & 1 DC)
- Max. Substrate temperature – 800 °C
- Base Vacuum – 8 x 10-8 mTorr
- Deposition uniformity – 2 %
- Gases allowed – Ar, N2

Different Parts of tool explained

Main Panel:

Main power control:

1. **Mains**: To Turn On/Off the tool.
2. **Emergency:** To shut down the tool in case of emergency.
3. **Water flow Alarm:** If there is any water flow error, this switch will glow. This can also beconfirmed by checking the backside LED, some or all of which will be OFF.
4. **Hoist:** This is to move the chamber lid up and down.
5. **Vacuum pump (Main chamber):** Not to be used

PID Heater controller:

1. **Power On/Off:** To turn on/off the heater.
2. **HEAT:** Can be set to local or remote mode or off.
3. **Temperature control:** To show the SET and current temperature.

Load Lock:

1. **Main power and Vacuum pumps:** To Turn On/Off the rotary pump power.

Gauge controller:

1. **Screen:** On screen it shows the chamber pressure. There are three different controllersto gauge different level of pressure.
    a. First: When pressure is below 3.5e-4 Torr.
    b. Second: When pressure is above 1e-03 Torr.
    c. Third: When pressure is between 3.5e-04 Torr and 1e-03 Torr.
2. **Sensor:** Usually we don't keep the first pressure gauge (Ion gauge) ON for too long. So tocheck it we press this button, let it settle for minute then turn off.
3. **DEGAS:** Confirm this and update

Adaptive pressure controller (VAT):

1. **Screen:** This shows the current pressure in both in terms of position of the gate valveand the pressure in Torr.
2. **Local and remote:** This can be set to local and remote mode.
3. **Open and close:** To fully open and close the gate valve. The value varies from 1000 (Open) to 0 (close).
4. **Setpoints**: These are different breakpoints between 0 and 1000.

Turbo controller:

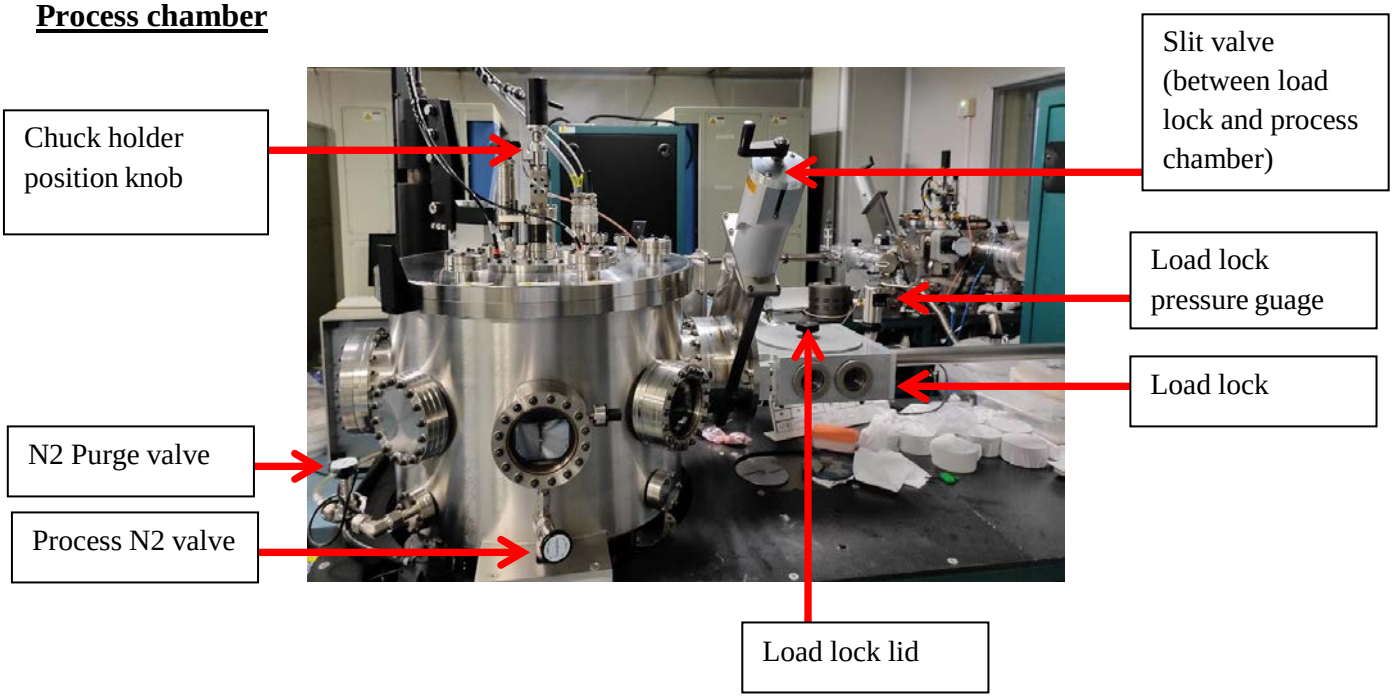
1. **Screen:** This shows different parameters of tubro pump.
    a. Power: As you turn on the turbo, it usually goes up to 100W as rotation speedincreases, but comes down to 6W after speed reaches maximum of 75kRPM.
    b. Voltage: This also has same trend as power. It increases up to 96V and thensettles at around 36V.
    c. Current: While the rotation is increasing, this is around 1.05A, but settles to0.15A.
2. **Measure:** This is to switch between different parameters.
3. **Start/Stop:** This is to start and stop the turbo.

Power supply:

1. **RF power supply:** There are total 4 RF power supplies. RF1, RF2, RF4A. On the screen itwill show,
    a. FWD: Forward power, which shows current level of power going towards the setvalue.
    b. REF: Reflected power, it shows the power reflected from the source. It should bezero.
    c. DCV: This is corresponding DC voltage value.

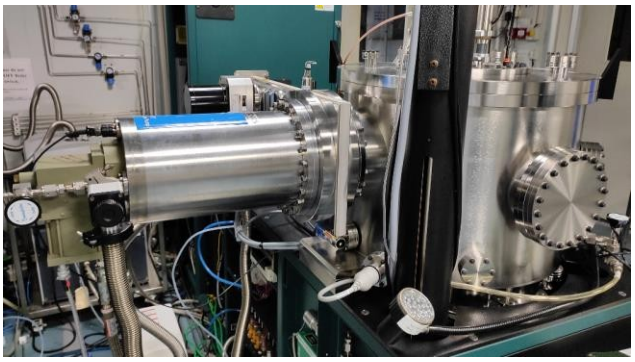
2. **DC power supply:**
    a. On Top it shows which gun is active.

Process chamber



1. In the above figure, the big cylindrical chamber is the main process chamber where thedeposition is done.
2. Process N2 valve: It is connected to a Mass flow controller (MFC).
3. N2 purge valve: Don't turn ON this valve. This will vent the chamber directly exposing thecryo directly to N2 and damage it.
4. Chuck holder knob: By default, it will be on L position, which means we have to load the chuck with substrate. Then move this position to E, engaged. This step will be reversed whileunloading.
5. Load Load lid: Carefully open this lid, when load lock pressure reaches atmospheric pressure.

CryoPump:



Cryopump basics can be found here:
LINK: https://www.cryosciences.com/_files/ugd/1aaeee_f20d35b25d6e4e08a48c64938b41f3af.pdf

https://www.cryosciences.com/_files/ugd/1aaeee_a35dd6a28ca5420d83958371799a2b98.pdf

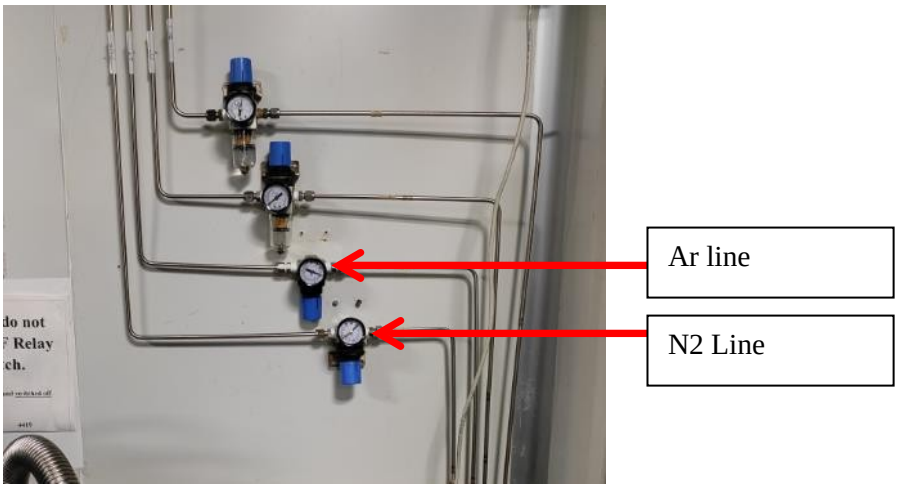
This is the reason for chamber pressure is in the range 8e-8 Torr. It's principle is based on cryosorption. There is a cold head inside this pump, in which highly compressed helium flows. This causes the cold head temperature to be around 10-12K. The activated charcoal array which surrounds this cold head adsorbs most of the gaseous content, bringing the pressure in the desiredrange. For more information, check out the link given above.

Cryo compressor:

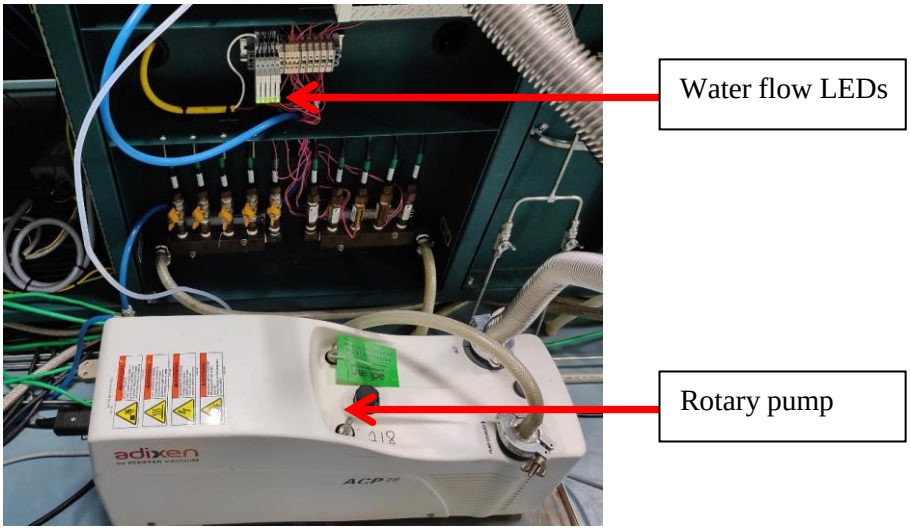
The helium in the cryopump first goes through this compressor, where it is compressed to 1690- 1725 kPa. This compressed helium is then expanded in the cold head, where this sudden adiabaticexpansion reduces the temperature of the gas and in turn the cold head to 10-12K.

Gas lines:

1. There are two gas lines which are going into the ATC sputter system (third line is of O2 whichis not allowed in the chamber, hence it is not used).
2. N2 pressure is kept at the marker shown in the figure. Don't increase the pressure above thismarker or it will cause the lid to open with a burst sound and can damage the O-ring.



Rotary pump:



1. The primary function of the rotary pump is to back up the cryo or turbo pump. It means to bring the pressure in the loadlock to 1e-02 Torr, at which point we can turn on the turbo pump. Direct turning on the turbo pump will require too much power and can also damageits blades.
2. In the above picture, water flow LEDs should always be ON. The system will shut down if any/all of them are off. Contact SO if this is the case.

Operating Procedure

General Operating Safety:

The sputtering system is a very complicated and expensive piece of machinery. There are many safety features built in to protect you from it and vice versa. It is to be used only by properly trainedpersonnel. The primary dangers include but are not limited to:

1. Mechanical injury from raising/lowering of chamber lid controlled by motorized hoist.
2. Electrical shock injury from exposed energized surfaces, cables, etc.
3. Mechanical injury from explosion/implosion generated from high/low pressures within thevacuum system.

Operation

Before loading the sample (also to be checked before leaving the system after the process)–

1. Check if the front panel is ON.
2. Check if the 5 green LEDs at the backside of tool are ON. This makes sure that the cooling water flow to the tool is proper.
3. Turn ON the process gases (Ar, N2, O2(if required)). Set the pressure of gases to ~20 psi.
4. Turn ON the value for venting N2.
5. The VAT controller should be in LOCAL mode and in OPEN position i.e the chamber must be continuously evacuated.

Loading process:

1. Turn OFF the LL chamber vacuum pump. Wait for the LL chamber to come to atm. pressure.
2. Take the lid off and keep it on the 3 rest points.
3. Place the sample on the sample holder.
4. Place the sample holder correctly on the transfer arm.
5. Place the lid and turn on the LL vacuum pump.
6. Wait for the pressure to reach 5e-5 Torr.
7. Open the gate valve between Main chamber & LL chamber.
8. Check if the position of the substrate height adjustment knob is below the bottom mark. If not, then rotate the knob in anti-clockwise direction until it reaches below the bottom mark.
9. Move the transfer arm into the Main chamber.
10. Rotate the substrate height adjustment knob to upper position.
11. Rotate the rotator to E position. If it does not rotate then adjust the knob a bit and then againrotate the rotator to L position.
12. Rotate the substrate height adjustment knob in anti-clockwise direction until it reaches belowthe bottom mark.
13. Check if the substrate holder is placed on the arm.
14. Move the transfer arm into the LL chamber.
15. Close the gate valve between Main chamber & LL chamber

Deposition procedure:

1. Rotate the substrate height adjustment knob to the height that you want to use for deposition. This is usually 32 mm.
2. The software should be ON.
3. Put the VAT controller in REMOTE mode. This closes the gate valve between chamber and cryo pump.
4. OPEN this gate valve from the software.
5. Turn the rotation ON.
6. Plasma striking
    i. Set Ar flow to 67 sccm and turn ON the gas. DO NOT turn the Ar flow ON if the gate valveis closed.
    ii. Set the pressure to 30 mTorr.
    iii. Set the time to 60s and power to 30W.
    iv. Turn the power ON.
    v. Wait for the plasma to strike.
    vi. Change the pressure to 3 mTorr (process pressure)

7. Power ramp up
    i. Ramp the power to desired power by 0.5W/s ramp rate for RF power and 1W/s for DC power.
    ii. Wait for some time (5 to 10min) at this power to pre sputter the target. This is needed for the materials that get oxidized easily, e.g Ti, Al etc.
8. Deposition
    i. Open the shutter. Deposition on the substrate begins.
    ii. Let the deposition happen for the desired time. Do not sputter continuously for >30 mins.
9. Power ramp down
    i. Ramp the power down to 0W by 0.5W/s ramp rate for RF power and 1W/s for DC power.
    ii. Turn of the power.

Skills and Risks

Skills: This section covers the parts of the operating procedure where you will require somepractice during hands-on session.

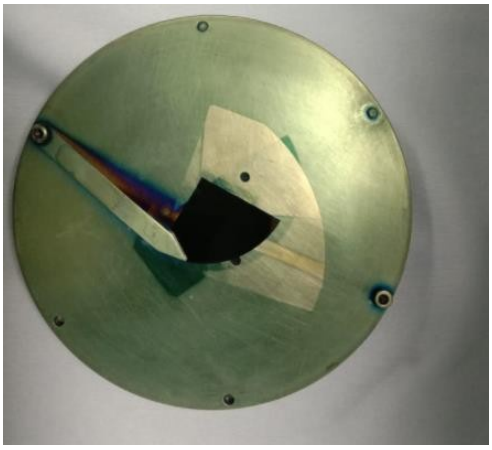
1. Going through the checklist: Usually users directly try to operate the tool without looking at the SOP and sometimes mistakes happen. To avoid this there is a checklist given at the end which you will have to go through while operating the system. In initial few runs you must gothrough each and every point given in the Operation procedure section (C). But later after gaining some confidence, you can switch to this checklist.

2. Loading and unloading the chuck: While loading and unloading the chuck you will have to change the position of the chuck holder knob from L -> E (while loading) and E->L (while unloading). There is a slight play when keeping chuck on the substrate holding arm. This can cause a small angular displacement of the chuck and may not properly hold or easily rotate from L-E or E->L. This requires some practice. Ask the operator/SO to let you practice this a few times.

3. Changing the RF/DC cables: You need to check the cables before starting the process. Each gun should have corresponding cable connected to the gun as mentioned in the software or change the cables and make necessary changes in the software whichever power supply you want to use. The cable changing is rather easy but a tedious task, hence you should practice this.

Risk: This section covers all the possible errors that you might encounter.

A. Loading of the sample
   a. Make sure to use mounting clips between ±60° wrt loading arm. If it is more than this, then it will cause the chuck to be misbalanced and create problems in loading.



   b. Be careful while loading the 4” samples, it may break if you tightened the screws too much.
   c. Always check the initial position of the chuck holding assembly. It should be abovethe mark.

B. Pre-deposition: Always pre-sputter for at least 5-10min, to make sure that plasma is stableand the power and DCV values are stable.
C. Deposition: There might be a possibility in case of Gd2O3 especially, that the plasma might fluctuate during the opening and closing the shutter, in that case decrease the power to 0Wand start again and go for slightly higher power (max 200W). Then lower down and open shutter.
D. Unloading the sample: Practice the unloading part in “skills” section.

Checklist

1. Check the initial conditions of ATC sputter.

2. Turn off the turbo pump, wait for 65kRPM and turn off the rotary pump. During this time you canload the sample on the chuck.

3. Close the gate valve, and then open the slit valve after it reaches the atmospheric pressure.

4. Load the sample in the holder arm. Put the lid and start the rotary pump. After it reaches 1e-02Torr, turn ON turbo and wait for it to reach 5e-06 Torr.

5. Load the sample inside as practiced or look up in the operating procedure if needed. Open thegate valve after checking that the slit valve is closed.

6. Turn on the laptop.

7. Change the cables according to the need and double check them in the software.

8. Start the pre-sputter and the main deposition, 20 min depositions and 10min break. During thedeposition keep track of the pressure, power, and DCV values.

9. After finishing the deposition, close the gate valve and unload the sample.

10. Open the gate valve after closing the slit valve.

11. Bring back the system to its initial condition.